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Total Productive Maintenance and effectiveness of Occupational Health and Safety Management Systems

Eric Boafo Dadzie

Abstract
Many manufacturing organizations already have occupational health and safety (OHS) management systems in place but for most of them, high standards of safety performance still cannot be assured. The success of an OHS management system depends on whether the organization has implemented the system proactively, which in turn is related to the safety culture of the organization. The project commenced with the identification of safety culture factors that can improve safety performance and can be enhanced by Total Productive Maintenance (TPM). TPM is a maintenance system which promotes productive maintenance but it also contributes to a positive safety culture through management incentive, management commitment, participation of management and workers, communication, education and training, working conditions and procedures, morale and job satisfaction, and attitude and risk perception. Questionnaires were designed based on the safety culture factors identified. These were then sent to companies with or without TPM to collect the opinions of workers on safety culture. T-test method was used to compare the results obtained from the two different sample groups, to verify the effectiveness of TPM on safety culture. Finally, a framework of TPM activities was developed for manufacturing organizations to improve safety performance.

Keywords: *Total Productive Maintenance, Occupational Health, Safety Management Systems*

1.0 DESCRIPTION OF THE RESEARCH UNDERTAKEN

The current approaches to occupational health and safety (OHS) management including BS 8800:1996, AS/NZS4804:1997, OHSAS 18001:1999 and AS4801:2000 have been introduced into Hong Kong. The government has also put continuous efforts to reduce industrial accidents. Yet a high accident rate is still a feature of manufacturing industries, as shown in the last five years' statistics compiled by the Labor Department (2001) of the HKSAR (see Table 1).

Year	1996	1997	1998	1999	2000
No. of Accidents	7205	7196	6334	5499	5436
No. of Fatalities	9	4	2	2	3
Employment	335177	306510	263714	247830	232039
Accident rate / 1000 workers	21.50	23.48	24.02	22.19	23.43
Fatality rate / 1000 workers	0.027	0.013	0.008	0.008	0.013

Table 1: Industrial Accidents in Manufacturing Industry (1996-2000)

It can be observed from the accident rate (see Figure 1, data from Table 1) that though OHS management systems have been introduced, the safety performance of manufacturing industry has not been improved since 1996.

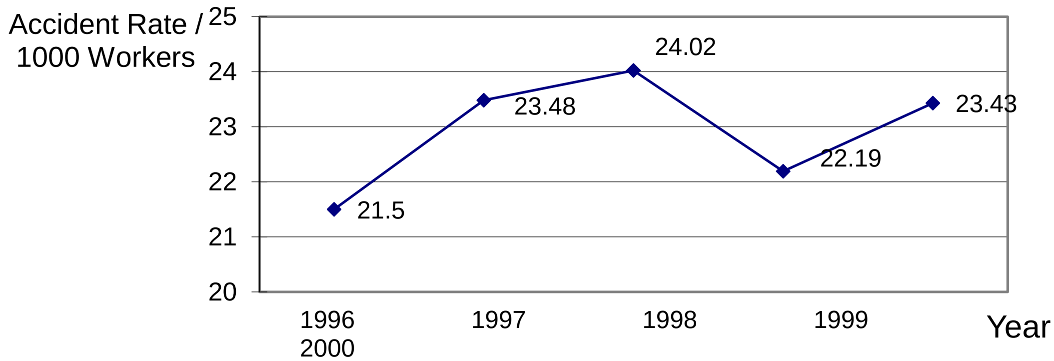

Figure 1: Accident Rate in Manufacturing Industry (1996-2000)

Even though there are OHS management systems in place, however, for many managers, there are insufficient economic incentives to improve safety. For them, safety is not and cannot be first. Instead, what is first is profit, mission, productivity or the strength of growth of their businesses (Michaud 1995). Even if safety does pay, by reducing the cost of insurance, compensation and man-days loss, employers are often not aware of this. Indeed, they frequently believe that it does not pay. A number of major UK studies have found that the perception that health and safety improvements are a "cost" rather than an investment is a significant de-motivating factor amongst management (HSE 1998). An example is Hopkins (1995) who does not agree that there are sufficient economic incentives for employers to improve safety. He argues that emphasizing 'safety pays' is not effective in gaining management attention. Instead, more emphasis is placed on health and safety now by management due to pressure from regulators, commercial pressure and higher employee expectations.

On the other hand, for many employees, managing safety and health is the responsibility of the management only. They seldom take an active part in participating in safety and health activities. They have little interest in protecting the property of their employers or in the safety of their fellow employees or in the safety record of their organizations. Some of them even think that reporting a health and safety concern will cause them to be regarded as a troublemaker. Thus, the problem statement of this dissertation is: Nowadays, many organizations already have OHS management systems in place. However, high standard of health and safety still cannot be assured.

1.2 Problem statement

Companies with OHS management systems in place still seem to have difficulties to have improvement in safety performance. One of the reasons is the lacking of means or methods to establish a positive safety culture. This can be supported by Kennedy & Kirwan (1998, p.250) who said, "Safety management at least in theory, appears to be competently equipped to handle accident prevention. However, the way that a safety management system exists on paper is not necessarily the way that it exists in reality, i.e. actual shop floor or even board room practices may not follow the espoused policies explicitly and implicitly laid out in official company documents. This is where the concepts of safety climate and safety culture come into the picture, as they represent the work environment and underlying perceptions, attitudes, and habitual practices of the workforce at all its various levels." The proposed solution to the problem statement in this dissertation is through the Total Productive Maintenance (TPM, definition refers to section 2.3) activities, both the management and workers will adapt a proactive approach towards safety

1.3 Primary Objectives

The primary objectives are to establish a framework of TPM activities to improve the effectiveness of the OHS management systems.

1.4 Secondary Objectives

The secondary objectives of this dissertation are as follows:

- To identify factors of safety culture on safety performance
- To investigate TPM's effectiveness to enhance safety culture
- To develop a TPM safety framework

1.5 Limitations of the Study

The present study reflects a number of limitations. Secondly, the theoretical nature of this study limits its direct relevance for occupational health and safety management systems. Therefore, it is hoped that future research may additionally focus on how student cognitions about learning are influenced in the context of everyday learning environments. The results could enable safety practitioners to encourage the adoption of occupational health and safety management systems which invoke a deep oriented and self-regulated study strategy.

1.6 Design and Overview of study

1.6.1 Scope of Study

The current approaches to occupational health and safety (OHS) management including BS 8800:1996, AS/NZS4804:1997, OHSAS 18001:1999 and AS4801:2000 have been introduced into Hong Kong. The government has also put continuous efforts to reduce industrial accidents. Yet a high accident rate is still a feature of manufacturing industries, as shown in the last five years' statistics compiled by the Labor Department (2001) of the HKSAR (see Table 1). Companies with OHS management systems in place still seem to have difficulties to have improvement in safety performance. One of the reasons is the lacking of means or methods to establish a positive safety culture. This can be supported by Kennedy & Kirwan (1998, p.250) who said, "Safety management at least in theory, appears to be competently equipped to handle accident prevention. However, the way that a safety management system exists on paper is not necessarily the way that it exists in reality, i.e. actual shop floor or even board room practices may not follow the espoused policies explicitly and implicitly laid out in official company documents.

1.6.2 Research Question

- What factors of safety culture on safety performance?
- What TPM's effectiveness to enhance safety culture
- What develop a TPM safety framework

1.6.3 Hypothesis

The hypothesis of this dissertation is: A manufacturing company with TPM in place has a more positive safety culture than one not implementing TPM.

1.6.4 Organisation of Study

Chapter 1 will look at the introduction, research questions, objective and policy relevance of the study and organization of the study Chapter two covers at the literature review and has reviewed both theoretical and empirical literature concerning project auditing in Ghana and beyond. Chapter 3 research methodology, Chapter 4 presents results and Analysis, Chapter 5 looks at the conclusion and recommendations

1.7 Summary

Even though there are OHS management systems in place, however, for many managers, there are insufficient economic incentives to improve safety. For them, safety is not and cannot be first. Instead, what is first is profit, mission, productivity or the strength of growth of their businesses (Michaud 1995). Even if safety does pay, by reducing the cost of insurance, compensation and man-days loss, employers are often not aware of this. Indeed, they frequently believe that it does not pay. A number of major UK studies have found that the perception that health and safety improvements are a "cost" rather than an investment is a significant de-motivating factor amongst management (HSE 1998). An example is Hopkins (1995) who does not agree that there are sufficient economic incentives for employers to improve safety. He argues that emphasizing 'safety pays' is not effective in gaining management attention. Instead, more emphasis is placed on health and safety now by management due to pressure from regulators, commercial pressure and higher employee expectations.

2.0 LITERATURE REVIEW

This chapter reviews the academic literature relevant to safety culture, TPM and effectiveness of OHS management systems. The objectives of the chapter are to identify factors of safety culture on safety performance and to identify TPM's effect on safety performance.

2.1 Development of the Study

Safety culture is the way an organization's norms, beliefs and attitudes to minimize exposure of employees to conditions considered to be dangerous. The goal is to develop an organizational norm in which employees are aware of the risks associated with their job and are continually on the lookout for potential hazards. Safety culture is a process, not a program; it takes time to develop and requires a collective effort (Vredenburgh 1998). Definitions of safety culture and safety climate from different institutions and scholars are tabulated in Tables 2 and 3. However, all definitions that attempt to capture the essence of safety culture, as described by Lee & Harrison (2000), are bound to be inadequate because its many manifestations are extensive, complex and intangible.

Nevertheless, two critical attributes may help to fill out the picture. First, in a healthy culture, the avoidance of accident and injury by all available means is the responsibility of every person in the organization. Second, the integration of role behaviors and the consolidation of social norms create a common set of expectations, a 'way of life' that transcends individual members. A culture is much more than the sum of its parts. Confusion between the terms 'culture' and 'climate' means that they have been used interchangeably. Some researchers (Glendon & Stanton 2000) distinguished between safety culture and safety climate while attempts had also been made to derive composite models. It is not the intention of this paper to go into the concepts of safety climate and culture in depth.

However, it is worth mentioning them for easy understanding of the literature review in the paper. Cooper (1998) described that safety culture was much boarder than safety climate as it referred to the whole, whereas safety climate referred solely to people's perception of, and attitudes towards, safety. Gonzalez-Roma, Peiro, Lloret and Zornoza (1999) explained that safety culture embodied values, beliefs and assumptions while safety climate was a descriptive measure reflecting the workforce's perceptions of the organizational atmosphere. Sutherland, Makin & Cox (2000, p.34) also explained that climate was a term that applied to the sum of individual perceptions of the organization; while culture, on the other hand was a group phenomenon, the expression of strongly held norms, consisting of shared beliefs and values. It was possible for organizations did not have such strong organizational norms. Thus, whilst all organizations had a safety climate, not all had a safety culture.

2.2 Different Theories

Ashby & Diacon (1996) postulate that the primary motivations associated with OHS management are those of regulatory compliance and avoidance of legal liabilities. However, Mohamed (1999) argues that zero-accident cannot be guaranteed by legislation alone. If management is only forced to implement an OHS management system due to regulatory pressure, it cannot be expected that the management system will be operated proactively. What is needed, in addition to legislation, is a change in corporate culture with regard to safety (Butler 1989).

