Developing a Safety Performance Scale (SPS) in departments of electrical and electronic engineering at universities: an exploratory factor analysis

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ABSTRACT: In this article, the authors focus on developing a Safety Performance Scale (SPS) with high validity and reliability for assessing group-level safety performance. In all, 164 teachers from departments of electrical and electronic engineering at various Taiwanese universities completed self-administered questionnaires in November 2006. This represented a response rate of 54.67%. The investigators used SPSS to perform an exploratory factor analysis and to make an internal consistency analysis. Three factors had eigenvalues greater than 4.3, namely: safety motivation, accident investigation and safety inspection. These three factors produced an accumulated explained variance of 77.75%. These three factors all also had Cronbach's αs greater than 0.92. The results show that the SPS developed in this study is both valid and reliable.

INTRODUCTION

While there are many management levels in any organisation, there are two general levels on which to assess safety performance, specifically: macro-measures and micro-measures. The former are used for larger units, or whole organisations, such as incident rates in a company; while the latter are used for lower and smaller units of an organisation, such as the number of supervisor inspections, communications or observations in a department.

It should be determined which level of the organisation is intended to be measured. As a rule, there are two kinds of assessment tools available in this context, namely: activity measures and results measures. Activity measures concern what steps are taken in order to ensure occupational safety, while results measures refer to whether those safety objectives have been accomplished [1]. Thereupon, the safety performance measures at the departmental level at a university measure the safety activities implemented by head teachers.

At the organisational level, many authors have proposed safety performance dimensions, such as safety organisation and management, hazard control and monitoring, safety training and education, accident investigation and statistics, safety motivation and communication, and so on [2-5]. However, at the management level, Petersen suggested safety performance measures of the supervisor, which may include the following activities:

- Inspection;
- Accident investigation;
- Training;
- Motivation, etc [1].

According to the current Taiwanese Labor Safety and Health Act and Regulations, safety training is a function of the Labor

Safety Department (organisational level) but a duty of the first line unit. Therefore, the authors divided the safety performance area at the departmental level at universities into safety inspection, accident investigation and safety motivation.

The purpose of this study is to explore the safety performance dimensions at the departmental level at universities. Another objective is to develop a Safety Performance Scale (SPS) and, through empirical study, ensure it has good validity and reliability as the tool to assess safety performance in electrical and electronic engineering departments at universities.

METHOD

Sample

When the study was carried out (in September 2006), there were 147 universities in Taiwan, 70 of which established electrical and electronic engineering departments [6]. In total, there were 2,913 teachers in these departments (including lecturers, assistant professors, associate professors and professors). The subjects were selected by way of purposive sampling based on their location and ownership, with two universities in the northern location, two in the central location, and two in southern location being chosen for the study. Thus, there were six universities (three public universities and three private universities) to be tested. In all, 50 subjects were selected from each university; thus, there were 300 subjects participating in the study. In mid-October 2006, the investigators posted each subject a questionnaire, souvenir and return postage, plus a cover letter was attached explaining the investigation's purpose. The investigators mailed two reminders to prompt the subjects to send back their questionnaires after completing the questions. The researchers received 174 questionnaires up till late November 2006, and after removing 10 invalid questionnaires, there 164 valid questionnaires, yielding a response rate of 54.67%.

Instrument

The Safety Performance Scale (SPS) in this study included the three following dimensions:

- Safety inspection;
- Accident investigation;
- Safety motivation.

All of the above dimensions included six items, so there were 18 items in total. The items in the safety inspection dimension were generated from the Labor Safety and Health Act and Regulations (regarding the supervisory function) and the supervisory measurement of safety performance (the area of inspections) proposed by Petersen [1]. The items of the accident investigation dimension were revised from the safety audit assessment (the area of accident investigation) as proposed by Schneid and the supervisory measurement of safety performance by Petersen [1][2]. The items of the safety motivation dimension were modified from Petersen's supervisory measurement of safety performance (the area of motivation) and Swartz's safety audit elements (the area of safety motivation) [1][3].

Data Analysis

The investigators used the *Statistical Package for the Social Science* (SPSS 12.0) as the tool for statistical analysis to perform an item analysis, validity analysis and reliability analysis of the SPS. The item analysis adopted a correlation analysis, the validity analysis employed an exploratory factor analysis, while the reliability analysis applied Cronbach's α coefficient.

RESULTS

Item Analysis

As shown in Table 1, each of the 18 items of the SPS showed a significant ($p < 0.01$) positive correlation with the total safety performance score (0.644 to 0.837). This means that each item in the SPS differentiates significantly in the same direction as the total scale, which indicates the appropriate discriminative power of each item [7].

Validity Analysis

In order to examine the construct validity of the SPS, the investigators employed an Exploratory Factor Analysis (EFA). This analysis shows that in distribution Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.928, indicating that the data were appropriate for this analysis [8].

Bartlett's test of sphericity was significant for the test ($\chi^2 = 2890.190$, $p < 0.001$) (Table 2), indicating that correlations existed among some of the safety performance scales.

The principal component analysis was used for the factor extraction of the SPS and a Varimax rotation was employed for better interpretability of the factor loadings. Moreover, in order to enhance interpretability, only those factor loadings greater than 0.50 were selected [9].

