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A Comparative Study on Commercial Aircraft Gliding Performance

Naufal Wafifauzan Efendi[1], Mufti Arifin[2], Muhamad Jayadi[3*]
[1,2,3] Aeronautical Engineering, Universitas Dirgantara Marsekal Suryadarma

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ABSTRACT

Aerodynamic principles are crucial for improving both efficiency and safety in commercial aircraft operations. This study compares three gliding strategies: (1) iterative calculation at a fixed 3° glide angle, (2) analysis of actual flight data from FlightRadar24, and (3) aerodynamic optimization using the drag polar method. The iterative approach produced relatively low descent rates 4.6–5.5 m/s and the longest glide times 1,100–1,323 s, offering safety benefits by enabling aircraft to reach more distant landing sites during emergencies. Actual flight data showed wider variations in descent rates 4.8–17.88 m/s and glide times 340–1,270 s due to operational requirements and ATC instructions. In contrast, aerodynamic optimization identified an ideal glide angle of 3.1°–4.1°, with higher descent rates 10.56–16.65 m/s but shorter glide times 366–577 s, representing the most efficient aerodynamic condition at maximum lift-to-drag ratio. Comparative analysis revealed that optimization median 512 s and actual data median 590 s yield greater aerodynamic efficiency, while the 3° fixed-angle approach median 1,186 s enhances safety margins. These results emphasize that glide strategy selection must balance efficiency and safety, integrating aerodynamic analysis with real operational data to support decision-making in commercial aviation.

Correspondence Author:
Muhamad Jayadi
Email: *jayadi@unsurya.ac.id*

INTRODUCTION

The aviation industry continues to advance in aerodynamics, materials, and propulsion technology to improve safety, efficiency, and sustainability [1]. For airlines, fuel efficiency is a key factor in reducing operational costs, which drives the adoption of aircraft with optimized wing designs, lightweight structures, and modern engines. These innovations not only support profitability but also align with global sustainability goals by lowering emissions.

An important aspect of aircraft efficiency is its gliding capability, which directly affects both safety and fuel management. Gliding refers to an aircraft's ability to sustain flight without engine power, such as in cases of fuel exhaustion or engine failure. Understanding glide performance enables pilots to identify safe landing options during emergencies while also contributing to overall operational efficiency [2], [3].

This study compares the glide performance of commercial aircraft using three approaches: (1) iterative calculation at a fixed 3° glide angle, (2) analysis of actual flight data from the FlightRadar24 application, and (3) aerodynamic optimization based on the drag polar method. The comparison aims to highlight differences between theoretical calculations and real-world performance, providing insights into strategies that balance efficiency and safety in commercial aviation.

METHODS

This research was conducted through several methodological stages, as illustrated in the flowchart in Figure 2.1. The first stage was the collection of aircraft technical specification information, with primary data obtained from scientific literature and the Aircraft Maintenance Manual (AMM) of several commercial aircraft operating in Indonesia. The main variables collected included aircraft type, empty weight, payload capacity, fuel weight (with 10% of the maximum fuel capacity considered for the glide calculation), wing area (S), drag coefficient at zero lift (Cd_0), and induced drag factor (k). These variables were essential to determine the aerodynamic performance of each aircraft and were compiled based on available references. The next stage involved the collection of aerodynamic data, which served as the foundation for the performance calculations.

Once the data was gathered, glide performance was calculated using aerodynamic equations outlined in the theoretical foundation. The calculations incorporated the values of wing area, Cd_0, and induced drag factor, as well as assumptions about aircraft mass and fuel load. The results of the computation were then verified by evaluating whether all aspects of glide performance had been covered. If any gaps or inconsistencies were found, the calculation process was repeated to ensure completeness and accuracy. Only when all criteria were satisfied did the study proceed to the analysis stage, where comparisons between different aircraft types were made.

