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Short communication

Scale development of safety management system evaluation for the airline industry

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ABSTRACT

The airline industry relies on the implementation of Safety Management System (SMS) to integrate safety policies and augment safety performance at both organizational and individual levels. Although there are various degrees of SMS implementation in practice, a comprehensive scale measuring the essential dimensions of SMS is still lacking. This paper thus aims to develop an SMS measurement scale from the perspective of aviation experts and airline managers to evaluate the performance of company's safety management system, by adopting Schwab's (1980) three-stage scale development procedure. The results reveal a five-factor structure consisting of 23 items. The five factors include documentation and commands, safety promotion and training, executive management commitment, emergency preparedness and response plan and safety management policy. The implications of this SMS evaluation scale for practitioners and future research are discussed.

1. Introduction

Continuously improving air safety has always been a critical undertaking for the airline industry, which in recent years has relied on the implementation of Safety Management System (SMS) to integrate safety policies and augment safety performance at both organizational and individual levels. SMS is widely recognized as providing a systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures (ICAO, 2006). The United Kingdom Civil Aviation Authority (UKCAA) defines SMS as a methodology by which a company manages safety throughout its organization, utilizing a systematic approach to ensure that all parts of its business are addressed and that all risks are identified and subsequently managed (UKCAA, 2002). The practice of SMS not only reflects the organization's commitment to safety, but is recognized as a critical ingredient in employee's perceptions about the importance of safety in their company (Fernandez-Muniz et al., 2007).

As the systemic origins of many aircraft accidents have lead to increased concern as to how organizations identify and manage risks proactively, the development of SMS has attracted greater interest (Hsu et al., 2010). Different from previous safety systems or models, SMS emphasizes the integration of the entire organization serving as one team, follow principles that are laid down at the top. The key to achieving successful implementation of SMS is thus to ensure that every employee participates in the system and fulfills their designated role.

Although the International Civil Aviation Organization (ICAO) has made the practice of SMS in the airline industry mandatory since 1 January 2009 (Maurino, 2007), how to actually carry out this policy is still a subject of considerable debate. Documents related to SMS issued by major aviation organizations around the world share a number of similar components, which are critical to the success of such systems. However, McCaugherty (1991) noted that the theories such documents embody can only ever offer generalizations, and never capture the richness of the situation that individuals encounter in practice. It is thus essential to internalize the requirements of SMS into the organizational culture and the daily routines of individual employees, so that staff will know how to integrate the system with their own duties. Based on this concept, as policy maker, top managers are obligated to demonstrate their appreciation of an SMS and commitment to its execution. In addition, middle and line managers, who generally need to carry out the SMS policies, have to embed the key elements and features in the job design for their subordinates.

When promoting SMS, the critical issues are how airlines policy makers identify the key components of the system, how managers weigh the importance of its various dimensions and steps, and how

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employees are taught to evaluate the effects of these safety practices. In the past decade, several academic studies have worked to identify the critical success factors required to build an effective SMS model (e.g. Dagdeviren and Yuksel, 2008; Hsu et al., 2010; Liou et al., 2008), while another focus in the literature has been the linkage between SMS and the actual safety culture of an airline (e.g. Gill and Shergill, 2004; McDonald et al., 2000; Remawi et al., 2011). Based on the results of the authors' prior exploratory qualitative research, there is a clear perception gap regarding the implementation of SMS between managers and hands-on employees in the airline industry (Chen and Chen, 2011). In order to further confirm these results by comparing them with the observed phenomena, it would benefit both academics and practitioners to acquire more quantitative evidence and empirical data. It is thus desirable to develop a comprehensive measurement scale, based on the perceptions of aviation experts and airline managers. More specifically, this study aims to adopt Schwab's (1980) three-stage scale development procedure to develop a customized SMS evaluation scale for the airline industry, which may be utilized as a tool to routinely assess airlines SMS performance. The process will be explained in detail in the following sections.

2. Scale development process and initial scale

Based on Schwab's (1980) scale development theory, three-stage procedures are applied to develop the SMS evaluation scale in this study. First, for the item development stage, scale items are initially generated from the SMS documentation issued by major aviation organizations and authorities worldwide and subsequently revised based on the comments made by aviation safety experts in in-depth interviews. Secondly, this paper employs maximum likelihood with VARIMAX rotation to perform the exploratory factor analysis, with the aim of defining the underlying structure among the variables and producing a more concise version of the evaluation scale. Finally, confirmatory factor analysis is undertaken to further quantify the goodness of fit of the resulting factor structure. The convergent and discriminant validities are also examined to gather further evidence of construct validity in the last step of scale development. The maximum likelihood method of estimation is utilized to analyze the data.