The EFA of the 18-item SPS produced three factors with eigenvalues greater than 1 (Kaiser criterion), which accounted for 77.75% of the total variance (See Table 3). The table also shows that each of the communalities of the 18 items was greater than 0.61. A scree plot of the size of the eigenvalues against the number of factors in their order of extraction is shown in Figure 1.

Table 1: Correlation coefficients of each item with the SPS.

Item Number	Item Total Score Correlation
1	0.823**
2	0.837**
3	0.792**
4	0.780**
5	0.825**
6	0.764**
7	0.671**
8	0.770**
9	0.762**
10	0.733**
11	0.657**
12	0.644**
13	0.746**
14	0.790**
15	0.762**
16	0.739**
17	0.748**
18	0.799**

Note: **$p < 0.01$

Table 2: KMO and Bartlett's test of sphericity.

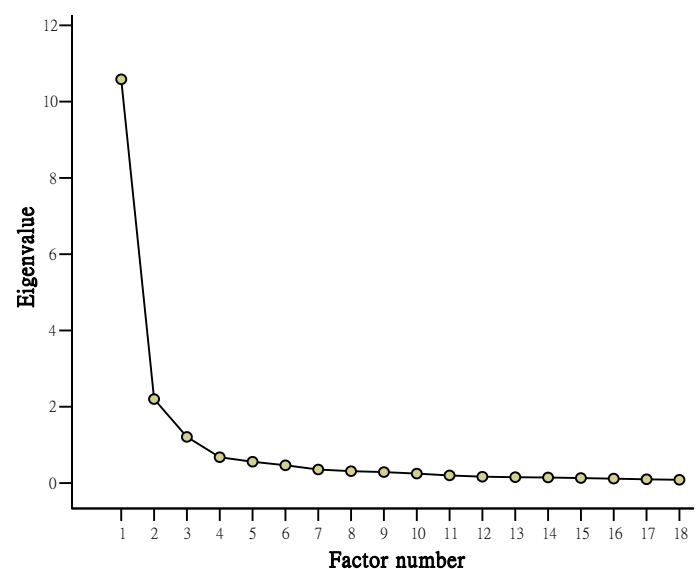| Kaiser-Meyer-Olkin measure of sampling adequacy	0.928	
Bartlett's test of sphericity	The approximate chi-squared distribution	2,890.190
	Degrees of freedom	153
	Significance	0.000

Figure 1: Scree plot of the factors.

Reliability Analysis

Internal consistency reliability was measured for each subscale of the SPS using Cronbach's α [10]. As shown in Table 4, the reliability coefficients ranged from 0.926 to 0.953, all of which are acceptable.

Table 3: The eigenvalues, communalities, factor loadings and explained variances of t safety performance scale by the EFA.

Factors	Eigenvalues	Item Number	Communalities	Factor Loadings	Explained Variances	Accumulated Explained Variances
Safety motivation	5.027	16	0.813	0.849	27.93%	27.93%
		17	0.780	0.822		
		15	0.757	0.792		
		14	0.764	0.770		
		18	0.756	0.761		
		13	0.728	0.752		
Accident investigation	4.588	11	0.785	0.846	25.49%	53.42%
		10	0.807	0.843		
		12	0.728	0.809		
		9	0.768	0.786		
		8	0.764	0.772		
		7	0.614	0.707		
Safety inspection	4.380	3	0.850	0.817	24.34%	77.75%
		4	0.835	0.794		
		6	0.788	0.792		
		5	0.849	0.773		
		1	0.793	0.706		
		2	0.816	0.699		

Table 4: Internal consistency of each subscale of the SPS.

Subscale	Cronbach's α
Safety motivation	0.939
Accident investigation	0.926
Safety inspection	0.953

DISCUSSION

Kaiser argued that a more explained variance will result if only those components with eigenvalues greater than one are retained [11][12]. The eigenvalues of these three factors in the SPS were all greater than 4.30, indicating that the SPS had good explanatory power to a certain degree. Cattell advised to keep all eigenvalues before the break point of the scree plot [13]. So, as Figure 1 shows, the authors retained the eigenvalues of the three factors in this study. Cattell and Jaspers, Browne and Linn suggested that while the number of variables is less than 40, if the criterion is to retain those with eigenvalue greater than one, the communalities should be greater than 0.40 [14-16]. In this study, the communalities of the 18 variables were greater than 0.61, so the accuracy of the SPS is supported.

According to Gay, what constitutes an acceptable level of reliability is determined by the type of test. Of course, a coefficient greater than 0.90 would be acceptable for any test. For achievement and attitude tests, the coefficient should not be less than 0.90 and for personality measures, it is acceptable if the coefficient is more than 0.70 [17]. Nunnally and DeVellis also supported that the minimum level of acceptability for the coefficient of a scale is 0.70 [18][19]. This contention was also supported by Cooper, who proposed that a different safety practice could be distinguished only if the coefficient is greater than 0.70 [20]. However, with a stricter criterion, DeVellis suggested that a scale would not make much academic contribution unless the coefficient is greater than 0.95 [19].

In this study, the values of the coefficient of these three subscales were all greater than 0.92. Accordingly, the SPS shows good reliability and academic level.

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