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Construct a Total Safety Performance for Semiconductor Industry

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Abstract:

By referring to the approaches of a safety performance evaluation and the corresponding aspects developed in past studies and also adopting the management mechanisms suggested in the Taiwan Occupational Safety and Health System guidelines, this study constructs the "Total Safety Performance Evaluation Method." and a safety performance questionnaire is designed by utilizing a semiconductor business in Taiwan as the subject to understand the current status of safety performance in the semiconductor industry by a statistical analysis of the outcome of the questionnaire survey.

The outcome reveals that the employees of the semiconductor business consider that the safety performance evaluation conducted for the elements of "worker participation," "risk assessment," "procurement management," "work permission," and "safety protection" is not well executed; however, it is well executed for the elements of, in descending order, "health examination," "emergency response," "safety audit," and "management of hazardous substances." The answers given in the questionnaire indicate that the employees are not enthusiastic about participating in safety promotion activities but confirm that the company conducts health examination on a regular basis.

Keywords: Safety Performance, Education and Training, Risk Assessment, TSPEM

Introduction

To achieve sustainable management and established targets, an enterprise has to invest certain resources such as manpower, money, and time. After investing such resources, the management will definitely take certain measures or apply appropriate methods to understand whether the resources invested to achieve health and safety targets, the projects established, and the personnel assigned to execute the projects have accomplished the expected results. Such measures or methods are defined as performance measurement [1]. Performance measurement is an indispensible task for business entities to ensure the execution and results of various health and safety management measures. In particular, the supervision of the execution of health and safety management and the measurement of execution performance not only demonstrate the ability of the management to achieve the overall health and safety targets but also serve as prerequisites for the promotion of a sound health and safety culture.

Arezes and Miguel [2] believe that the measurement of the safety performance of health and safety management systems can provide useful information for all activities of an organization, which can accordinglyplan strategies for risk control. In any occupational health and safety management system, a safety performance measurement is indispensible and must be executed. According to the description in OHSAS 18002 [3], the main purposes of a safety performance measurement are as follows: 1) keeping track of the degree of compliance of occupational health and safety policy with commitments as well as the progress of target achievement and continuous improvement, 2) monitoring exposures to determine whether applicable legal regulations or other requirements have been met, 3) monitoring incidents, injuries, and health impact, 4) providing data for the evaluation of the effectiveness of operational control measures and whether there is a need to modify or introduce new control measures, 5) providing data needed in health and safety activities as well as health and safety management system performance, 6) providing information required to improve assessment capacity, and 7) ensuring the fitness and sufficiency of resources (OHSAS 18002, 2008)[3].

Although many enterprises blindly pursue certification for their occupational health and safety management systems, they do not hire sufficient professionals to audit or evaluate the performance of their systems. Wu [4] surveys 250 businesses that have acquired the OHSAS 18001 [5] certification. More than 70% of these enterprises complain about the increase of cost and paperwork for certification, while most of the businesses lack the knowledge required to manage the occupational health and safety management system effectively; one of the reasons is that the management department does not know how to conduct a safety performance evaluation. Although the injury frequency rate (IFR) and injury severity rate (ISR) are extensively used by government agencies, they merely reflect the occupational health and safety conditions and do not provide any information regarding management improvement. To enable safety management systems to operate effectively, a general performance evaluation system is absolutely necessary, and measurable and achievable indicators must also be included.

Safety Performance in Theory

Zohar [6] suggests that safety performance indicates the recognition by the employees of an organization of the importance of safety. Brown & Holmes [7] propose that safety performance is the overall perception of the significance of safety issues. Niskanen [8] points out that safety performance is the specific overall perception of the employees of an organization, and this perception can be affected by the policy and practices of the organization. Cooper & Phillips [9] believe that safety performance is an aggregate of the perceptions of the employees toward their work environment. Coyle et al. [10] believe that safety performance represents the objective assessment of an organization's health and safety issues. Diaz et al. [11] assert that safety performance is the overall perception of the employees toward the work environment and that this perception affects their safety behavior. Wu [12] considers safety performance to be the overall performance of the safety management system.

The above definitions show that there are multiple elements of safety performance. Depending on the purpose, subject, or scope of study, there may be different interpretations, and this can be proven by the fact that different researchers have come up with dissimilar ideas about the elements of safety performance in past studies.

Types and Methods of Performance Measurement

Petersen [13] thinks that the biggest safety problem lies in performance evaluation. Traditionally, the measurement of work results and safety project effectiveness has often been carried out with inappropriate and invalid assessment approaches. For assessing the safety conditions of a company, a department, or equipment, IFRs and ISRs cannot precisely point out whether the system is effective, whether the diagnosis is accurate, or whether the system is under control. Glendon and McKenna [14] suggest that such accident and injury statistics lack sensitivity, and their accuracy is also questionable.

There are no timelines, and risk exposure is neglected. Hence, it is inappropriate to measure safety performance based on only accident data. Phillips and Williams [15] also agree that the use of injury frequency as an index cannot really assess the performance level of a safety system.

