

The Main Factors that Affect Pilot Attention and Decision Making During Landing Operation Leading to Runway Incursion

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Abstract. A runway incursion is a problem which rare to happen but has a great impact while happening. According to the Federal Aviation Administration (FAA), there are three categories that caused runway incursion: Operational error, Pilot deviation, Vehicle/Pedestrian deviation. The major caused is pilot deviation as much as more than half than other factors. The factors that possibly contribute to the human factors needed to find out. This paper will explore several caused such as systems environmental factors which outlined the runway condition, task factors related to complexity pilots' task, and human factors correlated with pilots' cognitive ability that contributes to the pilot attention and decision making during landing. Human factors still become a big problem on the runway incursion even though there have been many preventive actions. Based on the literature reviews process, this paper found that system environmental factors and task factors affect human factors on runway incursion.

1. Introduction

As advance transportation is increasing and human mobility needs, fast transportation is always being the main choice. This has also been offset by increasing the existing technology both inside the aircraft and the controller. Furthermore, the increasing of sophistication technology will affect the better accuracy but human factors become one of the causative factors of failure in the system or accident such as historic control [1]. The purpose of the research is to outline factors that caused runway incursion in the system and environmental factors including the natural environment of the airport and aircraft, task factors which have the effect to pilot mission, and human factors related to personal character and cognitive ability of the pilots. By those views in several research study, the main factors that affect pilot decision making and attention during the landing procedures could be developed. A runway incursion is rare to happen but have a big impact when it is happening [2]. For example, the worst runway incursion occurred in 1977 between PANAM 747-100 and a KLM Boeing 747-200 which caused more than 500 killed at the accident [3]. It has also been examined that most accidents were caused by pilot deviation [4]. Nevertheless, there also probability by other categories that leading to the pilot deviation during the runway incursion that still must be traced. To present a wider literature review, this paper will also identify quantitative methods to investigate a pilot error with several methods such as HEART [5]. The direction of this research to compare and contrast the research study that already exists about the system and environment factors, task factors, and human factors which possibly effects the pilot attention and decision making, so this is going to be a starting

point to do the paper review. Moreover, the limitation of cognitive ability research study that has been conducted in the aviation accident also been reviewed.

2. Theory

2.1. Systems and Environmental Factors

Ambati and Padhi (2015) said that historically the aircraft landing incursion occurred in the unfavorable approach which probably happened because of wind or unpredictable aerodynamic response because of ground effect [6]. According to the de Bruin and Jones (2016), for the airplane that will be landed during the crosswind must meet two important conditions. The flight path should be aligned with the runway and longitudinal axis should be placed in line with the runway. In bad weather, with a more specific condition in the crosswind, the last approach should be changed due to the safety of landing [7].

Zhang (2019) found that the night time condition was associated with decreased situation awareness and increased mental workload when evaluating the pilot's visibility by their eye movement measured. The higher pilot's cognitive workload indicates the more intensive attention by their pupil area. That condition suggests the pilot increase their situational awareness in more complex taxi route. By the experiment, they found that the pilots take more attention to the taxi route from the window at night [8].

Schönefeld and Möller (2012) have been discussed that runway incursions mostly occur in the aerodrome movement area, at which the attention of the pilot and cockpit is necessary to be increased [3]. The aerodrome is the airport surface used for taking off, landing, and taxiing aircraft. The general cause of the incursion in this area is the aircraft that proceeded to the runway without clearance or the aircraft that enters the runway that is still in use by other airplanes. In this place airplanes are usually too slow to leave the runway and too fast to stop, meanwhile, the current detection systems need approximately two until six seconds to respond to the situation. It is also convinced that the risk hazard might be caused by the airport design with two possible hazards such as inadequate marking and complicated airport design [9]. Therefore, the ATC has an important role to control the traffic in the aerodrome. The main role of the ATC in this part is to prevent the collision between aircraft with other aircraft or the aircraft with other vehicles [10].

