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A Study on Pilots' Behavior on Decision of Maneuvering Aircraft for Fuel Efficient Flight Operation

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ABSTRACT

The response to climate change of international air transport industry might be initiated by ICAO's CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) which will impact on international airlines' flight operation behavior in the future. Though the airlines' efforts to reduce fuel consumption has been a major issue in economics of aviation industry, the improvement of fuel efficiency in flight operation will have additional impact on their profitability by introducing carbon emission cost. The fuel consumption in flight operation will be somewhat influenced by pilots' technical action for maneuvering aircraft during flight operation. This study will investigate pilots' behavior on decision for tactical aircraft control for mission flight. The data will be collected by the survey through sample pilots asking about their intention and perception on fuel savings during flight operations. The data will be analyzed by AHP process and the study will find out the elements and factors influencing pilots' behavior on technical decision of flight and their weights on fuel saving effects.

Key Words : Fuel Savings(연료절감), Flight Operation(항공운항), AHP(계층분석), Climate Change(기후변화)

Ⅰ. Introduction

The international airlines needs to take more enhanced efforts to reduce CO_2 emission from near future because the implementation of CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) will force airlines to offset the overflow of the CO_2 emission than target volume. Though the airlines' efforts to reduce fuel consumption has been a major issue in economics of aviation industry, the improvement of fuel efficiency in flight operation will have additional impact on their profitability by introducing carbon emission cost. The airlines can consider various factors to minimize carbon emission or fuel savings in flight operation. As broad and essential strategies, they may reconsider the way of fleet management and flight planning, and network improvement. As concrete operational actions, they may also try to change the manners and processes associated to flight operation. This study focuses on flight operational actions related to fuel savings. Even though there are

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many measures for flight fuel savings, the critical actors for the implementation of fuel performance are pilots of the aircraft, and the fuel consumption in flight operation will be somewhat influenced by pilots' technical action for maneuvering aircraft during flight operation.

The purpose of the research is to investigate airline pilots' behavior on decision for maneuvering aircraft during flight operation. Especially, their attitude to environmental protection or climate change by saving fuel consumption will be closely studied. At first, the study will investigate the factors influencing pilots' decision for aircraft control during their mission flights through the survey of the opinion of experienced airline pilots. Once the factors are identified, Analytical Hierarchy Process (AHP) is applied to estimate the weight of each factor with the data gathered by questionnaire survey through airline pilots.

The one of easy and effective way is to encourage pilots to operate aircraft more efficient and fuel saving manner. This study may contribute on understanding pilots attitude and can help to find the way to motivate the pilots for efficient flight. The airlines may improve the way of pilots resource management by the results of dichotomous analysis.

II. Literature Review and Background Knowledge

2.1 Background Knowledge Related to the Study

It is necessary to understand the situation of aircraft control decision related to fuel efficient operation by pilots. As well known in aviation industry, the flight operation needs to be conducted under strict safety regulations. The safety regulations are usually not compatible with fuel efficient flight operations. However, the airlines are very sensitive in fuel savings in flight operations because the cost of fuel is the one of major cost items in airline operation. Fluctuating fuel price and supply, ever increasing financial competition and emerging worldwide environmental consciousness have forced most airlines to develop some type of fuel management program for their operations. (IATA, 2011).

The response to climate change of airline industry, like the CORSIA has become additional driver for fuel savings in the industry. Min and Kim (2011) emphasizes that we need to introduce aggressive incentive for reducing fuel consumption and GHG reduction. Yoon et al (2019) assert that the total amount of emission all the airlines made in the last three years was 116% more than the emission allowance imposed by the central government resulting in 10.7 billion KRW additional emission expense. They also found that to reduce the emission, airlines are washing engines, using ultra-light ULD and carts in the cabin, increasing the use of flaps and preventing the use of APU.

The pilots in airlines are key personnels in fuel efficient flight operations. However, they are traditionally more aware for safety than efficiency in flight. Therefore, it is necessary certain kind of incentive for pilots to conduct fuel efficient operation. According to the survey through airlines pilot of this research, there are only 4.6% of airlines pilots, who recognize their airlines provide obvious incentive to the pilots who achieves fuel efficient flight operations.

2.2 The Role of Flight Crews in Fuel Efficiency

ICAO recognizes the potential of fuel burn reduction in decisions made by flight crew in its Circular 303 AN/176 document. The flight crew can decide whether to opt for safety or efficiency.

Two areas for fuel efficiency improvements that involve flight crew decisions before flight are mentioned in Circular 303 AN/176. One possible decision that flight crew can take part in is the reduction of discretionary fuel.

