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HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM - AHP DRONE MODEL ASSESSMENT

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Abstract. Drone systems have become increasingly applied to various commercial, technical, agricultural, and military sectors. With the emerging significant effects on the frequency of drone accidents in many situations and areas, it has become increasingly necessary to form unmanned aircraft systems and usage limitations. The first step to do that is by highlighting the sources of accidents in the current process. The Human Factors Analysis and Classification System (HFACS) is the main technique for accident risk assessments in drone systems which clusters the accident key factors causes into 4 basic domains. In this study, 4 categories of drone experts participated in the study. The research utilized a new approach that integrates an analytical hierarchical decision-making model with the HFACS for drone accident causation investigation. The results of the study showed discrepancies among the different groups of drone operators and identified organizational factors and unsafe actions as being key issues in the evaluation.

Keywords: UAS; AHP; drone; HFACS; human factor; accident

1. INTRODUCTION

The necessity for regulation of drone usage has been a topic of greater social controversy as their use has become more widespread. Particularly, it seems that privacy and air safety will be the two key issues that legislation would focus on [1]. Drones cannot fly over another country's territory without that country's consent, according to international civil aviation regulations that have been in place since 1944 at the United Nations level.

The European Aviation Safety Agency (EASA) is in responsible of executive and regulatory obligations in the area of civil aviation safety at the European level. By the rules of the European Commission (EC) [2]. The European Parliament and Council have given EASA the power to manage remotely piloted aircraft systems (RPAS) and unmanned aircraft systems (UAS) with an operational mass of at least 150 kg.

Drones are a highly innovative and disruptive technology that has the potential to bring significant benefits, but they also carry a risk to society and past incidents involving airborne vehicles [3]. Because of the varying standards in drone legislation around the world, there are many issues with unmanned aircraft systems, particularly the high rate of accidents [4]. Human error is a leading cause of accidents in aviation, and it is also a significant contributing factor to accidents in drone systems [5].

To minimize long term safety hazards, human error frameworks like The Human Factors Analysis and Classification System HFACS and the "Reason's Swiss Cheese Model" [6] have been employed to identify and analyze the reasons of accidents due to human error.

Among the multiple accident analysis models, HFACS is one of the technical models that is most frequently used in the field to measure personal aspects. It was initially constructed using James Reason's Swiss cheese model.

The HFACS conceptual framework has been adopted to investigate the sources of accidents and mishaps in a variety of diverse industries, including constructions [7], rail transport systems [8], mining and material [9], safety and security [10], and aeronautics [11], [12].

To investigate the human factors in drone critical situations, the Department of Defense (DOD) has effectively utilize Human Factors Analysis and Classification System (HFACS) assessment for ten years [13]. In order to successfully minimize and avoid such events, it is crucial not to ignore the evident presence of humans in drone systems. Highlighting which variables have historically emerged and which ones need to be given priority can made easier with the help of the HFACS framework.

There has been a rise in the use of drones in recent years for a range of occupations across various industries [14]. Drones are employed in farms to obtain crop data to boost crop yields in the agricultural sector [15]. Drones are playing a vital role in environmental conservation efforts by creating detailed maps of forest vegetation and water structures [16]. In addition, drones are used in the mining industry for internal mapping and inspections, improving safety regulations [17]. The building and construction industry is increasingly using drones to map and assess building projects [18].

Drones are used by police, firemen, and other rescue professionals for monitoring and surveillance, search and rescue operations, and public safety initiatives [19]. Drones have become increasingly popular in the media and entertainment industries for filming and photography [20]. They offer a unique perspective of high-resolution aerial photography and filmmaking potential and can capture footage that would be difficult or impossible to obtain using traditional methods.

Furthermore, The Analytic Hierarchy Process (AHP) is an excellent approach for dynamic decisions utilized in a wide variety of applications like in the drone systems. AHP is a branch of the "Multicriteria Decision-Making (MCDM)" methods for computational scoring methodologies [21]. Making the best choice can be facilitated by this strategy for classifying meaning and significance [22]. By grouping complicated viewpoints into a series of pair-wise comparisons and formulating the scoring and ranking of the choices, the AHP also has the advantage of obtaining mutually subjective and objective factors.

There have been several previous studies that have used the AHP (Analytic Hierarchy Process) method in the analysis of drone operations [23]. For example, Ting et al. used AHP to evaluate a UAV training system based on visual stimulation [24]. Li et al. developed a UAV route evaluation algorithm based on CSA-AHP and TOPSIS to address the issue of UAV route evaluation [25].

