Interior design factors influencing fire disaster risk in domestic aircraft in Kenya

Francis Munguti Ndithya[1]
Nicodemus Nyandiko Omoyo[2]
Stanley Omuterema Oluchiri[3]

[1]fmndithya@gmail.com
[2]nnyandiko@mmust.ac.ke
[3]somuterema@mmust.ac.ke

[1] https://orcid.org/0009-0002-8501-3144
[2] https://orcid.org/0000-0003-2084-5230
[3] https://orcid.org/0000-0002-6381-7101

[1,2,3]Masinde Muliro University of Science and Technology, Kenya

https://doi.org/10.51867/ajernet.7.2.95

ABSTRACT

In-flight fire is a significant concern for aviation safety, and the interior design of aircraft such as size, construction materials, and seating layouts affect the fire spread and evacuation performance. The interior design vulnerabilities of domestic aviation in Kenya have progressed at an impressive rate. This study assessed the interior design factors influencing fire disaster risk in domestic aircraft in Kenya. It was guided by the Swiss Cheese Model of Accident Causation. The study was conducted at the Kenya Airports Authority (KAA) with a focus on airports in Kenya handling domestic air transport. The target population included aeronautical engineers, Airport Rescue and Firefighting (ARFF) personnel, and KCAA inspectors, totaling 160 individuals. Sample size was determined using the help of Krejcie and Morgan sampling table. The airports sampled were Jomo Kenyatta International Airport (JKIA), Wilson Airport, Moi International Airport, Kisumu International Airport and Eldoret International Airport. Wajir International Airport was excluded after being used for the pilot survey. The sample was 114 participants who were distributed proportionately. The study design used was descriptive and evaluative. Data collection was based on both structured questionnaires with 5-point Likert scale items and interview guides. Data was analyzed quantitatively using the IBM SPSS Statistics version 27.0 with the use of the descriptive statistics (frequencies, percentages, mean, and standard deviation) and the inferential statistics (Pearson correlation coefficients). Qualitative data was analyzed using the theme and reported verbatim. The study found that there were high perceptions of design influences with 54.6% (n=59) of respondents perceiving that aircraft size had a large or very large impact on emergency exit availability (M=3.54); 72.8% (n=67) believing that materials were very effective in preventing fire propagation (M=3.96); and 61.4% (n=62) acknowledging that materials contributed to the fire risk (M=3.01). There was mixed opinion regarding seating arrangements with 32.7% (n=33) indicating they were very influential to ease of evacuation (M=2.90). Pearson correlation analyses, however, showed that the interior design factors were weak and nonsignificant in predicting fire disaster risk (rs=.015 to .149, ps>.05), indicating that alone they are not good linear predictors of fire risk. Analysis of the ranking showed that perceptions of material fire resistance (M=3.96) and aircraft size–exit availability linkages (M=3.54) were more important than seating configuration effects. This study concludes that aviation professionals believe the most critical design considerations for fire safety are construction materials and the size of aircraft, but there is ambivalence about construction materials for aging fleets. This study recommends that given the results, KCAA require regular testing of the flammability of aircraft cabin materials for aircraft in domestic services in Kenya, including special focus on aftermarket changes and aging aircraft.

Keywords: Aircraft Interior Design, Domestic Aviation, Fire Disaster Risk, Fire Safety, Kenya Civil Aviation Authority (KCAA), Swiss Cheese Model

I. INTRODUCTION

Air transport is a key enabler of international economic and social integration. In-flight fires, however, are one of the biggest threats to aviation safety and are frequently caused by electrical problems, overheated equipment or material that is easily combustible in the cabin (Billings, 2018). As was established in the 2005 B747 freighter fire incident, fires can be highly destructive (Joint Aircraft Survivability Program Office, 2005). The Federal Aviation Administration (FAA, 2023) reported that there were more than 1200 incidents of smoke, fire or fumes annually in the United States, and nearly half of them were in cabin areas. Moreover, the International Civil Aviation Organization (ICAO, 2023) highlighted that more than 30% of the in-flight fire incidents were to result from ignition of cabin materials or failure in the electrical system, emphasizing the critical significance of the interior design in developing the fire risks.

The main causes of death in aircraft fires are due to smoke inhalation and toxic emissions from burning cabin materials (Stevens, 2014; Mouritz, 2009). Transport related disaster deaths is a major contributor of all disaster related deaths in Africa with aviation disaster also playing a key role (Bjornstig & Forsberg, 2016). Human error, design weaknesses, and operational failures (Moir & Seabridge, 2008; United Nations Office for Disaster Risk Reduction [UNDRR], 2015) are recurring contributors among other factors and indicate that regional aviation systems are susceptible to fire related disasters.