2.1. Item development

The official documents guiding and promoting SMS issued by Transport Canada (2002, 2008), the UK Civil Aviation Authority (UKCAA, 2002, 2010), Australian Civil Aviation Safety Authority (CASA, 2003, 2005, 2009), the International Civil Aviation Organization (ICAO, 2006), the Federal Aviation Administration (FAA, 2006, 2010) and the Civil Aeronautics Administration in Taiwan (CAA, 2007, 2011) are used to derive the major evaluation items at the first stage of the scale development.

The key components, elements, plans and steps to implement an SMS given in these documents are summarized in Table 1.

Table 1
The SMS key components/elements/implementation plans/steps.

Authorities	Key components/elements/implementation plans/steps
CASA (2003, 2005)	Four key elements (2003) • Top level management committed to safety • Systems are in places to ensure hazards are reported in a timely manner • Action is taken to manage risks • The effects of safety actions are evaluated Eight key elements (2005) • Safety policy and objectives • Organizational and staff responsibilities • Establishment and monitoring of levels of safety • Internal safety reviews • Internal reporting and management of safety concerns and incidents • Hazard identification/assessment/control and mitigation • Interfaces Change management
ICAO (2006)	10 steps • Planning • Senior management's commitment to safety • Organization • Hazard identification • Risk management • Investigation capability • Safety analysis capability • Safety promotion and training • Safety management documentation and information management Safety oversight and safety performance monitoring
FAA (2006)	Four key components • Policy • Safety risk management • Safety assurance Safety promotion
Transport Canada (2008)	Six key components • Safety management plan • Documentation • Safety oversight • Training • Quality assurance program Emergency response plan
UKCAA (2010)	11 contents of implementation plan • Safety policy • Safety planning, objectives and goals • System description • SMS components • Safety roles and responsibilities • Safety reporting policy • Means of employee involvement • Safety communication • Safety performance measurement • Management review of safety performance Safety training
Taiwan CAA (2011)	Four key elements • Safety policy and objectives • Safety risk management • Safety assurance Safety promotion

2.2. Qualitative validity of the initial scale

An initial draft of the measurement scale was developed by integrating the components, elements, implementation plans and suggested steps given in the official documents issued by the aviation authorities mentioned above. To provide qualitative validation of these, eight aviation safety experts from Taiwan's CAA, the Aviation Safety Council (ASC), the airline industry and the educational field were invited to take part in in-depth interviews to offer their professional opinions on revising the items. All the items were evaluated individually to confirm that (1) they are clearly representative of the respective dimension; (2) there are no double-barreled, double-negative, obscure or other inappropriate descriptions; and (3) they are highly relevant to the practical reality of SMS execution in the Taiwanese airline industry. The initial SMS evaluation scale consists of seven dimensions with 37 items.

3. Data collection and analysis

3.1. Participants and procedure

To collect comprehensive and practical information regarding the execution of SMS from the airline industry, managers working

Table 2
The results of exploratory factor analysis.

	Factor loadings	Eigen value	Variance explained (%)	Cumulated variance explained (%)
Factor 1: Documentation and commands (DC) (Mean = 6.18, S.D. = 0.62, α = 0.90)		18.69	50.51	50.51
DC1: Managers order clear commands for SMS operation.	0.69			
DC2: The contents of SMS manual are readily understood.	0.62			
DC3: System can precisely save, secure and trace the information.	0.61			
DC4: Establish an incentive system to reward the good SMS performance.	0.59			
DC5: There is an intranet system to share the SMS related information.	0.58			
DC6: Simple and unified standard for safety behavior.	0.57			
DC7: Documents are reserved and updated in a standardized format.	0.55			
Factor 2: Safety promotion and training (PT) (Mean = 6.00, S.D. = 0.72, α = 0.93)		20.9	5.65	56.16
PT1: Employees learn the concepts through training.	0.79			
PT2: Employees know how to execute SMS through training.	0.76			
PT3: Employees upgrade the self-managed ability through training	0.73			
PT4: Company provides training continuously.	0.58			
PT5: Employees construct the correct safety attitude through training.	0.56			
PT6: Company holds SMS promotion activities regularly.	0.54			
PT7: Company provides diverse training programs.	0.53			
Factor 3: Executive management commitment (EMC) (Mean = 6.36, S.D. = 0.63, α = 0.89)		1.92	5.20	61.36
EMC1: Top management participates in the SMS related activities.	0.76			
EMC2: Management handles safety issues following just culture.	0.72			
EMC3: Top management declares the determination to execute SMS, even when the company finance is in the down cycle.	0.70			
EMC4: Top management declares commitment in formal documents.	0.59			
Factor 4: Emergency preparedness and response plan (EP) (Mean = 6.45, S.D. = 0.51, α = 0.87)		1.38	3.72	65.08
EP1: Employees acquainted with the plan.	0.84			
EP2: Employees are trained to execute the plan periodically.	0.74			
EP3: Company simulates the plan periodically.	0.64			
EP4: Company establishes the plan with clear procedures and individual responsibility.	0.54			
Factor 5: Safety management policy (MP) (Mean = 6.37, S.D. = 0.61, α = 0.87)		1.14	3.07	68.15
MP1: Company develops the precise standard to monitor and evaluate the SMS performance.	0.70			
MP2: Company continuously improves the SMS performance.	0.69			
MP3: Company's internal reporting channel is highly accessible.	0.51			