Level 1 are those companies whose safety goals are to comply with regulation. Level 2 are those companies having safety management systems in place. Level 3 are those companies implement systems proactively and strategy for continuous improvement. Kennedy & Kirwan (1998, p.251) had summarized the relationship among safety management, climate and culture (see Figure 3). According to their findings, safety culture was a sub-element of the overall organizational culture. It was an abstract concept which was underpinned by the amalgamation of individual and group perceptions, thought processes, feelings and behavior which in turn gave rise to the particular way of doing things in the organization. The safety climate and the safety management were at lower levels of abstraction and were considered to be a manifestation of the overall safety culture. The safety climate was, therefore, a more tangible expression of the safety culture in the form of symbolic and political aspects of the organization. These factors in turn would characterize and influence the deployment and effectiveness of the safety management resources, policies, practices and procedures.

2.2.1 Proactive safety culture and safety performance.

Covey (1991) identified proactive as one of the seven habits of high effective people. He explained proactive as the power, freedom, and ability to choose responses to whatever happened to people, based on their values. According to Covey, when people are proactive, they tend not to blame people or circumstances for what happens to them. Proactive and reactive produce different outcomes. Proactive produces results; reactive produces excuses, or explanations. The strength of proactive is not a pushy sort of strength. It is internal strength, the strength of integrity, or the simple commitment to value or principle.

This can also be applied to OHS management. When someone is proactive, he will not have budged from his principle. When an accident occurs, he will not blame others or find excuses. He believes what happens has resulted from what he has chosen and hence he will develop control measures to prevent accidents from happening. HSE (1996a) postulates that the most effective way of preventing accidents and ill health at work is to manage the business in such a way as to encourage all staff to develop a positive culture towards health and safety. A good safety culture and an involvement in safety that goes through the organizational hierarchy, from top down to the workers, is essential for successful OHS (Seppala 1995).A strategic (top down) model to safety developed by Gleendon & Stanton (2000, p.205) clearly pictured the relationship of safety management system and safety culture described above (see Figure 4):

The success of an OHS management system depends on whether everyone in the organization is involved and whether a proactive approach has been adopted (Health and Safety Factbook 1998). Recent studies by Halme (1992), Seppala (1992) and Varonen & Mattila (2000) all concluded that the better the safety culture, the lower was the accident rate. This can be further supported by a case study on the injury rate of hospital employees done by Vredenburgh (1998). He concluded that while most of the participating hospitals implemented the reactive practices, what differentiated the hospitals with low injury rates was that they also employed proactive measures to prevent accidents. As described above, effective implementation of an OHS management system depends on the safety culture of the organization. There are many other studies which support this argument:

- Brabazon, Tipping & Jones (2000) said, "There is general agreement that an effective and proactive safety culture is essential to improve safety."

- Saari (1990) suggested, "After a certain point technology cannot achieve further improvement in safety, rather, organizational and cultural factors may be important - yet these have not been widely explored."

- Kennedy & Kirwan (1998) postulates that safety culture underpins safety management, which in turn determines work practices and system configuration.

- Krause (1993) also argues that employee behavior is a direct result of management system and is the final common pathway of most incidents. Management system in turn is influenced by the organization culture which has a substantial influence on, inter alia, priorities and the allocation of resources to health and safety effort.

- Seppala (1995) concluded in a recent study that a good safety culture and an involvement in safety that went through the organizational hierarchy, from top down to the workers, was essential for successful occupational safety and health. A training program helps the personnel to carry out various preventive activities effectively. It also helps establish a positive attitude towards safety and integrates safety with the production and quality goals.

2.2.2 Factors of a proactive safety culture

The above section described the relationship between a proactive safety culture and effectiveness of OHS management system. In this section, the factors for a proactive safety culture would be investigated. A model of safety climate produced by Seppala (1992) consisted of three factors: organizational responsibility for safety, workers' concern about safety and workers' indifference towards safety. Grote & Kunzler (2000) also described some examples of indicators used to assess an organization's safety culture, including: management commitment to safety, safety training and motivation, safety committees and safety rules, record keeping on accidents, sufficient inspection and communication, adequate operation and maintenance procedures, well-designed and functioning technical equipment, and good housekeeping. Another model of safety culture model.

Among the factors contribute to safety culture, some can be found in TPM. In this section, the effects of eight safety culture factors, which can be enhanced by TPM (to be verified in the Section 2.4) were described. The eight safety culture factors identified were: management incentive, management commitment, participation of management and worker, communication, education and training, working conditions and procedures, morale and job satisfaction, and attitude and risk perception. In the below sections 2.2.1 to 2.2.8, it would be verified that these 8 safety culture factors were important for good safety performance.

2.2.3 Management incentive' is essential for good safety performance

Managers are influenced by a variety of motives, among them economic incentives, fear of legal consequences, moral commitment and concern for their own reputations. These are numerous ways in which these motives can lead to action to improve OHS. But none of this is automatic. These motives will come into play only if management's attention is drawn to the relevant information (Hopkins 1995). Management's motive cannot be driven by legislation alone. A recent study (Brabazon et al. 2000) reported that senior management had not considered the risk of prosecution to be high. The number of regulatory visits carried out was perceived to be very low and so the likelihood of an inspector finding a non-compliance, and this leading to a successful prosecution was seen as acceptable in some cases. Furthermore, there was a temptation to introduce more paperwork as evidence to defend directors against prosecution.

It is perceived that (Brabazon et al. 2000) senior managers do not fully exploit their potential to improve health and safety. The lack of commitment is due to the poor understanding of links between good health and safety performance and business performance. The need for financial efficiencies is the main drive for change. Thus, management incentive is essential for good safety performance. Lack of incentives leading to management commitment becomes lip service to improve health and safety performance, but not a genuine commitment to action (HSE 1997). It is not surprising that the management commitment is very often low in many organizations as described in the next section.

2.2.4 Management commitment' is essential for good safety performance

Management commitment is the key factor of safety culture. Dedobbeleer & Beland (1998) found evidence for only two core factors in a review of safety climate surveys, one of which they called management commitment (another was risk perception mentioned below). Cheyne, Cox, Oliver & Thomas (1998) also reported management commitment as a prime factor in their predictive model of safety behaviors, giving some support to the primacy of this factor. In a study to compare plants with high and low injury rates by Koh (1995), it was noted that the most important workforce factor which accounted for the difference in safety performance was greater management commitment and involvement in the total safety programme.

Management commitment as the most critical element in a successful safety program can further be supported by various studies such as Cohen (1997), Zohar (1980) and Isla & Diaz (1997). However, in many cases, management commitment is low (Brabazon et al. 2000), implying a need to convince them of the importance of health and safety performance to the future prosperity of their company. Brabazon et al. (2000) also argue that there are thought to be still considerable operational obstacles which cause poor health and safety performance, most notably a lack of resources. It can be concluded that management support is crucial to ensure the success of OHS promotion programs. Furthermore, the commitment of top management to develop the safety program and joint regulation mechanisms appears to be an effective way for senior managers to impact indirectly on workers' safety initiatives behavior by influencing positively supervisory participative management of safety and workgroup cohesiveness (Simard & Marchand 1995), as discussed in the next section.

2.2.5 Participation of management and workers' is essential for good safety performance

Besides making commitment, management participation is also essential. This can be supported by Wentz (1998) who argues that to promote OHS, management should encourage and support safety by setting a good safety example; effectively managing health and safety programmes, attending health and safety meetings, performing inspections, investigating near miss accidents and reviewing safety performance at all levels. Participation of workers is important as well. The way forward for successful OHS management as described by Health and Safety Factbook (1998), is to involve everyone in the organization, including both the management and workers, using a proactive approach to identify hazards and to control those risks that are not tolerable.

Employee's participation is important" can be supported by a research in the chemical industry carried out by HSE (2001). The study concluded that companies that were seeking to make their safety management systems more effective regarded involving their employees as the preferred way of improving safety performance. They were not driven by regulatory demands alone. They reported a reduction in adversarial management-employee relations, better morale and an improved image in the eyes of clients and the general public. They maintained that the benefits of employee involvement outweighed the costs incurred. These views were shared by employees, trade unions and management alike.

Worker participation has many advantages. Hopkins (1995) pointed out that a policy of worker participation, involving workers in decision making about their work, a policy perhaps of self-directed work groups would make employees feel encourage to come forward with suggestions, which in turn would eliminate many little inefficiencies which were built into jobs-prooly-designed tasks, procedures which were not well connected and so on. Another advantage of worker participation as described by HSE (1997) is that it supports risk control by encouraging workers' ownership of health and safety policies.

It establishes an understanding that the organization as a whole, and people working in it, benefit from good health and safety performance. Pooling knowledge and experience through participation, commitment and involvement means that health and safety becomes everybody's business. Brabazon et al. (2000) also pointed out that workforce participation needed an open environment in which people could offer ideas, including when something had gone badly, without the possibility of blame. Thus the degree of worker participation was affected by the effectiveness and means of communication. In conclusion, good management of health and safety can only be achieved with the co-operation of the workforce. It is vital that the employees know what is expected of them and are aware of any risks to their health and safety that may arise at work and any safe systems of work that are applied (HSE 1995).

2.2.6 Communication' is essential for good safety performance

The first people to realize something may be going seriously wrong in an organization are usually those who work there. However, a recent study by HSE (1999) found out that employees often did not voice such concerns or they voiced them in a wrong way. Sometimes they thought that because it was only a suspicion they should not bother anyone about it. Or they might think speaking up would be disloyal to their colleagues. Often they feared they would lose their job or be victimized. This study argued that a good safety culture was "one where the mental attitude of both workers and management is such that when a risk to health and safety is perceived, it will be reported promptly to the designated people. They, in turn, will investigate it and remove or reduce any unwarranted risk." Merritt & Helmreich (1996, p.11) also said, "An organization needs to encourage and reward vigilance and inquiry from all its members, seeking to mend the system rather than killing the messenger."

Thus the channels for communication are important. Management feedback on the reports and the manner of feedback so that the employee can understand are also important; otherwise employees will be discouraged from further reporting of their concern on OHS. The study by HSE (1999) also pointed out "almost all organizations using a form acknowledge receipt of a report by means of a tear off slip or something similar. Feedback is vital, to maintain enthusiasm for a scheme, to disseminate the lessons learned, to stimulate other reports, and as a quality check. However, where the output from reporting schemes tended to be high-level statistical analyses aimed solely at management, employees would quickly lose faith in the procedure."

2.2.7 Education and training' is essential for good safety performance

The main priority for education and training so far as safety is concerned is the creation of a safety culture. Training is by definition an ongoing process continually reviewed and modified to take account of changing conditions, past experience and new developments. Safety must be inextricably woven into the entire tapestry of training procedures. Training should and must tighten safety awareness, and the intelligent understanding of possible hazards; thence how these may be minimized by good practice (HSE 1990). Upon employees are educated and trained to create safety culture in their organizations, can the safety performance be assured.

2.2.8 Working conditions and procedures' is essential for good safety performance

In a recent case study, Varonen & Mattila (2000) found that the safety climate correlated both with the safety level of the work environment and with the safety practices of the company, and the correlation between the safety climate and the safety of the 'work environment' was stronger. Glennon (1982) also identified 'procedures' as one of the most frequently themes used by other researchers in his review of safety culture. Flin et al. (2000) suggested that procedure was an issue that might merit inclusion in safety climate measures.