Kenya's domestic air travel has grown significantly, and the issue of fire safety has been a constant issue. The KCAA (2023) has reported that in-flight fires constitute 8% to 12% of the emergencies for domestic and regional operations. For example, a galley fire in 2019 on a domestic flight in Kenya revealed some gaps in inspection and design of the cabin. Even though there are many regulations, limited research exists that looks at how interior design factors (e.g., material flammability, seat layout and insulation) interact with human actions that affect fire risk. This lack of knowledge limits evidence-based interventions that are adapted to the local context of operations.

Whilst there are inherent risks of fire onboard aircraft, the use of personal electronic devices and Lithium-Ion batteries has increased the risk of fire onboard aircraft even more (FAA, 2023; ICAO, 2023). Adding to these risks are crew mistakes and failure to follow safety procedures. These facts make it imperative that systematic empirical study be conducted. This study, therefore, aims to assess the impact of interior design of domestic aircraft on fire disaster risk reduction, to suggest safer design strategies, increase regulatory compliance and improve fire preventative measures for the domestic aircraft in Kenya.

1.1 Statement of the Problem

In domestic aircraft, interior design factors are one of the important elements that affect the risk of fire disaster. Non-flame-resistant furnishings, old upholstery, lack of insulation, and restrictive seating can hinder evacuation and speed the spread of fire. According to ICAO (2023), more than 30% of all in-flight fires worldwide are caused by ignition of the cabin materials or an electrical fault. This is made vulnerable by the fact that the domestic fleet is aging and there is lack of retrofitting of fire-resistant materials and inconsistent inspection regimes in Kenya. According to the KCAA (2023), 8–12% of in-flight emergencies are fire-based, and the fire incident in the galley of 2019 was an instance of such in-flight emergency showing the weakness of the designs. The aviation sector in Kenya had more than 370,000 aircraft movements in 2018, but there is a dearth of empirical studies on vulnerabilities in interior design in the country. This lack of information puts both regulators and airline companies and passengers at unnecessary risk.

1.2 Research Objectives

This study sought to assess the interior design factors influencing fire disaster risk in domestic aircraft in Kenya.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Swiss Cheese Model of Accident Causation

This study draws on James Reason's Swiss Cheese Model of Accident Causation, an underlying model in the study of high reliability organizations. The model assumes that accidents are caused by a sequence of barriers, each of which has its own weaknesses or "holes," that are lined up so that hazards are allowed to pass through and harm the system (Reason, 1997). These layers often consist of organizational influences, unsafe supervision, preconditions for unsafe acts and unsafe acts themselves (Reason, 2000). The Swiss Cheese Model has been widely used in aviation safety to understand how latent conditions (such as design flaws, maintenance oversights, regulatory loopholes) combine with active failures (crew errors, passenger actions) to result in catastrophic failures (SKYbrary, 2023). Cockpit design weaknesses, for example, can lie dormant and become exacerbated by pilot fatigue or bad weather, and hence become a pathway for accidents to happen.

Interior design elements (flammable cabin materials, lack of insulation, seating configurations, and door/exit configurations) are latent conditions or "holes" in the design layer of defense (Reason, 1990) in the context of aircraft fire risk. These design shortcomings can be compounded with active failures (such as a late response by the crew, electrical system failures and passenger panic), and result in convergent pathways for fire initiation, fire spread and failure to evacuate. The model thus offers a solid theoretical framework for explaining that despite statistically weak correlations between individual design factors and fire risk, these factors are not individually insignificant, but rather that fire risk is an issue of interaction between the design factors.

2.2 Empirical Review

Initial computational studies determined that the size of the cabin is an important factor on the spread of fire and evacuation effectiveness. Galea and Markatos (1991) used the computational fluid dynamics (CFD) simulation to

model the smoke dispersion and egress patterns in large aircraft cabins and concluded that the longer the cabin the faster the propagation speed of the fire and the longer the evacuation time. This was verified by full scale fire tests conducted in wide-body aircraft by Sarkos (1996), which showed that as the cabin dimensions increased, so did the complexity of the exit signage and crew coordination needed to achieve safe exit in 90 seconds as required by the FAAs' standard (2023). These findings were followed by evacuation simulation studies that further supported these conclusions. Muir et al (1996) have performed mock-up tests that found the evacuation times were 25% to 40% longer for high-density seating arrangements than for standard arrangements. Galea et al. (2011) was able to build on this study and work done using agent-based modelling, which again established that the position of seats, width of aisles, and exit closeness were significant factors for the survival probability in fire scenarios. These studies were mainly based on wide-body, international class aircraft (such as Boeing 747 and Airbus A380) and few focused on smaller regional jets widely used in domestic fleets in Africa. The flammability of materials has always been a key factor in the safety of aircraft fire. National Research Council (1995) have conducted an experimental study on upholstery and panelling samples from commercial aircraft and determined that the widely used polyurethane foams used to make seat cushions released a large amount of heat and toxic smoke when burning. In response, regulatory bodies put in place more stringent flammability requirements, such as the FAA's 12-sec vertical burn test and oil burner test for 60 seconds of cabin materials (FAA, 2023).

