Human Factors Influencing Managementof Aircraft Fire Disasters at International Airports in Kenya

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ABSTRACT

The aviation sector plays a major role in driving a country's economic and social development. The safe transport of passengers and goods by aircraft is a concern of many a country. This study evaluated the human factors influencing the management of aircraft fire disaster at international airports in Kenya.Results indicated that thenumber of rescue and fire fighting (RFF) personnel required to manage an aircraft fire disaster at Kisumu and Eldoret international airports was low <17%.Similarly, the t-statistic p-value (p = 0.001)presented evidence that there was a significant difference between the fire service human resource at Moi and Jomo Kenyatta international airports even though the two airports are in the same RFF category.This study is important to the airport management for it provides guidelines for improvement on the management of aircraft fire disasters.

Keywords: Human factors, management, aircraft fire disaster, international airport.

1. Introduction

Aircraft-related fire disasters in the 21st Century are on the rise. The technological advancements and rising globalisation have necessitated increased air travel.A report by Industry High Level Group (IHLG), showed that in 2016the airlines carried around 3.8 billion passengers and fifty-three million tonnes of freightworldwide(IHLG, 2017).The aircraft fire disaster need not necessarily occur; measures on human factor put in place by the airport management can prevent the exposure to vulnerabilities and hazards, which result in catastrophic loss of lives and property, not to mention damage to the environment. The SHELL model is a conceptual model of human factor that assists in understanding the relationships between airport resources, environment and the human component(Han & Wang, 2016).

The SHELL model originated from SHEL model advanced by Elwyn Edwards in 1972. This model is an acronym, which stems its name from its initial letters: Software, Hardware, Environment and Liveware. Software refers to all the non-physical resources such as the civil aviation statutory requirements, manuals, standards and procedures. Hardware refers to all the airport physical resources such as airport fire vehicles, machines, tools and equipments used within the system (airport). The environment is the situation in which the other three components must function and it specifically encompasses the social as well as the physical space(airport) involved. Lastly, liveware represents the people (emergency responders) who operate within the airport. In 1975, Captain Frank Hawkins modified and expanded the SHEL model to SHELL to include a second “liveware” element in order to represent the liveware-liveware interaction (Han & Wang, 2016).

Globally, the aircraft fire disaster can sometimes involve dangerous goods such as explosives, flammables, oxidizing substances, toxins, radioactive materials, and corrosive materials carried on both passenger and cargo flights (ICAO, 2015; IFSTA, 2015). These transport of dangerous goods by airhave continued to rise worldwide due to new technologies and the use of new types of hazardous materials (Ellis, 2010).In contrast to the other transport methods, air transport is more international and the goods it carries are of higher universal value (Zhao, 2018). Further,transport of dangerous goods by aircraft other than it being highly strategic, is an important type of transportation to all governments (Şencan & Yavuz, 2017).However, incase of an aircraft fire, the impact is wider and the consequences are even worse than with other modes of transportation (Zhao, 2018).Similarly, emergency conditions and provisions require to be made available for protecting human health and the environment (Oluwoye, 2000).

Contrary to the fire stations in developed countries, in Africa the skills deficiencies that appear in developing countries is not only technical abilities but also management skills (Arendt, 2008). Fire service personnel are required therefore to undergo training on fires involvingdangerous goods in order to respond tothem effectively. A joint follow up project on promoting chemicals safety management in the African region developed by United Nations Environment Programme (UNEP) and International Council of Chemical Associations (ICCA) found out that, in Africa the available infrastructure for emergency response was ineffective and skills regarding emergency prevention and preparedness were limited (UNEP, 2013).

In Kenya, about58% of all aircraft fires occured within the airport's vicinity (Mariera, 2014).Lack of knowledge on technical and operational skills is one of the contributing factors affecting handling of fire disasters by most fire stations (Arendt, 2008). It follows, therefore, that only by means of a most carefully planned and rigorously followed programme of fire training that can there be any assurance that both personnel and equipment will be capable of dealing with a major aircraft fire should the necessity arise (ICAO, 2015).