2.2.9 'Morale and job satisfaction' is essential for good safety performance

'Morale and job satisfaction' is an essential factor for good safety performance can be supported by a recent HSE funded study based on approximately 1.5 million observations of people's everyday safety behavior over the course of a year (Cooper 1998, p.82). Cooper concluded that people with higher morale and job satisfaction would have better safety performance. Cooper believed that it was because autonomy or job control affected people's experienced responsibility, that was, the extent to which people felt personally responsible for the outcomes of their performance.

2.2.10 Attitude and risk perception' is essential for good safety performance

'Attitude and risk perception' is an essential factor for good safety performance. Phelps (1999, p.32) said, "A casual attitude can often result in a casualty." Goetsch (1998, p.139) also said, "Employee perceptions concerning the state of the work environment can affect both morale and performance." Employees' attitude is important for safety can be supported by the study of Marcus (1988) on 24 nuclear power stations in United State of America. Marcus concluded that those plants where the attitudes of employees favored control, responsibility and a generally proactive attitude towards safety had three times fewer 'error events' and a generally better safety record. In another study by Isla & Diaz (1997), it was found that those enterprises with higher scores on the climate scale also had a more positive safety attitude.

Risk perception is important for safety performance. This can be supported by a study on risk perception and safety on offshore petroleum platforms carried out by Rundmo (1995, p.1). Rundmo concluded that the higher the perceived risk, the more dissatisfied with safety status, the more accidents and near accidents they experienced. According to Rundmo (2000), risk perception might affect risk behavior and also the probability of accidents and health injuries. Risk perception was composed of a subjective assessment of the probability of experiencing an accident or a health injury caused by exposure to a risk source as well as emotions related to the source. Accordingly, Sjoberg (1993) suggested that an individual's experience of risk could be separated into one cognitive component and one emotional or affective component. Holmes, Gifford & Triggs (1998) also defined two factors in workers' perceptions of their safety climate. One was the demonstration of management commitment to OHS through actions and attitudes. The second factor was workers' involvement in OHS and the authors speculated that employee perceptions of risk and its control related to their views about responsibility for risk and its control.

Dedobbeleer & Beland (1998) considered risk perception as a fundamental component of safety climate and speculated that it was closely linked to the concept of workers' involvement or responsibility for safety, one of their two identified safety climate dimensions (another was management commitment mentioned above). Risk perception is not only related to employees, but also related to managers and employers. In a case study of perceptions and understandings of risk and its control in OHS among employers and employees of an Australian small, blue-collar business industry, carried out by Holmes et al. (1998), the findings showed that accounts of risk perceptions in the workplace that focused on employees could have limited implications for the practice of management and promotion of OHS. These accounts were incomplete without a concurrent examination of employers' and managers' risk perceptions.

The study of Holmes et al. (1997) found that many employers revealed that risk in OHS meant the effect of occupational injuries on work productivity and business finances. In contrast, employees regarded occupational injury risk as a normal feature of the work environment and an acceptable 'part of the job'. They described occurrence frequency in the context of their own working environment and experience rather than a statistical aggregate of other people and trades. Thus, the risk perception of employer and employee affects the safety culture of an organization.

2.2.11 Introduction to TPM

It is important to present the basic concepts of TPM before attempting to explain how TPM is related to safety culture. This section provides an introduction to TPM. In 1971, as described by Nakajima (1988, p.10), the Japan Institute of Plant Engineers (JIPE) developed the TPM and defined TPM as a system of maintenance covering the entire life of the equipment in every division, including planning, manufacturing, maintenance, and all other divisions, involving everyone from the top executives to the shop floor workers and promoting productive maintenance through morale-building management and small group activities in an effort to maximize equipment efficiency.

TPM, together with Total Quality Management (TQM) and Just-in-time (JIT) are the three most important activities surrounding the kaizen approach (Yamashina 2000), which is a continuous improvement concept and widely recognized as a strategic weapon to achieve world-class manufacturing (Cigolini & Turco 1997). In order to achieve world-class performance, more and more companies are replacing their reactive, fire-fighting strategies for maintenance with proactive strategies like preventive and predictive maintenance and aggressive strategies like TPM to improve productivity and quality (Swansion 2001). Another factor in achieving world-class manufacturing can be said to be its approach to health and safety issues. As TPM improves machine performance, reduces machine breakdown, improves working condition and procedures, encourages total participation of management and workers, requires continuous improvement and commitments to training and resources, TPM is believed to improve safety as well, as will be verified in the sections below.

2.3 Historical Thinking

2.3.1 A brief history of maintenance management

Traditionally, repairs and maintenance of equipment are the responsibility of the maintenance departments. The production workers, who usually are the first people to realize something may be going wrong in machines, are not involved with the care and maintenance of the machines since the performance of the machines is generally regarded as the responsibility of others. The objective of maintenance management is to increase equipment availability and overall effectiveness. Overall there have been four main periods of maintenance management (Nakajima 1988 & McKone 1996):

- Reactive (breakdown) maintenance (prior to 1950): During this phase little attention was placed on defining reliability requirements or preventing equipment failures. Typically equipment specifications included requirements for individual parts and failed to consider the reliability or availability of the entire system.
- Preventive maintenance (1950s): During this phase a maintenance system involved an analysis of current equipment to determine the best methods to prevent failure and to reduce repair time. Emphasis was placed on the economic efficiency of equipment replacements and repairs as well as improving the equipment reliability to reduce the mean time between failures.

- Productive maintenance (1960s): When the importance of reliability, maintenance, and economic efficiency in plant design was recognized, productive maintenance became well established. It included maintenance prevention pursued during the equipment design stages; maintainability improvement which modifies equipment to prevent breakdowns and facilitate ease of maintenance; and preventative maintenance including periodic inspections and repairs of the equipment.

- Total productive maintenance (1970s): TPM officially began in the 1970's in Japan and was designed to maximize equipment effectiveness. Development of TPM is shown in the next section.

2.3.2 The development of TPM

TPM originates from the fact that productivity, cost, inventory, production output, safety and quality all depend on equipment performance (Ravishankar, Burczak & DeVore 1992). The goal of TPM is to eliminate equipment breakdowns and defects caused by the production process (Ravishankar, Burczak & Devore 1992). When this has been accomplished, operation rates improve, quality and reliability of parts improve, costs and inventories decrease, and consequently worker productivity increases. Below is a brief summary for the historical development of TPM (CTPM 2001a, HKPC 2000, Nakajima 1988): TPM had its genesis in the Japanese car industry in the 1970s. It evolved at Nippon Denso, a major supplier of the Toyota Car Company, as a necessary element of the newly developed Toyota Production System. It was not until 1988, with the publication in English of the first of two authoritative texts on the subject by Seiichi Nakajima, that the western world recognized and started to understand the importance of TPM.

It soon became obvious that TPM was a critical missing link in successfully achieving not only world class equipment performance to support Total Quality Control (TQC) and Just In Time (JIT), but was a powerful new means to improving overall company performance. Since the early 90s, TPM has steadily spread throughout the western world, significantly improving the performance of manufacturing, and mining companies. The development of TPM is divided into three stages. The development is in line with the industrial environment in the world. Society of Manufacturing Engineers (1995) stated, "Productive is TPM's middle name." In the early stage of TPM, there were only five pillars, and TPM aimed at improving equipment efficiency and hence productivity. When quality was becoming a serious concern, the sixth pillar "Process Quality Management" was added at the 2nd stage of TPM. In 1990s, when the world progresses from mere growth to development, causing OHS to be mounting concern, a new element "Safety and Environmental Management" was also added to TPM.

The above is the development of the Japanese and Western approach of TPM. In Australia, the first generation is the same as the Japanese approach. In the third generation, there are now ten pillars. Macro focused equipment and process improvement, Work area management, Operator equipment management, Maintenance excellence management, Education and Training, People support systems improvement, Administration and support systems improvement, new equipment management, Safety and environmental management, and Process quality management. In Hong Kong, and so is this dissertation, the Japanese approached is adopted.

2.3.3 TPM Principles

Blanc (1993) defined six principles for TPM:

1. Improvement of product and process quality through zero mentality
2. Elimination of the six big losses (see Table 7)
3. Development of a clean, safe, well organized, and visually controlled work place.
4. Focus on chronic losses and root cause preventive problem solving.
5. Development of equipment management systems - (predictive maintenance, OEE tracking, preventive maintenance) which enhance TPM implementation and development.
6. Increase skill levels of operators and maintenance personnel and begin to transfer more equipment ownership to operators.

2.3.5 Autonomous Maintenance

Autonomous Maintenance is the second pillar of TPM (see Table 6). The word *autonomous* means independent. Autonomous maintenance refers to activities designed to involve operators in the maintenance of their own equipment (JIPM 1997, p.8). Operators learn the maintenance skills they need through a seven-step autonomous maintenance program (JIPM 1996, p.109) (see Table 8). Autonomous maintenance can only be achieved via good management practice (Prickett 1999, p.236). This should include the associated training of machine tool operators which must be undertaken to ensure their co-operation. Limited changes are needed to existing maintenance engineering practices to support the transfer of certain responsibilities and actions from maintenance staff to operators.

Such actions must be managed to ensure high levels of staff motivation. Some of the developments presented in this work were aimed at supporting the operators at the machine tool level by presenting maintenance related information to them in a form that they could use.

Step	Name	Activities	Related to safety
Eliminate unsafe conditions			
1	Clean and inspect	Eliminate all dirt and grime on the machine, lubricate, tighten bolts, and find and correct problems.	Identify and correct problems such as exposed moving parts, projecting parts, spattering of harmful substances
2	Eliminate problem sources and inaccessible areas	Correct sources of dirt and grime; prevent spattering and improve accessibility for cleaning and lubrication. Shorten the time it takes to clean and lubricate.	Take steps to correct problems related to covers, guards, etc.
3	Draw up cleaning and lubricating standards	Write standards that will ensure that cleaning, lubricating, and tightening can be done efficiently. (Make a schedule for periodic tasks.)	Establish and review work standards and daily check methods, etc.
4	Conduct general inspections	Conduct skills training with inspection manuals and use general inspections to find and correct slight abnormalities in the equipment.	Check and improve performance of safety and disposal devices.
Eliminate unsafe behavior			
5	Conduct autonomous inspections	Prepare standard check sheets for autonomous inspections. Carry out the inspections.	Correct stressful working postures and methods
6	Standardize through visual workplace management	Standardize and visually manage all work processes. Examples of standards needed: ● cleaning, lubrication, and inspection standards ● shop floor materials flow standards ● data recording method standards ● tool and die management standards	Assure workplace organization (5S) and maintain a proper working environment
7	Implement autonomous equipment management	Develop company policies and objectives; make improvement activities part of everyday practice; keep reliable MTBF (mean time between failures) data, analyze it, and use it to improve equipment.	Encourage everyone to take care of their own workplaces

Table 8: The seven steps of Autonomous Maintenance

2.3.6 Steps in developing a TPM system

Nakajima (1988, p.55) established a 12-step model in developing a TPM system. When TPM was introduced into the western world, Hartmann (2000) also established a 12-step Western model in developing a TPM system. The 12-steps of these two models are summarized in Table 9 below. Details of these two 12-steps models are shown in Appendices A and B.

