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The Route Analysis Based On Flight Plan

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Abstract. Economic development effects use of air transportation since the business process in every aspect was increased. Many people these days was prefer using airplane because it can save time and money. This situation also effects flight routes, many airlines offer new routes to deal with competition. Managing flight routes is one of the problems that must be faced in order to find the efficient and effective routes. This paper investigates the best routes based on flight performance by determining the amount of block fuel for the Jakarta-Denpasar flight route. Moreover, in this work compares a two kinds of aircraft and tracks by calculating flight distance, flight time and block fuel. The result shows Jakarta-Denpasar in the Track II has effective and efficient block fuel that can be performed by Airbus 320-200 aircraft. This study can contribute to practice in making an effective decision, especially helping executive management of company due to selecting appropriate aircraft and the track in the flight plan based on the block fuel consumption for business operation.

1. Introduction

The Economic growth gives a strong impact in the system transportation both land, sea and in the air. Especially, the use of air transportation or airplane was increasing in the over the world. Many airline companies were offered new routes and try to give the best facility in the airplane in order to deal with competition in the business. On the other hand, the company was using a various airplane with a different characteristic such as Boeing, Airbus, Bombardier (Canada), Sukhoi, CASA and so forth [1–3]. Thus, each airline has considered in their financing. The opening of these new routes flights will provide

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business opportunities for the public society. For instance, if at first these can only be reached by traveling overland, then with the opening of a new route flight and can be reached with a shorter time so that the economic growth will be better. However, the airline must be serious considering the fares flight associated with the ability of consumer purchasing power. Therefore, the airlines company have to make the right decision in purchase an aircraft.

Many factors need to be considered in determining the cost of airlines and aircraft Block Fuel that types of aircraft, passenger capacity, operating costs, maintenance costs, indirect costs and include the cost of performance, needs crew and aircraft purchase costs which are the best life cycle (Life Cycle Cost = LCC) [4]. According to [5], the concept of LCC can be used to save operating costs up to 15% cost. LCC analysis consisted of analysis of direct costs (DOC = Direct Operating Cost) and indirect costs (IOC = Indirect Operating Costs). LCC analysis is based on the financing used by companies Airbus [6] and the Boeing company method [7]. The selection of aircraft by measured the cost performance consisting of flight time, block time, flight distance, relative speed, block fuel and so on [8].

Flight time is calculated as the plane moves from the airport to the runway, take off, climb, crawl, decreased, until landing and stopped moving (final approach). The flight time can be calculated by dividing the distance and speed of the aircraft plus the time for 6 minutes or 0.1 hours for maneuverer (holding) in the air [9,10]. Block Time are traveling time when aircraft taking the route. The block time can be calculated by summing flight time and the average taxi-in (sliding in the parking lot) and taxi-out (zooming out parking) each 15 minutes or 0, 25 hours [10]. Flight speed can be calculated by using the data block time is called the block speed. While the block speed can be determined using a range of Block Time. The Flight distance to be travelled on a path that has been determined based on the phase of flight. Total distance can be divided into three parts such as go up (climb), crisscross and downhill [11]. After knowing the distance that will be taken, then the parameters that need to be known relating to that flight conditions plane performance during go up and declining. At the time, the plane goes up with a slant (incline climbing) that up to a certain height which is called the peak of ascent and the aircraft will continue to roam up to a certain distance and downhill (fly cruise top of descent) [12].

Avtur is the fuel used by aircraft which is occupying second largest cost item in cost after salaries of the employees. Aviation fuel represents about 20% or more of the total budget airline companies. Thus several airlines aggressively pursuing programs and achieved fuel savings at least 5% from the total budget of fuel that should be used. Fuel savings affect directly to the bottom line in extremely competitive environment. The airlines company will have a good competitive advantage if they can manage efficiently. Therefore, to compensate for any burning aviation fuel wasted in the airline must produce 15-20 dollars in additional revenue to achieve the same advantages. Consequently, the flight operations department must be responsible for the efficient management of fuel.

Some airline has undirected routes that takes extra time to reach the destination and certainly does not efficient and effective in economical perspective [13]. Another impact of the indirect airlines of this is the use of a more expensive airlines costs because the plane requires different Block Fuel. Besides, the use of certain types of aircraft also affects the cost of the flight. The operation of an aircraft will be efficient when using the right aircraft in accordance with the needs of passengers and has low operating costs.