The proposed model categorizes the errors and accidents of drone operators into four main categories based on the HFACS (Human Factors Analysis and Classification System) framework. It suggests that the current UAS (unmanned aircraft system) requires a review of the training and flying legislation system and policies for drone operations.

This study focuses on analyzing, measuring, and categorizing the contributing factors in drone operators' systems using the HFACS. It furthermore looks at the causes of human factor accidents from the operators' viewpoints while taking into account the industrial field of use. In the proposed investigation, the preferences of the following four operator categories will be presented: (i) commercial drone operators (ii) engineering drone operators (iii) military drone operators (iv) agricultural drone operators.

Therefore, in the paper, the Analytic Hierarchy Process (AHP) is used to build a generic hierarchical model. These decision-making frameworks are largely developed on two levels to comply with the HFACS framework to build evaluator preference loads. The Saaty-Scale is used for scoring to describe the data mathematically using generated matrices.

2. METHOD

Based on the MCDM approach, the options and sub-criteria must be decided upon or chosen in accordance with their qualities. In MCDM scenarios, a certain number of possibilities are built, prioritized by the evaluator, and scored using the overall hierarchy.

The Analytic Hierarchy Process (AHP), a work with multiple Decision-Making (MCDM) tool, which is the main research method used to examine the key elements of human component accident causation in drone systems.

HFACS (Human Factors Analysis and Classification System) is a tool that is used to analyse and classify human error in complex systems. It was originally developed for aviation, but it has also been applied to other fields, including the operation of drones.

HFACS is based on the idea that human error can be broken down into four levels:

- Unsafe acts: These are actions that result in an accident or incident, such as violation of a rule or procedure, or failing to follow established procedures.
- Preconditions for unsafe acts: These are the factors that set the stage for unsafe acts to occur, such as inadequate training, fatigue, or poor communication.
- Unsafe supervision: This refers to inadequate oversight or management of the system, which can contribute to unsafe acts or conditions.
- Organizational influences: These are the broader factors that shape the culture and environment in which the system operates, such as policies, procedures, and incentives.

By analysing and classifying human error using the HFACS framework, it is possible to identify the root causes of accidents and incidents and to implement corrective actions to prevent them from occurring in the future. This can be particularly important in the operation of drone systems, where human error can have serious consequences.

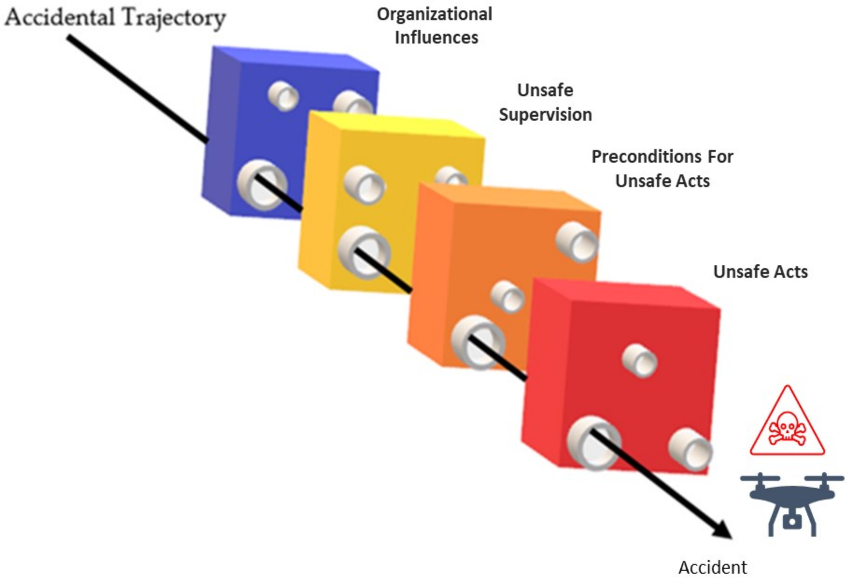

Figure 1 The 4 layers of HFACS captured by the Swiss cheese model

To reflect on the drone's system, the present authors developed a two-level hierarchy model from the HFACS with four key criteria captured from the "Swiss Cheese Model," as shown in Figure 1. The HFACS model categorizes the four main categories of organizational effects, supervision, preconditions, and unsafe behaviours as the primary elements of human factors accident causation aspects in aviation. In this research, fifteen sub-criteria that are suited for the drone's system were taken into account.