Step	Japan approach (Nakajima 1988)	Western Approach (Hartmann 2000)
1	Announce top management decision to introduce TPM	Collect information
2	Launch education and campaign to introduce TPM	Initial audit and presentation
3	Create organizations to promote TPM	In-plant TPM training
4	Establish basic TPM policies and goals	Study team training
5	Formulate master plan for TPM development	Feasibility study

6	Hold TPM kick-off	Feasibility study presentation
7	Improve effectiveness of each piece of equipment	Pilot installation
8	Develop an autonomous maintenance program	Plant-wide installation
9	Develop a scheduled maintenance program for the maintenance department	Introduction audit
10	Conduct training to improve operation and maintenance skills	Progress audit
11	Develop early equipment management program	Certification
12	Perfect TPM implementation and raise TPM levels	TPM award

Table 9: The twelve steps of TPM development

In a case study by Tsang & Chan (2000, p.153) to develop a TPM system in China, the 12 steps of the Japan Approach are divided into three phases as shown in Table 10.

Phase	Steps	Status in the case study
Pilot phase	T1 Announcement	The introduction of TPM was announced through internal correspondence and posters on TPM notice-boards. The maintenance manager was appointed the champion of TPM
	T5 TPM master plan	The master plan was developed by the TPM champion
	T3 Organize and promote TPM	A TPM committee was formed to steer the implementation program and monitor progress
	T2 Education campaign	Training on TPM concepts for supervisory staff was conducted by the champion. This was followed by training courses for operators focusing on discipline, proper use of equipment, cleaning and lubricating
	T6 TPM kick off	No special event was organized to kick off the program
	T7 Improve equipment effectiveness	This was initially focused on two pilot sites. The improvements were made by the maintenance department
	T8 Develop an autonomous maintenance program: A1 Perform initial cleaning A2 Address sources of contamination and inaccessible places A3 Establish cleaning and lubricating standards A4 Set overall inspection standards	Tasks A1-A3 were performed by the maintenance department in collaboration with production. Visual controls such as equipment nameplates and correct operating range displays on gauges, valve on-off indicators, etc. were introduced. Photographs were used to document the desired cleanliness of equipment and the workplace inspection checklists were prepared by maintenance
Promotion and Consolidation phase	T4 Establish basic TPM policies	The operator is responsible for providing primary care for his equipment - cleaning, lubricating, adjusting and inspecting
	T2 Education campaign	Steps T2 and T8 were extended to all production units
	T8 Develop an autonomous maintenance program - steps A1-A4	
Maturity phase	T9 Develop scheduled maintenance program	This is being done by maintenance
	T10 Conduct training to improve operation and maintenance skills	There is ongoing effort to prepare operators for the challenge of autonomous maintenance

	T11 Develop an early management program	Data are being captured to track equipment performance and optimize maintenance decisions
	T8 Develop an autonomous maintenance program: A5 Set autonomous maintenance standards A6 Assure process quality A7 Autonomous supervision	Simple PM tasks have been included in autonomous maintenance. There is ongoing training to enhance operators' awareness of the causal relationships between equipment conditions and output quality, and develop their data analysis and problem-solving skills for maintenance improvement
	T12 Perfect TPM implementation	This is the ultimate target to be accomplished

Table 10: Development of a TPM system-a case study in China (Tsang & Chan 2000)

2.3.7 Obstacles in implementing TPM

Bakerjan (1994) identified three major obstacles in introducing TPM:

- Lack of management support and understanding
- Lack of sufficient training
- Failure to allow sufficient time for its evolution

Davis (1997) outlined ten main reasons for TPM failure within UK manufacturing organizations:

- The program is not serious about change.
- Inexperienced consultants/trainers are used.
- The program is too high level, run by managers for managers.
- There is a lack of structure and relationship to strategic needs.
- The program does not implement change on the shop floor and is not managed.
- A lack of education and training for those expected to take it on board and provide support.
- Programs are initiated and run exclusively by engineering and seen by production as a project that does not involve them.
- Attempts to apply TPM in the same way it is implemented in Japan using the standard approach found in Japanese publications.
- TPM teams lack the necessary mix of skills and experience.
- Poor structure to support the TPM teams and their activities.

Hartmann (2000) also pointed out the reasons of failure in the installation of TPM, including:

- Lack of proper understanding of the total effort required
- Lack of management support
- Lack of sufficient tpm staff
- Union resistance
- Not enough training carried out
- Change of priorities
- Lack of persistence
- Failure to develop a good installation strategy
- Choosing the wrong approach

2.3.9 Empirical Study Analysis

2.3.9.1 Investigate TPM's effectiveness in enhancing safety culture

JIPM (1996, p.103) said, "Safety is a cornerstone of TPM. The basic principle behind TPM safety activities is to address dangerous conditions and behavior before they cause accidents." In Section 2.2, eight safety culture factors had been identified to improve safety performance. In this section, it would be shown that TPM could promote these eight factors and hence enhanced safety culture.

2.3.9.2 Implementation of TPM provides a good incentive for management

Manufacturing systems (Blanchard 1997) often operate at less than full capacity, productivity is low, and the costs of producing products are high. In dealing with the aspect of cost, experience has indicated that a large percentage of the total cost of doing business is due to maintenance-related activities in the factory, that is, the costs associated with maintenance labor and materials and the cost due to production losses. TPM aims to increase productivity through maximizing equipment effectiveness and minimizing losses in production (Schmidt 1997). This is a good incentive for management to implement TPM, which will promote safety together (JIPM 1996). TPM maximizes equipment effectiveness through reducing machine utilization losses caused by reduced processing speed, minor machine stoppages and process defects. In addition, TPM reduces the occurrences of equipment failure and the associated costs of repeated machine and process set up. Put in its most simple form TPM will increase the Overall Equipment Effectiveness (OEE, calculation see Appendix C) of manufacturing facilities by operating and maintaining machinery at an optimum level (Prickett 1999, p.236). TPM minimizes losses in production by eliminating major losses in production activities (Riis, Luxh & Thorsteinsson 1997). Naguib (1993, p.90) also said, "TPM enables operating equipment profitably by reducing equipment related losses. The "six major losses" as described by Swanson (2001), that TPM aims to remove are equipment failure, set-up and adjustment time, idling and minor stoppages, reduced speed, defects in process and reduced yield (see Table 7).

Besides maximizing productivity and minimizing losses, TPM is cost effective. It provides cost effective acquisition of equipment by selecting the correct machine for the job, with comprehensive documentation, training and spare parts availability (Naguib 1993, p.90). By decentralizing maintenance activities, such as planning and supervision, to the operators, the costs and performance of maintenance can sometimes be improved. A study by Maggard & Rhyne, (1992) showed that 40% of the traditional maintenance mechanic's work could be done by another employee, with minimal training, and another 40% could be performed with additional training. Steudel & Desruelle (1992) also argued that 80-90% of the maintenance work should be carried out by operators.

Below are three examples showing TPM provides incentives for management to improve productivity and safety together:

1. Yamato Kogyo, some motorcycle manufacturers, after implementation of TPM for five years, productivity improved by 150%, accidents dipped by 90%, and defects reduced by 95% (Turbide 1995).

2. Pirelli, a rubber industry in UK, over a 3-year period, showed a 31% reduction in accidents and near misses, a reduction from 600 hours to 40 hours lost arising from manual handling accidents (HSE 1996b).

3. Nissan Casting Australia - Dandenong Victoria, after implementation of TPM for 2 years, loss time injury decreased from an average of 60 hours per 1,000,000 hours in 1990-1994 to 3 hours per 1,000,000 hours in 1997-1998 (HKPC 2000, p.6.7).

2.3.9.3 Management commitment is important in TPM

For effective implementation of TPM (Roberts 1997), total commitment to the program by upper level management is required. To begin applying TPM concepts, the entire work force must first be convinced that upper level management is committed to the program (Roberts 1997). A case study by Bamber et al. (1999) found out that lack of management support would lead to failure of the implementation of TPM. Management commitment has been identified in section 2.2.2 as a core factor of safety culture, while TPM requires a culture where there is a commitment to ongoing improvement, and a commitment to treating each individual as a valued employee (Society of Manufacturing Engineers 1995). Thus if the management has the incentive to implement TPM successfully, a high commitment is necessary which will promote the safety culture eventually.

2.3.9.4 TPM encourages participation of management and workers

It has been identified in section 2.2.3 that 'participation of management and workers' is essential for a proactive safety culture. TPM program promotes worker involvement by preparing operators to become active partners with maintenance and engineering personnel in improving the overall performance and reliability of the equipment (McKone, Schroeder & Cua 1999, p.126). The word 'Total' means all people are involved, including management and workers. In the TPM framework, the goals (Riis et al. 1997) are to develop a maintenance free design and to involve the participation of all employees to improve maintenance productivity.

2.3.9.5 TPM enhances communication

It has been identified in section 2.2.4 that communication is essential for a proactive safety culture. TPM can enhance communication, and hence safety culture. As described by McKone et al. (2001), TPM helps to improve the organization's capabilities by enhancing the problem-solving skills of individuals and enabling learning across various functional areas. Successful change in technology depends on the deployment of organizational structures (see Figure 1) that enable individuals to work across functional boundaries to identify problems, develop solutions, and execute plans. Companies need to build the skills of their workforce and develop worker participation in order to compete through World Class Manufacturing. TPM changes the structure of the organization to break down traditional barriers between maintenance and production, fosters improvement by looking at multiple perspectives for equipment operation and maintenance, increases technical skills of production personnel, includes maintenance in daily production tasks as well as long-term maintenance plans, and allows for information sharing among different functional areas. Therefore, TPM should develop the capability of the organization to identify and resolve production and OHS problems and subsequently improve manufacturing practice and OHS.

2.3.9.6 TPM encourages education and training

It has been identified in section 2.2.5 that 'education and training' is essential to develop proactive safety culture. TPM encourages education and training through autonomous maintenance. As described by McKone et al. (1999, p.125), operators learn to carry out important daily tasks that maintenance people rarely have time to perform. These housekeeping tasks include cleaning and inspecting, lubricating, precision checks, and other light maintenance tasks and can be broken down into five S's (see appendix D). After these tasks are transitioned to operators, maintenance people can focus on developing and implementing other proactive maintenance plans. TPM is designed to help operators learn more about how their equipment functions, what problems can occur and why, and how those problems can be prevented through early detection and treatment of abnormal conditions. This cross-training allows operators to maintain equipment and to identify and resolve many basic equipment problems.

2.3.9.7 TPM improves working conditions and procedures

Roberts (1995, p.2) said, "Some injuries are preventable through manipulations of the Work environment." A workplace that is easy to work in must first be one where people can work without worrying. TPM can help to create such a workplace by getting rid of the three evils: difficulty, dirt and danger (JIPM 1996, p.104). After getting rid of the three evils, serious accidents may be avoided. As illustrated in the Bird's (1969) accident pyramid, for every major injury there are 10 minor injuries, 30 property damage accidents and 600 near misses. Many factors can cause major accidents. These factors are hidden in equipment and human work procedures. They are the problems people overlook every day because they seem too trivial. TPM can help to break down the pyramid by eliminating these tiny problems (JIPM 1996, p.106). Workplace organization and discipline, regular inspections and servicing, and standardization of work procedures are the three basic principles of safety. All are essential elements in creating safe workplace, and are also part of the activities of TPM (JIPM 1996, p.119).

