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# Significant Human Risk Factors in Aviation Maintenance

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**Abstract**

Aviation maintenance tasks are part of a complex organization, where individuals perform varied tasks in an environment with time pressures, and sometimes difficult ambient conditions. These situational characteristics in combination with generic human erring tendencies result in varied forms of error. Analysis of existing aviation maintenance data is a crucial step in meeting the aviation industry's need to improve aviation safety. We are approaches to investigate the significant human risk factors in aviation maintenance industry. Questionnaire through the modified human factors SHELL model was developed to categories the human factors variables that were derived from the literature review and the opinions of aviation personnel who involved in maintenance. The data were obtained from 18 aviation maintenance in Malaysia which has been listed in Malaysia Aviation Industry Report. The total of 315 respondents was received during the period of the survey. Several analysis techniques were used to analyze the survey data through exploratory factor analysis, reliability analysis and confirmatory factor analysis. The result showed that there are significant human risk factors in aviation maintenance and the result also provided approaches of Structural Equation Modeling (SEM) to verify the hypotheses in the path analysis model.

*Keywords*: Significant; human risk factor; aviation maintenance

**Abstrak**

Tugas penyelengaraan penerbangan adalah merupakan sebahagian daripada organisasi yang kompleks, di mana individu yang menjalankan pelbagai tugas dalam masa yang terhad dan berada dalam situasi yang mencabar. Situasi yang berbagai serta kelalaian manusia boleh menyebabkan berlakunya pelbagai aspek kesilapan manusia. Kajian tentang maklumat terkini adalah penting untuk menemukan apa yang diperlukan oleh industri penerbangan dalam membuat penambahbaikan kepada keselamatan penerbangan. Kami mengambil pendekatan untuk menyiasat tentang faktor manusia yang terpenting dalam penyelenggaraan penerbangan. Kajian ini menggunakan soal selidik yang berdasarkan model SHELL yang telah diubah suai untuk mengketegorikan faktor manusia yang diambil dari kajian literatur dan juga pandangan dari individu yang terlibat dalam penyelenggaraan. Data telah didapati dari 18 syarikat penyelenggaraan penerbangan yang tercatat di dalam laporan industri penerbangan di Malaysia. Sebanyak 315 responden telah diterima samasa kajian itu berlangsung. Beberapa teknik analisis data telah diguna pakai untuk menganalisis data, iaitu 'exploratory factor analysis', 'reliability analysis' dan 'confirmatory factor analysis'. Keputusan kajian menunjukkan terdapat faktor risiko manusia terpenting dalam penyelenggaraan penerbangan yang boleh mempengaruhi kesilapan manusia dengan penggunaan teknik Model Struktur Persamaan untuk menguji kebolehpercayaan dalam model kajian.

*Kata kunci:* Terpenting; faktor risiko manusia; penyelenggaraan penerbangan

## ■1.0 INTRODUCTION

Aviation maintenance personnel work on extremely sophisticated aircraft with complex integrated systems which are continuously upgraded and improved. The technological changes with respect to digital computer system and introduction of new materials requires that the maintenance personnel be trained to analyze, repair, inspect and certify these system in accordance with the quality standards defined by the aircraft manufacturers and Aviation Authorities. Aircraft maintenance is an essential component of the global aviation industry. It involve a complex organization in which each aircraft maintenance personnel performs varied task with limited time, minimal feedback, and sometimes difficult ambient conditions (Latorella and Prabhu, 2000). Maintenance in this context is essentially about keeping aircraft operational within a strict time schedule. The main role of aviation maintenance personnel is to categorize and judge the important of problem that could threaten the airworthiness of aircraft (Pettersen and Aase, 2008). Aircraft contain many rapidly developing advanced technologies, such as composite material structures, glass cockpits, highly automated systems, and build-in diagnostic and test equipment; therefore, the need to simultaneously maintain new and old fleets requires aviation maintenance personnel to be knowledgeable and adept in their work than in previous years (Yu-Hern Chang and Ying-Chun Wang 2010). However, the complexity of such operations naturally presents new possibilities for human error and subsequent break-downs in the system's safety net (CAA, 2002a).

In recent years, the aviation industry has gradually begun to make use of risk management and risk incident analysis ( Janic, 2000; Lee, 2006;Wong, 2006; CAA, 2007 ). Many accident reports now include risk factors in their conclusions. For example, on May 25, 2002, a B747-200 China Airlines passenger aircraft departing Taiwan for Hong Kong broke up in-flight; all 225 people on board were killed. The accident report by the Aviation Safety Council (ASC) in Taiwan found that the incident involve many items related to maintenance risks that had the potential to degrade aviation safety (ASC, 2005).