The Kenya National Cleaner Production Centre (KNCPC) found out that thebulk of the dangerous goods used in Kenya are imported and substantial amount of it are designated by international regulatory instruments as highly toxic (KNCPC, 2014).The safe air transport of these dangerous goods therefore is important to the government and enterprises of any country (Zhao, 2018). Human factor strategies such as the use of SHELL model is key inmanaging thesetypes of aircraft fire disasters effectively. It is against this backdrop that this studydetermined the human factors influencing management of aircraft fire disaster at international airports in Kenya.

2. Materials and Methods

2.1 Study area

This study targeted international airports in Kenya.These areJomo Kenyatta International Airport (JKIA), Moi International Airport (MIA), Kisumu Internationa Airport (KIA) and Eldoret International Airport (EIA).The locations of these airports are as follows: JKIA is bounded by latitude1° 20' 1.4" South and longitude 36° 55' 37.6" East. MIA is at latitude 4° 02' 05" South and longitude 39° 35' 44" East. KIA is at latitude 0° 05' 17" South and longitude 34° 43' 31" East and finally EIA is bounded by latitude 0° 24' 16" North and longitude 35° 13' 25" East respectively.The study area is shown in Figure 2.1.

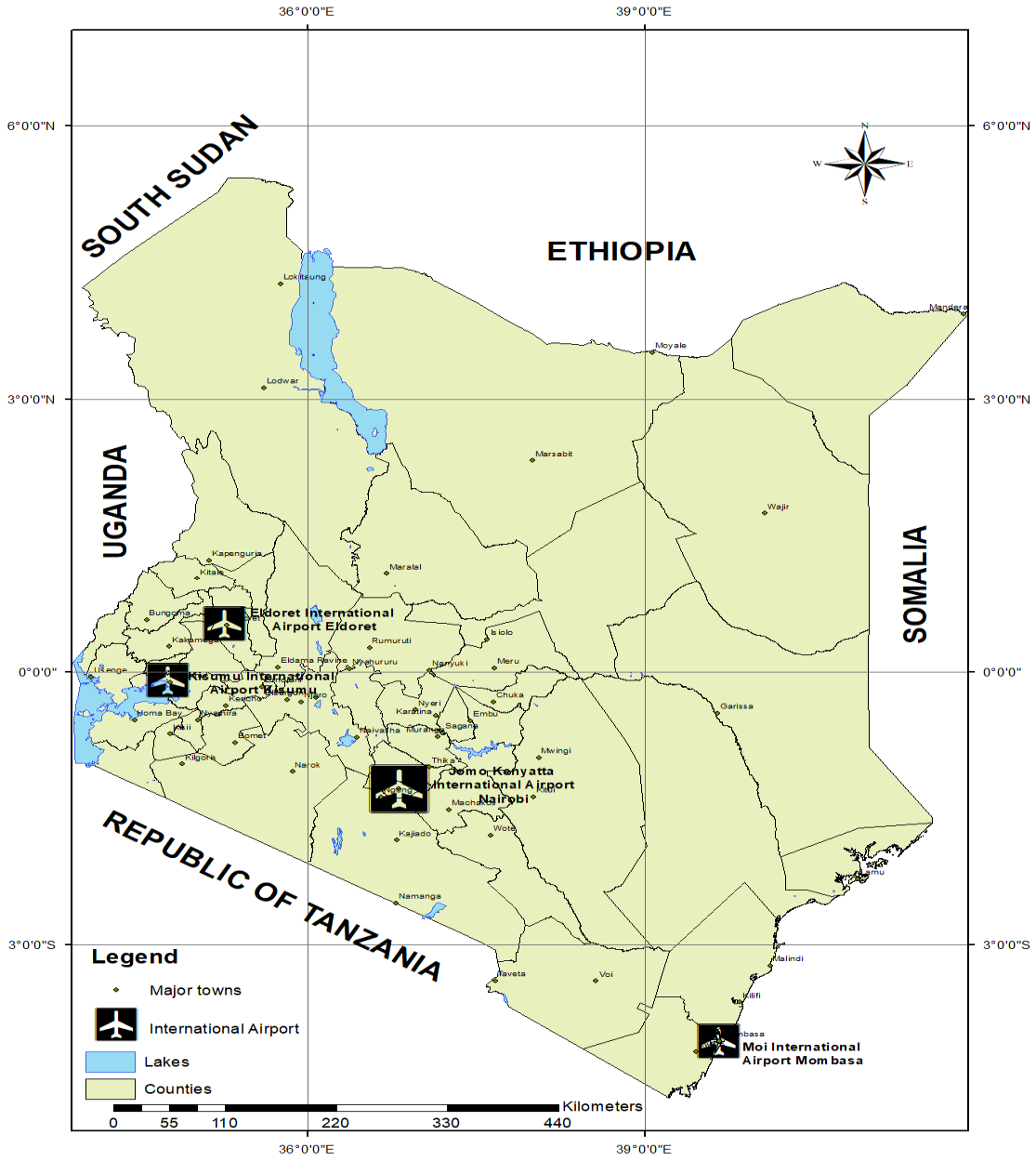

Figure 2.1: Map of international airports in Kenya
Source: Researcher, 2021

2.2 Research design and Sampling procedure

The study adopted descriptive and evaluation research design.Both qualitative and quantitative approaches were used in analysing the data. The sample size of 103 was extracted from the Krejcie & Morgan (1970) based on a population size of 132. Stratified random sampling was used to determine the number of fire service personnel per airport because of the variation in the number of fire fighters in the different airports. The stratified random sampling was used because it gives a better coverage of the population and the researcher has control over the sub-groups included in the sample (Castillo, 2009). Since the population for the key informant was small (5), a census inquiry was used and not a sample survey (Kothari, 2004). Quota sampling was used to sample Focus Group Discussion participants. Table 2.1 summarizes the sampling strategy and sample size used.

Table 2.1: Sampling strategies and sample size for the study

Study Population Units	Study Population Size (N)	Sample Size	Sampling method
Respondents			
Fire Service Personnel	132	103	Stratified random
Key informants			
Airport Fire Managers	4	4	Census Method
Aerodrome Fire Inspector from Kenya Civil Aviation Authority (KCAA)	1	1	Purposive
