Evaluating Total Load of Aviation Operators by Analytic Hierarchy Process (AHP)

Omar Alharasees and Utku Kale

Nomenclature

AHP	Analytical hierarchy process
MCDC	Multi-criteria decision making
PCM	Pairwise comparison matrix
ATCO	Air traffic controller
CR	Consistency ratio

1 Introduction

As the avionics system evolves to be more dynamic, automated, and complicated, assessing the aviation operators' total loads becomes more critical to the system's applicability and reliability in the aviation world.

The adaption of the current complex and dynamic aviation system needs to balance operator's loads in the innovative systems, which require feasible frameworks and concepts (Kale et al., 2020). In such an environment, operator performance is measured more intricately. Aviation operators deal with enormous data and relevant information as flight systems, including aircraft capabilities, radar, sensor systems, and many other appliances.

The future operator environment (cockpit, future ground control tower of pilots, and towers) and avionics systems need to be redesigned by considering various psychological parameters, human factors, and operator loads (Jankovics & Kale,

O. Alharasees (✉) · U. Kale
Department of Aeronautics and Naval Architecture, Budapest University of Technology and Economics, Budapest, Hungary
e-mail: oalharasees@edu.bme.hu; kale.utku@kjk.bme.hu

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2019). Therefore, this study focuses on evaluating operators' total loads using the analytic hierarchy process.

The analytic hierarchy process (AHP) is a well-known "multi-criteria decision-making (MCDM)" technique for multiple objective ranking procedures and an excellent approach for dealing with complicated decision-making (Saaty, 2008). This method can help decision-makers define priorities and make the optimal option (Saaty, 1990). Another advantage of the AHP is to capture both subjective and objective components of choice by reducing complicated judgments to a series of pairwise comparisons and then synthesizing the findings. Furthermore, the AHP includes a beneficial approach for assessing the consistency of the decision-maker's judgments, therefore eliminating decision-making bias.

The AHP is a theory of relative measuring on absolute scales of both actual and potential criteria based on a familiar involved participant's opinion as well as current measurements and relevant information. The primary focus of the AHP's mathematics is how to measure entities evaluating and weighing the critical characters. Because decision-making is diverse, the AHP has mainly been used to multi-objective, multi-criteria, and multiparty decisions, specifically in the engineering field (Nakagawa & Sekitani, 2004). The judgments generally made in qualitative terms are stated mathematically to create compromises among the various intangible objectives and criteria, rather than assigning a score based on a person's subjective judgment (Saaty, 2008). Finally, to cope with the difficulties, integrating repetitive and broad experiences would pour into a system of priorities. The AHP is built on four axioms: reciprocal judgments, homogenized characters independent within each level, hierarchical structure, and rank order expectations.

Many previous studies employed AHP in aviation in the literature. Bruno et al. assessed planes to maintain planned choices, demonstrating that cabin baggage compartment volume is the best aspect (Bruno et al., 2015). Chao & Kao discovered that policy and dependability were necessary standards for service quality (Chao & Kao, 2015).

Rezaei et al. (2014) assessed and designated the supplier in the airline retail business; the result of this research suggested that economic steadiness is a considerable standard in supplier selection (Rezaei et al., 2014). Chen et al. (2014) utilized AHP procedures to assess the significance of weighting the technical elements in aviation safety (Chen et al., 2014).

Other AHP studies were specified for the aviation operators, for example, Oktal H. and Onrat A. used AHP for characterizing the critical factors in airline pilots' candidates' selection (Oktal & Onrat, 2020). Havle and Kılıç (2019) identified and examined the circumstances that impact navigation errors in the North Atlantic region by combining a fuzzy analytic hierarchy process (FAHP) into the Human Factors Analysis and Classifying System framework (Havle & Kılıç, 2019). Kilic and Ucler (2019) applied AHP techniques to weigh stress factors among student pilots (Kilic & Ucler, 2019).

The research aims to evaluate the elements that influence and shape the total loads of aviation operators. The current study examines the preferences of the three operator categories (less skilled pilots, skilled pilots, and ATCOs) based on the primary criteria. In order to create a general hierarchical model, the analytic hierarchy process (AHP) is employed in this research. These decision-making models are primarily built on three layers in order to develop evaluator preference loads for (i) the assessment procedure, (ii) preventing complication, and (iii) lacking information from other AHP functions. In this study, the Saaty Scale was utilized for scoring to depict lost data utilizing matrices that could be computed using a particular technique.