2.4.9.8vAutonomous maintenance to remove hazards

Autonomous maintenance promotes safety by eliminating breakdowns and standardizing procedures and responses to equipment situations. It eliminates unsafe conditions and unsafe behavior from workplace by integrating safety issues into autonomous maintenance activities. It makes safety check items become part of equipment inspection check-lists. It plans and coordinates nonrepetitive maintenance tasks to avoid safety hazards (JIPM 1996, p.119).vAutonomous maintenance can prevent sudden equipment breakdown which in turn will avoid the accidents caused by malfunction of equipment. An empirical study (Maggard & Rhyne, 1992) showed that 75% of maintenance problems could be prevented by operators at an early stage, by frequent looking, listening, smelling and testing. However, these figures are case specified and are impossible to be used as generally optimum figures. Continuous education and training are necessary to fully decentralize maintenance to the operators.

2.3.9.10 TPM improves morale and job satisfaction

In section 2.2.7 it has been identified that 'morale and job satisfaction' is an essential factor of proactive safety culture. TPM can provide morale and job satisfaction and hence improve safety culture. This is supported by Roberts (1997) who said that the goal of TPM was to markedly increase production while, at the same time, increased employee morale and job satisfaction. Naguib (1993) also said that TPM improved employee morale and job satisfaction. This was achieved through increased involvement and autonomy on the job, providing interesting job assignments, and increased training and knowledge. In a case study of implementing TPM in mainland China, Tsang & Chan (2000) concluded that TPM embraced the concept of empowerment such that sufficient authorities, resources and freedom to contribute were given to equipment operators for establishing a sense of ownership.

TPM increases employee morale and job satisfaction by providing operators with a sense of ownership of the equipment. In TPM, operators will do most of the maintenance work on the equipment. Workers will treat their equipment as if it were their own car or truck. This means paying attention to the funny noises it makes, or the vibrations, or the leaks, or the smoke coming from the motors. It means keeping it clean so they can see problems before they become failures (Society of Manufacturing Engineers, 1995). Swanson (2001) said, "Under TPM, small groups or teams create a cooperative relationship between maintenance and production that helps in the accomplishment of maintenance work. Additionally, production workers become involved in performing maintenance work allowing them to play a role in equipment monitoring and upkeep. This raises the skill of production workers and allows them to be more effective in maintaining equipment in good condition." CTPM (2001c) also described that by creating a higher degree of employee participation, TPM increased employee morale and a sense of positive participation, especially as they saw their daily frustrations with equipment reduced.

2.3.9.11 TPM improves attitude and risk perception

As identified in section 2.2.8, 'attitude and risk perception' is essential for a proactive safety culture. TPM can improve workers' attitude and risk perception through the change of mindset and TPM activities described below. Maggard & Rhyne (1992) said, "The introduction of TPM means a significant cultural change, by shifting shop floor personnel from the dualism between production and maintenance to the partnership approach among all organizational functions." To implement TPM successfully it requires a dramatic shift in an organization's collective mindset (The Auto Channel 1998). As described by JIPM (1996), TPM required a shift in attitudes toward equipment from the traditional "I make it; you fix it" to "we take care of our own machines." Breakdown and minor stoppages, in particular, impact the activities of operators - the people who have the most contact with equipment and know it best. In TPM, eliminating breakdown is not a maintenance department responsibility nor is getting rid of defects a management's job. Everyone participates in reducing losses to zero - and everyone benefits. With total participation, TPM can make the "zero loss" workplace a reality. Implementation of TPM will have a profound, positive effect on the culture of a company. It will change the culture. It will change relationships across organizations of the company. It will distribute decision-making, and disperse the authority base (Society of Manufacturing Engineers 1995, p.19).

JIPM (1996) has also stressed the importance of hazard awareness training and active signaling in TPM. Hazard awareness training is a four-round approach that uses illustrations and photographs to train people to see and deal with potential dangers in equipment and work methods. Active signaling is used to prevent errors between people working together on maintenance or other tasks. In signaling, workers may call out to reach each other or use a visual signal to indicate what they are about to do and to make sure the other person gets the message.

2.3.9.12 riteria for assessing safety culture

Lee & Harrison (2000) said, "The proactive stance to safety is now almost universally accepted, if not always practiced. In consequence, there is an urgent demand for methods of assessment, for ways of diagnosing weakness; also for benchmarking the strengths of safety cultures across time and between organizations." Grote & Kunzler (2000) also said, "Assessing safety culture is not an issue of determining whether an organization does or does not have a safety culture, but rather an issue of determining shared as well as conflicting norms within and between groups in an organization and the relationship between these norms and safe performance." Different researchers have different criteria in assessing safety culture. Below four examples (A to D) shows the 35 criteria in assessing safety culture.

2.3.9.13 Reliability analysis of safety culture survey

In section 3.4, it was shown that quantitative questionnaires had been used by researchers to assess safety culture. The reliability of the results obtained had to be tested. Reliability is the extent to which a study's operations can be repeated, with the same results (Yin 1989, p.41). Reynaldo & Santos (1999) said, "Reliability comes to the forefront when variables developed from summated scales are used as predictor components in objective models. Since summated scales are an assembly of interrelated items designed to measure underlying constructs, it is very important to know whether the same set of items would elicit the same responses if the same questions are recast and re-administered to the same respondents. Variables derived from test instruments are declared to be reliable only when they provide stable and reliable responses over a repeated administration of the test." Burns (2000, p.339) introduced four methods for reliability measure: test-retest method, alternate forms method, split-half method and internal consistency method. In this dissertation, Cronbach's alpha as an internal consistency reliability index was used for reliability measure. Cronbach's Alpha has been widely used by researchers as a tool for reliability analysis in the surveys on safety culture, such as Lee& Harrison (2000), Willamson et al. (1997) and Roberts (1995).

RESEARCH METHODOLOGY

It had been reviewed from literature that TPM enhanced proactive safety culture. In this dissertation, the aim was to develop a framework of TPM activities for manufacturing organizations to improve the effectiveness of the OHS management systems.

3.1 Research Design

The research design was an analytical survey. Analytical surveys also referred to as diagnostic studies attempt to describe and explain *why* certain situations exist. In this approach two or more variables are usually examined to test research hypotheses. The results allow researchers to examine the interrelationships among variables and to draw explanatory inferences.

3.2 Ethical Issues

The participants were guaranteed that the identifying information will not be made available to anyone who is not involved in the study and it will remain confidential for the purposes it is intended for. The researcher sought permission to carry out the research from the University. The prospective research participants were fully informed about the procedures involved in the research and were asked to give their consent to participate. The participant remained anonymous throughout the study and even to the researchers themselves to guarantee privacy.

3.3 Research Methods

3.3.1 Samples

Through literature review, identified safety culture factors that affected effectiveness of OHS management systems and could be enhanced by TPM. Based on the safety culture factors identified, developed questionnaires to evaluate the safety culture of manufacturing organizations. Two sets of questionnaires were developed. Questionnaire A was designed for management people and questionnaire B for workers. 72 sets of questionnaires A were sent to the management of 72 companies to study the safety culture of the companies. Another purpose of this step was to find out those companies who were implementing TPM. After receiving the replies, those companies implementing TPM were asked by telephone whether they could help to distribute Questionnaire B to their workers.

3.3.2 Results

At the same time, evaluated the safety culture in ABC Company, which was going to implement a TPM system. The result obtained from the ABC Company was then compared with that obtained from another company which was implementing TPM. This was to identify whether these two companies had significant different safety culture. From the results obtained, the hypothesis of the paper was tested to show a company with TPM in place had a more positive safety culture than one not implementing TPM. After confirming TPM could help to improve safety culture, a framework of TPM activities would then be developed to improve effectiveness of OHS management systems in manufacturing industry.

3.3.3 Questionnaires

In ABC Company, questionnaires were distributed in a meeting in the 'safety awareness week' held by the company. The aims and background of the study were explained to all the employees. All respondents were supplied with sealable envelopes pre-addressed to the writer. Seven sets questionnaire (A) were distributed to the technical managers, engineers and safety officer. 85 questionnaires set (B) were distributed to the day-shift workers. Night shift workers (around 20) were not selected since their operations were much simpler and some of them did not need to operate a machine. Those workers who did not need to operate machines such as the cleaning ladies were also not included. Questionnaires (A) were also mailed to 72 manufacturing industries. All these were medium size industries (including the few largest manufacturing industries in Hong Kong) located in the major industrial estates. This had two objectives:

1. Sought companies who had implementing TPM and willing to distribute the questionnaire (B) to the workers.

2. If there were sufficient replies, the general status of safety culture in the manufacturing industries in Hong Kong could be studied.

There were only few manufacturing industries in Hong Kong implementing TPM. Question 25 of questionnaire (A) asked the respondents whether their organizations were implementing TPM. Out of the eleven replies, there were two organizations implementing TPM. The two companies were then contacted by phone and finally one (the PQR Company) agreed to distribute the Questionnaire (B) to the workers.

4.0 DATA ANALYSIS

Based on the eight safety culture factors identified in section 2.2, two sets of questionnaires, set (A) and set (B) were developed (see appendices P and Q). Set (A) was designed for management people and set (B) for supervisors and workers. A Chinese version of questionnaire set (B) was also prepared (see appendix R).

The background information of the respondent was collected from questions 1 to 4 in questionnaire A and questions 1 to 3 in questionnaire B. In each questionnaire, there were 20 quantifiable questions, with 5-point Likert scale. Each possible response was assigned a numeric value as below:

Strongly Disagree 1
Disagree 2
Neutral 3
Agree 4
Strongly Agree 5

Thus for a single respondent, the minimum score was 20 while the maximum score was 100. According to the 'TPM approach to effective OHS management' developed (see Figure 8), a higher score implied a more proactive orientation towards safety, reached a higher level of safety culture and finally higher effectiveness of the OHS management system. As described above, the questionnaire covered the eight factors relevant to safety performance identified in section 2.2. These factors could be enhanced by TPM. The questions were allocated into eight domains for analysis, according to the safety culture factors studied in the questions (see Table 12).

The 8 safety culture factors	Question number in Set (A)	Question number in Set (B)
management incentive	5, 6	4, 16
management commitment	7, 8, 18	5, 6
participation of management and worker	9, 10, 11	12, 20
Communication	19, 20, 21	13, 14, 18, 19
training and education	12, 13, 14	7, 8, 9
improve working conditions and procedures	15, 16	10, 11 15
morale and job satisfaction	24	17, 21
attitude and risk perception	17, 22, 23	22, 23

Table 12: Questions in eight domains

4.1 Context of Research Site

4.1.1 Replies received

In the safety culture survey of the ABC Company, 7 sets questionnaire (A) were issued and all were received. 85 sets questionnaire (B) were distributed to the workers and 78 replies received (Table 13). 72 sets questionnaires (A) were mailed to 72 companies but only 11 replies were received. Out of these two were implementing TPM. Only one company 'PQR' agreed to distribute questionnaire B to the workers and finally 21 replies were received. The other 10 replies of questionnaire (A), other than that of PQR, were not sufficient to give a clear picture of the general safety culture of manufacturing industries in Hong Kong and hence they were not studied in the paper.

	ABC Company (no TPM)		PQR Company (with TPM)		Others, include PQR
	Set (A) for Management	Set (B) for Workers	Set (A) for Management	Set (B) for workers	Set (A) for management
Sent	7	85	1	1 (other copied)	72
Received	7	78	1	21	11

Table 13: Number of questionnaires sent and received

4.1.2Average score of questionnaires A & B

The average score of each question in questionnaires A and B of both ABC Company and PQR Company were listed in the Table 14 and 15.