Focus Group Discussions			
Port Health, Kenya airport police unit,a member from airline operators committee, a representative from Emergency Operations Centre (EOC), pastor Civil Aviation Chaplaincy and a village elder	7-12 per group	1 FGD per airport (4FGDs)	Quota Sampling

Source: Researcher, 2021

2.3: Method of analysis

Both descriptive and inferential statistics were used. Descriptive data was analyzed and presented using frequency distribution and percentages. The frequencies of responses were calculated to determine the means of responses. According to Gay *et al.* (2011) the most commonly used method of reporting descriptive survey is by developing frequency distributions, calculating percentages and tabulating them appropriately. The data was represented as (mean ± standard deviation (SD). The inferential statistical procedure used in this study was t-test, which is a special case of the analysis of variance (ANOVA) using WINKS SDA Software, seventh Edition. The t-test was used to determine significant difference between two sample means.

The data was analysed based on thecategory of the airport in regard torescue and firefighting (RFF). The airports in the same RFF category share the same resource requirements(ICAO, 2015).According to the aeronautical information publication (AIP) by the Kenya Civil Aviation Organization (KCAA) Jomo Kenyatta international airport and Moi interntional airports areRFF category 9 while Kisumu international airport and Eldoret international airports are RFF category 7 (KCAA, 2018).

3. Results and Discussions

3.1Evaluation of Software Strategy

The study sought to establish whether the airport fire service hadstandard operating procedures (SOP) for managing all foreseeable types of aircraft fire (engine fire, wheel fire, aircraft internal fire etc). The results in Table 3.1 shows the findingsof international airports in line with theirrescue and firefighting (RFF)category. The International Civil Aviation Organization (ICAO) has defined the procedure for categorizing different airports for rescue and fire fighting (RFF) purposes(ICAO, 2015). The Kenya Civil Aviation Organization (KCAA) through itsaeronautical information publication (AIP)has categorized the different airports in the country for rescue and fire fighting (RFF) using the ICAO procedure.According to theaeronautical information publication Jomo Kenyatta international airport and Moi interntional airports are RFF category 9 while Kisumu international airport and Eldoret international airports are RFF category 7 (KCAA, 2018).The airports in the same RFF categoryaccording to ICAO(2015) share the same resource requirements.