The second area for potential improvement in efficiency by flight crew is in the decision of flight altitude and speed in accordance with the freezing point of fuel. In the take-off and climb stage, flight crew can decide whether to use full thrust or less thrust to get airborne and climb to cruise altitude. While derated and reduced take-offs can increase fuel consumption, it can significantly reduce engine wear and NOx emissions can also be reduced.

In the landing phase, flight crew can decide whether to reduce speed with reverse thrust and brakes or brakes only. According to Boeing, a 747 could save 65 kg to 70 kg of fuel by stopping using the brakes only.

IATA also provides guidance material to airlines for reducing fuel burn. In it's Guidance Material and Best Practices for Fuel and Environmental Management, IATA emphasizes the importance of timely, accurate and accessible advanced flight planning data for flight crew. This is especially so for flight crews preparing for flight out of an airport other than the airline's home base where access to data can be more limited. With less confidence in predicting flight conditions, flight crews can be motivated to make conservative decisions over decisions for improved efficiency.

IATA also notes the importance of minimizing fuel uplift for efficiency, but at the same time, emphasizes safety and risk management. Statistics show that the accurate flight planning systems used today allow contingency fuel to be usually left unused. The use of the flight management system (FMS) for pre-flight fuel calculations can also aid in more accurate prediction of fuel usage. During take-off, IATA recommends the use of reduced thrust and reduced flaps when possible. Reduced thrust take-off does not increase fuel efficiency, but lower engine temperature can significantly prolong the life of the engine. One percent reduction of thrust from full thrust at take off can result in ten percent increase of engine life as the most damage occurs at the highest few degrees. Reduced flap take-offs can result in significant fuel savings and improve second segment climb performance. Retracting flaps at lower altitudes can also reduce fuel burn as drag is reduced.

Constant monitoring and reporting of fuel burn during flight can provide higher levels of risk management and earlier decisions related to planned and estimated arrival times, flight profiles or unforeseen contingencies. Early estimation of arrival times can help in reducing holding time and plan more efficient flight paths and speeds.

During descent, the FMS will also manage an accurate and efficient descent profile unless irregular conditions arise. For accurate calculation of the descent profile by the FMS, wind information for the altitudes in the profile can be inserted. If this is not done, the FMS will assume wind profile based on constant decreasing wind level from winds at cruise level. Descent altitude and speed, or the energy of the aircraft, must be kept ideal to avoid alternating use of speed brakes and thrust.

Where conditions permit, implementation of constant descent operations (CDO) by airports can lead to significant fuel savings. CDO allow aircraft to continuously descend to the final approach fix on idle power and low drag without thrust or brake interruptions. CDO not only allow savings in fuel, but also on flight time and lowers noise levels while reducing workload of controllers and flight crew. Best in class airlines may utilize CDO wherever possible.

When landing, reduced flap landings can decrease fuel burn when the aircraft type and the runway length permit it. Reduced flap landings can reduce fuel burn, decrease noise and chemical emissions and improve safety margins in case a go-around is required.

Engine-out taxi-in procedure as a standard operational procedure (SOP) can reduce engine use and fuel consumption where conditions permit. Well designed engine-out taxi-in SOPs can encourage flight crew to use the process with minimal additional workload. While engine-out taxi-in can save fuel and brake wear, ground traffic conditions, taxi-in time, parking locations, local airport and airline regulations must be adequate.

Fuel efficiency schemes however, must be implemented with caution. Although flights generally carry fuel for contingencies, aggressive efficiency measures can lead to adverse effects of causing excessive inefficiencies and sometime lead to serious safety hazards. A report by Spanish Civil Aviation Accident and Incident Investigation Commission regarding an emergency landing due to low fuel on a Ryanair flight, states that Ryanair's fuel policy was found to be based specifically on minimizing fuel uplift for maximum efficiency. The investigation discovered that Ryanair aircraft frequently land with minimum landing fuel. The report states that if several aircraft with minimum fuel on board are forced to arrive at one airport, this could lead to a chain reaction of several simultaneous emergency landings due to insufficient fuel on board. Emergency landings are granted priority at the cost of delays to aircraft with fuel left over the final reserve level. Long holdings above the alternate airport can force these aircraft to consume additional fuel and possibly dip into final reserve fuel and in turn, declare another emergency (Civil Aviation Accident and Incident Investigation Commission (CIAIAC), 2010).

III. Research Methodologies and Procedures

Even though the aircraft operation for airlines is usually conducted considering safety and cost efficiency, we need to look for some other factors considered by pilots for their aircraft control during mission flight. Based on a few discussion with experienced airline pilots on the factors considered when they operate aircraft, the study selected four principle factors which can influence on pilots control decision for the aircraft operation; Safety, Fuel efficiency, On-time performance, and Comfort and convenience. The readers may generally understand the meanings of safety, fuel efficiency, and on-time performance in airlines' flight operation. The last factor, comfort and convenience means here pilot's accustomed habit or flight comfort for passengers and for themselves.

