The Development of a Safety Assessment Tool in the Manufacturing Industry

Thanwadee Chinda[1], Chutima Sae-Iew[2], Thanakorn Ruangsomboon[2], and Chayanit Kumut[2]

Abstract

Industrial safety is becoming an important issue in Thailand, and a number of attempts are made to reducing accident records and improving safety performance. This paper develops a safety assessment tool for the manufacturing industry. The exploratory factor analysis confirms the nine safety criteria, including five 'enablers' and four 'results', with a total of 47 associated attributes. A safety assessment tool is developed to measure an organization's current safety maturity level. An organization can use the tool to plan its safety improvement, by focusing on the weakest criteria shown in the tool with the lowest scores, to achieve higher maturity levels.

Keywords: Enablers, results, safety assessment tool.

Introduction

Safety is the condition to which risks are managed to acceptable levels. It is defined as a dynamic non-event that tends to be taken for granted, particularly in the face of continuous and compelling productive demands (Brueggmann, 2001). To improve safety, organizations need to measure their current status of safety, and plan for safety improvements. Over the past few years, attempts have been made to measure and benchmark the organizational and behavioral variables, and to present the aggregate score as an indicator of safety performance in the organizations. Wright et al. (1999), for example, developed a so-called 'safety culture improvement matrix' to be used as a self-assessment tool in assessing the organization's safety culture. Grau et al. (2002) investigated safety attitudes and their relationship with safety training, safety behavior, and generalized self-efficacy in Spain. In Thailand, safety has become an important issue, as a number of industrial accidents has been increased from 82,375 cases (in 1990) to 245,616 cases (in 1996), with the accident rate of 40 accidents per 1,000 workers (International Labor Organization, 2000). According to Mohamed (2002), accidents cause many human tragedies, de-motivate workers, and adversely affect the overall cost, productivity, and reputation of the industry. This paper, thus, aims to develop a self-assessment tool, using the European Foundation for Quality Management (EFQM) Excellence model as a basic model, to measure and improve safety in the organization. The six safety maturity levels are used to assess the current safety maturity level so that the organization can plan for its safety improvement to achieve higher maturity levels.

[1] Lecturer, School of Management Technology, Sirindhorn International Institute of Technology, Thammasat University 131 Moo 5 Tiwanont Rd. Bangkadi, Muang Pathumthani 12000 Thailand Tel. +66-2-5013505 ext. 2111 Fax. +66-2-5013524 Email. thanwadee@siit.tu.ac.th

[2] Undergraduate Student, School of Management Technology, Sirindhorn International Institute of Technology, Thammasat University 131 Moo 5 Tiwanont Rd. Bangkadi, Muang Pathumthani 12000 Thailand.

The European Foundation for Quality Management Excellence Model

The safety assessment tool is developed based on a widely used quality model, the European Foundation for Quality Management (EFQM) Excellence model. The EFQM Excellence model has been acknowledged as an effective way for organizations to improve the quality of their processes. It has been used in business generally, as well as in specific industries, such as hospitality and education (Camison, 1996; Sheffield Hallam University, 2003). The model, as shown in Figure 1, consists of nine criteria, five of which are 'enablers' and four of which are 'results'. The 'results' are brought about by 'enablers' and 'enablers' are improved using feedback from 'results'. The model assumes that leadership drives people management, policy and strategy, as well as resources, and that these three enablers collectively influence the ability to achieve the results through the implementation and improvement of suitable processes (EFQM, 2000).

In addition to the 'enablers' and 'results', the criterion weights are also an important part of the model. As shown in Figure 1, a total of 1,000 points is evenly split (500/500) between the 'enablers' and 'results'. The 500 points allocated to the enablers are distributed as follows: 100 points to Leadership, 80 points to Policy and Strategy, 90 points to People, 90 points to Partnerships and Resources, and 140 points to Processes. The 500 points within the four 'results' are distributed as: 90 points to People Results, 200 points to Customer Results, 60 points to Society Results, and 150 points to Key Performance Results (EFQM, 2000). Importantly, this allocation of points among the 'enablers', reflecting their relative contribution to the achievement of the 'results', is an area of much debate. For example, Eskildsen et al. (2001) examined the weight structure of the EFQM excellence model in the Danish companies and found that the perceived criterion weights vary from those allocated in the EFQM excellence model (i.e. 144 points to Leadership, 144 points to Policy and Strategy, 135 points to People, 136 points to Partnerships and Resources, 164 points to Processes, 87 points to People Results, 90 points to Customer Results, 54 points to Society Results, and 56 points to Key Performance Results). It also seemed as if Danish companies perceive the enabler criteria as equally important but this is not the case for the result criteria. For practical purposes, however, this study adopted the original enablers' allocation promoted by the EFQM Excellence model (as shown in Figure 1). These criterion weights are later used in the development of the safety assessment tool.

