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Energy efficiency in aircraft cabin environment: Safety and design

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ABSTRACT

Nowadays, aviation industry has been faced with technology challenges and safety requirements. Therefore, aircraft manufacturers give special attention to environmental building capacities regarding to passenger comfort and safety. This paper aims measuring safety and comfortability level of passenger accommodation during the flight. Since the environmental and safety issues could affect humans on a different level significance, this paper is based on the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method as a decision making tool for balancing those two inputs. With the aim of defining rank of existing world market aircraft the Saaty scale was used for developing the weight of different criteria whilst the improved TOPSIS method is used for ranking six aircraft: A320, A330, A340, B737, B747, B767 based on cabin environmental efficiency and safety.

1. Introduction

Nowadays, aircraft cabins have environmental problems similar to those of modern buildings, homes, offices, commercial places, etc. On the other hand, safety requirements are defined by more rigid measures. Some similarities could be found in fire protected systems. This issue is concerned by different regulatory standards worldwide since the studies show that people spend, on average more than 90% time indoors. As buildings, aircraft attempt to balance energy efficiency with other needs such as clean and fresh air, adequate ventilation and acceptable level of temperature and humidity. Different strategies such is mixturing outside air with recilculated air could result in increasing concentration of carbon dioxide (CO_2), volatile organic compounds (VOCs) or similar. On the other hand, contaminants may originate from cabin indoor sources such as panels, carpeting, etc. All this contaminants could impose building related symptoms by decreasing cabin air quality with health complaints of crew and passengers. Passengers could be affected by different health conditions depending on the time of exposure, while flight crew exposure could degradate pilot flight performance and reduce flight safety.

There is no such investigation within the literature that consider environmental stressors influence on passengers during the flight. The majority of authors analysed human performance and limitation related to flight and cabin crew or ATC [1] and airport [2] buildings. This paper explained other effects on passengers since there were recorded cases of panic due to the lower level of environmental conditions in cabin which directly mitigate flight safety. Some authors investigate influence of environmental on military pilots performances during the missions. The importance of the issue could be explained by 2P's dilemma, described as management dilemma of balancing protection (safety) versus productivity or level of service [3]. According to Hunt and Space [4], the role of predominant stressors has been changed during the time. Following figures present replacement of some stressors (Figs. 1 and 2).

2. Cabin safety

Cabin operations play a critical role in the safety of air transport worldwide. Historically, the role of cabin crew was seen as limited to evacuations in a post-accident scenario. Although this remains an essential duty of cabin crew, today the role of cabin crew goes beyond passenger evacuations. Cabin safety deals with all activities that cabin crew must accomplish during the operation of an aircraft to maintain safety in the cabin. Cabin crew contribute to safe, effective, and efficient operations in normal, abnormal and emergency situations. As demonstrated in numerous events, cabin crew play an important role in preventing accidents and serious incidents, including but not limited to events such as an in-flight fire, unruly passenger or decompression.

It is for this reason that international aviation organizations worldwide (EASA, ICAO, IATA, FAA, etc.) focus on cabin safety and continue to develop standards, procedures and best practices

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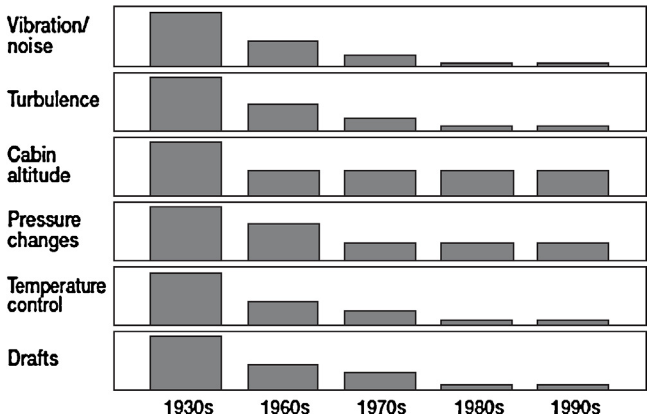

Fig. 1. Predominant stressors of the past.