Lyon (2008) reviewed the progress in the development of fire-resistant polymers and mentioned the carbon fibre composites and intumescent coatings which have a significant impact on enhancing the fire resistance of polymers, but these are still expensive for many area operators. The National Research Council (1995) also pointed out that the effectiveness of materials decreases with aging, which can be attributed to UV exposure, cleaning chemicals, and mechanical wear in use, and therefore is of concern to aging fleets in emerging aviation markets. Most material testing is done in laboratory conditions, which restricts external validity for operational conditions in the field (Purser, 2019). Information on material degradation over periods of years in tropical climatic conditions (as opposed to those found in the UK) is limited. The arrangement of seats affects both the ability to evacuate the passengers and access for emergency responders. Muir et al. (1996) showed that seating configurations in a narrow body aircraft for 3-3 seating at the aisle intersections caused delays in aircraft egress by up to 18 sec over the 2-2 aircraft seating configuration. Galea et al. (2011) also demonstrated that seat recline angle, and under-seat storage had impacts on trip hazards during low-visibility evacuations. But these results are largely based on simulations involving volunteer participants and may not reflect actual panic induced behaviours in emergencies (Moir & Seabridge, 2008). Further, most studies consider the same passenger demographics: the impact of cultural factors, passenger training or disability accommodation on evacuation dynamics are under-researched in Africa.

Research on the safety of African aviation has mainly focused on systemic issues and not the details of interior design. UNDRR (2015) compiled continental disaster data, including that on transport accidents, which disproportionately impact regions with outdated fleets, limited maintenance facilities and weak regulation. Likewise, according to the World Health Organization (2018), in Africa, about 45% of deaths in disasters are caused by transport-related injuries, although the data for aircraft were combined with other data. These macro-level analyses are useful for revealing structural vulnerabilities but don't show specific cabin-level design factors. Most sampling strategies relied on census, which precluded the ability to vary design factors in primary data collection, and used regulatory incident databases.

The best available empirical data on aviation fire risk in Kenya are from regulatory reports. In-flight emergency fire events were reported to be 8%-12% of domestic in-flight emergency events in the KCAA (2023) and the 2019 galley fire incident highlighted weaknesses in cabin design compliance and inspection protocol. However, descriptive statistics and classification of the incidents is used in these reports, and not empirical analysis of design variables like material flammability ratings, insulation effectiveness, or seating density measurements. Research in Kenya has been mainly on human factors. For instance, Onchonga *et al.* (2025) investigated safety culture among aircraft pilots and aircraft maintenance workers by surveying both groups and identified training gaps and noncompliance of procedures as factors associated with the likelihood of incidents. These studies were valuable but did not consider interior design as an independent variable and did not evaluate the performance of those materials in operational conditions in the local area.

III. METHODOLOGY

The study used a descriptive survey and evaluative research design (Creswell & Creswell, 2018). Data collection was conducted using a mix of quantitative and qualitative methods; the quantitative component involved the collection of quantitative data on perceptions of factors related to interior design through structured questionnaires, whereas the qualitative component involved the collection of qualitative data as insights from the context through structured open-ended responses and key informant interviews. The evaluative component focused on the current fire prevention measures regarding interior material, insulation and seating arrangements. The study was carried out at five purposively sample airports namely; (a) JKIA, Nairobi; (b) Wilson Airport, Nairobi; (c) MIA, Mombasa; (d) Kisumu

International Airport and (e) Eldoret International Airport. The airports have been chosen because of their importance in domestic aviation, with more than 85% of all Kenya's domestic passenger traffic going through them (KCAA, 2023). The airport of Wajir was only used for pilot testing of research instruments and was not sampled for the main data collection.

The target population was 160 aviation professionals, who directly have technical knowledge of aircraft interior systems, classified into three categories of profession: (a) aeronautical engineers (n = 65) who are responsible for aircraft maintenance, modification of aircraft interiors and airworthiness certification; (b) ARFF personnel (n = 58) who are emergency response specialists trained in aircraft fire suppression and evacuation procedures; and (c) KCAA safety inspectors (n = 37) who are regulatory officers engaged in safety audits and certification of domestic aircraft. The inclusion criteria were: (a) at least 2 years of experience in aircraft interior maintenance, aircraft safety inspection and/or emergency response; (b) recent (12 months) direct experience with domestic aircraft operations; and (c) willingness to sign a written informed consent form. These participants were selected by using purposive sampling technique who fit the inclusion criteria.