The research on operation distribution costs of aircraft companies named Euro Control Aircrafts was carried out from French research institute by [14]. They study focused on cost efficiency flight and environmental impact in order to obtain high efficiency during take-off it is necessary to determine the exact amount of the average weight of the aircraft when taking off (MTOW = mean take-off weight) and the utilization of flight mileage. The study knowing that there are two efficiencies, namely mileages flown and duration of the flight. Furthermore, from the amount of fuel combustion will also result in the calculation of delay cost per aircraft and per minute.

Mark et al., [14] provide a statement correlation between the mileage aircraft with the MTOW in a single flight. Harris [15] determine the cost of economic analysis by the distribution of Boeing aircraft flight operations, air mileage from Denpasar to California. The study focused on the direct costs and indirect costs. Direct costs include flight crew, fuel and oil, insurance, leasing, operating fly, airframe maintenance, engine maintenance, shrinkage and amortization. Indirect costs include passenger service, landing fees, aircraft services, traffic services, advertising and promotion, general administration, maintenance and shrinkage of equipment and other associated costs. In this study concluded that the total cost (TOC) is highly dependent on the availability of a seat mile (ASM = available seat mile).

Snare [16] determining the distribution costs of flight operations from the airline company Embraer 145 that is optimization of the cost of jet Stuttgart-Helsinki route. The analysis was performed on the focus of the study that the cost is affected by strong winds from the North and Baltic Sea. From the three results of this research was used in order to analyse costs.

Competition airline in terms of rates does not inevitable. Thereby, passengers choose the airline that has a good and new aircraft. Therefore, in this study investigates a new route by choosing an aircraft based on flight performance. The remainder of this paper is organized as follows: section 2 introduces the materials and methods in the design for determining flight plan routes; section 3 presents the result of the analysis; finally, section 4 summarizes the conclusion of the paper and future work.

2. Materials and Methods

To analyse flight routes, a number of steps were defined as shown in Figure 1 as follows:

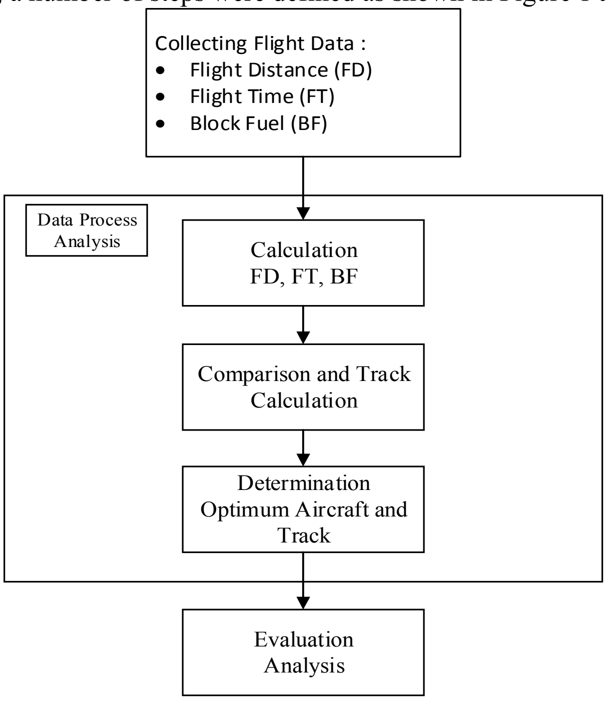

Figure 1. Design overview of the determination flight plans route

Flight plan (flight planning procedure) is fully geared to safety, having an impact on fuel saving and ideal for commercial aircraft operation. The flight plan is specific information about the flight plan by the pilot reported orally or in writing to the ATC clerk (air traffic control). Items that have to be considered in flight plan such as route, navigation, flight distance, flight altitude, flight time, fuel used the direction of flight, path and load [12]. However, in this work we consider flight distance, flight time and block fuel as a variable in order to analysed flight route because the objective in this study is to find the best routes based on flight performance by determining the amount of block fuel for the Jakarta-Denpasar flights route needed. The first phase to conducting the experimental design for determining flight plan is collecting flight data as show in Figure 1. In this study, several private data are required such as data operational flight plan from Jakarta-Denpasar route, block fuel data of aircraft from Jakarta-Denpasar flights route, specification data and departing aircraft from Jakarta-Denpasar route.