Several assumptions and limitations were also applied to simplify the analysis. The glide analysis was carried out for a descent from 30,000 ft to 10,000 ft, corresponding to a vertical distance of 6,096 meters. Air density was assumed to correspond to the condition at 20,000 ft, while the effect of ambient temperature was neglected. The configuration of all aircraft was assumed to be clean (no extended flaps, slats, or landing gear), with Cd_0 values reflecting this condition. For operational validation, descent data from Flightradar24 was utilized, specifically covering aircraft trajectories during descent from 30,000 ft. Data sampling was carried out on June 20, 2025, with flights selected according to consistency in altitude profile and availability of complete data records. However, the analysis did not account for environmental disturbances such as wind speed, turbulence, or weather conditions that could influence glide characteristics. Fuel load was fixed at 10% of maximum capacity, with no adjustment for weight reduction due to fuel burn during the glide phase. Finally, the analysis results were presented in the form of graphs to provide a clear visual comparison between aircraft types, followed by interpretation and conclusion drawing in the final stage of the research.

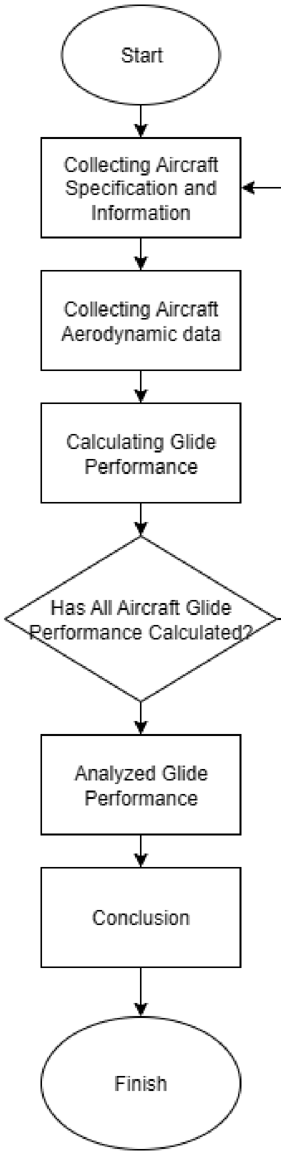

Figure 2.1 Flow Chart

2.1. Commercial Aircraft Specification

Table 2.1 Commercial Aircraft Specification [6 - 16]

Aircraft Type	Empty Weight (Kg)	Payload (Kg)	Fuel (kg)	Fuel 10% Weight (Kg)	S (m^2)	Cd0	k
B737-400	34820	18260	16080	1608	105,4	0,021	0,0372
B737-800	41413	20275	20819,2	2081,92	125	0,021	0,0365
B737-900	44677	20240	20820	2082	125	0,024	0,0365
B777-200	138100	95254	136940,8	13694,08	427,8	0,033	0,0396
B777-300ER	167800	168781	145031,2	14503,12	427,8	0,033	0,0396
A320	42600	16601	23877,6	2387,76	122,6	0,023	0,0334
A330-200	127000	48987	111363,2	11136,32	363,1	0,024	0,0343
A330-300	122000	55000	87200	8720	363,1	0,026	0,0344
A350-900	175000	53523	112653,6	11265,36	442	0,027	0,0364
B787-8	120000	41050	100964	10096,4	325	0,022	0,0361

2.2 Calculation Method

2.2.1 Iterative Calculation Method with a 3-Degree Angle

The iterative method in this research is used to determine the appropriate drag-to-lift ratio (Cd/Cl) value for a specific glide angle, namely 3°. The principle is that an iteration process is carried out by repeatedly changing the value of the Rate of Descent (RoD) until the Cd/Cl ratio approaches the target value, which is tan(θ). With a glide angle θ = 3°, the target Cd/Cl ratio value can be calculated as:

$$\frac{Cd}{Cl} \approx Tan\,(3°)$$

The iterative process is performed by guessing an initial RoD value, then calculating the glide velocity (V), lift coefficient (Cl), and drag coefficient (Cd). The calculated Cd/Cl result is compared to the target value. If a discrepancy exists, the RoD value is adjusted again until a Cd/Cl value close to that for a 3° angle is obtained [18].

Using this approach, values for RoD, glide velocity (V), glide time (t), and other aerodynamic parameters are obtained consistently for the specified glide angle.

2.2.2 Calculation Using Actual Data from the Flightradar24 Software

This method utilizes actual data from commercial flights obtained through the Flightradar24 application. The data used includes the aircraft's speed, altitude, and flight path during the glide phase. This data is then processed to calculate the Rate of Descent (RoD) and glide time at an angle close to 3°. This analysis reflects real-world operational conditions, allowing it to be compared with the results from theoretical calculations [19].

