# Chapter 9
# Subjective Decision-Making of Aviation Operators (Pilots, ATCOs)

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## Nomenclature

| | |
|---|---|
| ATCOs | Air Traffic Controllers |
| ATM | Air Traffic Management |
| ICAO | International Civil Aviation Organization |

## 9.1 Introduction

Operators "subjective decision-making" is considered as an important part in managing and controlling today's aviation sector. This means that they use the subjective situation awareness, situation analysis, and decision-making processes in aircraft controls (FAA, 1991). Operators must first characterize the scenarios issue, then choose a solution from a set of resources and make a subjective judgements followed by decisions in the event of an unanticipated and unforeseeable situations. As shown in Fig. 9.1, the resources are divided into two categories: (i) "active resources" such as physical, intellectual, and psycho-physiological behaviors, and (ii) "passive resources" such as knowledge, materials, and finance – the physical form of the aircraft control system.

There are numerous references and criteria for considering the subjective aspects of operators decision-making techniques. For example, Previous research analyzed the operator's workload subjectively and objectively. The aircraft control system is subjective, endogenous, stochastic, and dynamic due to the idea of human-operators (pilot or ATCO) loop, who are dynamically controlling information flow based on the flight circumstances using decision-making process (Papanikou et al., 2021). The system is endogenous because the control first initiates within the system while

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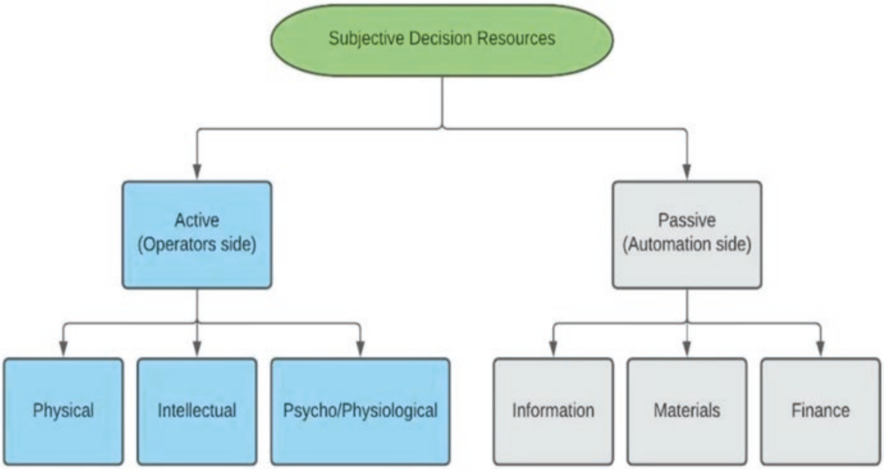


**Fig. 9.1** Subjective decision resources

being observed by the operator. The executed decision is based on the operator's current mental state, physical condition, situation awareness, knowledge, experience, and skill. The aforementioned explanation is known as the "subjective decision mechanism." (Wise et al., 2016).

Air transport capacity is expected to have a significant growth within the coming decades (Rohacs et al., 2016), prompting the funding of multiple international programs. With an increase in air transport traffic and the available networks, "subjective decision-making" has a greater influence on global aircraft safety. The current major ATM projects are mainly concentrating on (i) improving safety, (ii) decreasing ATM costs, and (iii) enhancing the environmental aspects. The first two aspects are connected to the operator's decision-making. Operators' decisions are influenced by their skills, abilities, practice, knowledge, and situation awareness. The management system of the aircraft is a dynamic, subjective, stochastic, and nerve (endogenous) system.

The "passive resources" are the resources of the aircraft, while the "active resources" are related to the operator itself. The active resources are defined by the operator decisions, which also determine how passive resources will be used. In this process, the remaining time, until the last moment, while the decision must be applied plays the most crucial role.

## 9.2 Method

The operator's subjective decision should always be comprehensively evaluated and maintained in the new networks at the beginning, establishing investigational procedures and represent subjective decision-making processes. The improved techniques might be used in a wide range of disciplines, including unmanned aero-nautical vehicle distance control.

As seen from the model in Fig. 9.2, the operator gathers the data about the situation of the "technical system," *Si,* that changes depending on the system performance and characteristics, environmental conditions, effects of other interacting systems, and realized control (management).