No.	Description of questions in Questionnaire A	Average Score for ABC (no TPM)	Average Score for PQR (with TPM)
5	The employer regards safety as an important matter as others like productivity and quality.	3.6	5
6	Safety goals are pursued proactively and on the company's initiative.	3.0	5
7	Management encourages safe behavior.	3.4	5
8	Safety proposals developed are swiftly implemented.	3.1	5
9	Management is involved in safety activities such as risk assessment, accident investigations & promotion programs.	3.7	5
10	Management is well informed about relevant safety issues.	3.3	5
11	Workers are eager to attend safety activities and training.	3.0	3
12	A lot is learnt from near misses.	3.1	4
13	Information needed to work safely is made available to all employees.	3.4	4
14	Workers are qualified to actively enhance operational safety.	3.4	3
15	Workers and supervisors participate in defining safe work practices.	3.1	4
16	Workers and supervisors are actively involved in removing hazards in the working environment.	3.4	4
17	Workers will raise concern on machine problems.	3.4	5
18	Safety problems with machines are swiftly solved.	3.6	4
19	A questioning attitude towards instruction is encouraged.	2.7	5
20	Management listens to workers' recommendations and will provide feedback.	3.6	4
21	The channels for the communication between management and workers are efficient and sufficient.	3.1	4
22	The managers in your plants really care about safety and try to reduce risk levels as much as possible.	3.1	5
23	Both management and workers regard safety as everyone's responsibility, and safety officers provide support.	3.3	4
24	Workers are motivated for safety by information and interesting tasks.	2.4	4
	Total for the 20 questions:	65.0	87

Table 14: Average Score of Questionnaire A

No.	Description of questions in Questionnaire B	Average Score for ABC (no TPM)	Average Score for PQR (with TPM)
4	Senior management regards safety as an important matter as others like productivity and quality.	3.0	3.6
5	Management provides enough safety equipment.	3.1	3.5
6	Management can do what they commit.	3.2	3.6
7	Accidents and near misses are studied and used as training materials.	3.3	3.6
8	Workers have been trained properly, including safety precautions as well as operation of the machines	3.2	3.7
9	Workers are always trained for the use of safety equipment.	3.1	3.7
10	Management is willing to improve the safety of the working environment.	3.3	3.6
11	Safety procedures are realistic.	3.4	3.5
12	Management actively participates in safety activities.	3.2	3.4
13	Management listens to workers' recommendations and will provide feedback.	3.2	3.2
14	Workers are encouraged to question instructions from management.	3.2	3.3

15	There are arrangements to check equipment to make sure it is free of faults.	3.4	3.7
16	Which one below is the best to describe the management of your company? (Choices refer to Appendix Q)	3.3	3.5
17	You regard safety as everyone's responsibility, and safety officers provide support.	3.1	3.8
18	You find it easy to communicate with the management.	3.2	3.4
19	Whenever you encounter any safety matters, you will report to the supervisor or safety officer.	3.4	3.4
20	You are willing to join the safety activities and trainings.	3.3	3.5
21	You take care of the machines which you are operating.	3.2	3.6
22	You believe that accidents are preventable.	3.0	3.6
23	You regard compliance with the safety rules as important. If people are not following the rules, accidents may occur.	3.2	3.8
Total for the 20 questions:		64.1	70.9

Table 15: Average Score of Questionnaire B

In summary, the average sum of scores for all 20 questions of questionnaire A and B for ABC Company and PQR Company were shown in the chart below.

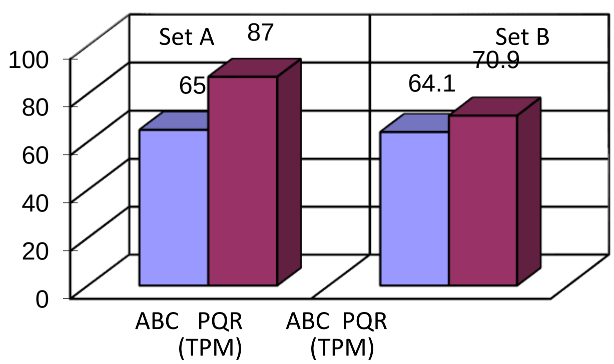

Figure 11: Average score of all 20 questions

From Figure 11, it could be observed that the average scores on both questionnaires (A) and (B) of PQR Company were higher than those obtained from ABC Company.

4.1.4 Results on each safety culture factor

In this section, the mean score of each question of Questionnaire (B) in different domains from ABC Company and PQR Company would be described. Reliability of the results obtained from questionnaire B of ABC Company would also be estimated. An internal consistency analysis, with Cronbach's alpha as an index, was used to test the reliability. Questions were allocated into eight domains as shown in Table 12. The inter-correlation among all the 20 questions together would be estimated. The inter-correlation among questions within each domain would also be estimated. All alpha values mentioned in this report referred to the Cronbach' alpha values of the results from questionnaire (B) of the ABC Company.

4.1.5 Results on Management Incentive

Mean = 3.1 (ABC) Alpha = 0.7187 (ABC) Mean = 3.5 (PQR)

Questionnaire B	Score	1	2	3	4	5	
4. Senior management regards safety as an important matters as others like productivity and quality.	ABC	1	16	45	14	2	Replies
	PQR	1	3	5	7	5	
16. Which one below is the best to describe the management of your company? (Choices refer to Appendix Q)	ABC	0	7	46	23	2	
	PQR	0	4	6	8	3	

Table 16: Results on Management Incentive

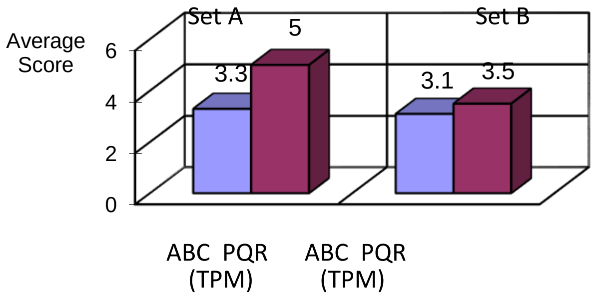

Figure 12: Average score on Management Incentive

5.3.2 Results on Management Commitment

Mean = 3.1 (ABC) Alpha = 0.7332 (ABC) Mean = 3.5 (PQR)

Questionnaire B	Score	1	2	3	4	5	
1. Management provides enough safety equipment.	ABC	0	19	35	19	5	Replies
	PQR	0	1	10	8	2	
6. Management can do what they commit.	ABC	0	20	34	15	9	
	PQR	0	0	11	8	2	

Table 17: Results on Management Commitment

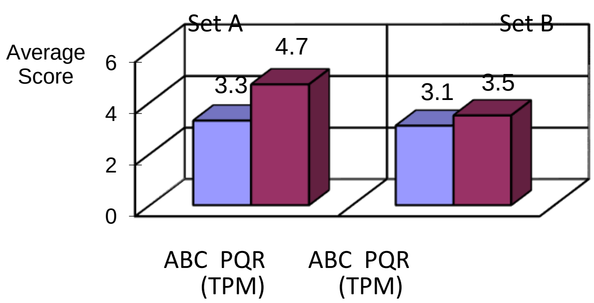

Figure 13: Average score on Management Commitment

4.1.6 Results on Participation of Management and Workers

Mean = 3.3 (ABC) Alpha = 0.5390 (ABC) Mean = 3.5 (PQR)

Questionnaire B	Score	1	2	3	4	5	
12. Management actively participates in safety activities.	ABC	0	14	36	23	5	Replies
	PQR		2	10	8	1	
20. You are willing to join the safety activities and training.	ABC	0	8	42	24	4	
	PQR	0	0	11	9	1	

Table 18: Results on Participation of Management and Workers

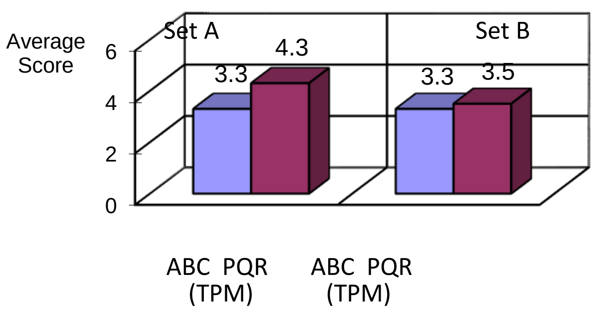

Figure 14: Average score on Participation of Management and Workers

4.1.7 Results on Communication

Mean = 3.3 (ABC) Alpha = 0.7287 (ABC) Mean = 3.3 (PQR)

Questionnaire B Score		1	2	3	4	5	
13. Management listens to workers' recommendations and will provide feedback.	ABC	0	12	44	18	4	Replies
	PQR	0	4	10	6	1	
14. Workers are encouraged to question instructions from management.	ABC	0	11	44	19	4	
	PQR	0	3	8	0	10	
18. You find it easy to communicate with the management.	ABC	0	18	31	25	4	
	PQR	0	1	12	7	1	
19.Whenever you encounter any safety matters, you will report to the supervisor or safety officer.	ABC	0	8	36	27	7	
	PQR	2	1	5	12	1	

Table 19: Results on Communication

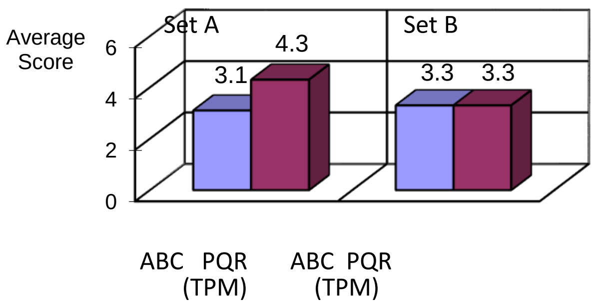

Figure 15: Average Score on communication

4.1.8 Results on Education and Training

Mean = 3.2 (ABC) Alpha = 0.7288 (ABC) Mean = 3.7 (PQR)

Questionnaire B Score		1	2	3	4	5	
7. Accidents and near misses are studied and used as training materials.	ABC	0	6	48	18	6	Replies
	PQR	0	0	10	9	2	
8. Workers have been trained properly, including safety precautions as well as operation of the machines	ABC	1	12	38	25	2	
	PQR	0	0	8	12	1	
9. Workers are always trained for the use of safety equipment.	ABC	0	19	37	19	3	
	PQR	0	2	5	12	2	

Table 20: Results on Education and Training

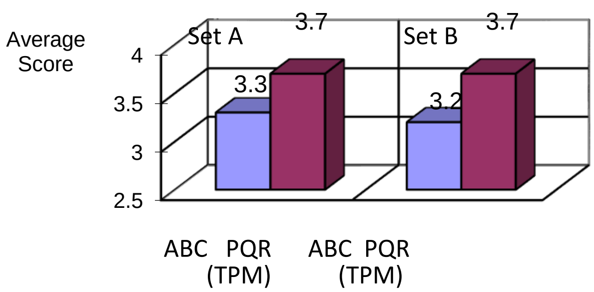

Figure 16: Average Score on Education and Training

4.1.9 Results on Working Conditions and Procedures

Mean = 3.4 (ABC) Alpha = 0.5974 (ABC) Mean = 3.6 (PQR)

Questionnaire B Score		1	2	3	4	5	
10. Management is willing to improve the safety of working environment.	ABC	1	6	47	20	4	Replies
	PQR	0	1	10	7	3	
11. Safety procedures are realistic.	ABC	0	5	40	29	4	
	PQR	0	2	7	11	1	
	ABC	0	5	42	27	4	