The British Standards Institution (BSI) released the BS 18004 "Guide to Achieving Effective Health and Safety Performance" in 2008 [16]. It is a consolidation of OHSAS 18001 (2007) [5], OHSAS 18002 (2008) [3], and HSG65 [1]. Founded on the conceptual framework of the requirements set forth in OHSAS 18001 [5], the guide defines performance indicators in accordance with the principles of the operation of safety management systems. Performance indicators are divided into active and passive ones. It is emphasized that business entities ought to conduct active performance surveillance by combining routine and periodic inspections as well as passive performance surveillance that can respond in case of management system failures (BS 18004, 2008) [16].

According to the classification of OHSAS 18001 [5], there are active and passive approaches to a safety performance measurement. BS 18004 [16] specifies that passive performance indicators should not be limited to passive surveillance statistics on hazardous incidents and injury cases but should include the complete statistics on all hazardous events, including incidents, accidents, and injuries. On the other hand, active performance indicators will be the results or statistics obtained through an active surveillance of occupational health and safety performance, including the operation of occupational health and safety plans and management systems.

BS 18004 [16] also specifies that active performance indicators should have the function of predicting all passive indicators. The results may not be consistent with the long-term performance, but they can provide early evidence of successes or failures. Passive performance indicators are important. They can serve as the basis of the final confirmation of the effectiveness of occupational health and safety management systems. However, there are hidden problems and limitations when using only passive indicators to measure occupational health and safety performance: 1) inability to identify the tendency of the management system operation due to limited numbers of injury incidents, 2) accident rate growth as a result of increasing workload, 3) the sick leave and injury leave taken failing to indicate the severity of work-related ailments or occupational diseases, 4) false reporting of incidents, 5) incident occurrence rates being affected by the number of employees and the level of risk in execution of various tasks, and 6) delays between a management system failure and the negative effect thereof. Therefore, the active and passive performance indicators need to be combined in an occupational health and safety performance measurement to confirm the operating status and effectiveness of management systems for having adequate risk control.

OHSAS 18002 [3], BS 18004 [16], ILO-OSH 2001 [17], and TOSHMS [18] provide descriptions of qualitative and quantitative approaches to performance measurement.

1. In quantitative measurement, numbers and levels can be applied to describe and record. Performance measured should be quantified as much as possible to facilitate a comparison of the results of execution in different periods. However, quantified indicators may lack accuracy.
2. Qualitative measurement is employed to describe conditions or situations that cannot be expressed in numbers, such as the comments of the health and safety committee in its decisions. Qualitative indicators are important, but they cannot be compared to the results of other performance measurement approaches.

Holistic approaches to safety performance evaluation

Sgourou et al. [19] recommend that all related factors in a management system should be consolidated to establish a set of safety performance indicators when conducting a safety performance evaluation. The factors are divided into three types:

1. Technical factors, including general factors—the type and design of equipment, degree of automation, work environment design, and maintenance, and safety-related factors—risk control system, personal protection equipment, and emergency control system.
2. Organizational factors, including general organizational systems—organizational structure, responsibility, assembly line, communication type, and change adaptation [20], and the safety management system in place, such as safety policy, safety responsibility, resources, and management commitment.
3. Human factors, as described in HSE [21]: "environmental, organizational, and job factors, and human and individual characteristics that influence behavior at work that can have an effect on health and safety."

Sgourou et al. [19], based on the depiction of the overall approaches and the evaluation methods using various characteristics as mentioned in related literature [22, 23, 24, 25, 26, 27, 28], suggest that a safety performance evaluation should have the following features:

1. The method adopted should be supported by a theoretic framework. There should be one or several theories or models adopted as a scientific framework to be the foundation of the method [22, 25].
2. The method adopted should be comprehensive, implying that the three aforesaid factors (technical, organizational, and human) should be consolidated, and their interrelations and relationships among the safety. management system, the organization, and the external environment (internal relations) should be considered.
3. The method adopted should be effective and reliable, passing all reliability and validity tests required for the specific type of methods.

Safety Management Systems

Mearns et al. [29] assert that the achievement of safety performance targets relies on the execution of the safety management system. In addition, Sgourou et al. [19] also believe that the overall approach must also include dynamic methods with the aforesaid factors and consider relationships among the safety management system, the organization, and the external environment. The theories and empirical evidence established in past studies with regard to safety management systems and safety performance such as McDonald et al. [30], Basso et al. [31], Lin et al. [32], Ng et al. [33], and Teo and Ling [34] offer several measurement concepts. Chang & Liang (2009) [35] use the management mechanisms described in OHSAS 18001 [5] and Deming's PDCA cycle, while also referring to the safety performance ideas of different scholars and specialists, and establish four principal factors: policy organization, implementation and operation, supervision and measurement, and management auditing. Furthermore, they also develop 20 safety performance elements and 101 attributes to assess paint manufacturers through safety audits.

The British Health and Safety Executive [1] adopted health and safety policy, health and safety organization, planning and execution, employee participation, health management, and safety audit as the six indicators for the elements of safety management systems. The safety performance evaluation described in the American National Standard for Occupational Health and Safety Management Systems of the American Industrial Hygiene Association [36] includes 10 items: loss of work hours, safety behavior percentage, number of near accidents, acceptance of employee suggestions and criticisms, percentage of statutory health and safety training conducted, average number of days taken to complete corrective actions, results of exposure surveillance, employees' loss of hearing, damage compensation for workers, and other objective indicators.