Figure 2 demonstrates the hierarchical model for the HFACS for drones with the components of each level.

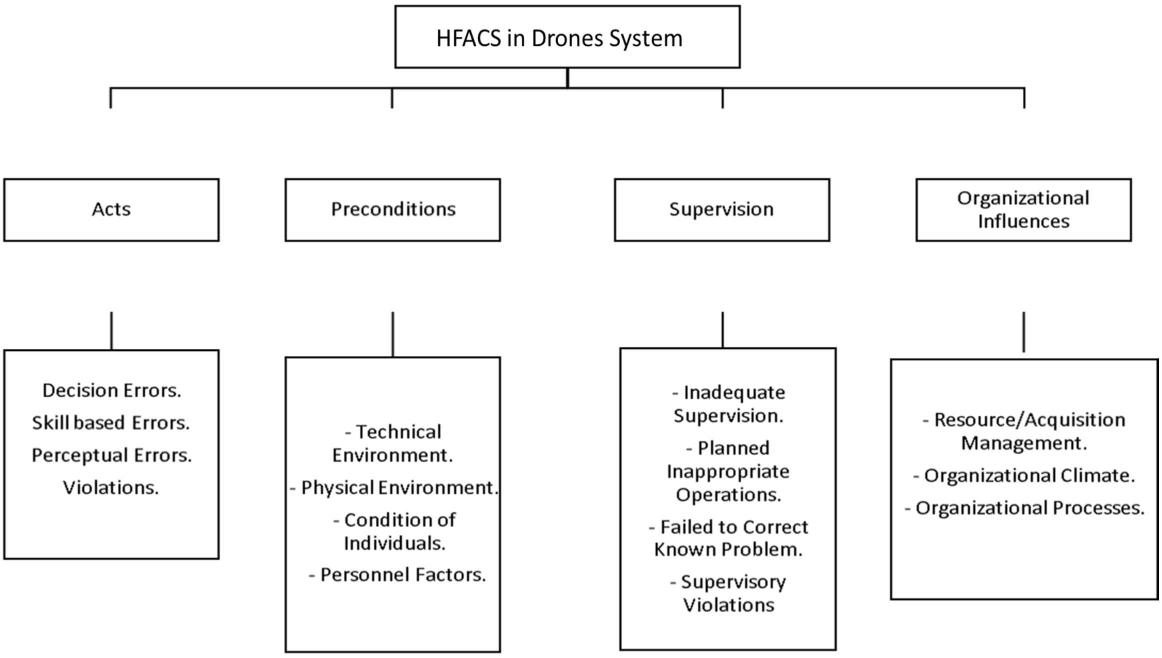

Figure 2 The hierarchical model

The AHP makes use of the special characteristics of pairwise comparison matrices (PCM), and the decision-makers' choice between certain pairs of alternatives demonstrates the significance and priority of one feature over another based on a scale (Table 1). Pairwise comparisons matrix (equation 1) represents the degree of the decision-preference maker's (Ai vs Aj, for all I j = 1, 2, or n) between specific pairs of choices which is given by the expression A = [aij]. The pairwise comparison matrix may be expressed as follows:

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & . & . & a_{1j} & . & . & a_{1n} \\ \frac{1}{a_{12}} & 1 & . & . & a_{2j} & . & . & a_{2n} \\ . & & . & & & & & . \\ . & & & . & & & & . \\ \frac{1}{a_{1j}} & \frac{1}{a_{2j}} & . & . & a_{ij} & . & . & a_{in} \\ . & . & & & & . & & . \\ . & . & & & & & . & . \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & . & . & \frac{1}{a_{in}} & . & . & 1 \end{bmatrix} \quad (1)$$

Table 1 Saaty Scale [26]

Numerical value	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values

The geometric mean of each category is calculated in the pairwise comparison matrices in order to provide prioritization recommendations and show the effect of each model component on each level. Since the most of expertise matrices are unreliable, the matrix consistency ratio must be lower than 0.1. For groups, CR is computed.

An online AHP-based survey of drone operators was developed and administered as part of this study. Figure 3 displays the participants' drone operations areas in a two-level hierarchical model.

Participants included 16 drone pilots from 10 different countries, which have been categorized into four groups as follows: (i) commercial drone operators (ii) engineering drone operators (iii) military drone operators (iv) agricultural drone operators. Figure 4 illustrates the participant's countries.