The first step done by the operator is to recognize and realize the current scenario, then evaluate the existing situation, and choose an appropriate decision while choosing the best action from a set of options using decision-making, and finally execution process. In the decision-making process, the operator selects the choice from the set of the "possible actions," *Sp,* including all the accessible or achievable devices, methods, and factors. The operator must then identify "disposable actions," $R_{\text{disp}}$, that might be applied in a given situation for controlling the system. Finally, the operator should choose the "required actions," $R_{\text{Req}}$, that moves the system to the proposed state. As a result, this process realizes and depends on the operator behaviors. In a more general approach, the operator has to initiate passive resources and then apply physical mechanisms and active resources (Simongáti, 2010).

The estimated subjective decision time explained in Fig. 9.3 could be calculated by considering the core features which contain "situation awareness," "decision-making," and "performance actions," although some external aspects could affect the decision time in a vital way such as the experience level of the operators and the human error factor.

It is important and crucial to understand that all the factors are interdependent with each other, which make calculating the exact required time a complex issue,

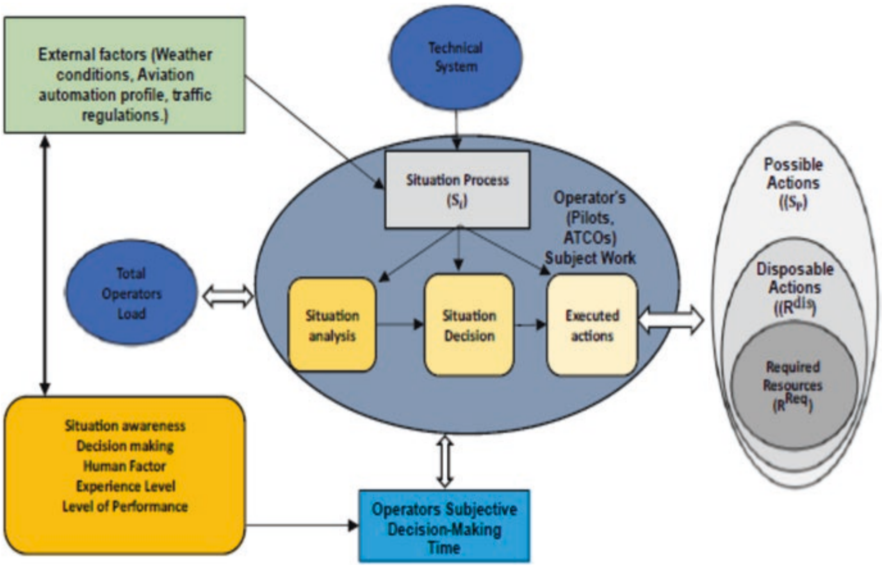


**Fig. 9.2** Subjective decision-making model


**Fig. 9.3** The estimated subjective decision time

yet an approximation is highlighted in the proposed equations. The successful decision can be made if the remaining time would be greater than the required time.

The quality of the operators' work might be described as with active resources ($R_{areq}$) that defines how passive resources ($R_{preq}$) are used. Other analogical possible characterization might be given by the velocity of utilization of the active resources.

The operator must have time ($t_{req}$) to understand and evaluate the given $\sigma_k$ situation $t_{uereq}(\sigma_k)$, making-decision $t_{decreq}(S_a)$ that intends to transit the situation from $Sk$ state into the $S_a$ state and the required time to perform the action $t_{reactreq}(\sigma_k, S_a)$:

$$t^{\text{req}} = t_w^{\text{req}}\left(\sigma^k\right) + t_{\text{dec}}^{\text{req}}\left(\delta^a\right) + T_{\text{react}}^{\text{req}}\left(\sigma_k, \delta_a\right) \tag{9.1}$$

There is not enough information on the physical, systematic, intellectual, and psychophysiology characteristics of the subjective analysis, on the way of thinking and making a decision of subjects-operators. Only limited information is available on the time effects, possible damping the non-linear oscillations, and long-term memory (Kasyanov, 2007). Figure 9.4 describes the simplified decision-making process at the final phase of the aircraft approach, the set of alternative situations were given by $t_0$, $x_0$, $S_a$:($\sigma_1$,$\sigma_2$) with the distribution of preferences $p(\sigma_k)$, where $\sigma_1$, $\sigma_2$ identifies the landing and the go-around, respectively.

The preferences are oscillating, because of the exogenous fluctuation (while decision altitude is getting closer) and the endogenous processes (depending on the uncertainties in the situation awareness and operators-pilot incapacity to make decisions). If pilots are able to overcome their entropy barrier up to command for go-around (reaching the decision minimum altitude), $t^*$, $x^*$, then they perform the proposed decision.