OHSAS 18001 [5] and ILO-OSH [17] are both occupational health and safety management system standards, but the management mechanisms suggested are different. The Taiwan Occupational Safety and Health Management System (TOSHMS) [18] is a set of guidelines in which key points and characteristics of ILO-OSH [17] from the International Labour Organization and OHSAS 18001 [5] from international certification bodies are consolidated. Traditional labor health and safety management system specifications focusing on specific areas are improved to be more effective in reducing workplace hazards and risks and in meeting international standards. Using the management mechanisms suggested in TOSHMS [18], this study has identified 23 major safety performance elements, including self-inspection, emergency response, Personal protective equipment, Hazardous materials management, safety protection, Risk assessment,Laws and regulations, Accident investigation & statistics, High-level commitment,Organization and responsibility,Education and training,Contractor management, procurement management, management of change, work permission, communication, Work environment monitoring, health examination, safety audit, planning review, execution review, Checking review, and worker participation.

Laws and Regulations

According to the suggestions and requirements for occupational health and safety management systems set forth in BS 8800 [37], OHSAS18001 [5], and ILO-OSH2001 (ILO (2001)) [17], the business entity's performance measurement plan must comply with related laws and regulations. Acting according to Taiwan's Labor Safety and Health Act, this study has developed 12 elements for the measurement of safety performance. They are machine safety protection, self- inspection, Personal protective equipment, emergency response, Hazardous materials management, laws and regulations, accident investigation and statistics, organization and responsibility, education and training, contractor management, Work environment monitoring, and health examination.

Studies Related to Safety Performance Elements

The elements of safety performance can be interpreted differently depending on the purpose, object, or scope of study. Therefore, scholars and specialists in and outside of Taiwan have dissimilar views and theories about how to present the elements of safety performance. For example, Cooper [38] defines 11 elements: accident statistics, number of most recent accidents, number of days with accidents, accident costs, safety audit scores, number of safety checks, number of employee safety training courses conducted, number of safety inspections conducted by the management, employee safety behavior criteria, safety attitude survey scores, and safety demonstration. Schneid [39] proposes six elements: safety responsibility of the management, safety targets, accident investigations, training supervision, regular safety training for workers, and fire control. Petersen [13] presents seven elements: organization, management, physical hazard control, occupational environment hazard control, investment and development, encouragement, and accident appraisals and reports. After referring to related literature, the authors of this paper consolidate homogenous or similar safety performance elements into one aspect and identify 22 safety performance elements, as shown in Table 1.

Safety performance elements	Source	Literature Reference
Self-inspection	Cooper(1998), Lin et al. (2004), Ng et al. (2005), Chang and Liang (2009), Sgourou et al. (2010)	(38,32,33,35,19)
Emergency response	Dupont(1996), Basso et al. (2004), Ng et al.(2005), Fernandez-Muniz et al. (2007), BSI (2007), Chang and Liang (2009), Sgourou et al. (2010), Hsu et al.(2011)	(44,31,33,45,5,35,19,43)
Personal protective equipment(PPE)	Ng et al.(2005), Teo and Liang(2006), Chang and Liang (2009), Sgourou et al. (2010)	(33,34,35,19)
Hazardous materials management	Lin et al. (2004), Ng et al. (2005), Chang and Liang (2009)	(32,33,35)
Safety protection(including Hazard contol)	Lin et al. (2004), Teo and Liang(2006), Petersen (2000), Chang and Liang (2009)	(32,34,13,35)
Risk assessment	Dupont(1996), Basso et al. (2004), Ng et al.(2005), Teo and Liang(2006), BSI (2007), Chang and Liang (2009), Sgourou et al. (2010), Hsu et al.(2011)	(44,31,33,45,5,35,19,43)
Laws and Regulations	Ng et al.(2005), Teo and Liang(2006), Chang and Liang (2009)	(33,34,35)
Accident Investigation & Statistics	Dupont(1996), Cooper(1998), Petersen (2000), McDonald et al. (2000), Basso et al. (2004), Ng et al.(2005), BSI (2007), Chang and Liang (2009), Hsu et al. (2011)	(44,38,13,30,31,33,5,35,43)
High-level Commitment	Dupont(1996), Cooper(1998), Schnied (1999), Petersen (2000), McDonald et al. (2000), Meams et al. (2003), Ng et al.(2005), Chang and Liang (2009), Sgourou et al. (2010), Hsu et al.(2011)	(13,49,39,13,30,29,33,35,19,43)
Organisation and Responsibility	Petersen (2000), Erickson (2000), McDonald et al. (2000), Basso et al. (2004), Lin et al. (2004), Ng et al.(2005), Teo and Liang(2006), Chang and Liang (2009), Sgourou et al. (2010), Hsu et al.(2011)	(13,49,30,31,32,33,34,35,19,43
Education and Training	Campbell et al. (1993), Dupont(1996), AIHA (1996), Cooper(1998), Ng et al.(2005), Teo and Liang(2006), Chang and Liang (2009)	(50,44,36,38,33,34,35)
Contractor Management	Dupont(1996), McDonald et al. (2000), Ng et al.(2005), Teo and Liang(2006), Chang and Liang (2009)	(44,30,33,34,35)
Work permit	Lin et al. (2004), Chang and Liang (2009)	(32,35)
Communication	Dupont(1996), Erickson (2000), Meams et al. (2003), Fernandez-Muniz et al. (2007), Chang and Liang (2009), Sgourou et al. (2010)	(44,49,29,45,35,19)
Work environment monitoring	Swacha et al. (1999), McDonald et al. (2000), Chang and Liang (2009)	(52,30,35)
Health examination	Teo and Liang(2006), Chang and Liang (2009)	(34,35)
Safety audit	Cooper(1998), Lin et al. (2004), Ng et al.(2005), Chang and Liang (2009)	(38,32,33,35)
Planing review	McDonald et al. (2000), Lin et al. (2004), Ng et al.(2005), Chang and Liang (2009)	(30,32,33,35)
Execution review	Basso et al. (2004), Lin et al. (2004), Ng et al.(2005), Fernandez-Muniz et al. (2007), Chang and Liang (2009)	(31,32,33,45,35)
Checking review	McDonald et al. (2000), Lin et al. (2004), Ng et al.(2005), BSI (2007), Chang and Liang (2009)	(30,32,33,5,35)
Safe behavior	Cooper(1998), Sgourou et al. (2010), Hsu et al. (2011)	(38,19,43)
Safety attitude	Cooper(1998), Sgourou et al. (2010), Hsu et al. (2011)	(38,19,43)