The most important step in aviation management is risk identification. If the risk cannot be accurately identified, it cannot be analyzed or evaluated. Once actual and potential hazards are identified, an assessment should be made of the cause and contributing factors and a decision should be made as to whether action is required (CAA, 2003). We aimed at evaluating the significant human risk factors in aviation maintenance industries. The objective to help aviation industries better understanding their major operational and managerial weaknesses in order to improve management and aviation maintenance operation. The study of questionnaire in Malaysia aviation industries was conducted to determine these significant human risk factors and to illustrate how empirical evaluation approach integrate expert opinion about the relative importance of these factors.

### 1.1 The Human Factors Model

Human factor practitioners typically concentrate on the interface among people and the other system elements. The important point of the system view is that humans cannot be isolated from other system components. The view is similar to that of ecologist, i.e. that all element in nature interacts. We can't change one aspect of the system without being concerned about its effects on other system (Endslev, 1996).

All aviation accidents are composed of four factors (Edwards, 1972), this is known as the SHEL model: software (e.g. maintenance procedure, maintenance manual, checklist), hardware (e.g. tools, test equipment, physical structure of aircraft, and instruments), environment (physical environment such as condition in the hangar, work environment such as work patterns, and management structures), and liveware (the person or people at the center of the model, including maintenance engineers, supervisors, managers, etc,) (CAA, 2002b). The model which identifies three kinds of interactive resources, it's indicated that the sources of all aviation accidents can be categorized as one (Liveware) or combination of three major relationships (Liveware-Software, Liveware- Hardware, and Liveware-Environment).

Hawkins (1993) modified Edwards' model to include the interactive nature of the person to person relationship (Liveware-Liveware) and called it SHELL. Hawkins used the relationship between liveware and software, liveware and hardware, liveware and environment and liveware and liveware to describe situations that the people encountered or what happened to them in the working environment. The model does not cover the interfaces that the outside human factors (Hardware-Hardware, Hardware-Environment and Software-Hardware) and is intended only a basic aid to understanding human factors (ICAO, 2003).

### 1.2 The Modified Model for Categorizing the Human Risk Factors in Aviation

We are in the era of organizational accidents (Reason, 1990, 1997). In recent years, there has been a shift in emphasis within the safety literature away from the individual-level that might be responsible for accident and incidents, and towards organizational and organization-related factors (Westrum, 1996; Neal *et al.*, 2000; CAA, 2003, 2007; Parker *et al.*, 2006; Ren *et al.*, 2008). When people are at the center of aviation safety, the quality, capacity, attitude, perception, and training of personnel are important and therefore highlighted. The organizational culture, organizational climate, managerial model, decision making pattern and aviation safety culture will also affect an individual (Mc Donald *et al.*, 2000; CAA, 2003; Arvidson *et al.*, 2006). Accidents are usually organizational or managerial issues composed of series of errors that are sometimes difficult for aviation personal to recognize and control.

In practice, the International Civil Aviation Organization's (ICAO) Human Factor Training Manual (ICAO, 1998) emphasizes the organizational issues of airline maintenance operations. Furthermore, the International Air Transport Association (IATA, 2006) has five categories for the accident classification system: human, technical, environmental, organizational, and insufficient data.

### 1.3 The Extended SHELL Model and Research Hypotheses

To examine the importance of the organizational aspect of the aviation maintenance system, we extended the SHELL model to explicitly include organization as a mediator factor. This extension enables the role played by the organizational aspect of the aviation maintenance system to be examined, through its interaction with the aviation maintenance personal. With the extended SHELL model, an aviation maintenance system is described as human factors interfaces in which the aviation maintenance personal (liveware) as a human factor interact with other human factors including others (liveware), physical resources (hardware), non physical resources (software), physical settings (environment), and non physical settings (organization).

In aviation accident analysis, organizational errors in relation to resource management, organizational climate, and operational processes have been highlighted in order to better understand and manage human error. These latent organizational failures can directly impact affect supervisory practices, as well as the conditions and actions of operators (Wiegmann and Shappel, 2003). In aviation maintenance, the efficiency and reliability of human performance are influenced by working conditions which stem from the overall organizational process (Isaac and Ruitenberg, 1999). Organization and management decisions made in the technical support, policies, workforce, finance and safety have significant impacts on the type of human error that can appear.