In regard to the question whether the airport fire service had standard operating procedures (SOP) for managing all foreseeable types of aircraft fire, the results for RFF category 7 airports revealed in Table 3.1 that67%, 75% in Kisumu and Eldoret international airports respectively agreed to its existence.Similarly, the results for RFF category 9 airports revealed in Table 3.1 that94%, 89% of Jomo Kenyatta and Moi international airport respectively agreed to its existence.

Table 3.1: Software Strategy

Whether there is SOP for managing all foreseeable types of aircraft fire					
Rescue & Fire Fighting (RFF) Airport Category	**Name of the International Airport**	**Yes**	**No**	**Not sure**	**Average Mean ± Standard Deviation**
7	Kisumu	67	8	25	0.67±0.49
	Eldoret	75	17	8	0.75±0.45
9	Jomo Kenyatta	94	4	2	0.94±0.24
	Moi	89	7	4	0.89±0.31

Source: Field Data (2020)

A t-test was done to determine whether there is a link between the software strategies betweenRFF category 7 airports. The t-statisticp-value (p = 0.681) presented evidence that the scores for software strategy at Kisumu and Eldoret international airports are not significantly different. Similarly, t-test was done to determine whether there is a link between the software strategies between RFF category 9 airports. The t-statistic p-value (p = 0.435) showed that the scores for software strategy at Jomo Kenyatta international airport and Moi international airports are not significantly different.

This indicates that international airports in Kenya are doing well in terms of ensuring that standard operating procedures for managing aircraft fire disasters are in place. According to Bodur (2018)laws and regulations are very useful, but they may not respond to all the local needs.Bodur (2018) observes that having standard operating procedures (SOP)is a necessity in increasing standard practices to mitigate the adverse effects of disasters.

Standard Operational Procedures (SOPs) is an important software strategy that can be used to save time when conducting an aircraft fire fighting. The aircraft fire can either be exterior or internal, which above all require different tactics and strategies (Kreckie, 2013). Thepurpose of standard operating procedures therefore is to ensure that key people or units in the event of an aircraft fire disaster actually happening carry out certain tasks in a specific way (IFRC, 2012) . According to Danny & Pierce, (2019)standard operating procedures will alleviate confusion on the fireground.

3.2Evaluation of the Hardware Strategy

The study sought to establish whether the fire service has adequate rescue and fire fighting equipment as required by international civil aviation organization and the results were presented in Table 3.2. The results for RFF category 7 airports revealed that58%, 50% in Kisumu and Eldoret international airports respectively agreed to its existence. Similarly, the results for RFF category 9 airports revealed that60%, 75% of Jomo Kenyatta and Moi international airport respectively agreed to its existence.

Table 3.2: Hardware Strategy

Whether there is adequate rescue and fire fighting equipment as per the ICAO requirements					
Rescue & Fire Fighting (RFF) Airport Category	**Name of the International Airport**	**Yes**	**No**	**Not sure**	**Average Mean ± Standard Deviation**
7	Kisumu	58	17	25	0.58±0.51
	Eldoret	50	33	17	0.50±0.52
9	Jomo Kenyatta	60	13	27	0.60±0.49
	Moi	75	14	11	0.75±0.44

Source: Field Data (2020)

A t-test was done to determine whether there is a link between the hardware strategies between RFF category 7 airports. The t-statisticp-value (p = 0.707)presented evidence that the scores for hardware strategy at Kisumu and Eldoret international airports are not significantly different. Similarly, t-test was done to determine whether there is a link between the hardware strategies inRFF category 9 airports. The t-statistic p-value (p = 0.186)showed that the scores for hardware strategy at Jomo Kenyatta international airport and Moi international airports are not significantly different.

In order for rescue and fire fighters to be able to perform their task safely in an aircraft fire disaster, one of the hardware to be provided to the fire fighters are the correct personal protective equipment (PPE).The job nature of fire service personnel poses numerous potential hazards. The risk of inhalation of carbon or smoke particles when extinguishing a fire, during an aircraft fire disaster, is very high. It is for this reason thatICAO (2015) require that the fire service to provide for all fire fighters with full Personal Protective Equipment(PPEs) such as self-containing breathing apparatus (SCBA), helmets, boots and protective clothing. According toYeung *et al.,*(2002) the fire personnel who are physically fit and have met the training requirements are the ones who should wear these PPEs during an emergency. This does not only apply to fire service personel but also organizations working with potentially hazardous chemicals to ensure safety of their staff (Khalil, 2015).