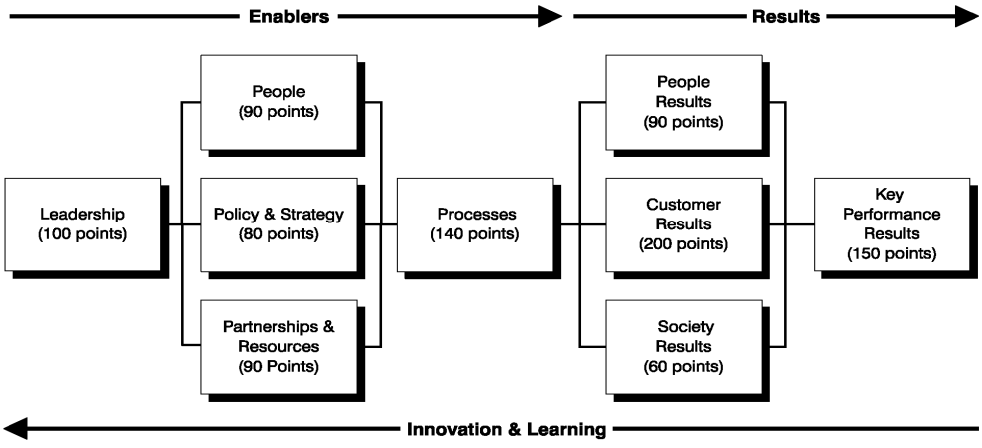

Figure 1. The EFQM Excellence Model

The nine key safety criteria comprise a number of attributes, which are carefully selected from safety-related literature, to explain their constructs.

- *Leadership* can be examined using five attributes: leadership commitment, consultative style, role model, safety accountability, and safety feedback (Hinze and Paker, 1978; Tam et al., 2004; Aksorn and Hadikusumo, 2008).
- *Policy and Strategy* consists of four attributes: productivity and safety targets, reward and recognition, updated safety standards, and safety policy (Langford et al., 2000; Potter, 2003; Teo et al., 2005).
- *People* is associated with seven attributes: peer review, safety empowerment, adequate supervision, compliance of safety rules, workers' involvement, safety perception, and teamwork (Dilley and Kleiner, 1996; Gyekye and Salminen, 2007; Aksorn and Hadikusumo, 2008).
- *Partnerships and Resources* consists of seven attributes: personal protective equipment, financial resources, safety-related resources, partnerships' awareness of safety, partnerships' involvement, partnerships' selection, and safety information (Wright et al., 1999; Langford et al., 2000; Aksorn and Hadikusumo, 2008).
- *Processes* is examined by seven attributes: safety maintaining program, risk assessment, safety documentation, benchmarking system, job clarity, organizational learning, and safety training (Pasman, 2000; Langford et al., 2000; Lingard et al., 2009).
- *People Results* is examined under four attributes: communication enhancement, job satisfaction, low turnover, and safe work behavior (Lardner et al., 2001; Mohamed, 2002; Paul and Maiti, 2007).
- *Customer Results* is associated with seven attributes: customers' satisfaction, customers' relationship, customers' expectation, and customers' perception (Mohamed, 2002; Karna, 2004; Europa, 2002).
- *Society Results* consists of four attributes: social image, public safety, social cost reduction, and social cooperation (Tang et al., 2003; The American Society of Safety Engineer, 2010).
- *Key Performance Results* consists of four attributes: total cost reduction, organizational performance, increased competitiveness, and reduced number of accidents (Pasman, 2000; Layne, 2003; Teo et al., 2005).

These nine criteria are used in developing a questionnaire survey to elicit respondents' opinions on the different attributes in the context of their current safety practices. It is important that an organization be able to assess its current safety maturity level, as the type of improvement method needed to support safety development differs as safety matures (Lardner et al., 2001). In this study, safety maturity levels is developed based on the capability maturity model to assist organizations in establishing their current level of safety maturity and in identifying actions required to improve their safety. Many researchers report the use of the safety maturity levels with a number of different levels, as well as respective score ranges for each level. The EFQM (2000), for example, divided a total of 1,000 points (see Figure 1) into five levels, while Tervonen and Pahkala (2008) divided the 1,000 points into six levels. In this study, the respondents are asked to give opinions on the levels and the score-ranges, and the final decision is to use safety maturity levels with the score-ranges recommended by Tervonen and Pahkala (2008) (see Figure 2).