However, several preventions systems have also been created based on technological methods. There are ten improvements in terms of minimalizing the runway incursion according to [4]. The flight crews convinced that better runway and taxiway lighting would prevent the runway incursions. Nevertheless, McLean and Monro (2004) said that it is only 6% of runway incursion which is caused by poor visibility. Because of the new development of the aircraft, the characteristic and multitasking of the pilots become very important to be considered. More than 70% of parts of visual information are provided in the machine interface, which absolutely affects the attention of the pilot [11].

2.2. Task Factors

It is convinced by [12] that a large error touchdown error is turbulence which occurred in the approach path and affects ground also reduces the accuracy of landing. Landing in the crosswind condition is a hard task to do for the less an expert pilot [7]. The uncertainty of the wind speed and

turbulence also causes difficulties for the landing approach. The pilot should understand the automatic system that should fully support the aircraft control to solve the turbulence, windy weather, and so on.

The automatic landing has been debated in the middle of 1962 by the Institute of Aerospace Sciences National Meeting [1]. The important thing is the automatic system should provide enough time for the pilot to take the decision in the critical phases and the information that will be needed should be readable [1]. It is criticized by Arnold (2015) that the role of the pilot lacks manual control proficiency in air transport aircraft accident and suggests that the checking procedure should be developed related to the pilot manual control, including manual throttle operation in the landing approach [13].

The US Department of Transportation FAA (2016) has written an advisory circular with the subject of Pilot's role in collision avoidance that mentions pilot responsibilities in clearing procedures, especially during landing approach. The pilot should take the right clearance procedure before maneuvering and entering the airport based on the information that has been given by the ATC. Zhang et al(2019) found that the complexity of a taxi route also involves situations that require more skill of consecutive turning and crossing runway operations. Cheng (2018) designed an application that provides the pilot's taxi routing information designed by usability approach and FAA regulation as a human-machine interface. In this application, a pilot can access the information of weather, time, and the warning of entering the wrong runway [14]. With further improvement, this application will be the increased pilot situational awareness and adaption of system technology.

2.3. Human Factors

Silva and Hansman (2015) said that seven of eight aircraft accidents were caused by the inconsistency of mental models on the flight crew [15]. The impact of age in decision making depends on the relative contribution, cognitive resources, and knowledge for a decision-making task. Further, aging has a relationship with the gradual reduction in the working memory and processing speed [16]. Aging is also associated with an increasing amount of knowledge due to the rise of the experience [17]. Older pilot mostly has more experience in flight hours duration and a slight decrease in the declarative domain-specific knowledge measure [18]. In the research paper by Morrow, (2011) the participants were asked to read six scenarios extended by two pilots in the airline company [19]. The scenarios are similar to the materials used in the airline that the pilot examines and by that point, they should be familiar with this research. This pattern is similar to the expert pilot in the case before, which focused on the situational information that is more important to interpret ambiguous text meanwhile the non-pilot focused on the recent information, which means the non-pilot has a lower level of understanding [19].

It is in line with the statement that generally the expert focuses on the most relevant aspects with the domain, which represented more abstract problem compared to novices [20]. Therefore, the understanding study showed that an expert understands the relevant text with domain in the level situational mode. Finally, there is a parallel in the attention literature, which found that the strategy of visual expert pilot's visual scanning strategies is more flexible than the novices' strategies (D. Morrow, 2004). In the age context of decision making, the older expert has the same possibility as the younger expert does to focus on the most relevant information. This finding is consistent with the research which is able to show that the older adults with the earlier domain knowledge are able to accomplish

the relevant task and sometimes spend more time than their younger counterparts in drawing inferences necessary to create situation models [22].

Schrivier et al (2008) were conducting a research study in expertise difference related to attention strategies in the pilot decision making [23]. The expertise was measured by several variables such as total flight hours, instrument flight hours, type of pilot certificate, and a general test of aviation knowledge. According to the Wickens (2000) the correlation of each cue will lead to the information processing models and help the person to recognize the problems. The result of this study is the more expert pilots will complete more necessary actions and more corrective actions. The findings in this research study clearly match the recent concept of decision making in the expert pilot, especially dealing with expert performance and naturalistic decision making. The limitation of this study is it is unable to trace the cues attention process because it is a latent measure and thus it is hard to detect [24].