2 Method

The MCDM technique demands that decision alternatives or sub-criteria be chosen or selected based on their qualities. In MCDM scenarios, a preset, restricted number of choice possibilities is assumed. Sorting, ranking, and scoring are all steps in the MCDM process.

The primary technique employed in the research is the analytic hierarchy process (AHP), one of the popular multi-criteria decision-making (MCDM) techniques, to investigate the major and main characteristics of pilots and ATCOs.

The current authors created a two-level hierarchy model containing the five main types of aviation operators' loads: (i) workload is the work done by an operator in a given time interval as it relies on human factors, skills, knowledge, practice, etc.; (ii) task load is the level of complexity and toughness when completing a task, which depends on the degree of difficulty, traffic demand, traffic regulations, etc.; (iii) information load is the volume of information and data collected from complex systems, which highly depends on the level of technology, weather conditions, and other aspects, as information overload might create confusion among operators; (iv) communication load is the level of awareness and understanding among operators and is highly altered by cultural norms, social relations, etc.; and (v) mental load is the physical and psychophysiological situation of the operators during operation and highly depends on the level of stress, performance action, etc.

Figure 1 shows the hierarchical model for the total loads of operators with the components of each level:

Because the AHP utilizes the unique properties of pairwise comparison matrices (PCM), the choice of decision-makers between specific pairs of options illustrates the importance and priority of a particular aspect over another based on a scale (see Table 1). The matrix of pairwise comparisons (see Eq. 1) $A = [a_{ij}]$ represents the strength of the decision-maker's preference between individual pairs of alternatives (A_i versus A_j, for all $i, j = 1, 2, \ldots, n$). The pairwise comparison matrix can be given as follows (Eq. 1):

Fig. 1 Hierarchical model of the operators' total load

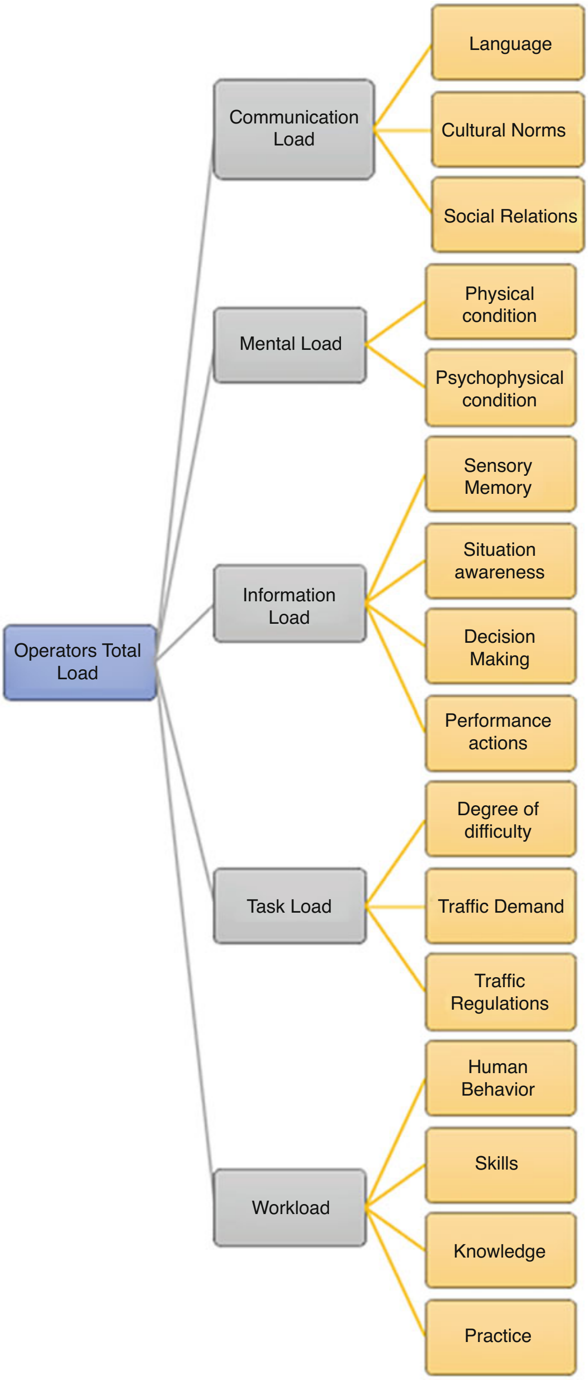


Table 1 Saaty Fundamental Scale

Numerical values	Verbal scale	Explanation
1	Equal importance of both elements	Two elements contribute equally
3	Moderate importance of one element over another	Experience and judgment favor one element over another
5	Strong importance of one element over another	An element is strongly favored
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favored by at least an order of magnitude
2,4,6,8	Intermediate values	Used to compromise between two judgments

