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Application of HFACS, fuzzy TOPSIS, and AHP for identifying important human error factors in emergency departments in Taiwan

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ABSTRACT

In previous studies, the frequency of error factors associated with medical adverse events seems to be the only criterion for understanding the distribution of error factors in hospitals. However, the types of error that occur most frequently in hospitals are not necessarily the most important. Therefore, this study integrated human error analysis and fuzzy TOPSIS to reconcile this discrepancy. The purpose of the study is to identity the important human error factors in emergency departments (ED) in Taiwan. Human factors analysis and classification system (HFACS) was used to analyze 35 ED adverse events to define the error factors. Multiple criteria decision making (MCDM) methods such as analytic hierarchy process (AHP) and fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) were applied to evaluate the importance of error factors. Results showed that decision errors, crew resource management, inadequate supervision, and resource management were the important human error factors related to ED adverse events. This study recommends that MCDM should be applied to further analyze the results based on the criteria.

1. Introduction

Human error is one of the common factors contributing to the majority of incidents and accidents occurred within complex systems (Wenner and Drury, 2000; Liang et al., 2010), such as a medical system. According to the report of the Institute of Medicine in 1999 (Kohn et al., 2000), medical adverse events might be responsible for 44,000 to 98,000 deaths and more than 1 million injuries in the United States hospitals per year. Since the estimate data is nearly three decades old, James (2013) updated the estimation using data from several studies published between 2008 and 2011. The results showed that, annually, at least 210,000 deaths were associated with preventable harm in hospitals. Similarly, a national survey conducted in France revealed that nearly 10,000 deaths were potentially related to medical adverse events whilst half of them could have been prevented with appropriate care (Freund et al., 2013). Regarding to the states of medical adverse events in Taiwan, the annual report from Taiwan Patient-safety Reporting system (TPR) showed that 56,297 adverse events occurred in 2015 and almost a third of the cases resulted in harm to patients (Taiwan Patient-safety Reporting System, 2016). Based on the literatures reviewed above, it is not surprising that medical adverse events are terribly common in hospitals.

1.1. Medical adverse events in emergency department

Medical adverse events are common in emergence departments (ED) and often lead to severe outcomes (Rothschild et al., 2010). Several studies indicated that at least 3% of all adverse events occurred in the ED (Calder et al., 2010; Stang et al., 2013). Thus, ED has been identified as a hospital location where adverse events are highly attributable to errors (Fordyce et al., 2003; Calder et al., 2010; Stang et al., 2013). The issues mentioned above are mainly resulted from disrupted sleep cycles, multiple interruptions, acute time constrains, patient acuity and complexity, and high patient volume and overcrowding (Chisholm et al., 2000; Trzeciak and Rivers, 2003; Fordyce et al., 2003; Epstein et al., 2012; Stang et al., 2013). Therefore, many studies have analyzed adverse events in ED and tried to understand the mechanism and composition of factors contributing to errors. Fordyce et al. (2003)

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identified 346 errors which occurred in ED and categorized them into diagnostic studies, administrative procedures, pharmacotherapy, documentation, communication, and environmental maintenance based on the error types. Friedman et al. (2008) used three types of error categories, including adverse event, near miss, and medical error to classify the errors in ED. However, these error types were the phenomena resulting from the mishaps in emergency treatment process, which could not represent the causes of the errors (Reason, 1990). Thus, in order to reduce the ED adverse events, an overall understanding of the reasons behind the phenomena is necessary.

There are two types of human errors, namely, active human errors and latent human errors. Reason (1995) indicated that active human errors lead to accidents with immediate influence. Latent human errors result in accidents indirectly, that is; the adverse consequences may hide within the system. The errors only become obvious when combining with other factors to breach the defenses of a system. Cosby (2003) constructed a framework for classifying the error factors in ED. The error types of this framework involved individual, teamwork, working environment, and management issues. In more detail, individual issues in this framework included skill-set errors, task-based errors, and personal impairment. Teamwork issues implied teamwork failure in ED; working environment issues included the environment in ED and in hospitals; management issues meant administration problem in hospital. Although the framework contains active and latent error factors, the classifying factors were still insufficient to help researchers to fully understand the causes of errors.

1.2. Human factors analysis and classification system

Human factors analysis and classification system (HFACS) is derived from Reason's Swiss cheese model (Reason, 1990, 1997); it provides an organizational framework for accident analysis (Daramola, 2014). In HFACS, errors are divided into four categories, including unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influence (Wiegmann and Shappell, 2001, 2003).