2.2.3 Aerodynamic Optimization Calculation

Aerodynamic optimization using drag polar aims to achieve an ideal balance between lift and drag forces on a flying object, such as an aircraft or a wing. The drag polar itself is the relationship between the drag coefficient (Cd) and the lift coefficient (Cl), commonly expressed by an equation where Cd_0 represents the parasite drag and $k \cdot Cl^2$ represents the induced drag resulting from lift generation. The optimization process is carried out by finding the Cl value that yields the maximum lift-to-drag ratio (L/D), as the aerodynamic performance is at its most efficient condition at this point [17].

Equation

In this study, the analysis was carried out using several fundamental aerodynamic equations that are widely applied in aeronautical engineering. The following equations were used to analyze aircraft gliding performance:

1. Lift Coefficient (Cl)

   The lift coefficient (Cl) describes the amount of lift generated by a surface in response to airflow. It is a primary factor in determining whether an aircraft can fly stably [4].

$$Cl = \frac{2W}{\rho V^2 S} \tag{2.1}$$

2. Drag Coefficient (Cd)

   The drag coefficient (Cd) represents the aerodynamic drag experienced by the aircraft, consisting of parasite drag (Cd0) and induced drag [4].

$$Cd = Cd_0 + k\,.\,Cl^2 \tag{2.2}$$

Where k is a factor describing the influence of wing aspect ratio and lift distribution. As Cl increases, induced drag also increases. Therefore, aircraft design seeks an optimal balance between lift and drag [5].

3. Groundspeed (V)
Groundspeed is the speed of the aircraft relative to the ground, influenced not only by airspeed but also by the glide angle (θ) [5].

$$V = \frac{RoD}{Sin\,\theta} \quad (2.3)$$

4. Rate of Descent (RoD)
The Rate of Descent (RoD) is the vertical speed of descent, affected by aircraft speed and descent angle [5].

$$RoD = V \sin\theta \quad (2.4)$$

5. Descent Time (t)
Descent time is the duration required for an aircraft to descend between altitudes [7].

$$t = \frac{h}{RoD} \quad (2.5)$$

6. Descent Angle (θ)
The descent angle is the angle formed between the glide path and the horizontal line.

$$\theta = tan^{-1}(\frac{Cd}{Cl}) \quad (2.6)$$

7. Cd/Cl Ratio
The Cd-to-Cl ratio is an indicator of aerodynamic efficiency. The smaller the Cd/Cl value, the more efficient the aircraft is in generating lift with minimal drag [7].

$$\frac{cd}{cl} = \tan\theta \quad (2.7)$$

RESULT AND DISCUSSION

3.1 Iterative Calculation using a 3-Degree Angle

Based on the calculation process, the results obtained in the table can be explained as follows: each aircraft has a different drag-to-lift ratio (Cd/Cl), gliding speed (V), rate of descent (RoD), and gliding time (t), depending on the aircraft's weight, wing area, and aerodynamic characteristics (such as C_d0 and the k factor). All aircraft in the list are assumed to be gliding from an altitude of 30,000 feet to 10,000 feet (equivalent to 6,096 meters) with a constant glide angle of 3 degrees. The initial cd/cl value was calculated using tan(3°) ≈ 0.05241, then optimized using goal seek to obtain the actual cd/cl value that results in the minimum gliding time.

The Boeing 737-400 has a gliding time of approximately 1,107 seconds (±18.45 minutes) with a gliding speed of about 105.2 m/s, a goal seek cd/cl value of 0.05253, and an angle of 3.01 degrees.

The Boeing 777-200, as a wide-body aircraft, has a longer gliding time of approximately 1,323 seconds (±22 minutes), with a gliding speed of 88 m/s and a higher goal seek Cd/Cl value of 0.05476, indicating the influence of the aircraft's size and weight on its efficiency.

The Airbus A320 shows a gliding time of 1,192 seconds (±19.9 minutes), slightly more efficient compared to larger wide-body aircraft despite its lower speed (±97.7 m/s), due to its more optimal wing area and cd/cl ratio.