Situation awareness is also an important factor to be outlined due to its relationship to the attention of pilots. The paper from Kilingaru et al (2013) investigated the eye movement of pilots for controlling the attention when getting information. By getting the data of the eye movement, the situation awareness was analyzed by using a knowledge-based approach [25]. The pilots' situation awareness can be defined by some performance of attention such as attention blurring, misplaced attention, and attention focusing [26]. The attention focusing is the stable attention in a certain instrument at the limited time which is grouped to identify the instrument being investigated. Misplaced attention will be identified with the short fixation in the instrument, so pilots spend more time outside the instrument than fixation in the relevant instrument.

The details that can be inferred from the knowledge base by applying the rules from the rule base are which particular instrument that was scanned, fixation duration in every instrument, moving time, the last time of scanning the instrument, the amount of time while observing the instrument after the last scan, the numbers of expected instrument that have been scanned or have not been scanned [25]. The result of the study is the fixation pattern of the pilots varies, depending on the flight hours, training, and performance that they have. It is also found out that in this research study the cockpit real time situation is different from the flight simulator that is conducted.

Sun (2015) assessed that the stress distribution of aircraft, when flying and touching the deck because of the landing stage and kinetic and kinematics modeling, is the most used approach. His research aims to develop a quantitative evaluation method of pilot errors during the aircraft landing process. The use of Human Reliability Analysis (HRA) is to avoid and minimize the risks due to human error. Human Error Assessment and Reduction Technique (HEART) is the HRA method that has been implemented in the research to evaluate the pilot error during landing approach and it also uses NASA as the evaluation method for the use of HEART. Each type of activity is outlined into the detailed typical action: setting the radar pattern, change the landing gear, descend the altitude, and etc [5].

3. Research Methodology

For this research, the literature review process is started from searching and selecting papers related to runway incursion. Searching paper is conducted by using Google scholars by entering "runway incursion" as the keyword. There are about 6640 papers shown based on that keyword. The papers were categorized based on the title, the author and the year of publication. Most of the papers published

around 1990 are related to the basic theory about runway incursion, while the newest papers are related more to identification and case study. Moreover, the reading was started with the abstract and conclusion in order to narrow and eliminate unrelated paper. The following is the framework in choosing paper for further identification.

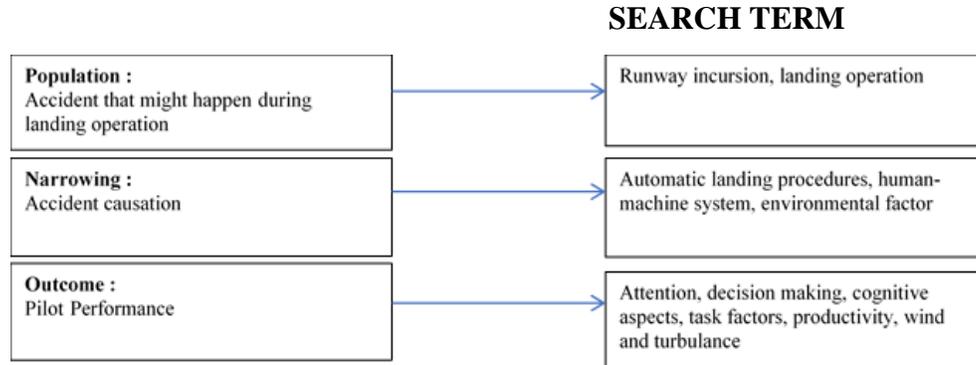


Fig. 1. Search terms paper

After doing paper screening based on figure 1, there are 24 papers that are finally selected to be reviewed. Some papers outline the landing procedure to build the understanding about process of landing, so those understanding hopefully can support the framework to find out the causation of runway incursion. Some papers are also reviewed based on the difference of experiment methodology in illustrating factors that affect pilot error during landing operation. Therefore information about years, methodology, result, and limitation of each paper will be compared to get the factors which contribute to a runway incursion.

