Classifying emerging Human Factors Risks in Eastern Africa Aviation Operations using HFACS analysis

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Abstract

Aviation safety in the African region has continued to be a concern for the International Civil Aviation Organization (ICAO) and the industry as a whole. Accident statistics show Africa's accident rate at 5.3 per one million departures with 3% of the worldwide traffic distribution (ICAO, 2013). Human error has been suggested to account for 70–80% of all aviation accidents. The Human Factors Analysis and Classification System (HFACS) methodology was applied to accident reports from two Eastern African countries: Kenya and Uganda. In all, 42 finalized reports for accidents occurring between 2000 and 2017 were analyzed. In all unsafe acts predominated with Kenya 44%, Uganda 50%. Categorizing violations found exceptional violations were highest with Kenya at 77% and Uganda 81%. Pre-conditions for unsafe acts follow closely after the unsafe acts. A comparison between Kenya and Uganda's HFACs analysis shows that both countries share two significant categories of unsafe acts (Breakdown of Visual scan x Vestibular Illusions and Poorly Executed procedures x Misinterpretation/misuse of information) with positive correlation coefficients. The rest of the shared categories are unsafe acts versus pre-conditions for unsafe acts (Forgotten Intensions x Crew Resource Management), unsafe supervision versus pre-conditions for unsafe acts and unsafe supervision versus pre-conditions for unsafe acts. The results were consistent with previous industry observations: Over 70% of aviation accidents in Africa have human factor causes. Adverse weather was seen to be a common secondary casual factor. Changes in flight training and risk management methods may alleviate the high number of accidents in Africa.

Keywords: Aviation, Aviation accidents, Eastern Africa, Human Factors, HFACs

INTRODUCTION

Many authors have done research and written reports about different accidents and incidents worldwide caused by human factors. In the Eastern Africa region, these human factors are not elaborately investigated and documented partly because common aeromedical conditions are not detectable at autopsy (hypoxia, spatial disorientation, fatigue, stress), complicating ability to indict medical causation. The persistent conclusion that developing countries have much poorer safety records has been the case in aviation safety research and continues to be so (ICAO, 2014). The Swiss cheese model stipulates that accident investigators must analyze all aspects of the system to fully understand the causes of accidents and improve safety. For example, if you go backwards from the moment of the accident, unsafe acts of cockpit crew will be the first level to be examined. Reason's model directs accident investigators to find hidden errors, from this point of view the model mentions additional levels of errors that could lead to an accident.

Human factors work has been done elsewhere but not in the Eastern Africa region. It is important to identifying emerging risk factors, characterize these risks through modeling exposure and consequences, prioritize the risk and make recommendations with regard to necessary improvements (GAO, 2012, Oster, 2013). That understanding is then translated into design, training, policies, or procedures to help humans perform better, and design airplanes and support products that help humans to perform to the best of their capabilities while compensating for their natural limitations.

METHODOLOGY

Document review analysis which involved the relevant information from final accident and incident investigation reports was done. A documentary review checklist consisting of all documentation about aviation final accidents and incidents investigation reports from Kenya and Uganda was examined and reviewed for selection of human factors related causes. The selected reports included those for aircrafts registered within Eastern Africa (Figure 1) and beyond but having accident or incidents occurring within Kenya and Uganda between 2000- 2017. Accidents and incidents involving human errors were then categorized by 4 types of personnel (ground crew, Air Traffic Controllers (ATC), maintenance and aircrew) who had direct or indirect influence on the occurrences. The contributing factors of the occurrences were coded into of Human Factors Analysis classification system (HFACS) categories based on the probable causes in each report. These HFACs levels are as follows; level 1 - unsafe acts, level 2 - preconditions for unsafe acts, level 3 - unsafe supervision, level 4 - organizational influences (Shappell & Wiegmann, 2003). The coding started from higher levels of failure to sub-categories, mapping each causal factor mentioned in the report to the HFACS categories (Yan & Histon, 2014). The analysis of the data consisted of two parts. In the first part, the data which was obtained after coding was explained in detail, with graphics and tables. The second part of analysis, was to transfer the data to SigmaPlot program and establish the nature of relationship between "Causal Factors" of HFACS which were examined. As a result, the relationship between operations and organizations in aircraft accidents was examined and visualized.