It can be concluded that smaller and lighter aircraft generally have shorter and more efficient gliding times, although their gliding speeds are not always higher. Aerodynamic efficiency is highly influenced by aircraft design, the drag-to-lift ratio, and the wing area relative to its weight. These results are important for energy planning and fuel efficiency during the gliding phase of a flight. The calculation results for other aircraft can be seen in Table 3.1 as follows:

Table 3.1 Iterative Calculation Result

Aircraft Type	Cd/Cl goalseek	Cd	Cl	V (m/s)	RoD (m/s)	t (s)	θ
B737-400	0,052530888	0,071	1,369	105,19	5,505	1107,267	3,00
B737-800	0,051293291	0,072	1,419562	102,46	5,362	1136,78	2,936
B737-900	0,051425394	0,082	1,607	98,680	5,164	1180,363	2,943
B777-200	0,054761592	0,119	2,176	88,039	4,607	1323,019	3,131
B777-300ER	0,054351517	0,121	2,237	103,52	5,418	1125,137	3,111
A320	0,048355737	0,074	1,537	97,687	5,112	1192,357	2,768
A330-200	0,049277686	0,078	1,602	96,930	5,072	1201,668	2,821
A330-300	0,049473848	0,085	1,724	93,075	4,871	1251,441	2,832
A350-900	0,051453136	0,092	1,793	93,999	4,919	1239,132	2,945
B787-8	0,050918545	0,075	1,484	101,795	5,327	1144,243	2,914

3.2 Calculation of Actual Data Flightradar24

This calculation aims to determine the glide performance of commercial aircraft from an altitude of 30,000 feet to 10,000 feet, based on actual speed (V) and rate of descent (RoD) data observed via FlightRadar24. Unlike the previous theoretical approach which used Goal Seek to optimize the Cd/Cl ratio, this study takes the V and RoD values directly from observations of real flights for aerodynamic analysis.

The results displayed in the table show that wide-body aircraft like the Boeing 777-300ER and Airbus A330-200 have higher RoD values, at 16.65 m/s and 13.08 m/s respectively. This reflects their ability to descend more rapidly due to their greater mass and higher cruising speeds. Conversely, narrow-body aircraft like the B737-400 and A320 have lower RoD values, at 10.97 m/s and 10.56 m/s respectively, indicating a shallower and slower descent. The descent time (t) varies from approximately 366 seconds (6.1 minutes) to 577 seconds (9.6 minutes), depending on the aircraft's aerodynamic efficiency and horizontal speed. Meanwhile, the average glide angle falls within a range of 3.1° to 4.1°, where a larger value signifies a steeper descent.

Table 3.2 Calculation of Actual Data Flightradar24 Result

Aircraft Type	Cd/Cl	Cd	Cl	V (m/s)	RoD (m/s)	t	θ
B737-400	0,0906	0,0356	0,3929	196,5	17,88	340,939	5,1791
B737-800	0,1059	0,0320	0,3021	222,2	13	468,923	6,050
B737-900	0,0949	0,0389	0,4105	195,4	8,4	725,714	5,4246
B777-200	0,1185	0,0495	0,4180	201	9,7	628,453	6,7607
B777-300ER	0,1129	0,0508	0,4501	230,9	11,05	551,674	6,4419
A320	0,0903	0,0364	0,4035	190,8	13,6	448,235	5,1652
A330-200	0,1173	0,0339	0,2888	228,4	4,8	1270	6,694
A330-300	0,0913	0,0417	0,4565	181	7,1	858,591	5,219
A350-900	0,0943	0,0439	0,4655	184,6	9,7	628,453	5,392
B787-8	0,1081	0,0330	0,3052	224,6	15,2	401,052	6,173

3.3 Aerodynamic Optimized Calculation

This calculation aims to determine the performance of commercial aircraft during the descent (glide) phase from an altitude of 30,000 feet to 10,000 feet, using an approach based on optimized aerodynamic data and actual speed (V) obtained from the flight tracking application FlightRadar24. The calculation is performed by considering the optimized lift coefficient (Cl), optimized drag coefficient (Cd), and the lift-to-drag ratio (Cd/Cl) to determine the glide angle (θ), rate of descent (RoD), and glide time (t). Unlike previous approaches that assumed a fixed angle (e.g., 3°), this calculation derives the glide angle based on the aircraft's actual aerodynamic characteristics, making the results more representative of real-world aircraft performance.