According to ICAO (2015)rescue and fire fighting (RFF) category 7 airports should have a minimum number of two (2) fire vehicles while for RFF category 9 airports it should have a minimum of three (3) fire vehicles.According to the results all the international airportshad adequaterescue and fire fighting appliances as required by ICAO. This indicates that in terms of hardware resource the international airports in Kenya are doing well. According to Sumathi et al., (2018) every airport must have adequate rescue and firefighting equipment in order to perform their emergency management role effectively.

According to IFSTA (2015) airport fire vehicle must operate effectively in both paved and unpaved terrains. The RFF vehicles should also be designed to carry full loads at high speeds in all weather conditions as well as difficult terrain. According to ICAO (2015), the rescue equipment provided on the fire vehicles should be commensurate with the level of aircraft operations.

> The body shape of the airport fire vehicle (Plate 3.1) indicates how steep the obstacles, such as rocks or logs, it can negotiate. The approach and departure angles of airport fire vehicles are indicators of off-road ability.

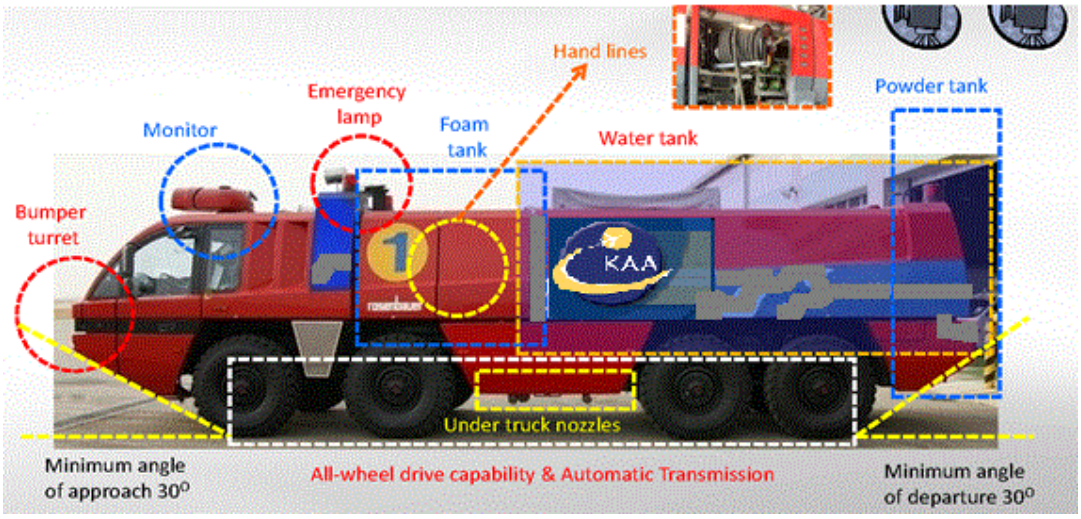

Plate 3.1 Components of Airport Fire Vehicle

3.3 Evaluation of Environmental Strategy

On evaluation of the airport environment, the study sought to establish whether the foam extinguishing agents used by the airport fire service is environmentally friendly. The results for RFF category 7 airports revealed in Table 3.3 that75% in both Kisumu and Eldoret international airports agreed that the foam extinguishing agents used by their airport fire service was environmentally friendly. Similarly, the results for RFF category 9 airports revealed that94%, 86% of Jomo Kenyatta and Moi international airport respectively agreed that the foam extinguishing agents used was eco friendly.