Table 1: Safety Performance Elements

Development Framework of the Total Safety Performance Evaluation Method

Despite the many elements of safety performance considered, the studies mentioned above have not achieved any consensus. The observation of the authors of this paper indicates that the elements included are inadequate, and specific safety performance elements are therefore constructed in this study. Besides existing safety performance elements, international standards and safety management guidelines are also considered, and safety performance studies conducted in the past are referred to in the evaluation of the safety performance of the semiconductor industry. Based on the management mechanisms suggested in TOSHMS [18] 23 safety performance elements (see Section 2.3) are established. According to related laws and regulations, 12 elements are established (see Section 2.4). In line with related literature, 22 elements are established (see Section 2.5), and three primary factors for the safety performance evaluation from previous studies, which were detailed in Section 2.2. Moreover, homogenous or similar elements are combined into one parameter. In total, three primary factors, including 25 safety performance elements, are synthesized, as shown in Table 2, and the "Total Safety Performance EvaluationMethod"(TSPEM) **is** constructed, as shown in Figure 1.

Factors	Safety Performance Elements
Technical factors	Self-inspection
	Emergency response
	Personal protective equipment (PPE)
	Hazardous materials management
	Safety protection
	Risk assessment

Table 2: Cont..........

Organisational factors	Laws and regulations
	Accident investigation
	High-level commitment
	Organization and responsibility
	Education and training
	Contractor management
	Procurement management
	Management of change
	Work permit
	Communication
	Work environment monitoring
	Health examination
	Safety audit
	Planning review
	Execution review
	Checking review
Human Factors	Worker participation
	Safe behavior
	Safety attitude

Table 2: Total Safety Performance Elements

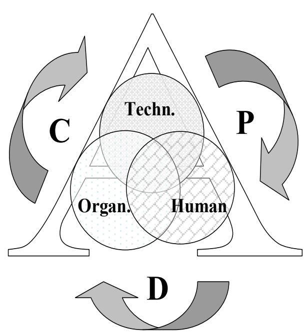

Fig 1: Total Safety Performance Evaluation Method

The TSPEM is defined as "Total Safety Performance Evaluation must be conducted with the technical, organizational, and human factors taken into consideration and in compliance with related regulations, the PDCA safety management system has to be implemented, worker participation must be achieved while individual safety attitude and conduct must also be valued."

Research Methods

Design of Questionnaire

To design the questionnaire for the evaluation of safety performance, the authors of this paper have referred to related studies, including the expert questionnaire developed by Chang & Liang [35], the safety performance questionnaires developed by Neal [40], Siu et al. [41], Su & Hsu [42], and Hsu [43], and the management mechanisms of occupational health and safety management systems, including BS 18004 [16], OHSAS 18001 [5], OHSAS 18002 [3], HSG 65 [1], and TOSHMS [18], before establishing the "Safety Performance Evaluation Questionnaire" in accordance with the 25 safety performance elements identified.

Questionnaire Validity

Before pre-testing the questionnaire, the authors of this paper met with representatives from the employees and management of the semiconductor business to solicit their opinions and suggestions with regard to the initial draft of the questionnaire as references for revision of the questionnaire and to establish validity. Subsequently, the questionnaire was presented to five health and safety specialists to review the questions and make necessary modifications to construct expert validity. These specialists had done safety work or research for at least 20 years and were extremely familiar with safety performance issues.