for five Taiwanese international airlines were invited to participate in the survey during the period from November 2010 to February 2011. The participants were asked to fill out a questionnaire consisting of 37 items measured with a seven-point Likert scale, ranging from 1 = "very unimportant" to 7 = "very important". To ensure the representativeness of the sample, the questionnaires were distributed to various departments (sorted into five categories, namely flight operations, maintenance, cabin service, airport and others). Managers were ranked in three categories, line managers (including trainers), middle managers and top managers. Other demographic variables and background questions gathered details of the respondents' gender, years of working in the airline industry and whether they had participated in an SMS related training program.

The respondent candidates were either directly contacted by the authors or through others working at the same companies. Their approval was sought before distributing the questionnaires via email, post or in person visits. There was a response rate of 91%, with 178 questionnaires being returned, of which 169 usable samples were obtained. The great majority of the respondents were male (66.9%), held positions as line managers (73.4%), with tenures of between 16 and 20 years (44.4%), and most had participated in the SMS related training programs (91.7%).

3.2. The results of EFA

Using the maximum likelihood extraction with VARIMAX rotation, five factors containing 25 items were extracted from the original 37 items scale. The eigenvalues suggested that a five-factor solution explained 68.15% of the variance of the evaluation scale. A factor was retained if its eigenvalue was greater than 1.0. The items under each factor were retained if the factor loadings greater than 0.5. Most items loaded heavily on one factor and not heavily on others, thereby demonstrating there was minimal overlap among

Table 3
Convergent validity of the constructs.

Constructs	Items	Item reliability			CR	AVE
		Standardized loadings	Standard errors	*t*-value		
Factor 1 Documentation and commands	DC1	0.77	0.028	11.53	0.89	0.59
	DC2	0.72	0.033	10.42		
	DC3	0.79	0.030	12.08		
	DC5	0.70	0.038	10.15		
	DC6	0.80	0.024	12.13		
	DC7	0.80	0.029	12.30		
Factor 2 Safety promotion and training	PT1	0.90	0.017	14.97	0.93	0.69
	PT2	0.90	0.021	14.89		
	PT3	0.82	0.032	12.89		
	PT4	0.75	0.032	11.16		
	PT6	0.83	0.028	13.11		
	PT7	0.77	0.051	11.69		
Factor 3 Executive management commitment	EMC1	0.87	0.022	13.57	0.87	0.62
	EMC2	0.85	0.023	13.17		
	EMC3	0.79	0.027	11.83		
	EMC4	0.68	0.045	9.56		
Factor 4 emergency preparedness and response plan	EP1	0.92	0.016	15.26	0.90	0.69
	EP2	0.92	0.014	15.28		
	EP3	0.74	0.036	10.98		
	EP4	0.73	0.025	10.85		
Factor 5 safety management policy	MP1	0.79	0.028	11.58	0.84	0.64
	MP2	0.83	0.028	12.35		
	MP3	0.78	0.022	11.62		

these dimensions. The community of each item was relatively high, ranging from 0.51 to 0.84. The overall α value was 0.90, and the values for each factor were well above 0.8, surpassing the satisfactory level of 0.7 required in basic research (Price and Mueller, 1986). The five factors were labeled on the basis of the attributes covered, namely Factor 1 “Documentation and Commands”, Factor 2“Safety Promotion and Training”, Factor 3 “Executive Management Commitment”, Factor 4“Emergency Preparedness and Response Plan” and Factor 5“Safety Management Policy” (see Table 2).

Table 4
Discriminant validity.