Table 3.3: Environmental Strategy

Whether the foam extinguishing agents used by fire service is environmentally friendly					
Rescue & Fire Fighting (RFF) Airport Category	**Name of the International Airport**	**Yes**	**No**	**Not sure**	**Average Mean ± Standard Deviation**
7	Kisumu	75	8	17	0.75±0.45
	Eldoret	75	17	8	0.75±0.45
9	Jomo Kenyatta	94	2	4	0.94±0.24
	Moi	86	7	7	0.86±0.36

Source: Field Data (2020)

The foam that is currently in use in all the international airports in Kenya is JetFoam 6% and is an eco friendly Foam Concentrate. JetFoam 6 contains no fluorosurfactants, no fluoropolymers, no organohalogens, no perfluorocarboxylic acids (PFCAs), no perfluorooctanoic acid (PFOA) and has no perfluorooctanesulfonic acid (PFOS). JetFoam 6 is 100% biodegradable.

Foam Agents is one of the most uprising forms of fire suppression in the fire service (Brandecker, 2018). There are classes of firefighting foams namely; foam meeting performance level A, B and C. In aircraft fire disasters, AFFF has been widely used. AFFF contain fluorosurfactants. Per- and polyfluoroalkyl substances (PFAS) are the active ingredients in fluorosurfactants.Although there have been limited studies of human health effects specifically related to use of AFFF (Glass *et al.,* 2014).The foam that are labeled as AFFF or AR-AFFF, contains perfluoroalkyl or polyfluoroalkyl substances, or both, as active ingredients(Darwin, 2004). These foam agents generate human and environmental health impacts (Brandecker, 2018).

In aircraft fire disasters, there are quantities of extinguishing agents required by International Civil Aviation organization (ICAO) to create conditions next to the fuselage of an aircraft tolerable enough to allow for the rescue of occupants, should there be an aircraft fire disaster(ICAO, 2015). Highlighting the risks and identifying alternatives to current fire extinguishing media is a strategy for making firefighting become more eco friendly. Reducing the impacts comes with finding alternative solutions to create the aircraft fire disaster environment less harmful and eco friendly. According to Brandecker (2018) although scene control and cleanup may reduce the environmental damage during fire suppression, introducing eco friendly extinguishing agents is more effective.

3.4Evaluation of Liveware Strategy

The study sought to establish whether the airport has the right number of fire service personnel required to manage a worst case aircraft fire disaster at the airport.The results for RFF category 7 airports revealed in Table 3.4 that83%, 92% in Kisumu and Eldoret international airports respectively disagreed on the existence of adequate number of fire service personnel. The results revealed a low mean score (M<0.17) for category 7 airports, an indication of poor staffing levels at these airports.

Table 3.4: Liveware Strategy

Whether the airport has the right number of fire service personnel					
Rescue & Fire Fighting (RFF) Airport Category	**Name of the International Airport**	**Yes**	**No**	**Not sure**	**Average Mean ± Standard Deviation**
7	Kisumu	17	83	0	0.17±0.39
	Eldoret	8	92	0	0.08±0.29
9	Jomo Kenyatta	54	42	4	0.54±0.50
	Moi	4	89	7	0.04±0.19

Source: Field Data (2020)

Similarly, the results for RFF category 9 airports revealed in Table 3.4 that42%, 89% of Jomo Kenyatta and Moi international airport respectively disagreed on the existence of adequate number of fire service personnel. The t-statistic p-value ($p = 0.001$) for RFF category nine airports presented evidence that there was significant difference between the fire service human resource at Jomo Kenyatta international airports and Moi international airport an indication of unequal staffing levels. This should not be the case, because JKIA and MIA are in the same RFF categories.According Akhter (2014) rescue and firefighting (RFF) is a specialized job, which requires adequate provision of human resource with professional knowledge, training and skills

4. Conclusions and Recommendations

In regard to software strategy, the study found out that majority of the respondents 67% indicated that their airports had standard operating procedures (SOP) for managing all foreseeable types of aircraft fire disaster (engine fire, wheel fire, aircraft internal fire etc). On hardware strategy, over 50% of the respondent in all the international airports in Kenya indicated that the fire service had the required number of rescue and firefighting equipment and fire vehicles as per their respective RFF airport categories. On environmental strategy, the results showed that the foam-extinguishing agents used by the airport fire service in allthe airports in Kenya were environmentally friendly. Further, on environmental strategy, the study found out that the JetFoam 6 is effective on extinguishing aircraft fire and is 100% biodegradable.Lastly, on liveware strategy, the study found out that most of the international airports did not have adequate fire service personnel.

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