During the extraction of safety performance content, four principles were adopted: 1) generality: the extracted safety performance statements can apply to different types of work; 2) discriminability: each statement is related to only one specific factor, not crossing between two factors; 3) readability: each statement is easily understandable and truly reflects the intended meaning; and 4) non-redundancy: each statement has its specific connotation, and no two statements are interchangeable. To comply with these principles, the authors of this paper consulted the five specialists, classified the factor that involved each question, deleted or consolidated questions that were similar in meaning or repetitive, and also removed or revised those whose meaning appeared obscure. The results were taken as the basis for the formulation of the safety performance rating scale.

Study Procedure Outline

1. By examining related literature and compiling data from safety performance studies conducted in and outside the country, the authors of this paper establish the "Safety Performance Evaluation Questionnaire."

2. The independent and dependent variables in this study are defined in accordance with the motive and purpose of study as well as the related literature examined. Employee background is taken as an independent variable, and there are 20 corresponding questions: 6 on work experience, 5 on occupational disaster experiences, 3 on training, and 6 on job satisfaction.

3. Regarding the dependent variable, 121 questions cover the 25 safety performance elements identified after referring to the management mechanisms established in related literature and the TOSHMS [18] Guidelines and consolidate homogenous or similar elements into one aspect. There is one repeated question included for a validity test. Of all the questions, 111 of them are positively worded and 10 negatively worded.

4. A five-point Likert scale is adopted: 1 represents "strongly disagree" and 5 "strongly agree." For negatively worded questions, the scores are calculated in a reverse way.

5. Fifty-five employees are randomly selected to participate in the preliminary testing of the questionnaire evaluating safety performance. The sample frequency distribution percentages are shown in Table 3.

Job Type	Number	Percentage (%)
Administrator	10	18%
Operator	32	58%
Other	13	24%
Total	55	100%

Table 3: Pretest Respondent Types and Percentages

6. Questionnaire reliability is calculated and analyzed to provide the basis for question elimination. The selection of question details is conducted using the Cronbach's alpha value as the standard in order to increase the Cronbach's alpha coefficient of the 25 safety performance elements and produce the Cronbach's alpha value after the modification of the 25 safety performance elements. After the pretest, the Cronbach's alpha value of each element is greater than 0.616 and that of the study population is 0.985. After modification, there are 104 questions in the official questionnaire.
7. Three hundred copies of the questionnaire are distributed in the semiconductor business. Two hundred and sixty-eight copies are retrieved, and the retrieval rate is 89.33%. The questionnaire copie retrieved are screened manually and sorted out. Those with incomplete basic respondent information or inconsistent answers are regarded as invalid. After eliminating 42 invalid copies, there are 226 valid copies, and the valid retrieval rate is 75.33%. The SPSS software is then applied to analyze the valid copies and perform reliability analysis, correlation analysis and analysis of variance (ANOVA).

Results and Discussion

This chapter focuses on the statistical analysis of the data on the questionnaire copies retrieved. The results and the discussion are as follows:

Analysis of the Safety Performance of the Business Studied

Table 4 shows the maximum values, averages, and standard deviations of the 25 safety performance elements.

Main Factors	Safety performance elements			Maximum Value	Average	Standard Deviation	Percentage	Safewty Performance Element Average (standard Deviation)
Technical factors	1	SI	Self-inspection	5	4.02	.45	80.44%	4.05(.40)
	2	ER	Emergency response	5	4.16	.43	83.22%	
	3	PPE	Personal Protective Equipment (PPE)	5	4.07	.42	81.35%	
	4	HMM	Hazardous materials management	5	4.12	.49	82.35%	
	5	SP	Safety protection (including Hazard control)	5	3.99	.50	79.76%	
	6	RA	Risk assessment	5	3.95	.52	79.00%	
Organisational factors	7	L&R	Laws and regulations	5	4.01	.48	80.27%	4.04(.44)
	8	AI & S	Accident investigation & statistics	5	4.07	.47	81.40%	
	9	HLC	High-level commitment	5	4.03	.50	80.67%	
	10	O & R	Organization and responsibility	5	4.03	.53	80.53%	
	11	E & T	Education and training	5	4.05	.46	81.06%	
	12	CM	Contractor management	5	4.01	.56	80.29%	
	13	PM	Procurement Management	5	3.98	.52	79.68%	
	14	MC	Management of Change	5	4.00	.54	79.94%	
	15	WP	Work permit	5	3.99	.55	79.76%	
	16	COM	Communication	5	4.00	.53	79.98%	
	17	WEM	Work environment monitoring	5	4.03	.49	80.69%	
	18	HE	Health examination	5	4.19	.46	83.89%	
	19	SA	Safety audit	5	4.14	.52	82.83%	
	20	PR	Planning review	5	4.08	.54	81.59%	
	21	ER	Execution review	5	4.01	.55	80.18%	
	22	CR	Checking review	5	4.00	.55	79.94%	
Human Factors	23	WP	Worker Participation	5	3.85	.58	76.90%	4.00(.44)
	24	SB	Safe Behavior	5	4.05	.44	81.04%	
	25	SA	Safety Attitude		4.06	.50	81.13%	

Table 4. Descriptive Statistics of the Safety Performance Aspects

By dividing the average by the maximum value of each dimension, the percentage can be obtained. Take "self-inspection" for example. When the average of 4.02 is divided by the maximum value of 5, the result is 80.44%. Similarly, the percentage of each dimension can be calculated. These percentage scores are then converted and presented in a radar chart, as shown in Figure 2.