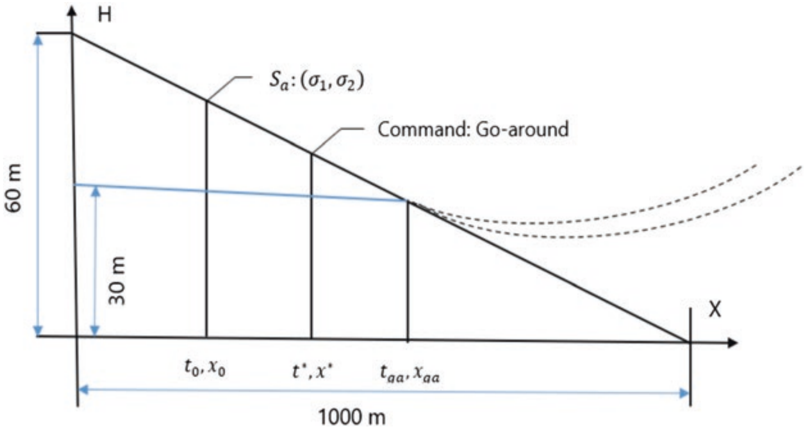


**Fig. 9.4** Aircraft final phase (landing, go-around)

## 9.3 Results and Discussion

The illustrated model utilized and examined the EU FP7 PPlane (Rohacs, 2010, 2012; PPLANE, 2011) to define the constraints of safe landings associated with private airplane pilots, named as less-skilled pilots in the current research. In a previous research (Kasyanov, 2007), the following values are recommended for a medium sized aircraft (weight of aircraft $W = 106$ N; wing area, $S = 100$ m$^2$; wing aspect ratio $A = 7$; thrust $T = 9.4 \times 104$ N; and velocity $V = 70$ m/s): $A = 8$; $B = 8$; $C = 20$; $D = 43$; $F = 0.8$; $H = 0.065$; $M = 0.065$; $N = 0.065$. Using these parameters, the subjective probabilities might be chosen as ($\sigma_1$) = 0.53, $P(\sigma_2) = 0.6$ and $\varepsilon_1 = 5.5 + 0.01t$, $\varepsilon_2 = 5.4 + 0.04t$ take into account the decreasing difference in the required and the available time for the decision.

In this research, a simulation model was created, by the current researcher, using the modified Lorenz attractor on MATLAB for the subjective decision-making of the pilots in different level of pilot expertise, namely (i) Cadet, (ii) less-skilled, (iii) skilled. and (iv) expert.

Chaotic Lorenz's model was introduced to describe the way of thinking of pilots during the final approach. The simulated parameters and model were utilized based on the real measured characteristics of pilots (Table 9.1). This model was used for investigating go-around and landing situations during final approach.

The results of using the described model for four different levels of pilots are shown in Figs. 9.5 and 9.6. The results demonstrate the chaotic character of the decision-making process for go-around and landing, which can vary depending on the level of experience of pilots.

According to these results, the cadet and less-skilled pilots are not able to make their final decisions easily in which situations create chaotic orbits seen in Fig. 9.5. The final decision time of the pilots can be calculated from these results by checking when s/he will not have any hesitancy between landing and go-around. The final

**Table 9.1** Aircraft parameters for four groups of pilots

| Cadet pilot | Less-skilled pilot | Skilled pilot | Expert pilot |
|---|---|---|---|
| A: 6 | A: 8 | A: 10 | A: 12 |
| B: 6 | B: 8 | B: 10 | B: 12 |
| C: 10 | C: 20 | C: 35 | C: 45 |
| D: 0 | D: 0.43 | D: 1 | D: 1.2 |
| F: 1.3 | F: 0.8 | F: 0 | F: 0 |
| H: 0.065 | H: 0.065 | H: 0.065 | H: 0.065 |
| M: 0.065 | M: 0.065 | M: 0.065 | M: 0.065 |
| N: 0.065 | N: 0.065 | N: 0.065 | N: 0.065 |
| $P(\sigma_1)$: 0.53 | $P(\sigma_1)$: 0.53 | $P(\sigma_1)$: 0.53 | $P(\sigma_1)$: 0.53 |
| $P(\sigma_2)$: 0.6 | $P(\sigma_2)$: 0.6 | $P(\sigma_2)$: 0.6 | $P(\sigma_2)$: 0.6 |