The Krejcie and Morgan (1970) table for finite population was used in determining the sample size. This was based on a population size (N) of 160 with a confidence level of 95% and margin of error of 5% giving 114 respondents. The sample allocation was based on the size of each professional subgroup: aeronautical engineers (65/160) x 114 = 46 respondents; ARFF personnel (58/160) x 114 = 41 respondents; and KCAA inspectors (37/160) x 114 = 27 respondents. Local flights volume was also considered in the allocation across airports and high, medium and low traffic airports were all represented. A structured questionnaire containing two parts was used to collect primary data: (a) Section A – Demographic and professional characteristics (5 items); and (b) Section B – Interior design factors and fire risk perceptions (24 items with 5-point Likert scales ranging from 1 = not at all to 5 = very large extent) and 4 open-ended questions for qualitative data. Secondary data was collected from regulatory reports (KCAA, 2023; ICAO, 2023), technical manuals (FAA, 2023) and aircraft maintenance records for triangulation.

A pilot survey of 30 aviation professionals (not included in the final survey) at Wajir Airport was conducted for instrument clarity, relevance and time taken to fill the instrument. Ambiguous items were revised, based on feedback, in a minor way. Establishment of content validity was done by three aviation safety experts. A content validity index (CVI) was calculated by rating items on the 4-point scale for relevance and the CVI was 0.89, which is above the suggested CVI of 0.80 (Lynn, 1986). A test–retest reliability was calculated after two weeks with the pilot participants (r = .82). Cronbach's alpha was used to measure internal consistency of the interior design constructs (α = .685). This value was considered acceptable for the exploratory study with multidimensional constructs (Tavakol & Dennick, 2011) although it is below the traditional cut-off point of .70.

IBM SPSS Statistics Version 27.0. was used to analyze quantitative data. Respondent characteristics and perception ratings were summarized using descriptive statistics (Ms, SDs and frequencies, percentages). Pearson correlation coefficients were used to analyze the linear relationships between the interior design factors and fire disaster risk perceptions using inferential analysis. A p value of $< .05$ was considered significant. Qualitative data was collected through open-ended questions and analyzed thematically using the six-phase approach developed by Braun and Clarke (2006) which included familiarisation, initial coding, theme search, theme review, theme definition and report production. Twenty per cent of responses were coded independently by two researchers with an agreement rate of 87%, which was discussed with them until agreement was reached.

The Directorate of Postgraduate Studies of Masinde Muliro University of Science and Technology granted clearance and all the stakeholders namely National Commission for Science, Technology and Innovation (NACOSTI), Kenya Airports Authority (KAA), and KCAA granted clearance for data collection. Written informed consent was obtained from the participants. Confidentiality was upheld using coded identifiers and data was held on password protected devices and machines, only available to the research team. Engagement was on a voluntary basis, and withdrawal was allowed at any time, without penalty.

IV. FINDINGS & DISCUSSION

4.1 Descriptive Results: Interior Design Factors and Fire Risk Perceptions

In terms of size of the aircraft, 54.6% (n = 59) thought that aircraft size strongly affected the availability of emergency exits (M = 3.54, SD = 1.12), meaning that there was a consensus that the size of the aircraft affected the evacuation dynamics. In terms of material fire resistance, 63.2% (n = 67) thought that construction materials can effectively prevent fire spread (M = 3.96, SD = 0.98), indicating that there was a high level of confidence in material standards. Material risk contribution, on the other hand, showed that 28.3% (n = 30) indicated that materials too are a source of fire risk (M = 3.01, SD = 1.24) and thus expressed some ambivalence on the performance of materials in operating conditions. A divided professional opinion existed for whether seating arrangements were "highly influential" in ease of evacuation (M = 2.90, SD = 1.31). In relation to seating and accessibility for emergency

responders, 42.4% (n = 39) felt that seating significantly impacted on accessibility for emergency responders (M = 3.02, SD = 1.28).

Table 1

Perceived Influence of Interior Design Factors on Fire Disaster Risk (N=114)

Interior Design Factor	Response Category	No Risk	Risk	% Perceiving Risk	Mean (SD)
Aircraft size determines emergency exit availability	Not at all	1	7	—	3.54 (1.12)
	Small extent	3	10		
	Moderate extent	2	14		
	Large extent	10	45	**54.6%**	
	Very large extent	2	14		
Materials prevent fire spread	Not at all	0	2	—	3.96 (0.98)
	Small extent	0	6		
	Moderate extent	4	13		
	Large extent	12	38	**63.2%**	
	Very large extent	2	29		
Materials contribute to fire risk	Not at all	3	7	—	3.01 (1.24)
	Small extent	2	15		
	Moderate extent	11	36		
	Large extent	1	25	**28.3%**	
	Very large extent	1	5		
Seating arrangement affects evacuation ease	Not at all	4	12	—	2.90 (1.31)
	Small extent	4	21		
	Moderate extent	7	22		
	Large extent	3	23	**31.1%**	
	Very large extent	0	10		
Seating affects responder accessibility	Not at all	2	9	—	3.02 (1.28)
	Small extent	7	23		
	Moderate extent	3	15		
	Large extent	5	31	**36.8%**	
	Very large extent	1	8		