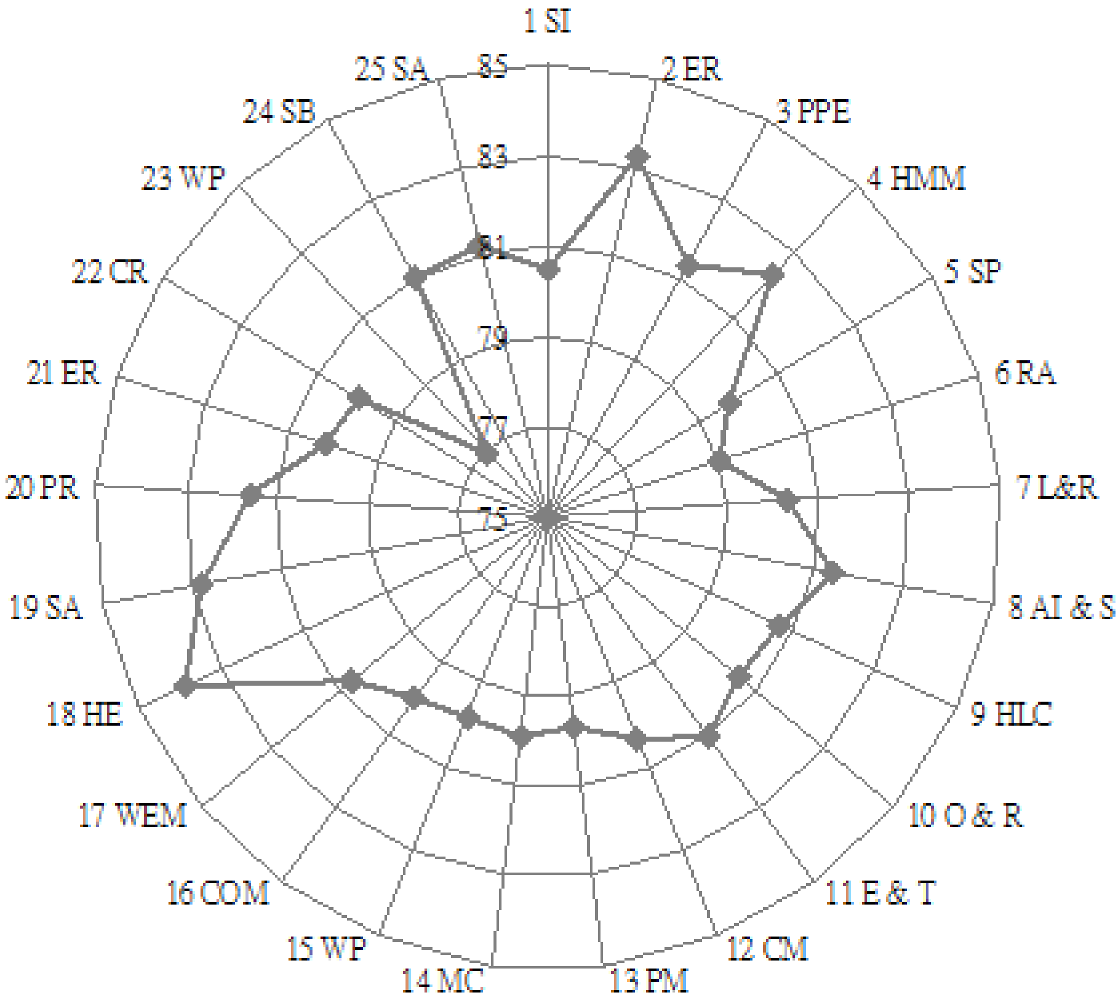

Figure 2: Radar chart of percentage scores of the safety performance of the semiconductor business studied

Table 4 indicates that the employees of the semiconductor business studied consider the safety performance in "worker participation," "risk assessment," "procurement management," "work permission," and "safety protection" is not well executed, but it is well executed in "health examination," "emergency response," "safety audit," and "management of hazardous substances." In addition, as shown in Table 5, the answers to the questions regarding worker participation indicate that the employees are not enthusiastic about participating in safety promotion activities (speeches, training, and safety sign design competitions), but as shown in Table 6, the employees confirm that the company conducts a health examination on a regular basis.

Question	Average	Standard deviation
I will attend dafety promotion activities (such as speeches, training, and safety sign design competitions.)	3.77	.87
I will express opinins for industrial safety improvement.	3.81	.79
I will report every safety problem I encounter at the workplace.	3.96	.56

Table 5. Analysis of Answers to the Questions onWorker Participation

Question	Average	Standard Deviation
The company conducts health examination on new employees.	4.28	.62
The company does not conduct routine health examination regularly.	4.45	.70
The company makes job assignment in accordance with the health examination results of the employees.	3.88	.76
The company conducts special health examination on employees doing hazardous work. The company conducts special health examination on employees doing hazardous work.	4.17	.65

Table 6. Analysis of Answers to Questions on Health Enhancement

ANOVA of Background and SafetyPerformance Elements

The statistics in Table 7 show that there is a significant difference between the employee background variable and the corresponding safety performance element.