As such, an effective (Liveware) aviation maintenance personal interface with less organizational deficiencies would better help reduce human errors created by other human performance interfaces of the system. In addition, an effective (Liveware) aviation maintenance personal interface derived from positive and innovative organizational climate will help the organization operating in a high-risk environment such as an aviation maintenance system to better manage and more easily adapt to ongoing changes (Arvidsson *et al.*, 2006). Mismatches at the above human performance interfaces have been regarded as sources of human error in which the aviation maintenance personal (liveware) play a vital role. To examine how this ideal situation has been achieved, it is thus hypothesized that:

H1: There is a positive & direct relationship human factors and human error in aviation maintenance.
H2: There is a positive & direct relationship human factors and organization in aviation maintenance.
H3: There is a positive & direct relationship organization and human error in aviation maintenance

## ■2.0 METHODOLOGY

### 2.1 Data Collection

The survey items on the questionnaire for measuring the three constructs of the research model in Figure 1 were obtain from existing literature including SHELL model (ICAO, 2003, CAA, 2002b, 2003, 2007 IATA, 2006). The expressions of the items were adjusted, where appropriate, to the context of aviation maintenance. The total of 84 survey items was considered for measuring the three constructs (Human Factors, Organization, and Human Error). A pre-test was performed with three aviation maintenance industries on the 58 survey items for the improvement in the content and appearance. The respondent was asking to complete the questionnaire. The respondents suggested that all statements were appropriate. A survey questionnaire containing the measurement items was distributed to aviation maintenance personal of all levels in 18 aviation maintenance industries, including supervisor, instructor, license aircraft engineer and technician. A total of 315 effective responses were received.

## ■3.0 RESULTS

### 3.1 Reliability Analysis

A reliability analysis was first carried out on survey data to ensure the internal consistency of the constructs. For exploratory research, Cronbach's alpha should be at least 0.70 or highest for a set of item to be considered and adequate scale (Nunnelly, 1978). An exploratory and confirmatory factor analysis was than conducted on a single and multiple constructs to extract the factors from the items retained after reliability analysis. The items retained are good indicators of their underlying factors extracted, which are used as the observed variables or indicators in the measurement model for measuring their corresponding constructs.

**Table 1** Regression weight for the constructs

| | **Unstandardized Estimate** | **p-value** | **Standardized Estimate** |
|---|---|---|---|
| HE <----- HF | 0.569 | 0.000 | 0.324 |
| ORG<----- HF | 0.501 | 0.008 | 0.252 |
| HE<-----ORG | 0.632 | 0.000 | 0.405 |

### 3.2 Structural Equation Modeling Analysis

The structural model with a path diagram shown in Figure 1 with the measurement model in Tables 1 and 2 was constructed. Ovals represent the constructs (Latent variables), and rectangles represent the factors (observed variables or indicators). Single headed arrows represent causal relationships between variables. Goodness of fit test was conducted with the survey data to examine the efficiency of the structural model. The chi-square of the structural model was significant ($\chi^2$ = 126.530, df = 50, p = 0.000) with the value of (($\chi^2$/df = 2.531) smaller than 3, indicating ideal fit (Bentler, 1998), the large chi-square value was not surprising, since the chi-square statistic has proven to be directly related to sample size.

To assess the overall model fit without affected by sample size, alternative standalone fit indices less sensitive to sample size were used. These indices included the goodness of fit index (GFI) the adjusted goodness of fit index (AGFI), the comparative fit index (CFI), and the root mean square error (RMSEA) (Schumacker and Lomax, 1996) To have a good model fit, GFI should be close to 0.90, AGFI more than 0.80, CFI more than 0.90, and RMSEA less than 0.10 [30]. An assessment of the structural model suggested and acceptable model fit (GFI = 0.939; AGFI = 0.905; CFI = 0.936; RMSEA = 0.070).

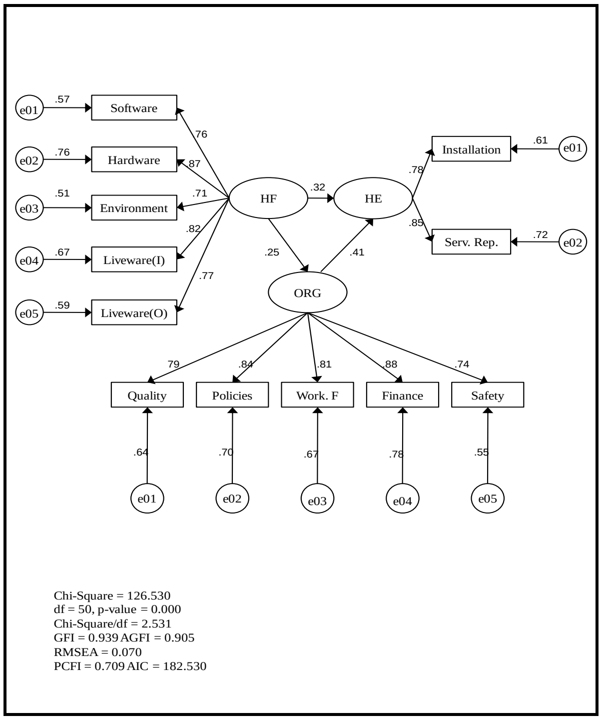

**Figure 1** The research model showing input and output variables with regression weight

## 3.3 Hypotheses Testing

In SEM analysis, the relationships among independent and dependent variables (constructs) are assessed simultaneously via covariance analysis. Maximum Likelihood (ML) estimation was used to estimate model parameters with the covariance matrix as data input. The ML estimation method has been described as being well suited to theory testing and development (Anderson and Gerbing, 1988; Hair *et al.*, 1998). Two sets of independent variables and dependent variables are used for testing research hypotheses *H1-H4* respectively. The first set has the human factors construct and the organization as independent variable, and human error as dependent variables. Figure 1 shows the result of the structural model. The values associated with each path (hypothesized relationship) are standardized path coefficients. These values represent the amount of change in the dependent variables for every single unit of change in the independent variable. For example, an increase of one unit in the human factors construct will cause an increase of one unit in the human error construct. Solid lines indicate supported relationship respectively.