Note. Percentages are based on the proportion of valid responses for each item that indicated a "Large extent" and "Very large extent" response to risk perception items. Means are based on 5-point scale (1 = Not at all; 5 = Very large extent). Sample sizes (n) are slightly different due to the number of missing responses. The study found that over half of aviation professionals felt strongly that aircraft size impacts on emergency exit availability. This isn't a unanimous decision; it's a moderate consensus. Size is seen as one of a number of factors that influence evacuation but not the most significant. The mean score of 3.54 suggests that perceptions are not at either end of the spectrum but rather around the 'moderate to large' influence.

As for materials, respondents made a distinction between the baseline performance of materials that meet the minimum flammability requirements (i.e., high confidence in fire prevention) and degraded performance of the materials when subjected to real world conditions (aging, poor maintenance, noncompliant retrofit, etc.). A minority thought that materials play a significant role in risk during operation. The domestic fleet is seen as generally compliant but pockets of high risk – not systemically high-risk. Kenyan aviation professionals did not consider seating configuration to be a critical fire risk factor. Seating means is close to 3.0 ("moderate extent") and the percentages are low for strong influence, indicating that seating is not seen as a primary factor compared to materials and size of aircraft. The domestic fleet in Kenya consists of smaller regional aircraft (Dash 8, Embryer) that do not have such extreme seating densities as the wide-body jets studied around the world. Also, they might correlate evacuation more with training and compliance of the crew and passengers rather than the seating arrangements. A KCAA Inspector gave the following qualitative insights.

"*The risk for a fire to spread before detection is also greater in larger aircraft than smaller regional jets, as the greater volume of the cabin provides more space for a fire to spread, though only if crew response is rapid*." (KCAA Inspector, KII-07, 2024).

4.2 Fire Risk Perceptions

Respondents (60 persons) who reported on in-flight fire incidents on domestic flights in Kenya had a mean score of 2.39 out of 5, with a standard deviation of 1.092, showing that majority of people (60.2%) did not observe or experience an in-flight fire on domestic flights in Kenya. But 39.9% said there were any fires, with 25.0% (27 respondents) reporting "sometimes," 9.3% (10 respondents) often, and 5.6% (6 respondents) always reporting fires.

Table 2

Frequency and Severity of In-flight Fire Incidents in Kenyan Domestic Flights

Frequency of occurrence of in-flight fires	Frequency	Percent
Never	23	21.3
Rarely	42	38.9
Sometimes	27	25
Often	10	9.3
Always	6	5.6
Total	**108**	**100**

4.3 Ranking of Interior Design Factors

The study sought to compute a rank of the most interior factor that leads to high fire disaster risk. Table 3 presents the findings.

Table 3

Mean Rankings of Interior Design Factors (Higher Mean = Stronger Perceived Influence on Fire Risk)

Rank	Interior Design Factor	Mean	Std Dev
1	Materials used in construction prevent fire spread	3.96	0.98
2	Aircraft size determines emergency exit availability	3.54	1.12
3	Aircraft size influences fire safety effectiveness	3.31	1.18
4	Seating arrangement affects responder accessibility	3.02	1.28
5	Materials contribute to fire risk	3.01	1.24
6	Seating arrangement affects evacuation ease	2.90	1.31

Material fire-resistance perceptions (M = 3.96) and aircraft size–exit availability linkages (M = 3.54) were the first two perceptions identified by the respondents as being most influential. Seating configuration effects received moderate to low ranking which is against the findings of the worldwide evacuation simulation studies (Galea et al., 2011) and therefore will require empirical validation in context.

4.4 Inferential Results: Correlation Analysis

Correlation analysis was conducted to test the relationship of the interior design aspects with the fire disaster risk on board domestic aircraft. Correlations in all variables examined were weak and not statistically significant. Fire safety effectiveness and availability of emergency exits had only weak positive relationships with the size of the aircraft, $r = 0.132$, $p = 0.174$, and $r = 0.015$, $p = 0.878$, respectively. No significant relationships were found between material composition and fire prevention, $r = 0.036$, $p = 0.714$, and contribution to fire risk, $r = 0.129$, $p = 0.187$. Seating arrangement was found to have a weak positive correlation with ease of evacuation, $r = 0.149$, $p = 0.128$ and ease of access for responders, $r = 0.093$, $p = 0.346$. All these relationships were not statistically significant (all ps > .05). The results indicate that size, material selection and seating layout of aircraft have no effective and consistent effects on safety outcomes of the sampled domestic aircraft compared with fire disaster risk.