The data operational flight plan was collected from one airplane company in Indonesia which is a limitation of the study. The route of Jakarta and Denpasar is busiest domestic flights in Indonesia. In the business terms, this route is called as the fat route, which it connects two major cities is Jakarta and Denpasar. Jakarta has 2 (two) commercial airports, Soekarno-Hatta Airport (CGK) and Halim Perdanakusuma Airport (HLP). Denpasar has 1 (one) commercial airport, which is Ngurah Rai (DPS) Airport. However, we selected Soekarno-Hatta Airport (CGK) cause this airport having a direct and indirect route to Denpasar. On the other hand, by referring on the number of aircraft activities that cover a total number of 12580 units arrived at Ngurah Rai Airport which largest percentage is experienced by Boeing (B737-400) is 39% and Airbus (A320-200) type is 9% in 2013. Then, Boeing 737-400 and Airbus 320-200 is selected in order to compared flight performance analysis. Based on the data from field observations for Jakarta-Denpasar route, it can be scripted 5 (five) flight tracks below:

1. **Track I** is Jakarta-Denpasar route with direct flights from CGK to DPS. In the flight plan, it can be written as CGK-HLM-KASAL-TOC-CA-PIALA-ANY-BA-SBR-RABOL-TOD-TALOT-KUTA-BLI.
2. **Track II** is Jakarta-Denpasar route with direct flights from CGK to DPS. In the flight plan, it can be written as CGK-HLM-KASAL-TOC-CA-PIALA-ANY-BA-SBR-RABOL-TOD-TALOT-KUTA-BLI.
3. **Track III** is Jakarta-Denpasar route with transit in Surabaya, i.e. SUB-CGK-DPS (alternative 1). In the flight plan, it can be written as CGK-HLM-KASAL-TOC-CA-PIALA-ANY-TOD-BA-SBR with alternate SBR-TOC-RABOL-TOD-TALOT-KUTA-BLI.
4. **Track IV** is Jakarta-Denpasar route with transit in Surabaya, i.e. SUB-CGK-DPS (alternative 2). In the flight plan, it can be written as CGK-HLM-KASAL-TOC-CA-PIALA-ANY-TOD-BA-SBR with alternate SBR-TOC-RABOL-TOD-BLI.
5. **Track V** is Jakarta-Denpasar route with transit in Surabaya, i.e. SUB-CGK-DPS (alternative 3). In the flight plan, it can be written as CGK-HLM-KASAL-TOC-CA-PIALA-ANY-TOD-BA-SBR with alternate SBR-TOC-RABOL-TOD-BLI

The second phase is Data Processing Analysis by calculating Flight Distance (Equation 1), Flight Time (Equation 2-4) and Block Fuel (Equation 5) as follows:

2.1 Flight Distance

Flight Distance that must be taken on the path that has been determined based on the phase of flight. The total distance can be divided into three sections, namely the distance travelled during the Climb, Cruise and Descent. Flight distance can be calculated from the sum of climbing distance, cruise descent, and descent distance in Equation 1 (citation):

$$S_{route} = S_{climb} + S_{cruise} + S_{decent} \tag{1}$$

Where,

S_{route} = total distance
S_{climb} = the distance travelled during the ascent flight
S_{cruise} = the distance travelled during the exploration phase of flight
S_{decent} = distance descent phase of flight subs decline

If the distance is known at every checkpoint, it can be applied for:

1. The distance from check point I to check point II = $x1$
2. The distance from check point I to check point III = $x1 + x2$
3. The distance from check point I to check point IV = $x1 + x2 + x3$
4. The distance from check point I to check point V= $x1 + x2 + x3 + x4$

To know the determination distance from each checkpoint can be seen on Figure 2.