The results displayed in the table show that wide-body aircraft such as the Boeing 777-300ER and Airbus A330-200 have higher RoD values, at 16.65 m/s and 13.08 m/s respectively. This reflects their ability to descend more rapidly due to their greater mass and higher cruising speeds. Conversely, narrow-body aircraft like the B737-400 and A320 have lower RoD values, at 10.97 m/s and 10.56 m/s respectively, indicating a shallower and slower descent. The descent time (t) varies from approximately 366 seconds (6.1 minutes) to 577 seconds (9.6 minutes), depending on the aircraft's aerodynamic efficiency and horizontal speed. Meanwhile, the average glide angle falls within a range of 3.1° to 4.1°, where a larger value signifies a steeper descent

Table 3.3 Aerodynamic Optimized Calculation Result

Aircraft Type	Cl	Cd	V FR (m/s)	Rod (m/s)	t (s)	cd/Cl	θ
B737-400	0,751	0,042	196,5	10,967	555,838	0,0559	3,199
B737-800	0,759	0,042	222,2	12,285	496,226	0,0554	3,169
B737-900	0,811	0,048	195,4	11,546	527,956	0,0592	3,388
B777-200	0,913	0,066	201	14,494	420,577	0,0723	4,135
B777-300ER	0,913	0,066	230,9	16,650	366,115	0,0723	4,135
A320	0,830	0,046	190,8	10,560	577,252	0,0554	3,173
A330-200	0,836	0,048	228,4	13,085	465,886	0,0574	3,284
A330-300	0,869	0,052	181	10,807	564,086	0,0598	3,423
A350-900	0,861	0,054	184,6	11,552	527,718	0,0627	3,588
B787-8	0,781	0,044	224,6	12,639	482,313	0,0564	3,226

3.4 Calculation Analyzed

3.4.1. RoD vs. V Between Methods

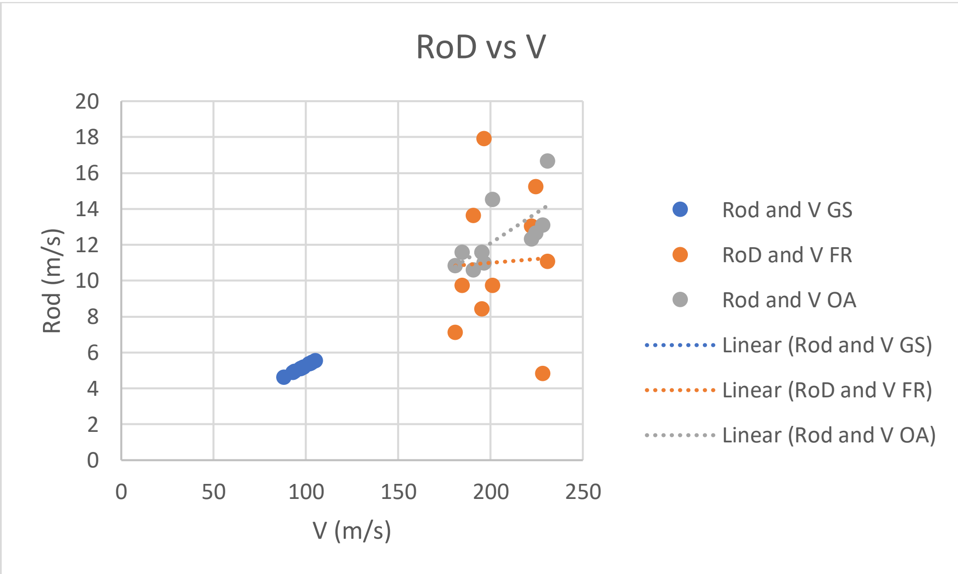

Figure 3.1 Graph RoD vs V between Method

The graph above illustrates the relationship between the Rate of Descent (RoD) and flight velocity (V) using three distinct calculation methods or approaches: GS (Goal Seek), FR (FlightRadar24), and OA (Aerodynamic Optimization). The horizontal axis (X) represents the ground speed in meters per second (m/s), while the vertical axis (Y) shows the RoD in m/s.

From the graph, it can be observed that the GS RoD vs. V data (blue) exhibits lower velocity values, approximately in the range of 90–110 m/s, with a relatively stable RoD hovering around 5 m/s.

This indicates flight conditions at low speed with minimal variation in RoD. In contrast, the FR (orange) and OA (gray) data show significantly higher velocities, ranging between 170–240 m/s, along with greater variation in RoD, spanning from 4 to 18 m/s.