As mentioned earlier, this study will investigate pilots' behavior on decision for tactical aircraft control for mission flight. Since the pilots are concerned more safety than any other factors in their flight operations, and their behavior considering other factors may be differentiated by the phase of flight operations, the study tries to segment the whole flight operations by four phases; pre- flight planning & briefing, engine start-up and take-off, climb-cruise-descent, and approach-landing-engine shut-down. Following figure is to show the structure of pilots' behavior for aircraft control during their whole mission flight in airlines.

It is well known that the procedure and methods of flight operation have to follow the manual provided by aircraft manufacturer and standards given by regulations of the government or international aviation organization. However, there will be some specular actions required for specific situation and a pilot involved may choose a decision among alternatives of the actions. The study utilizes AHP (Analytical Hierarchy Process) to investigate pilots' decision on tactical control of the aircraft for their regular mission flight to transport passengers or cargo in airlines.

3.1 AHP Analysis with Comprehensive Factors

A structured technique introduced by Thomas Saaty (1970), named the Analytic Hierarchy Process (AHP), is an effective tool to handle complex decisions. it is based on maths and psychology and potentially allows the decision maker to make the best decision by allowing for better priorities. AHP also has a unique usage in group situations for multiple situations. It essentially assists in understanding of the problem and allows the decision makers to find a solution that is best suited for them. The AHP will provide an in-depth and a logical framework for organizing a problem, which allows to quantify its elements and to relate those elements to the end-goal, as well as to evaluate alternative solutions. By reducing complex decisions to a series of pairwise comparisons, and synthesizing the results, AHP can capture both qualitative and quantitative aspects of the decision. Finally the AHP also includes a useful techniques to ensure decision makers' consistency in assessments to reduce process biases.

We tried AHP analysis with four flight phases and four factors of flight control decision for AHP hierarchy structure. The Fig. 1 is the hierarchial structure of the analysis. The AHP questionnaire tries to find the relative importance of each phase of flight operation, in terms of pilots' decision power. The second level is to decide the importance of each factor for their flight decision during each of flight phase.

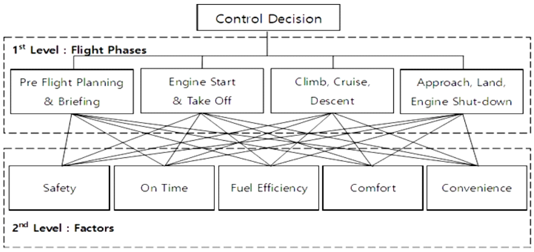

Fig. 1. Structure of control decision for pilots' flight operation

The data was collected by the survey through sample pilots. The respondents sampled from the airline pilots in South Korea. Following Table 1. is to show the characteristics of the sample pilots of the survey.

Table 1. Sampled respondents

Class		No. of Resp.
Sex	Male	94
	Female	3
Age	30s	11
	40s	39
	50s	35
	60s	12
Airline	FSC (Korea)	43
	LCC (Korea)	48
	Foreign airline	6
Flight time	~3,000	13
	3,001~5,000	16
	5,001~7,000	15
	7,001~10,000	28
	10,001~	25
Rank	Captain	78
	Co-Pilot	19

In the AHP analysis, the Consistency Index (CI) of the respondents is considered to be reliable when it is less than 0.10. As shown in Table 2, the level 1. CI value is 0.18, indicating low reliability. Level 2 CI values corresponding to Climb, Cruise, Descent, Approach, Land, and Engine Shut-down of Level 1 were slightly larger, indicating lower statistical effectiveness.

Respondents at Level 1 found that Pre Flight Planning & Briefing was the most important factor for fuel saving during the flight phase. At Level 2, all respondents were found to have an impact on aircraft operation. However, the reliability of the value is too low to insist the results.