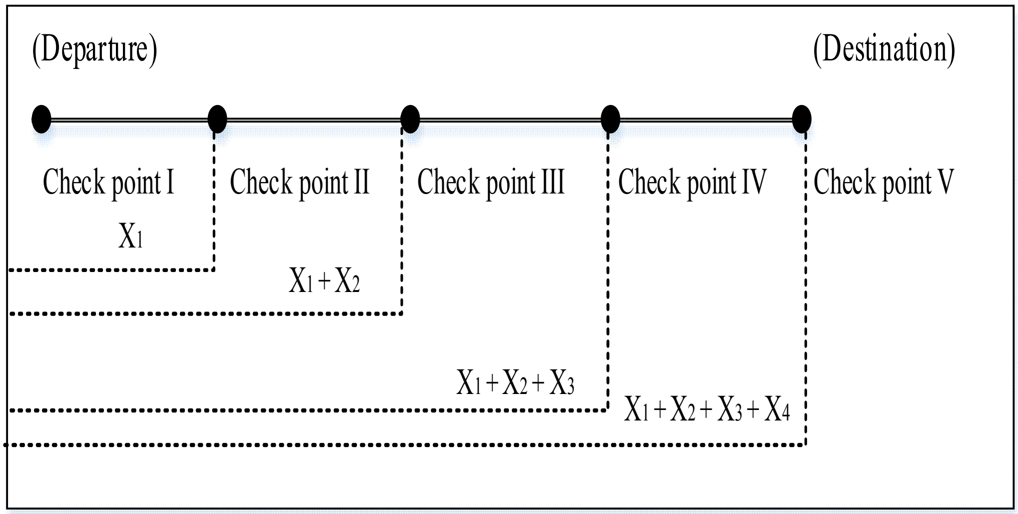

Figure 2. The distance from each checkpoint [12]

As mention previously, Jakarta –Denpasar have 5 flight tracks that must calculate using Equation 1, which is comparing based on two aircraft Boeing 737-400 and Airbus 320-200 for each track. The next step is calculating flight time that also compared based on two aircraft Boeing 737-400 and Airbus 320-200 for each track.

2.2 Flight Time

Flight time can be calculated from the distance that divided by the aircraft speed and added by 6 minutes or 0.1 hours to maneuverer (holding) in the air [15]:

$$Flight\ Time\ (T_f) = \frac{Range}{Speed} + Air\ Maneuverer\ Time\ = \frac{Range}{Speed} + 0.1 \quad (2)$$

$$\begin{aligned} Block\ Time\ (T_b) &= Taxi\ Out\ + Flight\ Time\ + Taxi\ In \\ &= 0.25 + T_f + 0.25 \\ &= T_f + 0.5 \end{aligned} \quad (3)$$

$$Block\ Speed\ (V_b) = \frac{Range}{Block\ Time} \quad (4)$$

2.3 Block Fuel

In Figure 3, show proses how block fuel can be calculated using Equation 5. Calculating Block Fuel from the sum of Trip fuel, holding fuel, alternate fuel and taxi fuel as follows:

$$Block\ Fuel\ = Trip\ fuel\ + Holding\ fuel\ + Alternate\ fuel\ + Taxi\ fuel \quad (5)$$