This graph demonstrates how the data collection method or analytical approach influences the interpretation of the relationship between velocity and RoD. The OA method displays the most consistent trend, showing a clear correlation between increased velocity and increased RoD. Meanwhile, the FR method exhibits irregular scattering, likely due to real-world flight data being influenced by various external factors such as air traffic control instructions, weather conditions, and pilot actions.

3.4.2. Glide Time (t) between Method Graph

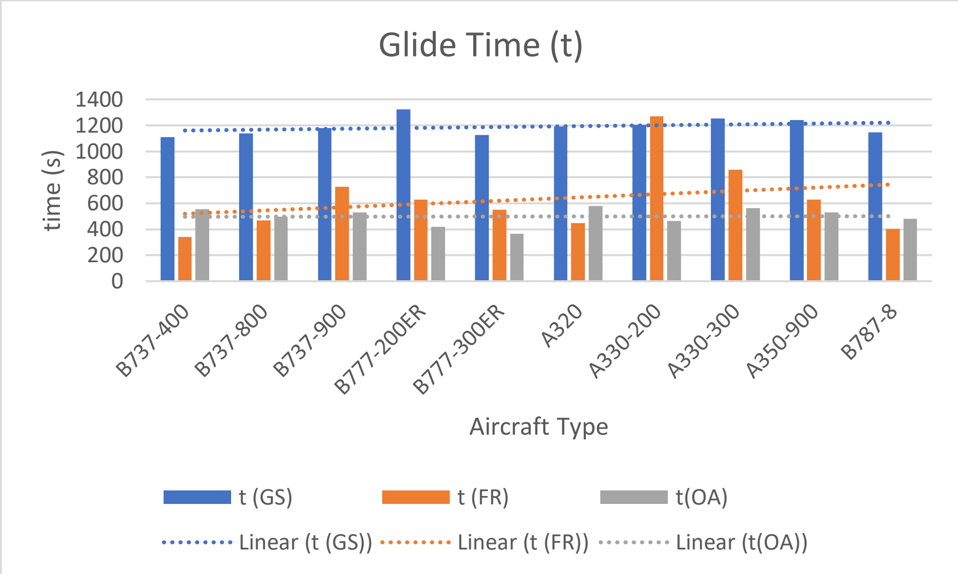

Figure 3.2 Descent Time (t) between Method Graph

The graph above compares the glide time (t) of various aircraft types based on three calculation approaches: GS (Goal Seek), FR (FlightRadar24), and OA (Aerodynamic Optimization). The vertical axis represents time in seconds (s), while the horizontal axis lists the different aircraft types, from the B737-400 to the B787-8. From this graph, it can be observed that the descent time based on the GS method (blue) is consistently the highest for all aircraft types. This indicates that the Goal Seek (GS) method estimates a longer glide time, as it does not fully reflect the actual vertical velocity during real-world operations. The FR method (orange), which uses data from FlightRadar24, tends to yield lower descent times compared to GS, but the results vary significantly between aircraft. For some aircraft, such as the A330-200, the FR time is even higher than the GS estimate, which may indicate variations in actual operational data due to external factors. The OA method (gray), based on aerodynamic optimization calculations, results in the shortest and most consistent descent times across almost all aircraft types. This demonstrates that under assumed optimal performance conditions, an aircraft can complete the glide process more quickly and efficiently.