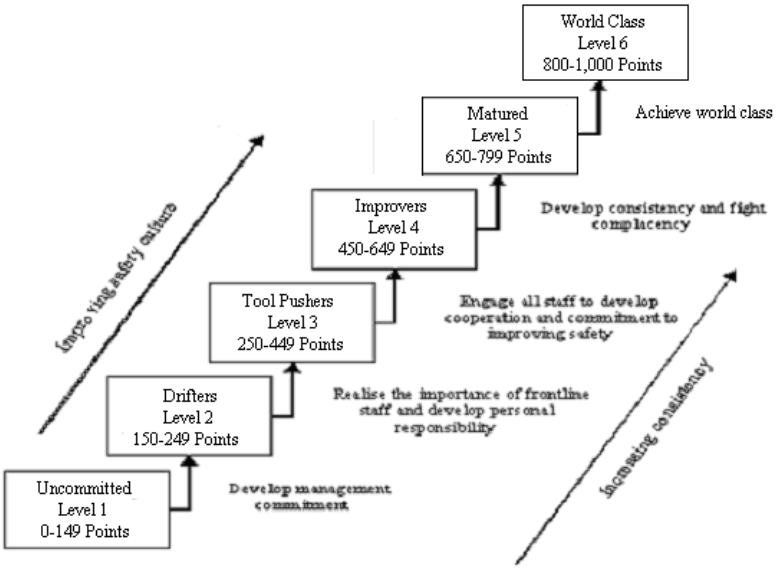

Figure 2. The Safety Maturity Levels

Questionnaire Survey and Preliminary Analyses

The 47 attributes listed earlier are used in a questionnaire survey development. A thousand questionnaires are distributed to a number of manufacturing companies, with 745 returns represented a response rate of 74.5%. From the returned responses, 42 are unusable, leading to 703 usable questionnaires for the analyses. Among the respondents, half of them have been working for their present organization for at least five years. Almost all of the respondents (92%) also report that their organizations have a formal safety policy, and they themselves have safety-related responsibilities. These prove the appropriateness of the sampled organizations involved in the survey.

After the data is collected, a number of data examination techniques are conducted. The statistical methods of the normality test, the outliers test, and the reliability test are performed to increase confidence in the data. Two important components of normality are skewness and kurtosis (Tabachnick and Fidell, 2007). According to Pallant (2005), the values of skewness < 2.0 and kurtosis < 7.0 are acceptable. The results demonstrate that all 47 attributes show normal distribution. The results also show no sign of outliers when performing the z-score test i.e. the z-scores for all the data are not exceed 3.29, at $p < 0.01$, two-tailed test (Tabachnick and Fidell, 2007). The reliability test is also conducted and the results have alpha values ranging from 0.80 to 0.90, all of which are considered reliable (Pallant, 2005). This, thus, increases confidence in the contribution of the 47 attributes to the measurement of their respective constructs.

Exploratory Factor Analysis

Following on preliminary analyses, an exploratory factor analysis (EFA) is performed to extract attributes into a number of factors that represent the interrelations among the set of those attributes (Pallant, 2005). In this study, the principal component method, with varimax rotation, is used to examine the dimensionality of the 30 attributes of the five 'enablers' and the 17 attributes of the four 'results'. A cut-off factor loading of 0.40 is used to screen out the attributes that are weak indicators of the constructs. The EFA of the 30 attributes, within the five 'enablers', results in five factors, accounting for 62.25% of the

total variance (see Table 1). Factor 1 is accounted for by six attributes, measuring Leadership; Factor 2 by four attributes, measuring Policy and Strategy; Factor 3 by seven attributes, measuring People; Factor 4 by four items, measuring Partnerships and Resources; and Factor 5 by nine attributes, measuring Processes. It is to note that the above analysis leads to three attributes (the 'financial resources', 'safety-related resources', and 'safety information' attributes), initially assumed to be associated with a certain enabler, to strongly correlate with another enabler. To illustrate, the 'safety information' attribute appears to be loading on Processes not Partnerships and Resources, as is initially hypothesized. This is partly supported by University of Illinois (2003) that the process of handling safety information (such as hazard, technology, and equipment information) is crucial to enhance safety performance. Following the re-allocation of the three attributes, the reliability test is re-applied to ensure the appropriateness of the groupings of the five 'enablers' extracted; the alpha coefficients range from 0.80 to 0.91, all of which are considered highly reliable. The new alpha value of Processes is also higher than the original value (from 0.89 to 0.91), proving the suitability of the relocation of the 'safety-related resources' and the 'safety information' attributes.