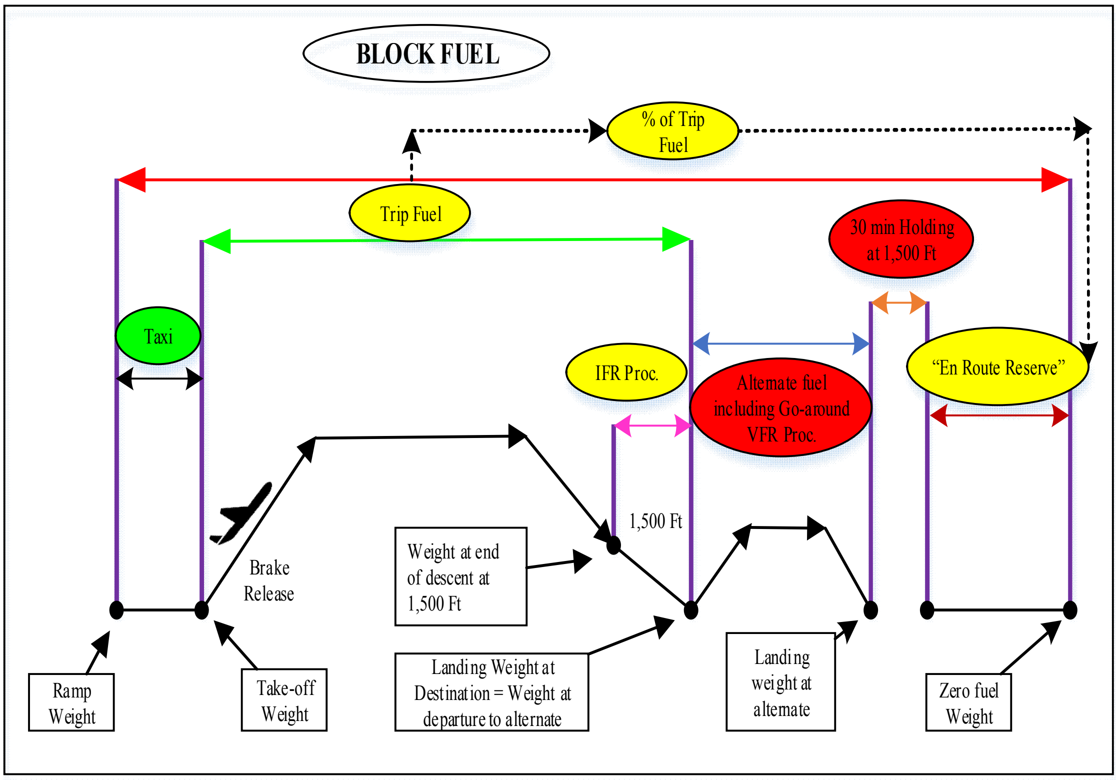

Figure 3. Block Fuel [9]

According to Equation 5, the first step that must calculate is Trip fuel where can be obtained from the sum of the fuel climb, cruise and descent as follows:

$$Trip\ Fuel\ = F_{climb} + F_{cruise} + F_{descent} \tag{6}$$

Where,

$$Time\ climb = \frac{Flight\ Level}{Rate\ of\ climb} \tag{7}$$

$$Time\ cruise = \frac{Flight\ Level}{Rate\ of\ cruise} \tag{8}$$

$$Time\ descent = \frac{Flight\ Level}{Rate\ of\ descent} \tag{9}$$

Then,

$$F_{climb} = \frac{Time\ climb}{60} X\ Fuel\ comsumption\ rate\ climb \tag{10}$$

$$F_{cruise} = \frac{Time\ cruise}{60} X\ Fuel\ comsumption\ rate\ cruise \tag{11}$$

$$F_{descent} = \frac{Time\ descent}{60} X\ Fuel\ comsumption\ rate\ descent \tag{12}$$

Holding fuel is the amount of fuel that must be prepared to do the holding during a fly over airport (typically min. 30 minutes) before a decision has made the moving flight to near an alternative airport while a landing slot is found if having problems in the airport destination. The amount of holding fuel it depends on the weight of aircraft. Moreover, Alternate fuel is the amount of fuel that is planned to be used from the destination airport to the other airport if the flight mission to the destination airport failed to materialize due to flight safety reasons. Then, taxi fuel is the amount of fuel burned during the trip from the apron to the end of the runway do line up in preparation for take-off. However, in this study holding fuel, alternate fuel and taxi fuel is collected from private data operational flight plan from Jakarta-Denpasar route based on two aircraft Boeing 737-400 and Airbus 320-200.

After calculating the flight distance, flight time and block fuel, comparison between aircraft type Boeing 737-400 and type Airbus 323-200 will be performed. In additional, comparison among tracks based on the Block Fuel, flight time and flight distance also carried out. The calculation results of Jakarta-Denpasar flight route will be compared to find out the most efficient aircraft and block fuel.

3. Result

The analysis was undertaken using a computer with the following specifications: Intel (R) Core (TM) i5-2450M CPU @ 2.50GHz (4 CPUs), 8 GB of RAM and Windows 8.1, 64-bit (6.3, Build 9600) as the operating system. As mentioned previously, after data was observation then the calculation flight distance, flight time and block fuel must be done. Thus, in Table 1 and 2 show the result of flight distance as follows:

Table 1. Flight Distance of B737-400 for each Track

Flight Profile	Distance (nm)				
	Track I	Track II	Track III	Track IV	Track V
Climb	56	26	101	104	104
Descent	51	67	149	161	155
Cruise	461	468	351	315	321
Trip	569	561	601	580	580
Actual B737-400	569	561	601	580	580
Different	0	0	0	0	0

Table 2. Flight Distance of A320-200 for each Track

Flight Profile	Distance (nm)				
	Track I	Track II	Track III	Track IV	Track V
Climb	65	26	101	92	92
Descent	58	67	149	134	130
Cruise	446	468	351	354	359
Trip	569	561	601	580	580
Actual B737-400	569	561	601	580	580
Different	0	0	0	0	0

As can be seen from Table 1 and 2, Flight Distance of airplane B737-400 and A320-200 for each Track show that there is no different trip and actual data from both airplanes. Afterward, Table 3 and 4, show the flight time from Jakarta to Denpasar for each track where Track II is the smallest flight time value 82 minutes (10 minutes less than the actual data), while the flight time of Track III is the largest flight time value 97 minutes (16 minutes less than the actual data).