3.4.3. Glide Angle Between Method

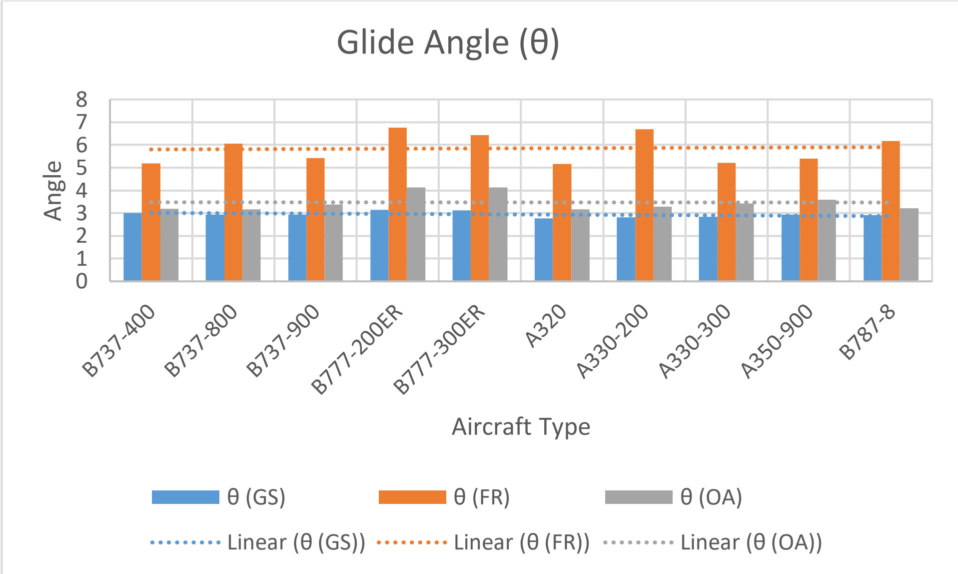

Figure 3.3 Glide Angle between Method

The vertical axis represents the angle magnitude in degrees, while the horizontal axis lists various aircraft types, from the B737-400 to the B787-8. The dashed lines indicate the linear trend for each respective method. The GS (Goal Seek) method exhibits lower and more consistent glide angles, consistently around 3°. This is a direct result of the flight angle being pre-defined as 3 degrees in its calculation assumption. The FR (FlightRadar24) method shows the highest glide angles, ranging between approximately 6°–7.5°, with a slightly increasing linear trend. This indicates that in actual flight conditions, aircraft maintain a steeper glide angle. This is likely due to the influence of external factors such as wind conditions, pilot maneuvers, or other specific operational requirements. Meanwhile, the OA (Aerodynamic Optimization) method shows angles that fall between the GS and FR values, approximately 4°–5°, and are also relatively stable. This signifies that the glide angles derived from the optimization calculations reside within a theoretically efficient and ideal range.

3.4.4. Calculation Result Comparison between Method

Tabel 3.4 Calculation Result Comparison between Method

Method	RoD (m/s)	Time (s)	Angle
3 Degree Angle Iterative	4,6-5,5	1100-1323	3
Actual Data Flightradar24	4,8-17,88	340-1270	5,1-6,7
Aerodynamic Optimization	10,56-16,65	366-577	3,1-4,1

The comparison results in Table 3.4 show that the 3-degree angle iteration method yields an RoD in the range of 4.6–5.5 m/s, with a glide time of 1100–1323 seconds at a fixed angle of 3°. The actual data from Flightradar24 shows a wider range of RoD, specifically 4.8–17.88 m/s, with a glide time of 340–1270 seconds and glide angles between 5.1–6.7°. Meanwhile, the aerodynamic optimization method produces RoD range of 10.56–16.65 m/s, with a significantly shorter glide time of 366–577 seconds and a shallower glide angle range of 3.1–4.1°.

3.4.5. Calculation Result Median Comparison between Method

Table 3.5 Calculation Result Median Comparison between Method

Meethod	RoD Median (m/s)	Time Median (s)	Angle Median
3 Degree Angle iterrative	5,139	1186,36	3
Actual Data Flightradar24	10,375	590,064	5,738
Aerodynamic Optimization	11,918	511,972	3,336

Table 3.5 shows that the lowest RoD (5.14 m/s) and the longest glide time (1186 s) were obtained from the fixed 3-degree angle iteration method. Conversely, the highest RoD (11.9 m/s) with the shortest time (512 s) was produced by the aerodynamic optimization method at an angle of approximately 3.3°.

CONCLUSION

The comparison of various glide strategies shows that the strategies with the fastest glide times—namely the aerodynamic optimization approach (median time 512 s) and actual flight data (median time 590 s)—provide higher aerodynamic efficiency. However, the strategy that results in a longer glide time, such as the fixed 3-degree angle iteration approach (median time 1186 s), offers a distinct advantage from a safety perspective. With a shallower glide angle and a longer duration, the aircraft has a greater opportunity to reach a safe landing area in emergency situations, such as a loss of thrust or engine failure. Therefore, the selection of an ideal glide strategy must consider a balance between operational efficiency and safety, depending on the specific situation and the requirements of the flight.

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