RESULTS

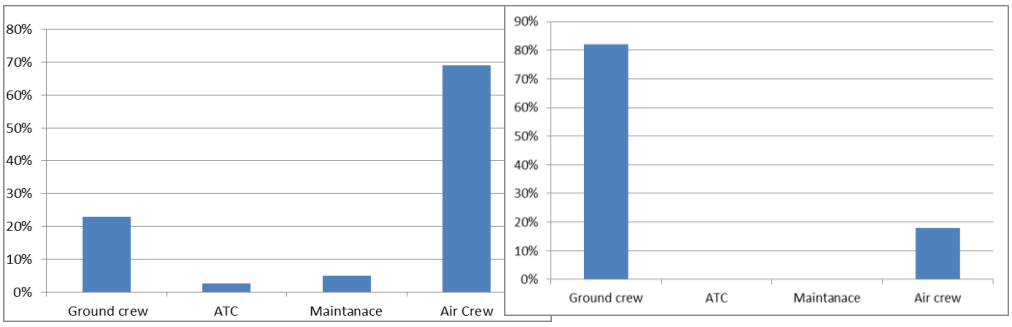

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Figure 2: The four main target group categories of HFACS in A. Kenya and B. Uganda

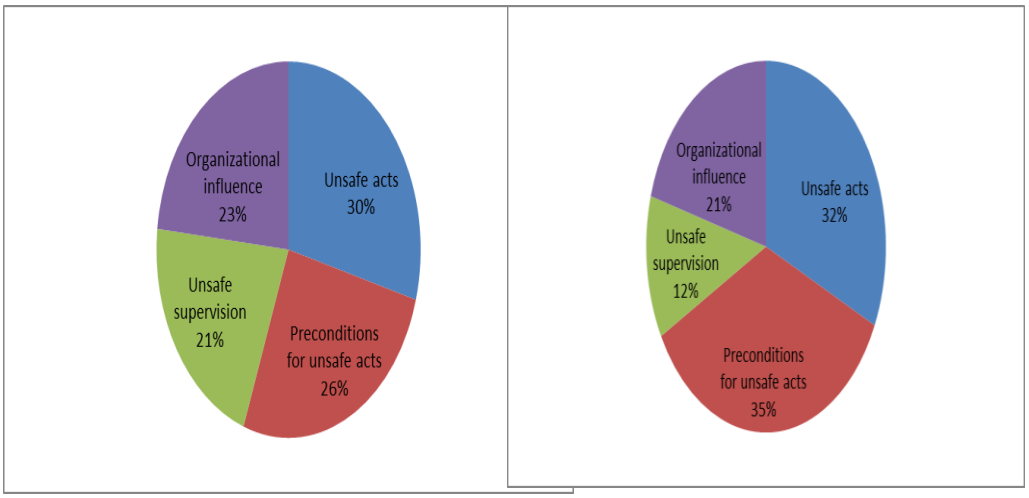

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Figure 3: The ratio of four main factors of HFACS affecting each other in A. Kenya and B. Uganda

Unsafe acts analysis

These were examined in the two categories: Errors and violations. As a result of analysis and coding the ratio of unsafe acts is given Figure 3 bellow.

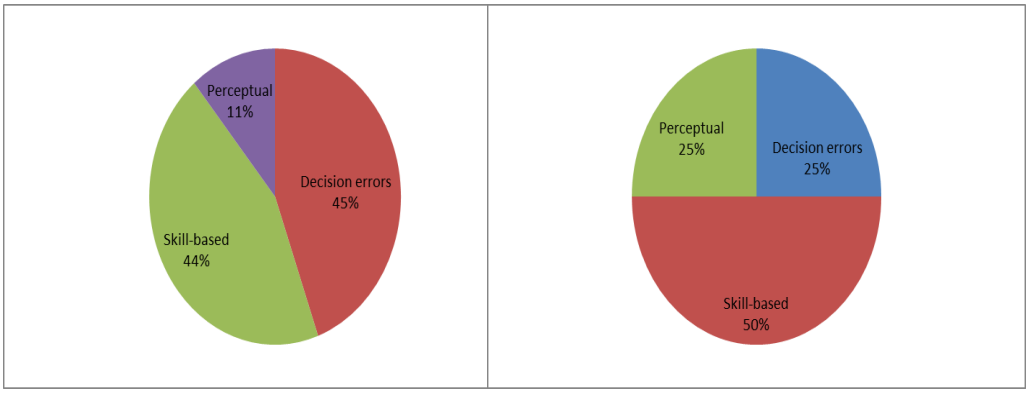

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Figure 4: Percentage of errors for A. Kenya and B. Uganda