15. There are arrangements to check equipment to make sure it is free of faults.	PQR	0	0	9	9	3	

Table 21: Results on Working Conditions and Procedures

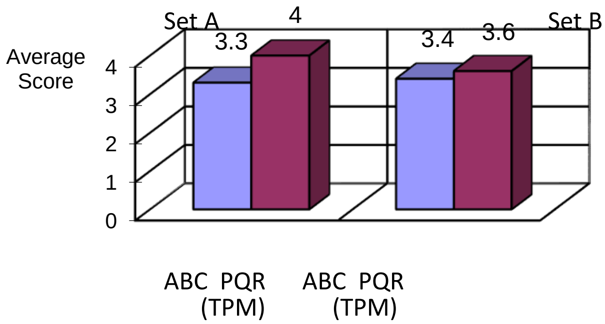

Figure 17: Average score on Working Conditions and Procedures

4.1.10 Results on Morale and Job Satisfaction

Mean = 3.1 (ABC) Alpha = 0.5758 (ABC) Mean= 3.7 (PQR)

Questionnaire B	Score	1	2	3	4	5	
17. You regard safety as everyone's responsibility, and safety officers provide support.	ABC	1	17	40	13	7	Replies
	PQR	0	1	6	10	4	
21. You take care of the machines which you are operating.	ABC	1	16	36	19	6	
	PQR	0	2	7	10	2	

Table 22: Results on Morale and Job Satisfaction

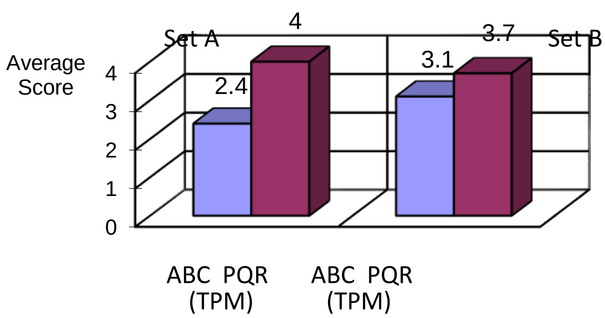

Figure 18: Average score on Morale and Job satisfaction

4.1.11 Results on Attitude and Risk Perception

Mean = 3.1(ABC) Alpha = 0.6798 (ABC) Mean = 3.7 (PQR)

Questionnaire B	Score	1	2	3	4	5	
22. You believe that accidents are preventable.	ABC	1	24	34	15	4	Replies
	PQR	0	0	11	7	3	
23. You regard compliance with the safety rules as important. If people are not following the rules, accidents may occur.	ABC	0	21	29	21	7	
	PQR	0	1	7	9	4	

Table 23: Results on Attitude and Risk perception

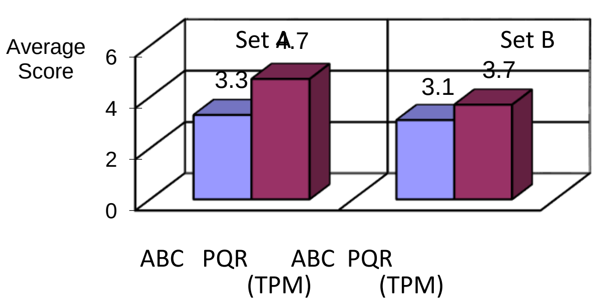

Figure 19: Average score on Attitude and Risk Perception

4.2 Reliability Analysis

The values of alpha were summarized in Table 24. The SPSS (version 10.0) outputs of the reliability analysis could refer to the appendices shown in Table 24. Reynaldo & Santos (1999) said that Cronbach's alpha of 0.70 was the cutoff value for being acceptable. There were 4 domains shown in the table with alpha values lower than 0.7. The other 4 domains and the 8 factors together had alpha values higher than 0.7 and were considered acceptable.

Safety culture factors	Question numbers	Cronbach's alpha	Appendix
All the 8 factors	All 20 questions	0.9041	G
1. management incentive	4, 16	0.7187	H
2. management commitment	5, 6	0.7332	I
3. participation of management and worker	12, 20	0.5390	J
4. communication	13, 14, 18, 19	0.7287	K
5. education and training	7, 8, 9	0.7288	L
6. improve working conditions and procedures	10, 11 15	0.5974	M
7. morale and job satisfaction	17, 21	0.5758	N
8. attitude and risk perception	22, 23	0.6798	O

Table 24: Summary of Cronbach's Alpha value for each domain

4.2.1 Testing of the hypothesis

The hypothesis of the paper, as described in section 1.3 is: "A manufacturing company with TPM in place has a more positive safety culture than one not implementing TPM." There were two sets data obtained for questionnaire (B), one from ABC Company and another from PQR Company. A *t*-test was conducted to determine whether there was a significant difference between the means of scores on safety culture from the two groups. Using the software of SPSS (version 10.0), the below results were obtained (see Table 25):

Group Statistics

COMPANY	N	Mean	Std. Deviation	Std. Error Mean
SCORE PQR	21	70.90	9.32	2.03
ABC	78	64.14	9.52	1.08

Independent Samples Test

	Levene's Test for Equality of Variances		*t*-test for Equality of Means						
	F	Sig.	*t*	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
SCORE Equal variances assumed	.171	.681	2.904	97	.005	6.76	2.33	2.14	11.39
Equal variances not assumed			2.940	32.153	.006	6.76	2.30	2.08	11.45

Table 25: Output of t-test analysis

From the output (see Table 25), $t = 2.904$
At degree of freedom df = N1 + N2 - 2 = 76 + 21 - 2 = 97,
the significant level (2-tailed) = 0.05
The *t* value (2.904) is larger than the significant level (0.05).

Result of the *t*-test analysis: An independent-samples *t*-test was conducted to evaluate the hypothesis that 'a manufacturing company with TPM in place had a more positive safety culture than one not implementing TPM'. The mean score of safety culture of the PQR Company (M = 10.90, SD = 9.32) was significantly different from (t = 2.904, df=97, two-tailed p=0.05) and higher than that of ABC Company (M = 64.14, SD = 9.52). Therefore, the null hypothesis was rejected.

5.0 EVALUATION OF THE RESEARCH

Unless otherwise specified, the data and discussion in this section all referred to the questionnaire (B) of ABC Company. Since many people did not reply questions 25 and 26, results of these two questions, concerning their attitude to do the maintenance works, were not discussed.

5.1 Findings and Discoveries

Management Incentive (Questions 4 and 16): In this domain, alpha = 0.7187, internal consistency was acceptable. In question 16, 59% of respondents selected 'management accepts the fact that there are problems but is unable to solve them because they don't want to know how to attack them'. In question 4, 58% of respondents gave a neutral response to 'senior management regards safety as an important matter as productivity and quality'. The results showed the management incentive to put safety first was not high. A TPM system, which can improve productivity and safety together, should be a good incentive for the management to operate.

Management commitment (Questions 5 and 6): In this domain, alpha = 0.7332, internal consistency was acceptable. In both questions, around 44% of respondents had neutral response to 'management provides enough safety equipment' and 'management can do what they commit'. For each statement, there were around 25% of respondents who answered with disagree. This implied that the management commitment was not high. When looking at the results from PQR Company, there was only one respondent who disagreed with the former statement and none disagreed with the later. Implementing TPM thus able to show the employee the management's commitment.

Participation of management and workers (Questions 12 and 20): In this domain, alpha = 0.5390, internal consistency was unacceptable. The participation of management in question 12 and the participation of workers in question 20 were appeared not to be inter-correlated. 18% of the workers considered the management had not actively participated in the safety activities while 46% had a neutral response to this question. 10% of the workers were not willing to join the safety activities while 54% had a neutral response. The results were not strange since the 'morale and job satisfaction' of the workers were extremely low (as discussed in 6.2.7) and hence many workers had no intention of joining the safety activities.

Communication (Questions 13, 14, 18, 19): In this domain, alpha = 0.7287, internal consistency was acceptable. The results (score) in this domain were not bad when compared to the results of the PQR Company. But there were still 23% of respondents who felt difficulties in communicating with the management (question 18).

Education and training (Questions 7, 8 and 9): In this domain, alpha = 0.7288, internal consistency was acceptable. From question 9, it was noted that around 24% of respondents claimed they had not been trained in the use of safety equipment. In contrast, a relatively high score was obtained from PQR Company since 'education and training' is one of the eight pillars in TPM.

Improve working conditions and procedures (Questions 10, 11 and 15): In this domain, alpha = 0.5974, internal consistency was unacceptable. The three questions in this domain were appeared not to be inter-correlated. The ABC Company got the highest score in this domain. 23%, 37% and 35% had positive response to the three questions: 'management is willing to improve the safety of working environment', 'safety procedures are realistic' and 'there are arrangements to check equipment' respectively; and around 50% of the respondents had a neutral response to these questions. The negative responses to these questions were 6-9%. PQR Company still had a higher score in this domain. There is still much room for ABC Company to improve and TPM can help.

Morale and job satisfaction (Questions 17 and 21): In this domain, alpha = 0.5758, internal consistency was unacceptable. The two questions in this domain were appeared not to be inter-correlated. 22% of respondents did not agree that safety was everyone's responsibility (question 17). 21% of respondents did not take care of their machines (question 21). This was one of the two domains in which ABC Company had the lowest score while PQR Company had the highest score. A TPM system is believed able to improve this safety culture factor.

Attitude and risk perception (Questions 22 and 23): In this domain, alpha = 0.6798, internal consistency was only just unacceptable. It was critical to learn from the results that 31% of the respondents did not believe accidents were preventable (Question 22) and 27% of respondents did not regard complying with safety rules was important (Question 23). This was also one of the two domains in which ABC Company had the lowest score while PQR Company had the highest score. A TPM system is believed able to improve this safety culture factor.

5.2 Limitations

There are two major constraints in the study: ABC Company planned to implement TPM but still has not implemented it. Due to time constraints of the study, the safety culture of the ABC Company after implementation of TPM could not be measured and compared with that obtained before the implementation. There are very few organizations in Hong Kong implementing TPM. The ABC Company and the PQR Company in the study come from different types of manufacturing industries. Another major difference between the two companies is that ABC Company has around 120 workers while PQR has only around 50 workers.

One important common factor between the two companies is that both companies has had OHS management systems in place for just less than two years at the time of the survey. This study established two sets of questionnaires to measure the safety culture of the ABC Company, one for management and one for workers. This chapter mainly used the results from questionnaire (B) (for worker) to evaluate the safety culture of the ABC Company since there were 78 replies but only 7 sets of data of questionnaire set (A) were available. This appears reasonable since the internal consistency of the scores for all the 20 questions in questionnaire (B) is high (Cronbach's alpha equals to 0.9041 as estimated in section 5.4). This also appears reasonable since it is the workers who face the accidents and their attitude and perception are different from those managements who normally have little hazards in their workplaces.

There were two criteria in selecting the safety culture factors to evaluate the safety culture of the ABC Company. First, these factors must have been successfully used by other researchers to measure safety culture. Second, TPM must be able to enhance such factors. The eight safety culture factors selected can fulfill these two criteria. The results were used to picture the safety culture of the ABC Company and by comparing them with those obtained from the PQR Company, to see whether TPM could enhance the eight safety culture factors identified. From the reliability analysis of the results of questionnaires (B) of ABC Company (section 5.4), four of the Cronbach's alphas obtained for the eight domains were acceptable (alpha larger than 0.7) and four were not (alpha smaller than 0.7). Nevertheless, the results were analyzed by dividing the 20 questions into these eight domains.

