Utilization of Human factors Intervention Matrix( HFIX) to Develop Aviation Safety Management Strategy

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Abstract

This study applied Human Factors Intervention Matrix (HFIX) framework and Analytic Hierarchy Process (AHP) to develop human errors intervention strategy. Our AHP questionnaire, designed based on the 31 incident scenarios that were taken place between 2009 and 2011 and included 72 safety recommendations to reduce specific human errors, was distributed to commercial airlines related personnel and was completed by eight managers and eleven pilots of commercial airlines and eight officers of Taiwan Aviation Safety Council (ASC). The results specified that each approach in HFIX framework possesses its unique characteristics under consideration of different criteria. This study has demonstrated that the HFIX framework can apply to the reduction of human errors from five different approaches. The study also suggests that each commercial airline selects appropriate intervention strategies in accordance with its own demands and resource limitations, and AHP can serve as a tool to assist its decision makers to evaluate their diversified strategies with different criteria in developing aviation safety management strategies.

Keywords: Human Errors Intervention, Human Factors Intervention Matrix, Analytic Hierarchy Process, Commercial Airline, Pilot

1. Introduction

According to an analysis of global safety data involving commercial air transport aircraft with a maximum certificated take-off mass of more than 2,250 kilograms, the accident rates are between 3.5ppm and 4.5ppm during 2002 and 2011[1]. Human errors not only do not decent but also become the major cause of aviation mishaps[2]. Safety is a non-negotiable characteristic in the aviation industry. Keeping safety flight is the utmost goal and diversifying tools are being continually developed to satisfy the goal[3]. As can be seen on the first column in Figure-1, safety management system (SMS) is a structured method to identify, delineate, communicate, control, eliminate and search the risk. However, a commercial airline rarely has sufficient resources to implement all the human errors intervention strategies simultaneously. Hence, a rationalization process is critical to take place in order to evaluate the importance and likely success of the strategies[4].

Wiegmann and Shappell [5] proposed a safety management process, as illustrated in Figure-1, that integrates Human Factors Analysis and Classification System (HFACS), Human Factors Intervention Matrix (HFIX), and ergonomic theory to assist corporations to remedy human errors. The HFACS is the most popular framework for investigating human errors in flight operations. It addresses human errors at four levels[6]:
level, unsafe acts of operators - active failures, is the level at which the majority of accident investigations are focused. Failures at this level can be classified into two categories: errors and violations.

2. Level two, preconditions for unsafe acts - latent/active failures, addresses the latent failures within the causal sequence of events as well as the more obvious active failures. It also describes the substandard conditions of operators and the substandard practices that they perform.

3. Level three, unsafe supervision - latent failures, traces the causal chain of events producing unsafe acts up to the level of the front-line supervisors.

4. Level four, organizational influences - latent failures, describes the contributions of the most elusive of these latent failures, fallible decisions of upper levels of management which directly affect supervisory practices, as well as the conditions and actions of front-line operators.

The HFIX can be applied to develop intervention strategies when causation of occurrence was identified[7]. HFIX matrix pits the level-1 of HFACS (unsafe acts) against the five different safety approaches and the five evaluating criteria. The unsafe acts were described as operators commit errors or violation that includes decision errors, skill-based errors, perceptual errors and violations. These unsafe acts can be mitigated by the following five approaches: organizational/ administrative, human/ crew, technology /engineering, task/ mission and operational/ physical environment approach. Additionally, the strategies can be evaluated by criteria of feasibility, acceptability, cost, effectiveness and sustainability.