Table 1: Errors in both Kenya and Uganda

Decision errors	Kenya (%)	Uganda (%)
Poorly executed procedures	37.5%	0%
Improper choices	37.5%	50%
Misinterpretation or misused information	25%	0%
Skill-based errors		
Break down of visual scan	0%	0%
Inadvertent activation/deactivation	25%	0%
Forgotten intentions	12.5%	33.3%
Omitted items on checklist	12.5%	33.3%
Manner or skill with which one flies	50%	33.3%
Perceptual error		
Misjudging distance	50%	50%
Visual illusions	50%	50%
Vestibular illusion	0%	0%

The table 1 above shows, the highest proportion of decision errors was the improper choices with Kenya at 37.5% and Uganda at 50%. Poorly executed procedures were next with Kenya at 37.5% and lastly misinterpretation/ misuse of information at 25%. (Note that percentages will not add up to 100% because each accident typically associated with multiple causal factors across several causal categories).

When skill-based errors were examined, the commonest of all decision errors was the manner with which one flies with Kenya at 50% and Uganda at 33.3%. Other factors with high rates were inadvertent activation/deactivation of controls with Kenya at 25%, forgotten intensions and omitted items on the checklist had same ratings of Kenya 12.5% and Uganda 33.3%. When the perceptual errors were examined, misjudged distance/altitude/airspeed factors and visual illusions were both seen at Kenya 50% and Uganda at 50%.

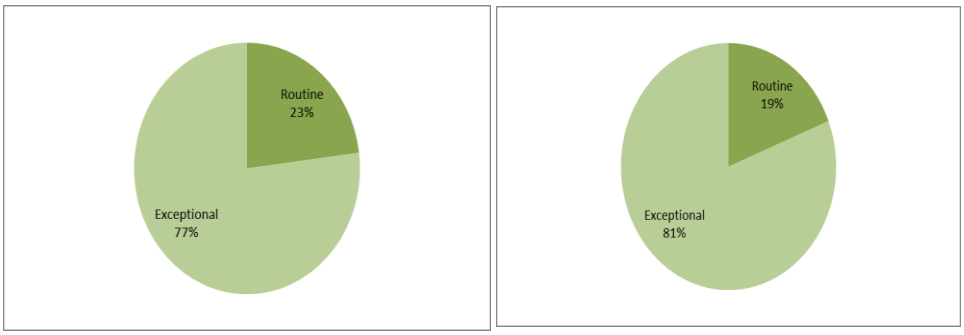

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Figure 5 shows Percentage of violations for A. Kenya and B. Uganda

The figure 5 shows the most frequent types of violation were exceptional violations with Kenya at 77% and Uganda 81%. Routine violations were lower with Kenya 23%and Uganda 19%. This tallies with Munene 2016 who classified a total of 55 of the 72 civil accident investigation reports involving aircraft occurring within Africa irrespective of ownership or country of registration were selected for analysis. The numbers per country were as follows: Kenya, 11 of 14; Nigeria, 10 of 13; and South Africa, 34 of 45. These reports were considered to have one or more human factors as

causal and contributory factors. In line with Shappell and Wiegmann's (1997) observation, 76% of African aviation accidents were related to human factors (Munene 2016). His findings show of the 55 accidents analyzed in Kenya, Nigeria and South Africa (2000- 2014) unsafe acts of the pilot operators were observed, 56.4% (31) of them exhibited skill-based errors, making it the most common category of human factor failure. The similar findings in the current study show Kenya 44% and Uganda 50% on skilled based error. These errors were observed in a majority of South Africa's accidents (82%), an indicator of its prevalence in Africa's accidents.