The ANOVA result indicates the significance α<0.05. The details are as follows:

Main Factors		Safety performance elements	Education		Job		Years of Service	
			F test	Significance	F test	Significance	F test	Significance
Technical factors	1	Self-inspection	5.917	.003	2.484	.024		
	2	Emergency response						
	3	Personal Protective Equipment (PPE)						
	4	Hazardous materials management						
	5	Safety protection (including Hazard control)	5.258	.006				
	6	Risk assessment						
Organisational factors	7	Laws and regulations			2.168	.047		
	8	Accident investigation & statistics						
	9	High-level commitment						
	10	Organization and responsibility						
	11	Education and training						
	12	Contractor management	3.990	.020	2.870	.010		
	13	Procurement Management	3.858	.023				
	14	Management of Change	4.655	.010				
	15	Work permit						
	16	Communication	4.285	.015				
	17	Work environment monitoring	3.977	.020	2.484	.024	3.418	.018
	18	Health examination					2.691	.047
	19	Safety audit	7.224	.001	2.777	.020		
	20	Planning review	4.058	.019				
	21	Execution review						
	22	Checking review						
Human Factors	23	Worker Participation	4.303	.015	2.864	.010		
	24	Safe Behavior						
	25	Safety Attitude						

Table 7. ANOVA of the Background Variable and Safety Performance Aspects

As shown in Table 7, regarding education, significant differences appear in self-inspection, safety protection (including hazard control), contractor management procurement management, management of change, communication, work environment monitoring, safety audit, planning review, and worker participation. In self-inspection, for example, it shows that different education among employees havedifferent performance (F-test, $p<0.05$), as shown in Table 8. For the same reason, significant differences also appear in self-inspection, laws and regulations, contractor management, work environment monitoring, safety audit, and worker participation with regard to job responsibilities. Those in higher positions tend to identify more with these safety performance elements. In years of service, significant differences appear only in work environment monitoring and health examination, meaning that senior employees identify more with these safety performance elements.

Question	Senior High / Vocational School or Lower	College / University	Graduate School and higher	F test	Significance
The company has established self-inspeection plans.	3.99(.50)	3.92(.67)	4.57(.79)		
The machine equipment is inspected on a monthly basis (such as forklifts,fixed cranes, lifts, etc.)	4.09(.63)	3.97(.68)	4.57(.53)		
Operational check-ups are conducted on the machine equipment before operation begins.	4.03(.69)	3.90(.66)	4.43(.79)		
The fire facilities are inspected regularly (fire extinguishers, emergency lights, etc.)	4.15(.56)	4.13(.62)	4.57(.79)		
The emergency response equipment is inspected regularly.	4.07(.63)	4.02(.68)	4.57(.53)		
The safety protection equipment is inspected regularly (such as insulating gloves,fall protection equipment, etc.)	3.96(.82)	3.91(.75)	4.57(.53)		
	4.05(.41)	3.98(.46)	4.55(.52)	5.917	.003
$p<0.05$, two -tailed, 95% significance ^{0}					

Table 8. ANOVA of Education and Self-inspection

Correlations between the Safety Performance Elements

The Pearson coefficient is applied to conduct statistical analysis to determine the correlations between the safety performance elements. The results indicate there are **positive** and significant correlations between the 25 safety performance elements ($p<=0.01$, two-tailed test). As shown in Table 9, a high correlation appears between high-level commitment and accident investigation & statistics (average r = 0.836), indicating that support and commitment from the company's high-level management will positively affect accident investigation and statistics. A high correlation also appears between execution review and planning review (average r = 0.821),