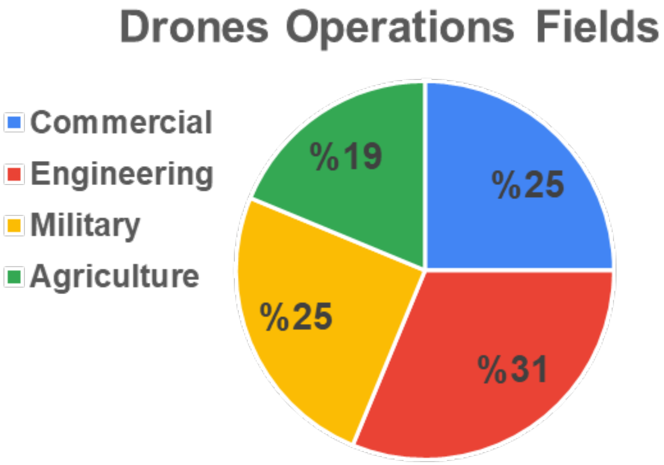

Figure 3 Drone operations fields

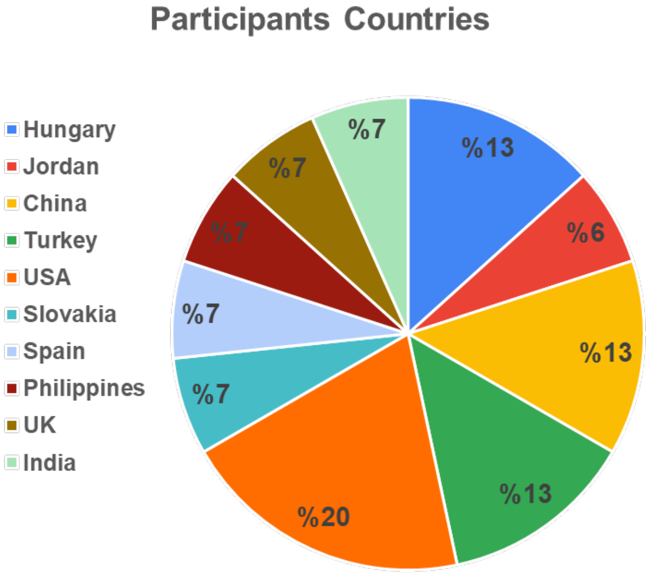

Figure 4 Participants drone pilots Countries

3. RESULTS AND DISCUSSIONS

The AHP technique quantifies and presents the model's participants' preferences before comparing and contrasting the groups overviews. The AHP technique will draw attention to the important characteristics based on pairwise comparisons. The replies have been compiled and examined using the geometric mean.

The important characteristics (weights and consistency ratio) have been calculated for the first level of the HFACS model for each group in the pairwise comparison matrices (PCM), tables (Tables 2, 3, 4, and 5) based on the responses from the four groups of drone pilots and using the AHP procedure, assessing and weighting the characteristics in each level independently:

Table 2 Commercial drone pilots PCM

HFACS	Organizational Influences	Supervision	Preconditions	Acts	Weights
Organizational Influences	1.00	1.68	2.99	1.57	37.63 %
Supervision	0.59	1.00	1.61	0.35	17.12 %
Preconditions	0.33	0.62	1.00	0.37	11.53 %
Acts	0.64	2.83	2.74	1.00	33.72 %
CR= 0.0310	Sum=				100 %

Table 3 Engineering Drone pilots PCM

HFACS	Organizational Influences	Supervision	Preconditions	Acts	Weights
Organizational Influences	1.00	2.43	1.38	1.30	34.59 %
Supervision	0.41	1.00	0.68	0.72	16.13 %
Preconditions	0.72	1.48	1.00	0.63	21.81 %
Acts	0.77	1.38	1.58	1.00	27.47 %
CR= 0.0129	Sum=				100 %

Table 4 Military Drone pilots PCM

HFACS	Organizational Influences	Supervision	Preconditions	Acts	Weights
Organizational Influences	1.00	2.45	3.66	0.87	36.41 %
Supervision	0.41	1.00	2.03	0.36	16.37 %
Preconditions	0.27	0.49	1.00	0.46	11.21 %
Acts	1.14	2.78	2.16	1.00	36.01 %
CR= 0.0342	Sum=				100 %