It had been shown in Chapter 5 that the PQR Company with TPM in place had a more positive safety culture than that of the ABC Company, which had not implemented TPM. The next step was then to develop a framework of TPM activities based on the literature and findings from the safety culture surveys. This framework was intended to be useful for most manufacturing companies to improve their safety performance. TPM places an emphasis on people and machine. Management's support and participation are also important for successful implementation of TPM. A framework of TPM activities, based on the 'People', 'Management', 'Machine and Environment' was developed (see Figure 20).

5.3 Recommendations

Hartmann (2000) recommended to have a pilot installation, covering 10 to 25% of a plant's equipment, before plant-wide installation of TPM. An example of a TPM committee for pilot installation of TPM was designed for ABC Company (see Figure 21), based on the proposal of HKPC (2000, p.17.6), which was specially designed for medium size organizations in Hong Kong. A Steering Committee had to be set up first. Two production lines were proposed for the pilot installation and implementation of TPM system. Other companies can have similar set up, depending on their own organization structure.

Responsibility of the Champion in the TPM Steering Committee

- Report direct to the Technical Director (Sponsor)
- Ensure the problems and concerns raised by the TPM coordinator immediately raised and solved.
- Introduce TPM to all employees
- Ensure all employees receive sufficient training and support
- Promote TPM and motivate employees to join
- Gather and distribute the information for TPM

Responsibility of the TPM Coordinator

- Direct report to Technical Director, TPM Champion and TPM Steering Committee
- Organize all TPM activities
- Co-ordinate all TPM teams
- Leading TPM monitoring and planning teams
- Support the supervisor of each TPM teams
- Co-ordinate and assist to solve the problems encountered by the TPM teams
- Encourage all employee participation

- Gather and distribute TPM information

Manage small group activities: Nakajima (1988, p.109) said, "A small group promotes itself and satisfies company goals as well as individual employee needs through concrete activities." Teams or groups should set goals compatible with the larger goals of the company and achieve them through group cooperation or teamwork. The basic steps to manage small group activities as described by JIPM (1995) are:

1. Choose a team leader
2. Select a project
3. Set targets
4. Schedule activities and assign roles
5. Study current conditions
6. Establish plans
7. Implement
8. Analyze results and prevent backsliding

Conduct step audit for training and mutual learning: Step audits are audits conducted by shop floor managers to see how the teams are doing. These are chances for people on the shop floor to learn what the boss thinks and expects - and for the boss to recognize the hard work shop floor people have done and to gain a better understanding of current problems. (JIPM 1996, p.75)

Make equipment and workplace safe Clean and inspect (Step 1 of Autonomous Maintenance)**:** In TPM, cleaning is inspection (HKPC 2000). Cleaning does not simply mean polishing the outside of a machine; it means getting rid of the years of grime coating on every part of the machine. As part of initial cleaning, detect and correct any problems such as exposed moving parts, projecting parts, spattering of harmful substances, loosen and missing screws.

Eliminate problem sources (Step 2 of Autonomous Maintenance): Very often machines get dirty soon after cleaning. It is necessary to eliminate sources of leaks, spills and dust. Deal with major contamination sources through focused improvement. Modify equipment to make cleaning and lubrication easier. Improve cleaning and lubrication standards where necessary. Apply tags to equipment to label the problems found (see Appendix F) and remove tags only when problems solved.

Draw up cleaning and lubrication standards (Step 3 of Autonomous Maintenance)
Team members decide what standards they need to follow to prevent deterioration of their equipment. Establish and review work standards and daily check method. Looking at suppliers' standards for lubrication to ensure warranty on equipment. Include key safety procedures in provisional cleaning and checking standards.

Planned maintenance and predict failure: Carry out planned and preventive maintenance on equipment. Prevent recurrence of chronic failures. Perform regular equipment diagnoses such as checking for corrosion, cracking, wear and brittle.

Implement 5S (definition refers to Appendix D)
Use 'Seiri - organization' to eliminate unnecessary items.
Use 'Seiton - neatness' to establish a permanent place for everything essential.
Use 'Seiso - Cleaning' to find ways to keep things clean and eliminate contamination.
Use 'Seiketsu - Standardization' for easy inspection.
Use 'Shitsuke - Discipline' to ensure proper methods of handling production activities.

Develop safety conscious people

Conduct general inspections (Step 4 of Autonomous Maintenance)**.** Operators participate in general inspections and become more familiar with their equipment (JIPM 1997, p.31). Safety check that addresses the following types of issues (JIPM 1996, p.110):

- Leaks and spattering
- Heat
- Equipment load
- Reduced performance
- Vibration and excessive noise
- Electrical leakage and static electricity
- Problems during operation
- Problems during processing or execution

Carry out visual workplace management (step 6 of Autonomous maintenance): Develop workers' safety awareness through visual workplace management. This is to assure workplace organization (done by 5S) and maintain a proper working environment by:

- sorting out and arranging objects in the workplace properly
- defining procedures that need to be followed
- performing equipment precision checks
- facilitating operator tasks

Link safety education and training to skill training: Through the use of accident case studies and the findings in safety audits, link safety education and training to skill training. A model (see Figure 22) to link safety education and training to skill training has been developed by HKPC (2000, p.15.4). Aware to safety will become a habit after education, training and practice.

Present the One-point Lesson: This is a 5-10 minutes' self-study lesson drawn up by team members and covering a single quality or safety issue; or a single aspect of machine structure, functioning or method of inspection. A one-point lesson provides a way for team leaders and members who have special training or knowledge about equipment to share their knowledge with their teammates (JIPM 1997, p.105). A standard form of one-point lesson is shown in Appendix E.

On-the-job coaching to each individual: The more people know about their equipment and processes, the more safely they can work. Collect examples of near misses and compile them into on-point lesson sheets are some examples of on-the-job coaching to each individual.

Self-audit: Identify and record near misses. Use checklists to check safety of equipment. Self-audits promote effective monitoring and evaluation of progress. (Suzuki 1994, p.143)

Commitment and support of management

Address sources of human error: While it is impossible to train people never to make mistakes, they can learn to be safety-conscious. Management plays an important role in addressing sources of human error and has the responsibility to train everyone addresses safety issues.

Develop an education and training program: Establish a detailed education and training program (Suzuki 1994, p.293) that

- covers all specializations and grades
- sets standards for acquiring the necessary knowledge and skills, and
- devises effective training curricula

Draw up a budget for safety: A budget in place is the easiest way to show employee the management's commitment.

Involve senior management in auditing team activities: The person in charge of TPM programs in the company serves as a coach for the shopfloor teams and keeps team activities energized and on track. In addition, managers are asked to conduct periodic reviews of team activities. Having managers guide team activities through the audits or check clarifies management policies and priorities, boosts team member motivation, and helps ensure satisfying activities (JIPM 1996, p.90).

Devise a program of accident prevention training: Devise a program of accident prevention training using illustrations, and practice safety procedures on the actual equipment during autonomous maintenance activities.

Conduct autonomous inspection (step 5 of autonomous maintenance): This is to revise the cleaning inspection, and lubrication standards developed. The inspection can help to streamline those tasks and correct stressful working postures and methods.

Carry out consistent autonomous management (step 7 of Autonomous Maintenance): This is to confirm the activities of autonomous maintenance continue, so as to ensure everyone takes care of his own equipment and workplace.

Develop an early equipment management program: This is the eleventh step of the 12-step model developed by Nakajima (1988) as shown in Appendix A. This program includes the establishment of assessment criteria for safety of new products and machines. Suzuki (1994) said, "Poor design is a major cause of reduced profitability, impaired production efficiency, and low OEE". A good planned new installation or process at the development design stage can minimize wastage and equipment breakdown as well as enhance safety operation. Even though a new setup has been smoothly designed, problems may come out during test-running, commissioning and start-up. An early equipment management program includes improvement activities at various stages: the equipment investment planning stage, design, fabrication, installation and test running, as well as commissioning.

Discussion on the framework of TPM activities developed: This dissertation developed a framework of TPM safety activities for the manufacturing industry to improve safety performance. The framework is important since most literature and studies on TPM were mainly concerned with productivity, but not safety. The figures of improvement in safety performance due to implementation of TPM can be found in literature, but these were very often by-products of the figures in productivity improvement. There is a gap on how to implement safety management within the TPM environment. The framework developed is a start to fill the gap.

Environment, equipment and people are very often regarded as components of system safety. The framework developed also started with these three components, with the addition of a new component, management. Equipment and environment were combined to a single component since TPM very often tackles these two problems together. People and management are linked by 'communication'. Thus the four components of the framework are 'people', 'communication', 'management', and 'equipment and working environment'. The targets of these components are to prevent behavior originated accidents, enhance communication, operate management systems reliably and prevent equipment / workplace originated accidents. A lot of TPM activities were allocated into the framework to achieve the targets.

The TPM committee was specially designed for the ABC Company. Upon implementing TPM, the safety culture of ABC Company can then be enhanced. Other companies can have similar set up, depending on their existing organization structure and size of the plants.

5.3 Further Study and Research

Based on the results and constraints of the study, it is recommended that: There has been much research on the relationship between safety and quality, and also between TPM and productivity. The figures of improvement in safety performance due to implementation of TPM are very often by-products of the research. Studies on how TPM improves the safety performance are rare. Further research on this topic is necessary to support the findings of the study.

For future research, measuring the safety culture of an organization before and after implementing TPM; or comparing the safety culture between two organizations of similar background in the manufacturing field, similar number of employees, similar size of plants, similar years of OHS management system in place, similar organization structure and safety structure etc. will give a more reliable result as well.

The framework of TPM activities developed in the study is only a start. The effectiveness and practicality of the framework have to be confirmed by further studies. Further studies on how to integrate the existing safety structure of an organization into the TPM structure are also recommended.

5.5 Conclusion

In this study, it had been shown that a manufacturing company with TPM in place had a more positive safety culture than one not implementing TPM. Notwithstanding the limitations of this study, the results provide strong empirical support for the proposed solution, namely to establish a TPM system (see Figure 7 for the TPM approach to effective OHS management) to tackle the problem 'high standards of health and safety still cannot be assured even though OSH management systems have already been in place."

The study demonstrates that effectiveness of an OSH management system depends on the safety culture of the organization, and that the safety culture is a result of whether the organization has adopted a proactive or reactive approach towards safety. TPM can enhance eight safety culture factors that can influence the 'proactivity' of an organization. The eight factors identified are management incentive, management commitment, participation of management and worker, communication, education and training, improve working conditions and procedures, morale and job satisfaction, and finally the attitude and risk perception.

This dissertation evaluated the safety culture of the ABC Company based on the eight safety culture factors identified. These eight factors have been used by researchers to evaluate safety culture and have been shown effective. The results showed that there is much room for the company to improve. It is critical to learn from the results that in ABC Company many respondents did not believe accidents are preventable and did not regard complying with safety rules as important. The company has a plan to implement TPM. The framework of TPM activities developed in the dissertation can give a guideline for ABC Company to set up and implement the TPM activities that can improve the safety performance of the company. The framework can also be a general guideline for medium size companies in manufacturing industry to set up TPM activities to improve safety performance. The first step to world-class manufacturing is to implement TPM successfully and to create a very active organization. When TPM becomes a common practice in daily production of the ABC Company, it can be said that the company has commenced a journey to word-class manufacturing.

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