Table 4

Association between interior design factors and flood disaster risk on-board domestic aircraft

		Fire Disaster Risk
Aircraft size influences fire safety effectiveness.	Pearson Correlation	0.132
	Sig. (2-tailed)	0.174
	N	108
Aircraft size determines emergency exit availability.	Pearson Correlation	0.015
	Sig. (2-tailed)	0.878
	N	108
Materials prevent fire spread.	Pearson Correlation	0.036
	Sig. (2-tailed)	0.714
	N	106
Materials contribute to fire risk.	Pearson Correlation	0.129
	Sig. (2-tailed)	0.187
	N	106
Seating arrangement affects evacuation ease.	Pearson Correlation	0.149
	Sig. (2-tailed)	0.128
	N	106
Seating affects responder accessibility	Pearson Correlation	0.093
	Sig. (2-tailed)	0.346
	N	104

Note. There is no strong linear correlation between any of the individual interior design factors and the fire disaster risk perceptions, as all of the correlations are weak (|r| < .20) and statistically non-significant (p > .05). The obtained weak and nonsignificant relationships indicate that on their own, the interior design elements did not strongly predict aviation professional fire risk perceptions. This discovery is parallel to the Swiss Cheese Model (Reason, 1990), which suggests that accidents have a complex nature, and are a consequence of a number of latent and active failures rather than one single cause. Design weaknesses (such as flammability of materials, arrangement of exits) can only increase risk if they combine with other weaknesses in operation (such as slow crew reaction, poor maintenance).

4.5 Discussion

This study focused on the aviation community's outlook on the interior design factors that affect fire disaster risk in domestic air fleets of Kenya. The results show subtle professional decision-making with respect to aircraft dimensions, materials and seating layouts, and statistically the results of the various design factors and the fire risk were determined to have weak positive linear relationships. These findings highlight the need for a systems approach to aviation fire safety, as described in Reason's (1990) Swiss Cheese Model, in which the latent vulnerabilities in design may be compounded by operational, human and maintenance factors to affect the risk outcome.

Most of the respondents (54.6%) felt that aircraft size had a great impact on the availability and effectiveness of emergency exits in case of a fire on board an aircraft (M = 3.54, SD = 1.12). This result is consistent with previous computational and experimental studies that have shown that the dispersion of smoke can be complicated in larger cabin volumes and the length of the escape routes can increase (Galea & Markatos, 1991; Sarkos, 1996). But the near zero correlation between size of aircraft and fire disaster risk perceptions, r = .015, p = .878, indicates that the size of the aircraft is not linearly related to risk outcomes in operations. Instead, the connection is dependent on intermediate factors like crew procedure training, visibility of the exit signage and compliance by passengers during emergencies. Consensus in this study was moderate which may be due to the diversity of Kenya's domestic fleet, made up of a variety of regional turboprops and narrow body jets, with different spatial layout and evacuation procedures.

One significant difference became apparent in the attitudes of the professionals relative to the construction material used in cabins. Sixty-three percent of the respondents (M = 3.96, SD = 0.98) felt that the materials effectively inhibit fire propagation, while only 28.3% felt that the materials are significant contributors to fire propagation (M = 3.01, SD = 1.24). This is not to say that these findings are contradictory, but instead a fine-grained professional judgment; respondents seem to be distinguishing between general (baseline) and specific (context) vulnerabilities. This high level of confidence is likely due to compliance with the flammability standards of KCAA (2023) and ICAO (2023) where the cabin interiors are required to be subjected to rigorous tests. In contrast, the low level of concern about material-driven risk may indicate that there are no perceived issues with material-driven risk across Kenya's domestic operations, systemic degradation and noncompliant retrofits or aging fleet components. The perceptions contrast with laboratory tests that have recorded the high flammability and the amount of toxic smoke emitted by some polyurethane foams if they are ignited in a controlled environment (Purser, 2019). The low correlations between material perceptions and fire risk, rs(104) = .036–.129, ps > .05, also support the idea that material performance is not a single factor that determines the likelihood of fire disaster.