Table 5 Agricultural Drone pilots PCM

HFACS	Organizational Influences	Supervision	Preconditions	Acts	Weights
Organizational Influences	1.00	0.74	2.88	0.79	25.02 %
Supervision	1.36	1.00	4.38	0.55	31.13 %
Preconditions	0.35	0.23	1.00	0.63	11.20 %
Acts	1.26	1.82	1.59	1.00	32.64 %
CR= 0.0894	Sum=				100 %

The perspectives of the four groups would show the disparities between them, which may be obvious as skill level and work category expand. It would be straightforward to assess and compare distinct individual drone accident causation elements from other overviews by comparing different participant groups. As can be seen from the preceding tables, the majority of the drone pilot categories' findings indicated that organizational influences and the likelihood that unsafe acts would be the main cause of accidents were the most crucial factors from their perspectives, reflecting the significance of legislation in drone operations.

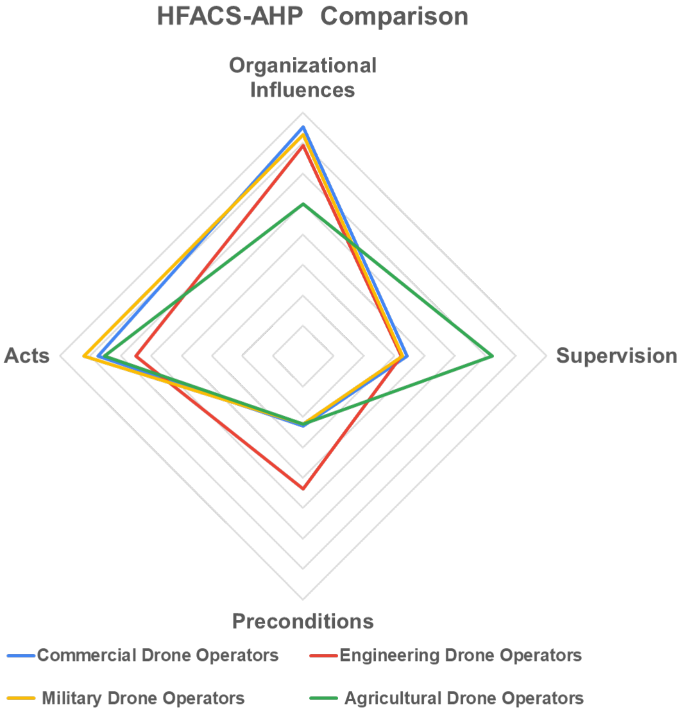

Figure 5 HFACS-AHP comparison for all pilots' categories

However, engineering drone pilots illustrate more consistent overviews between the model aspects. On the other hand, agricultural drone pilots' criteria show some fluctuations and highlight the need for supervision in the drone's current systems in agricultural industries,
Figure 5 represents a comparison between the four drone pilot categories' overviews of the HFACS-AHP Model.

4. CONCLUSIONS

The results demonstrated a preferred order and scalability for the Human Factor Analysis and Classification System (HFACS) accident causation in drone operations based on the participating pilots' replies to the AHP process. This selection order and weighting highlight the critical elements inside each level and give a clear image of the vital aspects. AHP in particular, played a significant role in analysing important characteristics in a potential drone environment and reducing crucial human errors.

The disparities between the individual viewpoints in the model are acquired to explain the present Unmanned Ariel System (UAS) strategy using qualitative and quantitative criteria as well as the conventional, fundamental, and simple analytical hierarchical process (AHP) decision-making procedure. The survey's findings were based on the participation of 16 drone pilots, divided into four groups.

According to the hierarchal model, three of the expert groups identified organizational influences as the most significant factor. For example, the commercial pilots' group ranked organizational influences as the top factor, with 37.6% of the hierarchy. In contrast, the agricultural drone pilots identified unsafe acts as the most critical factor, representing 32.6% of the hierarchy, followed by unsafe supervision at 31.1%.

Additionally, the engineering drone pilots placed a higher weight (21.8%) on precondition aspects compared to the other groups (around 11%), demonstrating a discrepancy between the groups. This highlights the usefulness of the AHP method in considering all viewpoints and not ignoring any discrepancies.

The findings showed that the system's experience level and practice elements were identified by existing challenges with drone licensing, regulatory frameworks, and varied industry situations.

The results of this study highlighted the value of drone pilots' decision and skill in the system. This study shows that the drone pilots' legislation and unsafe actions have a huge effect on the HFACS model for the vast majority of participants. The effects on the first level of the organization may be examined if there were a uniform understanding of the license need for drone pilots.

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