Analysis of Precondition for Unsafe Acts

Table 2: Preconditions for unsafe acts in both Kenya and Uganda

Preconditions for unsafe acts	Kenya (%)	Uganda (%)
Substandard conditions of operation		
Adverse mental states	11%	14%
Adverse physiological states	33%	21%
Physical/Mental limitations	51.9%	35.7%
Substandard practices of operation		
Crew resource management	3.7%	14%
Personal readiness	0%	14%

The table 2, shows preconditions for unsafe acts has physical/ mental limitations at 51.9% for Kenya and 35.7% for Uganda. This is followed by adverse physiological states with Kenya at 33% and Uganda at 21%. Adverse mental states follow with Kenya at 33% and Uganda 21%, least were Crew Resource Management (CRM) and personal readiness respectively.

Analysis of Unsafe Supervision

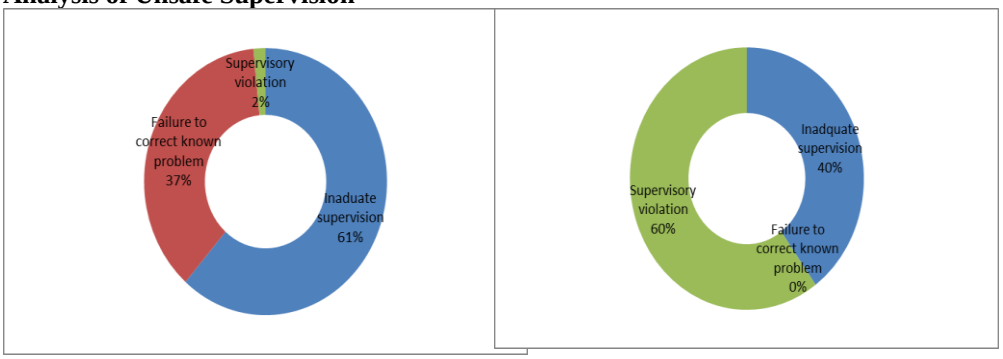

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Figure 6: Percentage of unsafe supervision for A. Kenya and B. Uganda

The figure 7 below shows organizational influences with resource/ acquisition management for Kenya at 43% and Uganda at 50%, the contribution of organizational process in Kenya at 48% and Uganda at 13%. Organizational climate factor is relatively high in Uganda at 37% as compared to Kenya at only 9%.

Analysis of Organizational Influences

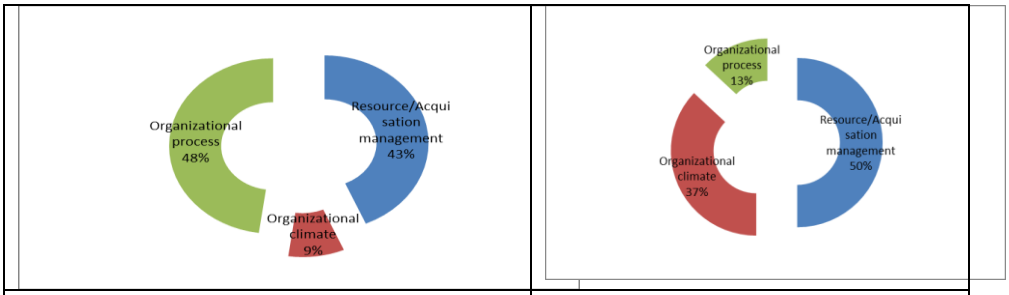

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Figure 7: Percentage of organizational influence for A. Kenya and B. Uganda