Main Factors		Safety performance elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	1	Self-inspection	1																								
	2	Emergency response	.794(**)	1																							
	3	Personal Protective Equipment (PPE)	.799(**)	.776(**)	1																						
	4	Hazardous materials management	.689(**)	.698(**)	.748(**)	1																					
	5	Safety protection (including Hazard control)	.685(**)	.605(**)	.687(**)	.708(**)	1																				
	6	Risk assessment	.700(**)	.604(**)	.743(**)	.666(**)	.714(**)	1																			
Organisational factors	7	Laws and regulations	.776(**)	.685(**)	.766(**)	.689(**)	.661(**)	.741(**)	1																		
	8	Accident investigation & statistics	.755(**)	.731(**)	.783(**)	.775(**)	.751(**)	.742(**)	.778(**)	1																	
	9	High-level commitment	.719(**)	.621(**)	.741(**)	.728(**)	.712(**)	.765(**)	.795(**)	.836(**)	1																
	10	Organization and responsibility	.691(**)	.629(**)	.711(**)	.689(**)	.695(**)	.793(**)	.766(**)	.757(**)	.814(**)	1															
	11	Education and training	.758(**)	.689(**)	.790(**)	.676(**)	.672(**)	.768(**)	.796(**)	.793(**)	.797(**)	.795(**)	1														
	12	Contractor management	.686(**)	.606(**)	.675(**)	.664(**)	.622(**)	.739(**)	.760(**)	.715(**)	.786(**)	.730(**)	.745(**)	1													
	13	Procurement Management	.711(**)	.617(**)	.656(**)	.693(**)	.727(**)	.785(**)	.731(**)	.741(**)	.768(**)	.781(**)	.713(**)	.772(**)	1												
	14	Management of Change	.693(**)	.630(**)	.662(**)	.589(**)	.650(**)	.685(**)	.656(**)	.698(**)	.698(**)	.659(**)	.681(**)	.598(**)	.735(**)	1											
	15	Work permit	.651(**)	.558(**)	.692(**)	.746(**)	.682(**)	.740(**)	.711(**)	.747(**)	.788(**)	.756(**)	.739(**)	.699(**)	.750(**)	.645(**)	1										
	16	Communication	.669(**)	.613(**)	.703(**)	.694(**)	.711(**)	.699(**)	.681(**)	.746(**)	.745(**)	.741(**)	.737(**)	.720(**)	.725(**)	.673(**)	.748(**)	1									
	17	Work environment monitoring	.726(**)	.640(**)	.737(**)	.716(**)	.659(**)	.723(**)	.728(**)	.738(**)	.747(**)	.748(**)	.742(**)	.752(**)	.762(**)	.713(**)	.791(**)	.790(**)	1								
	18	Health examination	.692(**)	.671(**)	.744(**)	.653(**)	.616(**)	.647(**)	.748(**)	.728(**)	.740(**)	.710(**)	.758(**)	.702(**)	.661(**)	.651(**)	.664(**)	.678(**)	.719(**)	1							
	19	Safety audit	.661(**)	.617(**)	.576(**)	.579(**)	.499(**)	.523(**)	.538(**)	.619(**)	.555(**)	.522(**)	.580(**)	.562(**)	.547(**)	.534(**)	.447(**)	.465(**)	.539(**)	.631(**)	1						
	20	Planning review	.677(**)	.595(**)	.685(**)	.622(**)	.696(**)	.762(**)	.691(**)	.723(**)	.737(**)	.799(**)	.730(**)	.696(**)	.769(**)	.701(**)	.697(**)	.723(**)	.730(**)	.671(**)	.568(**)	1					
	21	Execution review	.679(**)	.566(**)	.674(**)	.629(**)	.674(**)	.740(**)	.682(**)	.695(**)	.734(**)	.769(**)	.729(**)	.673(**)	.786(**)	.669(**)	.736(**)	.753(**)	.728(**)	.606(**)	.470(**)	.821(**)	1				
	22	Checking review	.698(**)	.612(**)	.668(**)	.694(**)	.694(**)	.760(**)	.689(**)	.730(**)	.736(**)	.745(**)	.711(**)	.700(**)	.752(**)	.644(**)	.770(**)	.698(**)	.752(**)	.631(**)	.575(**)	.690(**)	.767(**)	1			
Human Factors	23	Worker Participation	.548(**)	.415(**)	.527(**)	.576(**)	.578(**)	.601(**)	.622(**)	.594(**)	.659(**)	.621(**)	.573(**)	.593(**)	.608(**)	.456(**)	.622(**)	.628(**)	.544(**)	.566(**)	.394(**)	.567(**)	.545(**)	.608(**)	1		
	24	Safe Behavior	.642(**)	.572(**)	.620(**)	.635(**)	.618(**)	.588(**)	.605(**)	.645(**)	.600(**)	.604(**)	.618(**)	.566(**)	.613(**)	.557(**)	.611(**)	.597(**)	.588(**)	.600(**)	.563(**)	.533(**)	.534(**)	.644(**)	.636(**)	1	
	25	Safety Attitude	.648(**)	.548(**)	.652(**)	.638(**)	.592(**)	.658(**)	.663(**)	.671(**)	.689(**)	.712(**)	.696(**)	.616(**)	.642(**)	.558(**)	.683(**)	.638(**)	.646(**)	.655(**)	.515(**)	.598(**)	.674(**)	.710(**)	.627(**)	.796(**)	1

Table 9. Correlation Analysis of the Safety Performance Aspects

indicating that the company's reinforcement of planning review will facilitate planning review. A high correlation also exists among organization and responsibility and high-level commitment (average r = 0.814), indicating that well-defined organization and responsibility in the company can result in high-level commitment.

Conclusions

In this study, holistic approaches to the safety performance evaluation in previous studies and the management mechanism of the TOSHMS [18] were considered. This study proposes that technical, organizational, and human factors, including 25 safety performance elements, must be considered, and the management mechanisms of the TOSHMS [18] were considered, as well as compliance with related regulations. The"Total Safety Performance Evaluation Method" (TSPEM) was established on the basis of safety performance elements reported in previous research, in which safety performance was defined more extensively and in more detail. The TSPEM could be employed as a model for the establishment of safety performance in other industries.

It is thus obvious that to identify the actual problems of an organization in order to come up with solutions to reduce accidents and construct a good safety performance, activities must be conducted with technical, organizational, and human factors taken into consideration as well as in compliance with related regulations, the PDCA safety management system has to be implemented, and worker participation must be achieved while individual safety attitude and behavior must be valued.

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