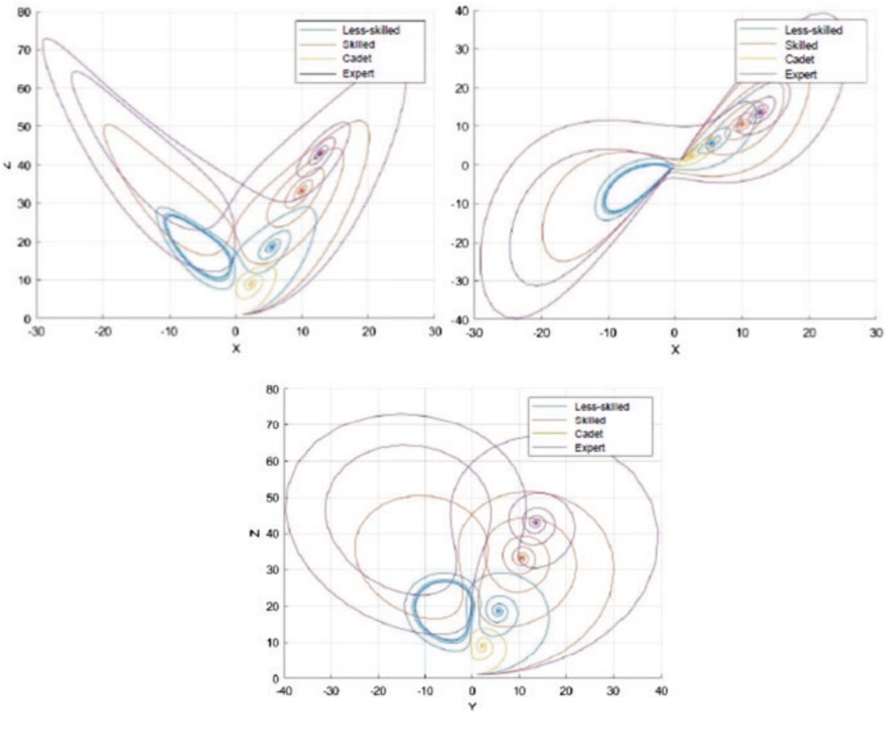


**Fig. 9.5** Pilots way of thinking and decision-making process for four different levels of pilots (yellow: cadet, blue: less-skilled, orange: skilled and purple: expert pilot)

decision is made when the probability of a specific situation (landing or go-around) gets stable as shown in Fig. 9.6.

The results could be summarized as follow:

- Cadet pilot entropy would quickly decrease, the hesitation is very high, and the final decision was taken in about 10 s.

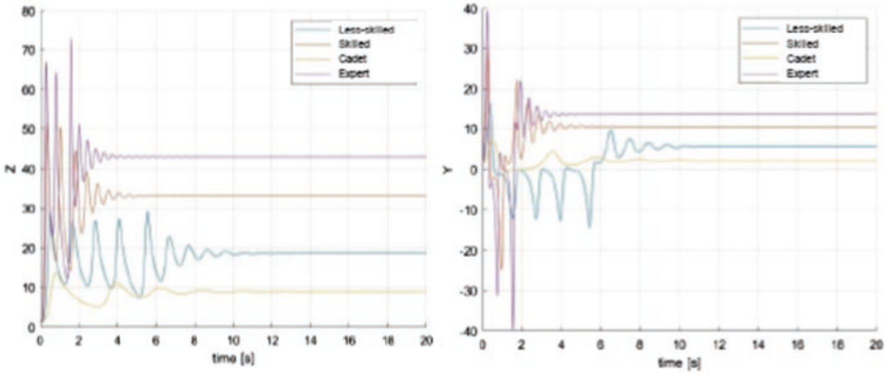


**Fig. 9.6** Results of using the developed model to landing by four different levels of pilots

- The less-skilled pilot entropy would decrease, the hesitation is still very high, and the final decision was taken in about 8 s.
- The skilled pilot entropy would be decreased, the hesitation is reasonable, and the final decision was taken in about 4 s.
- Expert pilot entropy would quickly be decreased, the hesitation is optimum, and the final decision was taken in about 2 s.

## 9.4 Conclusion

Due to the increasing number of mishaps in comparable flight scenarios, the research underlined the urgent need to recognize and acquaint aviation operators with subjective Aeronautical Decision-Making in the final approach phase.

The modified Lorenz attractor was used in MATLAB to simulate the subjective decision-making process of four groups of pilots with different levels of expertise in the aircraft final phase (landing and go-around) by measuring “hesitation frequency” and “decision-making time.”

The outcomes show that the time needed for less-skilled pilot is 4 times more to make a decision between landing and go-around compared to the expert pilots. This model is well usable for the investigation of the endogenous dynamics of the pilot decision-making from different skills and experience. The result of the research suggested that this method improves pilot training and helps instructors to specify the pilots’ weak points as well. These results demonstrate that the model is suitable to investigate the different levels of pilots expertise while checking their way of thinking and decision-making process.

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