$$A = \left[a_{ij}\right] = \begin{bmatrix} 1 & a_{12} & . & . & a_{1j} & . & . & a_{1n} \\ \frac{1}{a_{12}} & 1 & . & . & a_{2j} & . & . & a_{2n} \\ . & & . & & & & & . \\ . & & & . & & & & . \\ \frac{1}{a_{1j}} & \frac{1}{a_{2j}} & . & . & a_{ij} & . & . & a_{in} \\ . & . & & & & . & & . \\ . & . & & & & & . & . \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & . & . & \frac{1}{a_{in}} & . & . & 1 \end{bmatrix} \tag{1}$$

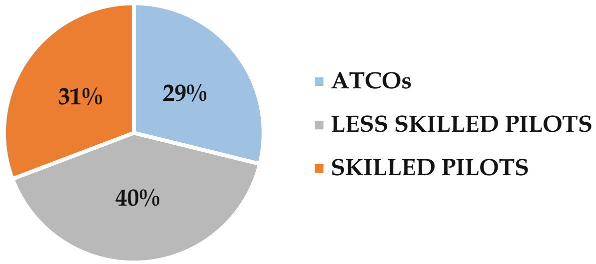
In order to calculate the pairwise comparison matrices to priories the effect of each aspect in the model within the same level, the geometric mean of each group was utilized. The matrix consistency ratio should be less than 0.1, as most experience matrices are not consistent. CR for groups is calculated.

3 Questionnaire

In this research, an online AHP based survey was designed and performed among operators, focusing on the operators' major characteristics from various perspectives. The purpose of the questionnaire is to quantify the most important issues as seen through the eyes of the operators, based on their experience and knowledge.

The questionnaire was created based on aviation operators (pilots, ATCOs) in this research. There were 52 participants (13 females), 37 pilots, and 15 ATCOs. The participants were arranged into three groups: (i) less skilled pilots (average age 22), (ii) skilled pilots (average age 35), and (iii) ATCOs (average age 34). Figure 2 demonstrates the participant groups' percentages in the questionnaire.

Fig. 2 Survey participants



4 Results and Discussions

After analyzing and visualizing the participants' preferences in the model, there will be some differences between the groups' overviews. AHP method will highlight the critical characteristics based on pairwise comparisons. The responses have been collected and utilized by using the geometric mean.

Based on the collected responses of the three groups of aviation operators and by employing the AHP process, evaluating and weighing the characteristics in each level individually, the following tables (Tables 2, 3, and 4) show the aspects (the weights, final score, and consistency ratio) which have been computed for the first level in the operators' load model characteristics from each group:

Combining the three groups' opinions would show the variations between the groups, which could rise due to the experience level and the type of the job. Comparing different groups of participants would make it easier to evaluate and weigh various individual aspects of aviation operators' total loads from other overviews.

The survey highlighted that the communication loads are the strongest factor in the model in the first hierarchy level, as illustrated by Fig. 3.

Pilots and air traffic controllers in aviation communication do not have face-to-face contact or a visual speech interface to interact with each other; consequently, they must communicate purely through voice. Their communication is primarily done by radio transmissions written in a specific phraseology meant to be as precise and efficient as possible. As a result, their listening and speaking skills are extremely vital.

A noticeable fluctuation of the opinions is clear between the groups in the third and fourth critical factors (information and mental loads) within the first level of the model.

Looking into the second level of the model (see Fig. 4) for the sub-criteria of the communication loads also provides a clear overview of the specific issue from the operators' eyes which is the level of language among aviation operators based on the participants. In fact, communication errors are a main factor in the aviation world accidents, but with the accelerated automation development in the aviation industry, the issue is shifting toward the type and volume of information the aviation operator receives within a specific timeframe.