Table 3. Flight time of B737-400 for each Track

Flight Profile	Time (min)				
	Track I	Track II	Track III	Track IV	Track V
Climb	9.00	4.08	16.20	16.86	16.86
Descent	10.38	13.48	32.03	34.00	34.00
Cruise	64.39	64.69	49.12	44.20	45.24
Trip	84	82	97	95	96
Actual B737-400	94	92	113	104	106
Different	10	10	16	9	10
In (%)	11%	11%	14%	9%	9%

Table 4. Flight time A320-200 For each Track

Flight Profile	Time (min)				
	Track I	Track II	Track III	Track IV	Track V
Climb	10.38	4.08	16.20	14.87	14.87
Descent	11.74	13.48	32.03	28.40	28.40
Cruise	62.25	64.69	49.12	49.74	50.62
Trip	84	82	97	93	94
Actual B737-400	94	92	113	104	106
Different	10	10	16	11	12
In (%)	10%	11%	14%	11%	11%

As noted above, the flight time shows that Track II is the track with the smallest flight time and Track III is the track with the largest flight time. Furthermore, in Table 5 and 6 show the result of Block Fuel as follows:

Table 5. Block Fuel of B737-400 for each Track

Flight Profile	Fuel (kg)				
	Track I	Track II	Track III	Track IV	Track V
Climb	603	273	1533	1535	1535
Descent	111	144	352	373	373
Cruise	2820	2833	2098	1893	1934
Trip	3535	3251	3983	3801	3842
Block	5618	5334	6066	5884	5925
Actual B737-400	4836	4099	5445	4305	4795
Different	1301	848	1462	504	953
In (%)	27%	21%	27%	12%	20%

From Table 5 and Figure 4 below, it can be seen the number of Block Fuel of each track where the track with the Block Fuel of Track II for B737-400 aircraft type is the smallest, i.e. 5334 kg (848 kg less than the actual data);

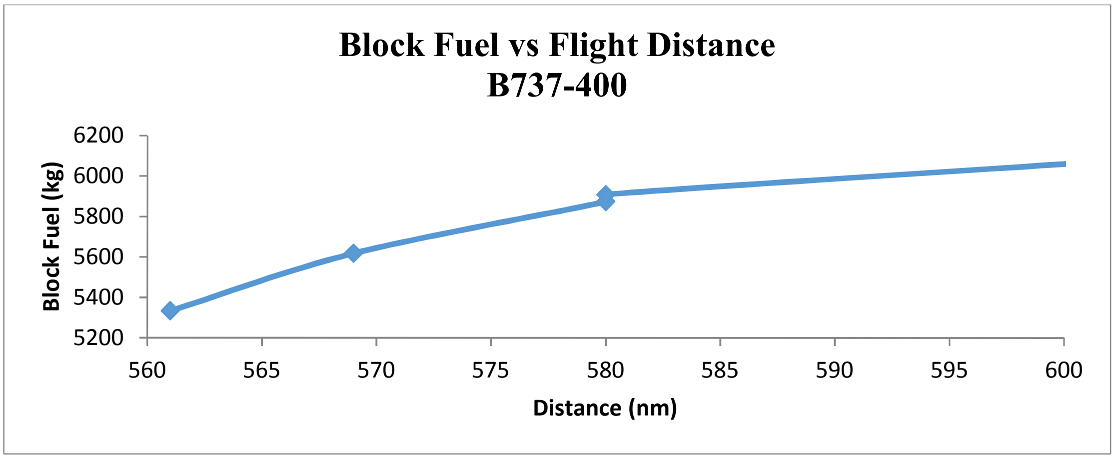

Figure 4. Block Fuel Vs Flight Distance of B737-400

Table 6. Block Fuel of A320-200for each Track

Flight Profile	Fuel (kg)				
	Track I	Track II	Track III	Track IV	Track V
Climb	696	241	1356	1199	1199
Descent	112	128	312	276	276
Cruise	2415	2510	1859	1881	1912
Trip	3223	2879	3526	3356	3387
Block	5306	4962	5609	5439	5470
Actual B737-400	4836	4099	5445	4305	4795
Different	1613	1220	1919	949	1408
In (%)	33%	30%	35%	22%	29%

From Table 6 and Figure 5 below show the smallest Block Fuel for A320-200 aircraft type is 4962 kg while Block Fuel of Track III is the largest for B737-400 aircraft type, i.e.6066 kg (1462 kg less than the actual data) and the largest Block Fuel for A320-200 aircraft type is 5609 kg.