The lowest prioritization of determinant of fire disaster risk was the seating arrangement. The percentage of respondents who strongly agreed that the seating layout has a significant impact on the ease of passenger evacuation (M = 2.90, SD = 1.31) and that the seating layout can have a moderate impact on emergency responders' ability to access (M = 3.02, SD = 1.28) were low. These results contradict results from evacuations simulations on the global level, which have consistently highlighted the challenges of high-density seating configurations due to long egress times as well as aisle clearance issues in the event of an emergency (Galea et al., 2011; Muir et al., 1996). The difference may be explained by some contextual issues. Secondly, Kenya's domestic aviation industry is dominated by regional aircraft, which are smaller and have fewer passengers and less complex cabin configuration as compared to the wide body commercial aircraft used in international studies. Second, the aviation community in this context may be more likely to think of evacuation issues as being more related to human and procedural issues (e.g., crew reaction time, passenger panic, or lack of safety briefings) than to the actual seating layout. Third, existing research of seating effects in an operational context in East Africa is limited, and the results might influence professional perceptions of regulatory issues that are already in the forefront, such as material certification and exit configuration, instead of new ergonomic issues. The nonsignificant correlations between seating variables and fire risk (rs = 0.093–0.149; ps > .05) also indicate that in the local context, seating is regarded as a secondary fire risk amplifier.

The consistent low and statistically insignificant results of the correlation between single interior design factors and fire disaster risk perceptions should be carefully interpreted from a theoretical point of view. These do not detract from the importance of the design variables but do support an aviation safety perspective that is based on a systems approach highlighted by Reason's (1990) Swiss Cheese Model of Accident Causation. The model suggests that catastrophic events are likely to be caused by a combination of latent and active failures, and that neither type of failure in isolation is sufficient to cause the event. Within this context it is difficult to capture the multiplicative and

interactive nature of risk pathways through bivariate statistical analyses. From the results of present study, it is concluded that the interior design factors as necessary conditions are insufficient conditions to escalate the fire disaster. Only in the context of other organizational, human and environmental factors do their operational implications become apparent. This interpretation helps to explain the apparent contradiction of high perceptual ratings of some design factors and low statistical associations with risk outcomes and is a reminder that aviation safety needs to be considered using multilayered, system-dynamic lenses, not a linear causal model.

The patterns observed in the perception have implications for the regulatory strategy and fleet management in the domestic aviation industry in Kenya. The high level of confidence in the material fire-resistance suggests that the current certification procedures are generally considered to be effective, however the moderate concern with regards to material degradation suggests there may be some areas that require improving with respect to the management of longitudinal monitoring and maintenance oversight. Regulatory agencies might consider adopting a phased audit program that would concentrate on the high utilisation aircraft, especially those flying in tropical climates where heat, humidity and exposure to chemicals can cause deterioration of materials (Lyon, 2008; National Research Council, 1995). Likewise, moderate consensus exists around the issue of aircraft size and exit availability, which suggests aircraft-type specific evacuation guidelines and not fleet-wide, standardised guidelines. Respondents did not focus on seating configuration, but international evidence should be interpreted with caution, and regulators should consider having localized evacuation simulations for predominant domestic aircraft types before deprioritizing considerations of ergonomic design. Overall, a systems-oriented strategy that considers design compliance, maintenance attention, crew training, and preparedness of passengers will have a greater impact than focusing on any one of the interior factors.

Theoretically, this research confirms the use of the Swiss Cheese Model in new aviation contexts, and how 'latent design conditions' influence risk perception on the ground, along with operational realities. Cross-sectional perceptual data also has methodological limitations; professional judgements may not necessarily correspond with the objective measurements of risk, or with the actual dynamics of an event. Future work should be performed by mixed-methods designs, which will validate perceptual surveys through an empirical basis such as CFD simulation, controlled burn tests, and time-motion evacuation studies specific to the regional aircraft configuration. Longitudinal studies of material degradation, inspection compliance and incident reporting over time would add additional support to causal inference and evidence to update regulations. However, the results of the current study serve as an initial empirical baseline to understand vulnerabilities in interior design in the domestic aviation industry in Kenya, and the need for context specific and systems-oriented safety intervention.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The statistical correlation between each of the design factors and risk perceptions was weak and not significant, whereas the ranking analysis and theoretical framing of the findings indicates that they do have practical value. The study's conclusion is that aviation professionals believe the most critical design considerations for fire safety are construction materials and the size of aircraft, but there is ambivalence about construction materials for aging fleets. Moderate ratings were given to the effects of seating configuration, indicating a need for contextual empirical validation in regard to the operations of regional aircraft in Kenya. There is some evidence that bivariate relationships are weak, suggesting that there may be systems interaction between interior design elements and operational and human factors that can increase fire hazards. Evidence-based interventions involve more than descriptive perceptions; they call for design-risk relationships to be experimented with in local operational contexts.