Table 2 Less skilled pilots' PCM for the first level

Less -skilled Pilots						
Operators Total Loads	Comm. Load	Mental Load	Info Load	Task Load	Work Load	Weights
Communication load	1	4.45	4.51	2.89	1.14	39.35%
Mental Load	0.22	1	2.62	2.04	0.48	15.48%
Information Load	0.22	0.38	1	3.16	0.43	11.71%
Task Load	0.35	0.49	0.32	1	0.49	8.38%
Workload	0.88	2.09	2.32	2.05	1	25.08%
CR= 0.096	Sum=					100%

Table 3 Skilled pilots' PCM for the first level

Sklled Pilots						
Operators Total Loads	Comm. Load	Mental Load	Info Load	Task Load	Work Load	Weights
Communication load	1	3.98	3.60	4.13	0.82	36.33%
Mental Load	0.25	1	0.95	1.60	0.35	10.91%
Information Load	0.28	1.05	1	3.73	0.45	14.95%
Task Load	0.24	0.63	0.27	1	0.39	7.46%
Workload	1.22	2.84	2.23	2.58	1	30.34%
CR= 0.047	Sum=					100%

Table 4 ATCOs' PCM for the first level

ATCOs						
Operators Total Loads	Comm. Load	Mental Load	Info Load	Task Load	Work Load	Weights
Communication load	1	7.05	3.36	5.67	1.01	39.71%
Mental Load	0.14	1	0.61	0.90	0.28	6.99%
Information Load	0.30	1.65	1	4.37	0.33	14.52%
Task Load	0.18	1.12	0.23	1	0.21	6.01%
Workload	0.99	3.53	3.03	4.75	1	32.77%
CR= 0.036	Sum=					100%

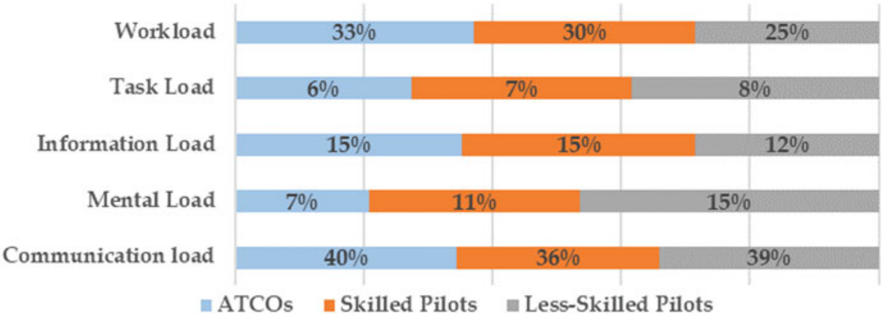


Fig. 3 The total load of the aviation operators

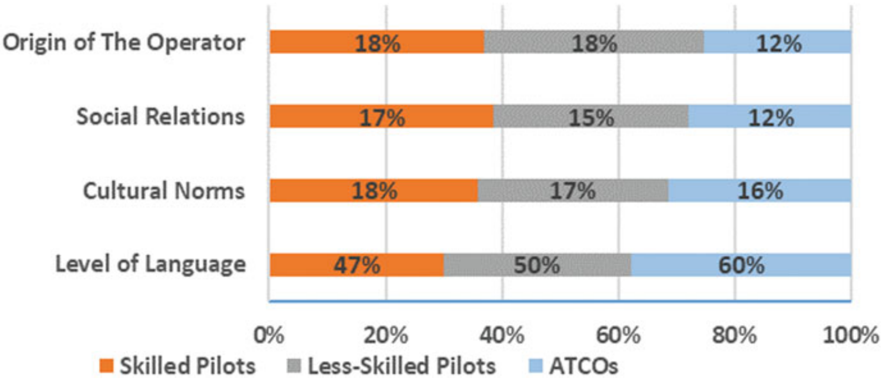


Fig. 4 Sub-criteria of the communication load

Based on the participant's opinions, the information errors could be the most critical issue for the futuristic pilot environment after the communication, especially with introducing some automated systems in the aviation communication process.

5 Conclusion

The findings demonstrated a priority ranking and scaling of the operators' total loads within each level, which is a great indicator of the significant elements. To better understand the futuristic operators' environment and manage critical scenarios, employing multi-criteria procedures, specifically AHP, illustrated a critical role. The inconsistencies between the perspectives are shown using quantitative and qualitative criteria using the traditional, classic, and simplified analytical hierarchical process (AHP) technique for decision-making.

The results of this survey were based on a total of 52 participants from 3 groups of aviation operators (less skilled pilots, skilled pilots, and ATCOs), and it should be mentioned that the results could change if more participants and more groups are included.

The results show that the communication load plays a dominant role in the operator total load model from all participants, followed by the operators' workload.

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