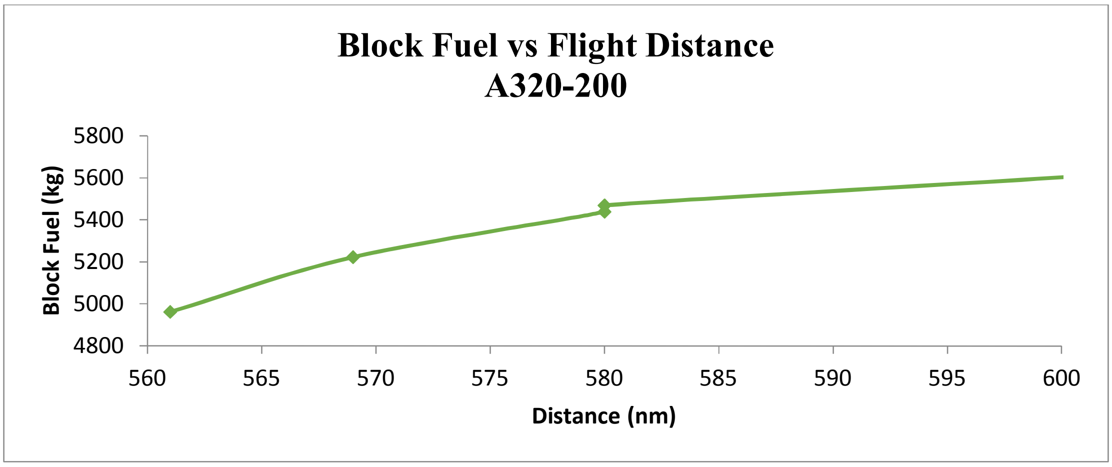

Figure 5. Block Fuel Vs Flight Distance of A320-200

The comparison of Block Fuel between aircraft types of B737-400 and A320-200 that it can be seen in the following table:

Table 7. The difference calculation results for Block Fuels of B737-400 and A320-200

Flight Profile	Fuel (kg) B737-400 minus by Fuel (kg) A320-200				
	Track I	Track II	Track III	Track IV	Track V
Climb	-10	69	379	336	336
Descent	0	38	112	97	97
Cruise	405	241	-16	12	22
Trip	395	349	475	445	455
Block	395	349	475	445	455
Block B737-400	4836	4099	5445	4305	4795
Different	8%	9%	9%	10%	9%

The result shows in Table 7 that the A320-200 aircraft type is more efficient fuel than the B737-400 aircraft type, approximately 8-10% smaller.

4. Conclusion and Future Work

This paper has introduced the comparison between two aircraft types Boeing 737-400 and Airbus 320-200 based on block fuel for each track from Jakarta-Denpasar. The result showing that, In corresponding to actual data of the available flight plan and the calculation results and discussion on the block fuel for each track and aircraft types of B737-400 and A320-200, it can be concluded that the Track II is the track with the smallest Block Fuel, it is 5334 kg (848 kg less than the actual data); and the smallest Block Fuel for A320-200 aircraft type is 4962 kg, while the largest Block Fuel of Track III is 6066 kg (1462 smaller kg compared to the actual data); and the largest Block Fuel for A320-200 aircraft type is 5609 kg.

The main conclusions are that Track II is the track with the smallest flight time, it is 82 minutes (10 minutes less than the actual data), while the flight time of the Track III is the track with the largest flight time, i.e. 97 minutes (16 minutes less than the actual data). Block Fuel of B737-400 (results of count) proved to be 12-27% less fuel than the B737-400 Block Fuel of actual data at available flight plan. This gives the meaning that the results of calculations (which actually applies to new aircraft) is more fuel efficient than the actual data (aircraft that have been used). Block Fuel of A320-200 (new aircraft) is smaller than the 8-10% Block Fuel of B737-400 (new aircraft). This gives meaning that the A320-200 aircraft type is more fuel efficient.

By this reasoning, our work can contribute to practice in decision making due to selecting appropriate aircraft and the track in the flight plan based on the block fuel consumption. This paper has the limitation that we have only studied one route from Jakarta-Denpasar, which in further open new lines of research.

Acknowledgement

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