The HFIX framework is described diagrammatically in Figure-2

Analytic Hierarchy Process (AHP) is one of the most widely used multiple criteria decision-making tools and has been extensively applied in different fields such as planning, selecting a best alternative, resource allocations resolving conflict, and optimization[8]. Vaidya and Kumar[9] describe the basic steps of AHP methodology as:

1. State the problem.
2. Broaden the objectives of the problem or consider all actors, objectives and its outcome.
3. Identify the criteria that influence the behavior.
4. Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.
5. Compare each element in the corresponding level and calibrate them on the numerical scale. This requires $n(n-1)/2$ comparisons, where $n$ is the number of elements with the considerations that diagonal elements are equal or ‘1’ and the other elements will simply be the reciprocals of the earlier comparisons.
6. Perform calculations to find the maximum Eigen value, consistency index CI, consistency ratio CR, and normalized values for each criteria/ alternative.
7. If the maximum Eigen value, CI, and CR are satisfactory then decision is taken based on the normalized values; else the procedure is repeated till these values lie in a desired range.
2. Method

Material. The data were derived from the narrative description of incident occurring in commercial airlines between 2009 and 2011. The data set comprised of 31 incident reports that included specific causes and 72 safety recommendations from investigators. Our previous study has classified these recommendations into five approaches of HFIX framework (organizational/ administrative, human/ crew, technology/ engineering, task mission, and operational/ physical environment) [10] and their readiness for future analyses.

Build the hierarchy. This empirical study used the AHP and HFIX framework to build hierarchy structure, as illustrated in Figure-3.

![Figure-3: The evaluation hierarchy of human factors intervention strategy](image)

Evaluation criteria. In order to better evaluate the human factors intervention strategy, HFIX framework proposed five criteria to aid managers for making decisions.

1) Feasibility evaluates whether a strategy is liable to be successful in current situation[11]. Our study adopted factors of logistic capacity, resource allocation, and timing to evaluate feasibility of human errors intervention strategy.

2) Acceptability evaluates whether the organization’s stakeholders are likely to support the new strategy. The consideration for evaluating acceptability focuses on the return and risk involved. Culture awareness is also required in order to determine the likely acceptance of the strategy by the organization itself.

3) Cost examines the tangible and intangible expenses of implementing a strategy. When a corporation carries out human errors intervention strategy, it may incur financial cost and opportunity cost, and benefits could be emerged, too[12]. Our study hence adapted cost-benefit analysis (CBA) to assess the corporation’s program.

4) Effectiveness evaluates whether a strategy facilitates to achieve the goal. The goal of implementing human errors intervention strategy includes direct goal, e.g. mitigating human errors, and indirect goal, such as enhancing corporate competition and image. Our study adopted these factors to examine effectiveness of strategy.

5) Sustainability evaluates whether a strategy satisfies needs of future stakeholders[13]. Our study considers economic, social and environmental aspects to examine sustainability of a human errors intervention strategy.

3. Research results

Our study adopted AHP to assess the importance(weight) of these intervention approaches on different criteria. The AHP questionnaire that based on scenario of the 31 incidents was completed by eight managers and eleven pilots of commercial airlines and eight officers of Taiwan Aviation Safety Council(ASC). All twenty seven questionnaires passed consistency test based on the respondent’s Consistency Index (C.I.) and Consistency ratio (C.R.) values.

The research results are summarized in Table-1. The study found that organizational/ administrative approach had the highest weight value of 0.25 in acceptability, followed by feasibility (0.22) and cost-benefit(0.19). In human/ crew approach, both criteria of feasibility and acceptability got high weight(0.21), followed by effectiveness (0.19). In technology/ engineering approach, weight of effectiveness had the highest value (0.23), followed by sustainability (0.22) and acceptability (0.21). In task/mission approach, both criteria of effectiveness and sustainability got same weight value (0.21), followed by feasibility(0.20). In operational/ physical environment approach, the top three weighting criteria are effectiveness(0.25), sustainability (0.24) and acceptability (0.22).

4. Discussion
The x-axis of HFIX framework comprised five intervention approaches, and each approach possesses unique characteristics under consideration of different criteria.