Table 1. Five 'Enablers' Extracted from the 30 Attributes

Attribute	Factor Extracted				
	Leadership	Policy and Strategy	People	Partnerships and Resources	Processes
Leadership commitment	0.76				
Consultative style	0.70				
Role model	0.64				
Safety accountability	0.56				
Safety feedback	0.50				
Financial resources*	0.46				
Reward and recognition		0.67			
Updated safety standards		0.64			
Safety policy		0.63			
Productivity and safety targets		0.46			
Safety perception			0.71		
Compliance of safety rules			0.69		
Teamwork			0.64		
Adequate supervision			0.61		
Workers' involvement			0.57		
Safety empowerment			0.56		
Peer review			0.52		
Partnerships' involvement				0.79	
Partnerships' awareness				0.75	
Partnerships' selection				0.70	
Personal protective equipment				0.50	
Safety training					0.74
Job clarity					0.71
Safety documentation					0.68
Organizational learning					0.66
Risk assessment					0.64
Safety maintaining program					0.63
Safety-related resources*					0.61
Safety information*					0.58
Benchmarking system					0.57

Note. * Items relocated to another 'enabler'

The EFA of the 17 attributes extracts four factors, accounting for 84.55% of the total variance (see Table 2). Factor 1 consists of four attributes measuring People Results. Factor 2, Customer Results factor, comprises five attributes. Factor 3 is associated with four attributes measuring Society Results. Lastly, Factor 4 consists of four attributes to explain Key Performance Results. There is no relocation of the attributes, thus confirming the construct validity of the four 'results' with their associated attributes (with the alpha values ranging from 0.87 to 0.89).

Table 2. Four 'Results' Extracted from the 17 Attributes

Attribute	Factor Extracted			
	People Results	Customer Results	Society Results	Key Performance Results
Job satisfaction	0.75			
Communication enhancement	0.72			
Low turnover	0.71			
Safe work behavior	0.65			
Customers' relationship		0.77		
Loyal customer		0.72		
Customers' expectation		0.71		
Customers' satisfaction		0.71		
Customers' perception		0.63		
Social cost reduction			0.79	
Public safety			0.77	
Social image			0.70	
Social cooperation			0.60	
Increased competitiveness				0.77
Organizational performance				0.71
Reduced number of accidents				0.70
Total cost reduction				0.67

Safety Assessment Tool Development

The confirmed five 'enablers' and four 'results', together with their 47 attributes, are used for the development of a safety assessment tool. The tool consists of six maturity levels with a total score of 1,000 points (see Figure 2). The management team is responsible in assessing and filling the scores in the assessment tool. Members of the team should come from different departments, such as human resources, safety, maintenance, and production departments, to gain mixed opinions and perceptions of safety practices in the organization.

In the safety assessment tool, the score of each of the five 'enablers' and four 'results' is calculated from its associated attributes' scores (the score of each attribute ranges from 1 to 5 points based on the 5-point Likert scale). To explain, Leadership consists of six associated attributes, thus, its maximum score becomes 30 points (i.e. six attributes with a maximum point of each attribute of five). Accordingly the maximum scores of the other eight criteria are: 20 points for Policy and Strategy, 35 points for People, 20 points for Partnerships and Resources, 45 points for Processes, 20 points for People Results, 25 points for Customer Results, 20 points for Society Results, and 20 points for Key Performance Results.

Based on the EFQM Excellence model (see Figure 1), the criterion weight of each criterion is varied. A maximum score of each criterion must, therefore, be adjusted to match with the weights assigned by the EFQM Excellence model. Hence, a maximum

score of Leadership is multiplied by 10/3 to make the adjusted score of 100 points (i.e. 30 x 10/3 = 100 points). Likewise, the multiple weights of the other eight criteria are: 4 for Policy and Strategy, 18/7 for People, 9/2 for Partnerships and Resources, 28/9 for Processes, 9/2 for People Results, 8 for Customer Results, 3 for Society Results, and 15/2 for Key Performance Results. A sample of safety assessment tool is illustrated in Table 3. The score for each attribute is filled by management team of an organization, and the total point is calculated. In this example, a total score of this organization is 584 points, representing the fourth maturity level (as it falls in the range of 450 – 649 points).