Relationship analysis

Table 3: Kenyan data analysis for the various HFACs levels

	Correlation Value	p-Value
Level 4 x Level 4		
Resource management x Organizational Climate	0.381	0.0347
Level 4 x Level 2		
Adverse Mental state x Resource Management	0.381	0.0347
Level 3 x Level 2		
Physical and Mental states x Supervisory violations	0.411	0.0219
Crew Resource Man agent x Failure to correct known problem	0.558	0.00120
Level 3 x Level 1		
Forgotten intensions x Failure to correct known problem	0.558	0.00120
Misinterpretation/ misuse of information x Failure to correct known problem	0.358	0.0478
Misjudgment of distance x Inadequate Supervision	0.416	0.0200
Level 1 x Level 2		
Vestibular Illusion x Personal Readiness	1	0.0000002
Breakdown of Visual scan x Personal Readiness	1	0.0000002
Forgotten Intensions x Crew Resource Management	1	0.0000002
Misinterpretation/ misuse of information x Crew Resource Management	0.695	0.00000455
Poorly Executed Procedures x Crew Resource Management	0.558	0.00120
Manner or skill of flying x Adverse Physiological state	0.390	0.0303
Level 1 x Level 1		
Routine Violation x Exceptional Violation	0.512	0.00343
Omitted items in the check list x Routine Violation	0.558	0.00120
Inadvertent Activation X Routine Violations	0.358	0.0478
Improper choices x Exceptional Violations	0.411	0.0220
Improper Choices x Routine Violations	0.358	0.0478
Breakdown of Visual scan x Exceptional Violations	1	0.0000002
Inadvertent Activation x Misjudgment of distance	0.695	0.00000455
Inadvertent Activation x Omitted items in the checklist	0.695	0.00000455
Misinterpretation/ misuse of information x Forgotten intentions	0.695	0.00000455
Improper Choices x Omitted items in the checklist	0.695	0.00000455
Poorly executed procedures x Forgotten intentions	0.466	0.00859
Poorly executed procedures x Misinterpretation/misuse of information	0.358	0.0478

The pair(s) of variables with positive correlation coefficients and P values below 0.050 tend to increase together. For the pairs with negative correlation coefficients and P values below 0.050,

one variable tends to decrease while the other increases. For pairs with P values greater than 0.050, there is no significant relationship between the two variables.

A comparison at different HFACs categories shows that Kenya has more human factors risks at unsafe acts level1 x level1 with 12 categories having significant positive correlation coefficients and $p < 0.05$. This is followed by unsafe acts versus pre-conditions for unsafe acts Level1 x level2 which has 6 categories. The least number of risks are recorded at organizational influences level4 x level4 with only one significant category.

Table 4: Ugandan data analysis for the various HFACs levels

	Correlation Value	**p- value**
Level 4 x Level 3		
Inadequate Supervision x Organizational Process	0.671	0.0201
Level 4 x Level 1		
Manner or skill with which one flies x Organizational Process	1	0.0000002
Routine violations x Organizational Climate	0.671	0.0201
Visual Illusions x Organizational Climate	0.671	0.0201
Level 3 x Level 2		
Physical and Mental Limitations x Supervisory Violations	0.671	0.0201
Level 3 x Level 1		
Vestibular Illusions x Failure to correct known problem	1	0.0000002
Breakdown of visual scan x Failure to correct known problem	1	0.0000002
Misinterpretation or misuse of information x Failure to correct known problem	1	0.0000002
Poorly executed procedures x Failure to correct known problem	1	0.0000002
Manner with which one flies x Inadequate Supervision	0.671	0.0209
Omitted items on checklist x Inadequate Supervision	0.671	0.0209
Level 2 x Level 1		
Omitted items on the checklist x Personal Readiness	0.671	0.0209
Inadvertent activation of switches x Personal Readiness	0.671	0.0209
Misjudgment of Distance x Crew Resource Management	0.671	0.0209
Forgotten intentions x Crew Resource Management	0.671	0.0209
Misjudgment of Distance x Adverse Mental States	0.671	0.0209
Forgotten Intensions x Adverse Mental States	0.671	0.0209
Level 1 x Level 1		
Visual Illusions x Routine Violations	1	0.0000002
Breakdown of Visual scan x Vestibular Illusions	1	0.0000002
Misinterpretation/ misuse of information x Vestibular Illusions	1	0.0000002
Poorly executed procedures x Vestibular Illusions	1	0.0000002
Forgotten Intensions x Misjudgment of Distance	1	0.0000002
Improper Choices x Misjudgment of Distance	0.671	0.0209
Improper Choices x Forgotten intensions	0.671	0.0209
Misinterpretation or misuse of information x Breakdown of Visual scan	1	0.0000002
Poorly Executed Procedures x Breakdown of Visual scan	1	0.0000002
Poorly Executed Procedures x Misinterpretation /misuse of information	1	0.0000002

The pair(s) of variables with positive correlation coefficients and P values below 0.050 tend to increase together. For the pairs with negative correlation coefficients and P values below 0.050, one variable tends to decrease while the other increases. For pairs with P values greater than 0.050, there is no significant relationship between the two variables.