**Organizational/administrative approach.** This approach focuses on the way in which the organization and supervisors may need to modify to improve safety[14]. Among the 31 incident reports, investigators suggested several workable recommendations in this approach. The recommendations were, for example, changing managers/ supervisors involvement and oversight/ monitor, paying more concentration on establishing, issuing, modifying and revising the navigation route map, standard operation process(SOP) and regulations, and applying policies of human resource management such as selection, incentive, and promotion, to build upon safety culture of organization. These recommendations got supports from high level managers because they not only can be applied immediately but also require lower cost. Therefore this approach has high weight in acceptability (0.23) and feasibility (0.22), but low weight in sustainability(0.13) when considering influence of interfering conditions.

**Human/ crew approach.** The recommendations of this approach focus on changing or improving the individual worker or work team to enhance situation awareness and job satisfaction. Among these incident reports of the study, implementable recommendations include holding training course with qualified trainer periodically, enhancing front-line operators situation awareness and professional skill with scenario-base training, building objective and workable apprising system and reward for safe behavior. The recommendations of human/ crew approach would benefit teamwork and create harmonious collaborations, therefore it has higher weight in criteria of feasibility and acceptability. On the contrary, the weight of cost-benefit is lower because human resource management may incur higher budget.

**Technology/ engineering approach.** This approach focuses on change or improvement in tools, technology, and job aids to remediate human errors. This study found several implementable suggestions from incident reports, such as improving warning or alarms to increase operators' awareness of abnormal conditions, developing new system to enter into “failsafe” mode when problems occur, scheduling survey new technologies or products in market, and proving adequate spare parts or redundancy and SOP to prevent breakdown or interference during operation. The study found that recommendations of technology/ engineering approach have higher weight in criteria of effectiveness and sustainability, which means that improving performance and stability of equipment can enhance flight safety significantly.

**Task/ mission approach.** The approach focuses on ways of changing operators' task to reduce errors and improve flight safety. This study found that implementable recommendations may include using checklist or automatic facilities to reduce requirement for human memory, performing double-check with team member to avoid errors occurring in important steps, developing reward system to
reinforce the behaviors of compliance with safe work practices, redesigning procedure and checklist to be clearer or more user-friendly, and rewriting procedure to delete ambiguous or inapplicable safety criteria. Since the recommendations of task/mission approach can be applied to discipline pilots processing information with efficient method, to modify task to reduce aircrew’s work-load and opportunity for error, the approach got higher weight in criteria of effectiveness, sustainability and feasibility, but lower in cost-benefit criterion.

Operational/physical environment. Recommendations of the approach focus on improving both operational environment (e.g., workspace layout and design) and physical environment (e.g., temperature, lighting and noise). Since these recommendations facilitate improving comfortable of workplace and reducing worker pressure, the approach got higher weight in criteria of effectiveness and sustainability, while the criteria of feasibility and cost-benefit are lower because improving objective is widely and cost is highly.

5. Conclusions

The Human Factors Analysis and Classification System (HFACS), which based on Reason’s model of human error[15], describes that active failures associated with the performance of front-line operators in complex systems, and latent failures that lie dormant within the system that combines with other local factors to breach a system’s defences. Active failures of operators have a direct impact on safety. However, latent failures are spawned in the upper levels of the organization and are related to management and regulatory structures. On the other hand, the HFACS is applied to develop intervention strategy of human errors with five difference approaches and evaluate it with five criteria. Aviation industry is an open system and all commercial airlines operate into a wide range of airports that are not owned by the airlines. Therefore airplane maintenance is often provided by third parties and ATM/ATC is provided by the air traffic service providers of the national authorities of the countries into which they either operate or overfly. As a result the external environment, internal conditions, and corporation goal of the airline should deliberate, when it scheme and select new human errors intervention strategies. Our study found that each approach in HFACS framework possess its unique characteristics under consideration of different criteria, which suggest that commercial airlines select appropriate intervention strategies in accordance with each airline’s own demands and resource limitations, and AHP can serve as a tool to assist decision makers to evaluate the diversified strategies in developing aviation safety management strategy with various criteria.

6. References