Table 3. A Safety Assessment Tool

Factor and Attribute	Points Given	%
Leadership		
1. Leadership commitment	3	
2. Consultative style	3	
3. Role model	3	
4. Safety accountability	2	
5. Safety feedback	2	
6. Financial resources	2	
Total Leadership score (100 points maximum)	15 x 10/3 = 50	50%
Policy and Strategy		
7. Reward and recognition	2	
8. Updated safety standards	4	
9. Safety policy	3	
10. Productivity and safety targets	3	
Total Policy and Strategy score (80 points maximum)	12 x 4 = 48	60%
People		
11. Safety perception	3	
12. Compliance of safety rules	4	
13. Teamwork	5	
14. Adequate supervision	3	
15. Workers' involvement	3	
16. Safety empowerment	2	
17. Peer review	2	
Total People score (90 points maximum)	22 x 18/7 = 56.6	62.9%
Partnerships and Resources		
18. Partnerships' involvement	2	
19. Partnerships' awareness	2	
20. Partnerships' selection	2	
21. Personal protective equipment	3	
Total Partnerships and Resource score (90 points maximum)	9 x 9/2 = 40.5	45%
Processes		
22. Safety training	3	
23. Job clarity	3	
24. Safety documentation	2	
25. Organizational learning	2	
26. Risk assessment	2	
27. Safety maintaining program	2	
28. Safety-related resources	3	
29. Safety information	3	
30. Benchmarking system	2	
Total Processes score (140 points maximum)	22 x 28/9 = 68.4	48.9%

Table 3. A Safety Assessment Tool (Cont.)

Factor and Attribute	Points Given	%
People Results		
31. Job satisfaction	3	
32. Communication enhancement	3	
33. Low turnover	3	
34. Safe work behavior	2	
Total People Results score (90 points maximum)	11 x 9/2 = 49.5	55%
Customer Results		
35. Customers' relationship	2	
36. Loyal customer	2	
37. Customers' expectation	3	
38. Customers' satisfaction	4	
39. Customers' perception	3	
Total Customer Results score (200 points maximum)	14 x 8 = 112	56%
Society Results		
40. Social cost reduction	2	
41. Public safety	2	
42. Social image	3	
43. Social cooperation	2	
Total Society Results score (60 points maximum)	9 x 3 = 27	45%
Key Performance Results		
44. Increased competitiveness	3	
45. Organizational performance	3	
46. Reduced number of accidents	4	
47. Total cost reduction	2	
Total Key Performance Results score (150 points maximum)	12 x 15/2 = 90	60%
Total score (maximum of 1,000 points)	584	58.4%
Safety maturity level (level 1 – level 6)	4	

At this level, the majority of staff in the organization is convinced that health and safety is important from both a moral and economic point of view. Managers and frontline staff recognize that wide ranges of factors cause accidents, and that the root causes are likely to come back to management decisions. Frontline staff accept personal responsibility for their own, and others, health and safety. The organization puts a significant effort into proactive measures to prevent accidents. A number of workers are willing to work with management to improve health and safety, as seen by the high percentage (62.9%) of People score. It is also clear that Partnerships and Resources is the weakest enabler in enhancing safety in this organization, as it achieves the least scores (i.e. lowest percentage, 45%) compared with the other four 'enablers' (see Table 4). Likewise, Society Results has the lowest percentage (45%) compared with the other three 'results'. Thus, to plan for safety improvement and progress through to higher maturity levels, the organization should pay more attention to improving Partnerships and Resources by, for example, ensuring that the organization's partners aware of hazards and involve in safety-related decisions; including safety in the contractors and suppliers selection; and providing adequate personal protective equipment, such as safety belts and safety shoes, to needed employees and stakeholders. The organization should also focus more on achieving higher Society Results score, by, for example, promoting and contributing good safety campaigns to the society, as well as getting local people involve in those campaigns.

Conclusion

Developing and maintaining an effective safety implementation is crucial in any organization. In this study, a safety assessment tool is developed, based on a widely used EFQM Excellence model, to assist an organization in measuring its safety status and planning for safety improvement. The tool consists of nine criteria, including five 'enablers' and four 'results'. Each of the nine criteria is associated with a number of attributes to explain its construct. Exploratory factor analysis confirms these nine criteria with as total of 47 attributes. It is to note that the analysis leads three attributes initially assumed to be associated with a certain enabler, to strongly correlate with another enabler. To explain, the 'financial resources' is relocated from Partnerships and Resources to Leadership, while the 'safety-related resources' and 'safety information' are relocated from Partnerships and Resources to Processes.

A safety assessment tool is developed based on the confirmed five 'enablers' and four 'results'. An organization can use this tool to assess its current safety maturity level, by summing the scores of the nine criteria that are adjusted with their criterion weights (the maximum score is, thus, 1,000 points). To achieve higher maturity levels, the organization should then focus on the weakest criteria shown in the tool with the lowest scores. There is a limitation in this study. The safety assessment tool is developed based on the questionnaire survey targeting Thai organizations, thus, it might not be a best tool to prescribe the way of developing safety in other countries.

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