A comparison at different HFACs categories shows that Uganda has more human factors risks at unsafe acts level 1 x level 1with 10 categories having significant correlation coefficients with $p < 0.05$. This is followed by unsafe acts versus pre-conditions for unsafe acts Level 1 x level 2 with 6 categories of correlating factors at p

< 0.05 and unsafe acts versus unsafe supervision level 1x level 3 with 6. The least number of risks are recorded at organizational influences level 4 x level 3 with only 1 significant correlation.

Table 5: Comparison of Kenya and Uganda data analysis for the various HFACs levels

	Value	**p-Value**	**Value**	**p- Value**
Level 3 x Level 2	Kenya	Kenya	Uganda	Uganda
Physical and Mental limitations x Supervisory violation	0.411	0.0219	0.671	0.0209
Level 3 x Level 1				
Misinterpretation/ misuse of information x Failure to correct known problem	0.368	0.0478	1	0.0000002
Level 2 x Level 1				
Forgotten Intensions x Crew Resource Management	1	0.0000002	0.671	0.0209
Level 1 x Level 1				
Breakdown of Visual scan x Vestibular Illusions	1	0.0000002	1	0.0000002
Poorly Executed procedures x Misinterpretation/misuse of information	0.358	0.0478	1	0.0000002

The pair(s) of variables with positive correlation coefficients and P values below 0.050 tend to increase together. For the pairs with negative correlation coefficients and P values below 0.050, one variable tends to decrease while the other increases. For pairs with P values greater than 0.050, there is no significant relationship between the two variables.

A comparison between Kenya and Uganda's HFACs analysis shows that both countries share two significant categories of unsafe acts level 1- level 1 with positive correlation coefficients and p <0.05. The rest of the shared categories are unsafe acts versus pre-conditions for unsafe acts level 2 x level 1, unsafe supervision versus pre-conditions for unsafe acts level 3 x level 1and unsafe supervision versus pre-conditions for unsafe acts level 3 x level 2.

Table 6: Comparison of Kenya data analysis for the various HFACs with 17 countries worldwide Dönmez, K., Uslu, S. (2018)

	Kenya	**Kenya**	**Worldwide**	**Worldwide**
Level 3 x Level 2	Value	p- value	Value	p- value
Crew Resource Management x Failure to correct a known problem	0.558	0.0012	0.506	0.000

Table 7. Comparison of Uganda data analysis for the various HFACs with 17 countries worldwide Dönmez, K., Uslu, S. (2018).

	Uganda	**Uganda**	**Worldwide**	**Worldwide**
Level 4 x Level 3	Value	p- value	Value	p- value
Organizational Process x Inadequate Supervision	0.671	0.0209	0.654	0.000
Adverse Mental States x Skill Based Errors	0.671	0.0209	0.307	0.009

The above comparison in table 7 shows that Kenya shares significant HFACs risks at the level of pre-conditions for unsafe acts versus unsafe supervision level 2 x level 3. While Uganda shares significant HFACs risks at unsafe supervision versus organizational influences with 17 countries worldwide.

DISCUSSION

Unsafe Acts: These were examined in the two categories: Errors and violations. Table 3, 4 and 5 depicts a level of poor performance of tasks/teamwork, forgotten intentions and vestibular illusions in both countries. Based on Prof James Reason's findings in Human Factors a high level of unsafe acts in both countries is due to: Latent conditions which are inevitable flows in the system that will eventually lead to error e.g. poor design, procedures or management. Or due to active failures which are frequently caused by unsafe actions by people involved in the safety system. This is due to a lack of situational awareness by the respective crew. Situational awareness relates to how aware the individual is of their surroundings and the task unfolding in real time. Our heightened level of concentration on a particular task may divert attention away from other seemingly less important areas or tasks. This could be due to direct violation of systems or due to insufficient training and poor planning. This is further justified by Munene (2016) who observed violations at 36% of Kenya's accidents with instances where the pilots did not follow company procedures or policies for operations, exceeded the aircraft manufacturer's demonstrated performance capability, or failed to prepare adequately for the flight they performed.