The standardized regression weight and p-values for structural relationships as shown in Table 1. The result shows that, the standardized regression weight for H1was found to be 0.324 (p-value < 0.001). This result was support to H1 that the HF has direct and positive impact on HE. Table 1 also presents the relationship between HF and ORG efforts. The standardized regression weights for the hypothesized relationship between HF and ORG was found positive (0.252) and insignificant (p-value > 0.001), the result does not provide support to H2 have a direct and positive impact on ORG effort. The standardized regression weight for the direct relationship between ORG effort as found to be positive (0.405) and significant (p-value < 0.001) confirming H3 that ORG had direct and positive impact on HE.

## 3.3 The Significant Human Risk Factors in Aviation Maintenance Industry

The purpose of this research is to determine if there are significant human risk factors in aviation maintenance. The findings of this research reveal that there are significant human risk factors in Malaysia aviation maintenance industry. The research supports (Y.-H. Chang and Y.-C. Wang 2010) findings that the human factors have a positive impact to the aircraft maintenance. The results of the study also agree with (M. Noor Said, 2012) indicated that human errors were caused by one or several components failures among Software, Hardware, Environment and Liveware in a system. From the path analysis, we can observe that human factors and organization were significant towards dependent variable human error. The significant level was referring 95% confidence level with p-value < 0.001. With reference to the significant importance, independent organization factors (0.405) were more significant compared to independent human factors (0.324) which referring to the estimate value stated in the Table 1.

**Table 2** Regression weight of the items

| | Unstandardized Estimate | p-value | Standardized Estimate |
|---|---|---|---|
| SW <------- HF | 1.000 | 0.001 | 0.754 |
| HW<------- HF | 1.214 | 0.001 | 0.871 |
| ENV <------- HF | 1.069 | 0.001 | 0.714 |
| LW(I)<------- HF | 1.110 | 0.001 | 0.818 |
| LW(O) <------- HF | 1.120 | 0.001 | 0.768 |
| QS <------- ORG | 1.000 | 0.001 | 0.803 |
| CP <-------ORG | 0.920 | 0.001 | 0.836 |
| WF <------- ORG | 0.908 | 0.001 | 0.818 |
| FS <------- ORG | 0.878 | 0.001 | 0.883 |
| SC <------- ORG | 0.867 | 0.001 | 0.741 |
| INST<------- HE | 1.000 | 0.001 | 0.781 |
| SR <------- HE | 0.910 | 0.001 | 0.848 |

Based on weight and ranking, the order of significance of the five dimensions when we studied the result as presented in Table 2, with human factors as dependent variable and software, hardware, environment, liveware (I) and liveware (O) as independent variables, it indicated that software, hardware, environment, liveware (I) and liveware (O) were significant at 95% confidence level (p-value < 0.001) with software took as reference group. In this model, hardware (0.871) is the most significant risk factors, followed by liveware (I) (0.818), liveware (O) (0.768), software (0.754) and environment (0.714).

Furthermore, when we took quality support as reference factor, we found that quality support, company policy, workforce, finance strategy and safety culture were significant in 95% confidence level (p-value < 0.001). Finance strategy (0.883) is the most significant risk factors influence organization. It continues the significant with other independent variables company policy (0.836), workforce (0.818), quality of support (0.803) and safety culture (0.7.41).

## ■4.0 CONCLUSION

The empirical findings of a questionnaire survey of 315 aviation maintenance personnel in Malaysia shows that the model and approach are both strategically effective and practically acceptable for categorizing the significant human risk factors.

The result reveal that the aviation maintenance companies may want to propose management strategies related to the significant human risk factors to minimize the human error. Our findings also suggest that the Civil Aviation Authority may consider asking management level groups in aviation companies such as human recourses and maintenance departments, to focus on significant human risk factors to improve aircraft maintenance performance and reducing error. Specifically, these significant human risk factors are related to the hardware, liveware (I), environment, and liveware (O). Aviation maintenance companies also have to focus other significant human risk factors under organizational such as financial strategy, policies, manpower and safety culture. When employee professionalism is protected and the individual staff members have the company attention, safety and human error costs should be reduced.

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