Constructs	DC	PT	EMC	EP	MP
DC	0.76				
PT	0.75**	0.83			
EMC	0.75**	0.67**	0.79		
EP	0.62**	0.69**	0.59**	0.83	
MP	0.54**	0.54**	0.60**	0.57**	0.80

Note. Square root of average variance extracted (VE) is shown on the diagonal of the matrix.
** $p < 0.01$.

3.3. The results of CFA

Confirmatory factor analysis was conducted using the LISREL 8 structural equation analysis package (Jöreskog and Sörbom, 2002) with a covariance matrix to test the convergent validity of the constructs. The convergent validity of the CFA results should be supported by the item reliability, construct reliability and average variance extracted (Hair et al., 1998). One item from Factor 1 Documentation and Commands (i.e. DC4) and one item from Factor 2 Safety Promotion and Training (i.e. PT5) were removed from the scale due to the insufficient factor loading. Postulating that each item would load onto its respective dimension, the measurement model fit the data reasonably well ($\chi^2 = 375.39$, df = 210) in line with the following fit indices: RMSEA (0.06), CFI (0.98), NFI (0.96), AGFI (0.80). As shown in Table 3, the reliability of the remaining 23 items was ensured since the *t*-values associated with each of the standardized loadings were found to be significant ($p < 0.01$). In addition, the construct reliability of all the constructs exceeded the recommended level of 0.7 (Hair et al., 1998), while the average variance extracted of all the constructs exceeded 0.5, confirming the amount of variance explained by the construct (Hair et al., 1998).

Discriminant validity, assessed by comparing the construct correlations with the square root of the average variance extracted (Fornell and Larcker, 1981), was also examined. The results in Table 4 indicate that the square root of the average variance extracted for each construct was greater than the levels of the correlations involving the construct, thus confirming the discriminant validity. These results provide further evidence of the construct validity in the last step of scale development. The confirmatory quantitative evidence for the evaluation scale developed in this work was thus obtained.

4. Discussion and conclusion

Five factors containing 23 items extracted from the initial SMS evaluation scale have been identified in this research. It is noteworthy that most of the items excluded by the exploratory factor analysis were related to the dimension of “Safety Oversight and Audit” from the initial scale. Despite the importance of these items in the related documentation produced by the relevant authorities, they are regarded as part of the regular operations at the professional level, and thus airlines are expected to have already performed most of these items (e.g. there is an independent safety oversight department in the company) based on the existing civil laws. In addition, significant correlations among the variables may have led to the problem of collinearity and reduced the factor loadings for some items, and thus these items were eliminated when adopting the confirmatory factor analysis.

To develop a customized SMS evaluation scale for the airline industry, this paper employed both qualitative and quantitative methods to first obtain the comments from aviation experts, and then analyze assessments from airline managers to derive the empirical evidence based on their practical views. The results of an ANOVA test indicated that managers with different ranks and working in different departments provided consistent responses to all the variables. It is well-known that managers play an essential role as liaisons between the front line operators and the company, and are thus usually viewed as the vehicle through which organizations influence the workforce (Fogarty and Shaw, 2009). This is especially true for the line managers, who have dual positions as both executors and inspectors, and thus their perceptions in identifying the critical elements of SMS deserve more attention.

Since the execution of SMS is regarded as essential to upgrading the air safety performance, it is vital to have an effective tool to evaluate its implementation. The documents and guidance materials issued by international and domestic civil aviation authorities offer sufficient references for airlines to undertake SMS. However, it takes time and effort to integrate the concepts of SMS into an airline's organizational culture. In order to construct a working environment in which all employees agree on and are able to implement an SMS, the primary step is to appreciate how employees relate the concepts of this system to their work. Therefore, employee evaluations of how their companies perform the SMS programs can be used as a clear signal of the effects of adopting SMS in practice. The evaluation scale developed in this paper may be applied as both a reference and tool for airlines to conduct such employee surveys with regard to SMS performance.

As for the limitations of this study and directions for further work, the criterion-related validity of the scale developed should be further examined by conducting more surveys on a larger scale within the airline industry. The evidence obtained from the greater number and variety of airline personnel could then be used to provide a more comprehensive reference for airlines. Meanwhile, extending the application of the SMS evaluation scale will be beneficial to both academics and practitioners. Airlines usually promote their SMS programs by offering training courses or hosting various activities. It is thus crucial to gather employee's perceptions of SMS before and after taking such courses or participating in these activities. Furthermore, the effects of SMS execution may also be examined in future studies to identify whether it is a mediator or moderator of the safety performance, depending on the research design.

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