4. Result and Discussion

The broad literature was reviewed and got 24 papers which hopefully able to support the objective of this paper. During the reviewed, the main factors that affect attention and decision making pilot can be categorized into three part such as environmental factors, task factors, and human factors. Some paper only reviewed about the environmental factors and some of them outlined task factors. The most finding paper outlined about human factors. However, we need to consider about all factors that contribute to runway incursion so that the table of each paper needs to be built for comparing the methodology and result in order to find out the main factor that affects attention and decision-making pilot.

Table 1. Result of paper review

Category	Object	Ref Number
System and environmental factors	Wind	[6], [7]
	Time of landing	[8]
	Aerodrome movement area	[3], [9]
	Aircraft technology	[4], [11]
Task Factors	Landing in the crosswind	[7], [12]
	Automatic landing	[1], [13]
	Taxi route	[8], [14]
Human Factors	Mental model	[15]
	Age	[16],[17],[18], [22]
	Expertise	[19],[20],[21],[23]
	Situation awareness	[25],[26]

Based on the literature above, several factors that affect pilot attention and decision making can be found those are: systems and environments in the aircraft such as the interface of the new development aircraft, airport visibility, weather, time, and communication between pilots-ATC. In that part the factors that might cause the runway incursion were outlined and surprisingly the human machine problems still become an issue. It has also provided several methods to prevent the runway incursion such as improved the runway visibility, created more sign, and development of the technology to detect the movement in the ground area and understanding the taxi route. The task factors also mentioned about the complex task for the pilot due to the automatic landing procedures and the most errors occurred during the landing procedure. Mainly factors related to the aircraft interface is dissolved, by this problem the attention of pilot could be distracted. Moreover, the automatic landing which created an easier technique for the pilot during the crosswind will create a new problem related to the cognitive ability of the pilot.

The last part of the research which outlined the human factors give some ideas about cognitive ability and factors that influence pilot behavior. The most common factors that could affect pilot decision making and attention is the experience of the pilot and ages. Mental models also found to be an important part of decision making and situation awareness was found very linked with the attention of the pilot and there is a paper that mentioned it become the most factors of an aircraft accident. This paper depicted a model of runway incursion factors based on the literature that has been analyzed. Figure 2 shows that environmental factors and task factors lead to the existence of human factors.

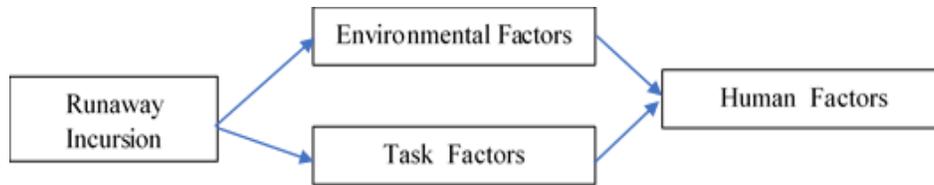


Fig. 2 Conceptual Model

However, it still limited resources found in the runway incursion field. Most of the research study was conducted by flight simulator and gave the pilots several conditions and scenario to know their capability. The HEART methods which conducted by Sun et al (2015) is helpful to support this research due to created several error prediction conditions during the landing procedure that could be based on the prospecting main factors in the pilot attention and decision making leading to a runway incursion.

5. Conclusion

A runway incursion is any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and takes off of aircraft. The factors that possibly contribute to runway incursion which are systems environmental factors which outlined the runway condition, task factors related to complexity pilots' task, and human factors correlated with pilots' cognitive ability that contributes to the pilot attention and decision making during landing. Based on the literature review this paper explored that systems environmental factor and human factor contribute to human factor on runway incursion. Several limitations of the

previous study are the numbers participants recruited is lacking, this is affecting the validity of the data and some actions in the experiment were not clearly mentioned.

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