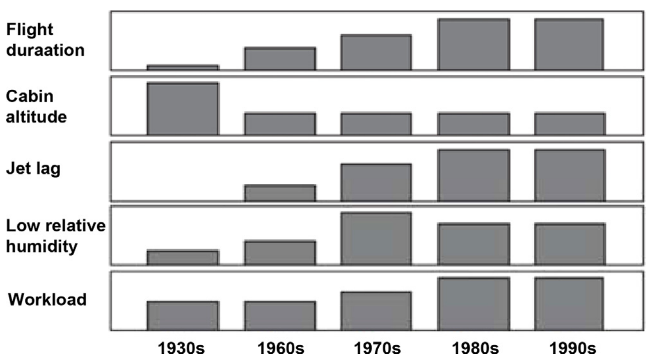

Fig. 2. Predominant stressors of the present.

to ensure safety in all aspects of cabin operations. Those organizations work with airlines, manufacturers and other industry partners in raising standards and implementing best practices. Cabin safety is a critical component of aviation safety as is an airline's safety management system which includes proactive data collection and the ensuing prevention activities regarding: cabin design and operation, equipment, procedures, cabin crew training, human performance and crew resource management and passenger management.

Aviation community seeks to continuously contribute to the reduction of incidents/accidents, and costs associated with ensuring the safe operation of commercial aircraft. This is achieved through the:

- development and promotion of recommended practices for the industry;
- analysis of worldwide trends and the initiation of corrective actions which offer tangible solutions;
- cooperation with aircraft manufacturers in developing technical installations, equipment and design;
- improving safety management system implementation and practice.

From the statistical point of view IATA [5] recorded findings are as follows:

- Out of the 81 total accidents in 2013, 37 contained a cabin safety dimension 62% of these accidents occurred on turboprop aircraft;
- 57% of these accidents occurred during the landing phase;
- 49% of these accidents resulted in a hull loss;
- 38% of these accidents occurred on jet aircraft;
- 30% of these accidents involved IATA members;
- 16% of these accidents resulted in fatalities.

In terms of cabin-related events, the breakdown is as follows:

- The predominant cabin-related event was evacuation, which accounted for 95% of all cabin-related events;
- 2 accidents involved a ditching.

Aviation industry has forced strong measures to provide safer air transportation by three blocks of defence [6] defined by professor Reason [7]. Those are regulation, procedures and training. This paper obtained results from other studies considered under those circumstances [8–10].

3. Cabin environment conditions

Cabin environment conditions are regulated by the supplied outside air. Fig. 3 presents typical modern aircraft ventilation system based on cabin of the Boeing B767 airplane which is provided by the engine compressors, cooled by air-conditioning packs located under the wing center section, and mixed with an equal quantity of filtered recirculated air.

Average air per passenger is 20 cubic feet per minute (half is filtered recirculated air and half is outside air) which provides complete cabin air exchange every 2–3 min. High air exchange rates are important due to maintenance of temperature, cabin pressurization, air flow, etc.

Cabin environmental conditions could generate in some cases hazards which are the basis for safety risks casual factors. In the literature, aviation hazards are always present in 3 possible states: acceptable, acceptable with monitoring actions and not acceptable under any condition [11]. It is important to understand that hazards are always present but the difference is by their nature: meteorological conditions, human factor, technical procedure, operational procedure, etc.

This paper analyses typical cabin environmental conditions during the flight time of occupants. Main comfort capabilities could be measured by total air supply to cabin, flow of outside air, cabin air temperature, volume per passenger, cabin noise and CO_2 cabin exhaust. Table 1 presents some results provided by simulation time for the aircraft Boeing B767 [12].

Physical measurements show that the data recorded from the instrumentation of the cabin and ventilation system were normally distributed and therefore tabulated as means and standard deviations (SD). Table 1 shows a summary of the quantities held constant during the 4 conditions (Columns 2–6), and of the resulting RH and CO_2-levels (Columns 7–9). The daily averaging period was from the time when steady conditions had been reached for RH and CO_2 until the end of the simulated flight.

Different cabin condition could provide variety of reaction on passengers on board. Some research [12] has detected following passenger reaction on provided conditions based on their subjective assessments. Data from subjective assessments and objective physiological tests could not be assumed to be normally distributed, and were therefore analyzed using the non-parametric Friedman two-way analysis of variance by ranks, followed by the Wilcoxon matched-pairs signed-ranks test for those cases in which the Friedman P-value was <0.05. Subjects with missing data were omitted from the analysis. Table 2 shows the significant results that were obtained.

4. Method for aircraft ranking based on measuring safety and comfort parameters

Presented paper describes a decision making methodology for aircraft ranking based on the TOPSIS (Techniques for Order Preference by Similarity to Ideal Solution) method. The TOPSIS method