Edwards (2013) notes that most human factors impact situational awareness and may then affect human performance. Endsley and Rodgers (1996) concluded that attention distribution strategies may sometimes lead to reduction in situational awareness. If attention is not directed to certain key information in the environment, situational awareness cannot be maintained. Subsequently the reduction in situational awareness is likely to lead to a decline in human performance. Most human factors impact situational awareness and may then affect human performance. The relationship between workload and stress may also be relevant to the interaction of situational awareness and workload. Martins, *et. al.,* (2014) states that the flaws in the commitment of decision-making in emergency situations and the lack of perception related to all elements associated with a given situation in a short space of time indicate, often lead to lack of situational awareness. Martins, *et. al.,* (2014) further stipulates that this scenario contributes to emotional disorders and a growing hidden problem in the aeronautical field. He also states that the unexpected automation surprises reflect a complete misunderstanding or even the misinformation of the users. It also reveals their inability and limitations to overcome these new situations that were not foreseen by the aircraft designers.

Misinterpretations and forgotten intentions are depicted in Table 3 and 4: These arise due to communication problems which include; lack of communication brought about when a person forgets to pass on pertinent information to colleagues, or when a written message is mislaid. Poor communication is typified by a person who does not make the message clear; does not emphasize what the receiver needs to know and consequently receives inappropriate information, or a written report is barely legible handwriting. Sternberg (2000) further states that the mind of the pilot is influenced by cognition and communication components during flight, especially if we observe all information processed and are very critical considering that one is constantly getting this information through their instruments. There is information about altitude, speed and position of one's aircraft and the operation of its hydraulic power systems. If any problem occurs, several lights will light up and warning sounds emerge increasing the volume and type of man-machine communication which can diminish the perception of detail in information that must be processed and administered by the pilot. All this information must be processed by one's brain at the same time as it decides the necessary action in a context of very limited time. There is a limit of information that

the brain can deal with which is part of natural human limitation. It can lead to the unusual situation in which, although the mind is operating normally, the volume of data makes it operate in overload, which may lead to failures and mistakes if we consider this man as a biological machine. Communication is a prominent factor that impacts situational awareness. Koester (2003) investigated situational awareness and results showed that at potentially critical situations, relevant communication types increased and general communication dropped.

Precondition for Unsafe Acts: While unsafe acts can lead to the largest single cause of aircraft accidents, the analysis of the preconditions for unsafe acts is just as important. These preconditions could be due to direct violation of systems or due to insufficient training and poor planning for example starting a task without planning how best to do it almost certainly leads to an error. It is important to note that pre-conditions for unsafe acts always follow closely after the unsafe acts.

Analysis of Unsafe Supervision also has contribution to the cause of aircraft accidents and incidents in the study region, this can be attributed to the cockpit crew controlling the aircraft. However, there may be errors and violations made by the managers and supervisors, behind the causes of aircraft accidents.

Organizational influences are the last of the HFACS levels and it shows us how the top-level organization or management has an impact on aircraft accidents. These reports were considered to have one or more human factors as causal and contributory factors.

CONCLUSSION AND RECOMMENDATIONS

Unsafe acts followed by preconditions for unsafe acts still dominate in the study region. This research sought to identify the contributory human factors to the selected accidents. The selection of the two countries' accident and incident data aimed to capture the diversity of Eastern Africa aviation human factors risks. The limited number and access to accident reports for Uganda shows a need for African countries to follow other countries' lead in having a robust aviation safety organization that investigates and documents for their accidents. The low number of accident reports from Uganda is a limitation for the study and therefore is considered an initial step in understanding human factors as contributors to accidents in Africa. A larger dataset and multiple coders should be used in future research. Accident and incident reports in Uganda, be made readily available to the public on the Ministry of Works website like is the case for Kenya.

BIODATA

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