Table 2. Weight of anticipated potential of fuel savings by phases of flight operation

Lv.1 (Wt.)	Lv.1 CI	Lv. 2 (Wt.)	Lv.2 CI
Pre flight planning & briefing (0.410)	CI / 0.18	Safety (0.603)	CI / 0.07
		On time (0.115)	
		Fuel efficiency (0.114)	
		Comfort (0.195)	
		Convenience (0.72)	
Engine start & take off (0.155)		Safety (0.39)	CI / 0.06
		On time (0.171)	
		Fuel efficiency (0.189)	
		Comfort (0.125)	
		Convenience (0.125)	
Climb, cruise, descent (0.179)		Safety (0.313)	CI / 0.12
		On time (0.213)	
		Fuel efficiency (0.129)	
		Comfort (0.155)	
		Convenience (0.190)	
Approach, land, engine shut-down (0.257)		Safety (0.367)	CI / 0.18
		On time (0.132)	
		Fuel efficiency (0.176)	
		Comfort (0.15)	
		Convenience (0.167)	

※ $(CI) = (\lambda max - n) / (n - 1)$

We experienced serious difficulties in getting consistent responses from sample pilots from the AHP questions formulated based on the hierarchy of the figure above. Because the questions which ask the importance of each phase or factor seemed vague to respondents. Especially, for the second level, the factor, "Safety" is so predominant that other factors are almost disregarded.

3.2 Refined Composition of the Hierarchy

Because the factor of 'Safety' is predominant to all other factors, the respondents might ignore other factors in AHP response, and the result of analysis has become inconsistant. So, we revised the hierarchy of the study based on the insight attained through the initial survey and additional discussions with airline pilots and managers in flight operation departments of commercial airlines.

Changes in expressions:

- "Control Decision" to "Flight Tactics for Fuel Savings".
- The question in the AHP questionnaire for the first level hierarchy: "what phase of flight operation do you feel is more contributable in improving fuel efficiency by pilots?".

For the second level we used specific flight decisions for each phase of flight operation based on pilots' interviews conducted for this study.

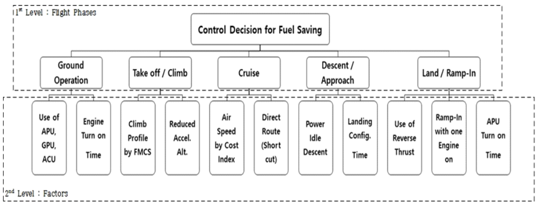

Fig. 2. Refined structure of control decision for fuel saving

IV. AHP Analysis Results

4.1 Data Characteristics and Statistical Significance

Survey on 24 national FSC and LCC pilots to discover in which phase efficiency improvements can be made.

Consistency Ratio (CR), representing the consistency for each level was smaller than 0.1 and the results of the AHP was considered acceptable.

Table 3. Refined weight of anticipated potential of fuel savings by phases of flight operation

Lv 1	Weight	Level 2	Weight
Ground opt	0.092	Use of APU, GPU, ACU	0.689
		Engine turn on time	0.311
Take off / climb	0.321	Climb profile by fmcs	0.565
		Reduced accel. altitude	0.435
Cruise	0.337	Air speed by cost index	0.230
		Direct route	0.770
Descent / app.	0.149	Power idle descent	0.459
		Landing config. time	0.541
Land / ramp-in	0.101	Use of reverse thrust	0.402
		Ramp-in with one engine	0.329
		APU turn on time	0.269

※ (CR) = (CI / RI) × 100%

4.2 Significance of flight control tactics in fuel savings

Responses considered the cruise phase (0.337) to have highest potential for efficiency improvements. That is because the cruise is the longest flight phase, and there would be more chances to achieve fuel efficiency.

On the other hand, ground operation, with a weight of 0.092, was the phase considered to have the least potential for efficiency improvements. Because the portion of consumed fuel at this phase is very small, they recognize there would be least chance of fuel savings.

In the second level, the 'Direct Route' factor in the Cruise Phase was the most important according to responses. In general, pilots may request a direct route after making a detour from bad weather area, but they do not request it to their destination on the way from a planned air route for fuel savings.

The second most important factor is 'Power Idle Decent' and the third is 'Climb Profile by FMCS'. In order to do 'Power Idle Decent', it requires descending from the point indicated by the FMCS, but it is often difficult to do due to air traffic conditions. The procedure of 'Climb Profile by FMCS' is also not easy to apply due to heavy traffic, airspace separation, and military activities.

V. Conclusions

The airlines have to take measures to reduce the emission of green-house gas (GHG), in response to ICAO's CORSIA implementation in near future. The reduction of GHG emission is almost the same as reducing fuel consumption.

The study utilized AHP analysis for the achievement of the research objectives and the required data had gathered through a survey to sampled pilots in airlines.

There will be various strategies and tactics applicable to flight operation for fuel efficiency in flight operations. Pilots' participation in this endeavor is indispensable. This study reviewed possible methods for reducing fuel burn in flight operations by pilots and tried to investigate the tactical decisions and their importance in conserving fuel in flight operations. The study identified pilot preferences for decisions for aircraft control during mission flights of airlines. For further study, the authors plan to investigate the variance in pilots' preferences on the matter according to the level of awareness of climate change issue, background of their flight education and training, or by policy of affiliated airlines.

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