The Framework of HFACS was shown in Fig. 1. The "unsafe acts" category is the research focusing on accidents. The behavior of operators that directly lead to and/or form active errors in accidents in medical processes are described. Taking decision errors for example, lack of patient information, professional medical knowledge, and experience may result in decision errors. The latent errors in accidents lead to the errors in the category of "predictions of unsafe acts", which are considered as the psychological precursors of the failures in the category of "unsafe acts". For example, physical/mental limitations, referring to medical operations that go beyond the operator's control, occurs when an operator takes on an operation required more experience than he has or she is unfamiliar with its treatment.

The category of "unsafe supervision" also relates to latent errors. For this category, the causes of an unsafe act can be traced back to the level of frontline supervisions. For instance, inadequate supervision occurs in the situation where a manager does not share experience, supervise, monitor, and train team members when necessary or provides insufficient support throughout. The category of "organizational influences" is considered as a latent error category in accident analysis. It is commonly related to faulty decisions with direct impact on supervisory practices at management level. For example, resource management refers to decisions, made by decision makers of the highest level in an organization, on overall distribution of assets, such as staff establishment and training and purchase of equipment.

Li and Harris (2006) analyzed 523 accidents in the Republic of China (ROC) Air Force between 1978 and 2002 through the application of the HFACS framework. The results revealed several key relationships between errors at the operational level and organizational inadequacies at both the immediately adjacent level (preconditions for unsafe acts) and higher levels in the organization (unsafe supervision and organizational influences). Diller et al. (2013) applied HFACS to investigate 105 medical adverse events, over 1700 errors occurred in operational and organizational level were identified. The structure of HFACS has been widely used in studies analyzing aviation accidents and other fields (Li et al., 2008; Chauvin et al., 2013; Daramola, 2014; Chiu and Hsieh, 2016; Madigan et al., 2016). HFACS framework contains errors categories related to technical operation, staff management, and organization operation; consequently, the full picture of an incidence can be revealed through analyzing human errors. The current research, therefore, applies HFACS framework to investigate medical adverse events in emergency departments in Taiwan.

1.3. Multi-criteria decision-making method

In the previous studies, the frequency of error factors associated with medical adverse events seems to be the only criterion for understanding the distribution of error factors in hospitals. For instance, Fordyce et al. (2003) analyzed the adverse events in ED and recorded the frequency of error factors of six categories. Lisby et al. (2005) identified several error types and recorded the frequency of the errors from the medication adverse events. Freund et al. (2013) analyzed ED adverse events and recorded the frequency of errors of five categories. However, the types of error that occur most frequently in hospitals are not necessarily the most important ones. Important cross-criteria error factors such as preventability and reproducibility were absent in the previous studies. Wang and Chou (2015) assessed the management issue related to patient safety in hospital by multi-criteria decision-making (MCDM) method. Chiu and Hsieh (2016) identified the human error factors in aviation maintenance tasks with HFACS and successfully applied one of the MCDM method with four criteria to generate the efficient improvement strategies.

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a well-known MCDM method. It has been commonly used to solve decision-making problems in many different research fields, such as aviation safety, supply chain management, healthcare, chemical engineering, and business and marketing management (Behzadian et al., 2012; Kuo et al., 2012; Kannan et al., 2014; Chiu and Hsieh, 2016). TOPSIS, proposed by Hwang and Yoon (1981), considers the performance of alternatives while taking multiple criteria into account at the same time (Bai et al., 2014). Its primary concept is that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. However, in a decision-making process, TOPSIS was insufficient to deal with the vagueness or ambiguity problems (Kannan et al., 2014; Chiu and Hsieh, 2016). Being aware of this limitation, we have incorporated TOPSIS with fuzzy set theory. By doing so, the decision-makers are able bring unquantifiable, incomplete, or non-obtainable information and partially uncertain facts into the decision model (Kannan et al., 2014; Chiu and Hsieh, 2016).

Previous research has pointed out that the real word system cannot be fully represented by the data of crisp numbers (Kannan et al., 2014; Chiu and Hsieh, 2016). This insufficiency results from the vagueness, imprecision as well as the subjective nature of human reasoning, judgement, and preferences. To bridge the gap, the fuzzy set theory was developed to model the uncertainty of human judgement. The fuzzy set theory represents the selection of decision-makers by linguistic values. The selections are then converted to fuzzy numbers so that the MCDM problem is dealt with. What is more, triangular fuzzy numbers (TFN) have been taken as an effective approach to formulating decision issues related to subjective and imprecise information (Chang and Yeh, 2002; Chang et al., 2007; Torlak et al., 2011). Accordingly, the fuzzy set theory and TOPSIS were jointly applied to identify the important error factors to improve patient safety in ED, and TFN were used to evaluate the selections of decision-makers.

Additionally, analytic hierarchy process (AHP), developed by Saaty (1990), illustrates how to determine the relative importance of alternatives in MCDM problem. The advantage of this method is easy to