5.2 Recommendations

Given the results, KCAA require regular testing of the flammability of aircraft cabin materials for aircraft in domestic services in Kenya, including special focus on aftermarket changes and ageing aircraft. Create guidelines for aircraft size – exit design compatibility audits including data from evacuation simulations of regional aircraft types. Improve the coordination between KCAA, airlines and maintenance services providers to make sure that design weaknesses are taken care in safety management systems.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding Declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

Billings, C. E. (2018). A Concept of Human-Centered Aviation Automation. In *Aviation Automation* (pp. 34-48). CRC Press.

Bjornstig, U., & Forsberg, R. (2016). Transportation disasters. *Koenig and Schultz's Disaster Medicine: Comprehensive Principles and Practices* (pp. 294-320). https://shorturl.at/njafA

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Federal Aviation Administration. (2023). *Cabin safety and fire prevention: Technical guidelines*. U.S. Department of Transportation. https://www.faa.gov/aircraft/safety/cabinsafety

Galea, E. R., Filippidis, L., Wang, Z., Lawrence, P. J., & Ewer, J. (2011). Evacuation analysis of 1000+ seat blended wing body aircraft configurations: Computer simulations and full-scale evacuation experiment. In *Pedestrian and evacuation dynamics* (pp. 151-161). Boston, MA: Springer US. DOI:10.1007/978-1-4419-9725-8_14

Galea, E. R., & Markatos, N. C. (1991). The mathematical modelling and computer simulation of fire development in aircraft. *International journal of heat and mass transfer*, *34*(1), 181-197. https://doi.org/10.1016/0017-9310(91)90185-H

International Civil Aviation Organization. (2023). *Safety report*. Montreal, Canada. https://www.icao.int/sites/default/files/sp-files/safety/Documents/ICAO_SR_2023_20230823.pdf

Joint Aircraft Survivability Program Office. (2005). *Aircraft fire incidents and survivability: Lessons from the B747 freighter fire* (Report No. JASP-2005-08). U.S. Department of Defense.

Kenya Civil Aviation Authority. (2023). *Annual safety report*. https://www.kcaa.or.ke

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30*(3), 607–610. https://doi.org/10.1177/001316447003000308

Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing Research, 35*(6), 382–385. https://doi.org/10.1097/00006199-198611000-00017

Lyon, R. E. (2008). Materials with reduced flammability in aerospace and aviation. *Advances in fire retardant materials*, (pp. 573-598). DOI:10.1533/9781845694701.3.573

Moir, I., & Seabridge, A. (2008). *Aircraft systems: Mechanical, electrical, and avionics subsystems integration* (3rd ed.). Wiley. https://shorturl.at/LP3B9

Mouritz, A. P. (2009). Review of smoke toxicity of fiber-polymer composites used in aircraft. *Journal of aircraft*, *46*(3), 737-745.

Muir, H. C., Bottomley, D. M., & Marrison, C. (1996). Effects of motivation and cabin configuration on emergency aircraft evacuation behavior and rates of egress. *The International Journal of Aviation Psychology*, *6*(1), 57-77. https://doi.org/10.1207/s15327108ijap0601_4

National Research Council. (1995). *Fire- and smoke-resistant interior materials for commercial transport aircraft*. The National Academies Press. https://doi.org/10.17226/5073

Onchonga, P. O., Lukose, T., & Muthoni, G. (2025). Safety Performance In The Aviation Industry In Kenya: The Role Of Maintenance Training. *Journal of Tourism, Hospitality and Travel Management*, *3*(2), 67-79. DOI:10.58229/jthtm.v3i2.413

Purser, D. A. (2019). Toxicity assessment of combustion products in aircraft cabin fires. In *SFPE handbook of fire protection engineering* (6th ed., pp. 2845–2872). Springer. https://shorturl.at/VEOm9

Reason, J. (1990). *Human error*. Cambridge University Press https://shorturl.at/TMCNK

Reason, J. (1997). *Managing the risks of organizational accidents*. Ashgate.

Reason, J. (2000). Human error: Models and management. *BMJ, 320*(7237), 768–770. https://doi.org/10.1136/bmj.320.7237.768

Sarkos, C. P. (1996). Application of full-scale fire tests to characterize and improve the aircraft postcrash fire environment. *Fire Safety Journal, 27*(1), 1–25. 10.1016/s0300-483x(96)03496-8

SKYbrary. (2023). *James Reason's Swiss Cheese Model*. Trajectory of accident opportunity. https://skybrary.aero/articles/james-reason-hf-model

Stevens, R. (2014). *Fire dynamics in enclosed transport environments*. Elsevier.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

United Nations Office for Disaster Risk Reduction. (2015). *Global assessment report on disaster risk reduction*. https://www.undrr.org/publication/global-assessment-report-disaster-risk-reduction-2015

World Health Organization. (2018). *Global status report on road safety 2018*. https://www.who.int/publications/i/item/9789241565684