A study of total productive maintenance implementation

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Abstract *This paper focuses on a study of total productive maintenance (TPM) in three companies. The companies implemented TPM because of the business difficulties they faced. In all three companies senior management had supported TPM and set up suitable organisational structures to facilitate its implementation. The companies had followed Nakajima's seven steps of autonomous maintenance, although different TPM pillars had been adopted, with the common ones being improvements, education and training, safety, and quality maintenance. The main differences in TPM implementation related to the use of ABC machine classification system and the role of facilitators.*

Practical implications

This paper details for practitioners how three companies have approached the implementation of TPM. It provides practical guidance on the type of TPM process which is suitable for different circumstances and in relation to specific strategic company objectives. From the data provided practitioners are able to grasp the importance of a relevant infrastructure, in particular, the role played by TPM co-ordinators and the type of training which is required for different levels of the organisational hierarchy. The seven TPM pillars (i.e. focussed improvements, autonomous maintenance, planned maintenance, quality maintenance, education and training, early equipment maintenance, and safety and the environment) are critical to the success of TPM, and each case study highlights the means of putting these pillars in place.

Introduction

The Japanese, based on the planned approach to preventive maintenance (PM), evolved the concept of total productive maintenance (TPM). Nakajima (1986) outlines how, in 1953, 20 Japanese companies formed a PM research group and, after a mission to the USA in 1962 to study equipment maintenance, the Japan Institute of Plant Engineers (JIPE) was formed in 1969, which was the predecessor to the Japan Institute of Plant Maintenance (JIPM). In 1969, JIPE started working closely with the automotive component manufacturer – Nippondenso – on the issue of PM, and when the company decided to change roles of operators to allow them to carry out routine maintenance this was the beginning of TPM. Tajiri and Gotah (1992) point out that whilst TPM was communicated throughout Japan only a small number of factories took up the challenge. It was the severe economic situation in the early 1970s that accelerated the adaptation of TPM, propagated by the seven-step programme developed by the Tokai Rubber Industries (see Nakajima, 1989).

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In the early 1990s, Western organisations started to show interest in TPM following on from their total quality management (TQM) interventions. Whilst there are a number of publications (e.g. Nakajima, 1988, 1989; Suzuki, 1994; Sekine and Arai, 1998; Hartmann, 1992; Wilmott, 1994) on the subject, there is little in the way of empirical study and analysis. The more academic papers focus on the relationship of TPM with other productivity initiatives (e.g. Maggard and Rhyne, 1992) and discussion of a specific application of TPM and the benefits (e.g. Koelsch, 1993). This paper examines how TPM was implemented at three companies, with particular focus on the: TPM journey; TPM processes used; role of TPM co-ordinators; and the company's TPM goals. In summarising the main findings of the study, a comparative analysis of the different approaches is presented. The study was conducted by semi-structured interviews with key personnel, note-taking of TPM meetings, and analysis of company documentation.

Company A

This case study is based on a UK plant which was opened in 1968 to increase production in the range of rubber products produced by the group. The group has around 38,000 employees and achieves annual sales of some £4.5 billion covering a range of products.

The economic recession of the early 1990s badly affected the markets for the products of the plant at the focus of the study. In order to achieve success in this highly competitive market, Company A recognised it would have to become "world class". An analysis of the product market highlighted the constant growth rate of the high-performance product segment and the need for: innovative products with progressively shorter life cycles; more rigorous quality standards for both original equipment (OE) and replacements; and greater attention to environmental matters. At the time this analysis was undertaken there was a gap between the activities of Company A and the strategic targets of the group. Company A was also experiencing inadequate skill levels, low employee participation in its affairs, and a lack of application of appropriate continuous improvement methodologies. To address these issues Company A decided to implement TPM.

The TPM journey started in the early 1990s when the company launched its seven pillars of TPM: individual improvements; autonomous maintenance; education and training; TPM in the offices; safety; early equipment management and quality maintenance. Two years later they were awarded the JIPM preventive maintenance (PM) Award, and are now regarded as one of the TPM leaders in the UK.

TPM process

A TPM steering committee was set-up with the site director as chair and production, maintenance, human resources, and continuous improvement managers as members, along with trade union representation. The overall aims for TPM were to:

- achieve zero losses in accidents, defects and failures;
- create a corporate system to maximise efficiency of the process;
- involve all sectors including production, development and administration;
- involve all employees from senior management to operators and clerical staff; and
- develop small group activities.

Under a cost deployment pillar, the actual costs for each function were broken down. Pareto analysis was carried out to identify the relevant costs and their associated benefits to enable improvements to be assessed with respect to financial benefits. For the latest two-year period for which data were available, the costs of TPM were estimated to be £400,000, with benefits of over £2m.

The company analysed its six big losses (i.e. breakdowns, set-ups, speed losses, minor stoppages, lack of material and defects), according to the methodology of Nakajima (1989), and used the overall equipment effectiveness (OEE) measure to set targets to reduce these losses. It also identified its value-added, semi-value added and non-value added operations; with semi-value added operations being minimised and non-value added operations eliminated.

The autonomous maintenance process provided the company with its biggest changes to organisational culture and competencies. The company followed Nakajima's (1988) seven steps of autonomous maintenance (i.e. initial cleaning, countermeasures for the causes and effects of dirt and dust, cleaning and lubricating standards, general inspection, autonomous inspection, organisation and tidiness, and full implementation of autonomous maintenance) and during the first step of cleaning and tagging, which were undertaken in the first two years, they generated 11,600 tags.

In order to prioritise improvement activities, the company adopted an ABC classification system similar to that detailed by Suzuki (1992). Out of a total of 329 machines, TPM activities were carried out on only the top ten, with detailed breakdown analyses and corrective measures instituted. A programme of machine restoration was then followed with emphasis on fitting countermeasures to make it easier for operators to clean, inspect, ensure quality and optimise output. With the implementation of autonomous maintenance, the gradual change from breakdown maintenance, to planned, preventative and predictive maintenance was achieved, with consequential changes to the organisation, and operation of the maintenance function.

All the managers were trained in TPM and this knowledge helped them to support the strong TPM drive from senior management down to the shop floor. Operators were trained mainly on autonomous maintenance techniques. The company suggestions scheme was removed after the management team decided that it hindered progress with TPM.

TPM co-ordinators

When TPM was first implemented, three TPM co-ordinators were appointed, reporting to the continuous improvement manager. Their role was to facilitate the implementation of TPM by working with the TPM teams and team leaders. The company still has the co-ordinators, but the cell leaders carry out the majority of the facilitation work. To provide technical support to the teams, improvement engineers were allocated to each department.

Strategic objectives

The strategic objectives for the group of which company A is part are to:

- standardise organisational models world-wide;
- increase autonomy and empowerment to all organisational levels;
- introduce effective and efficient teamworking;
- make empowered team structures;
- improve flexibility and reaction time to customer needs; and
- improve competitiveness, quality, performance and cost.

The organisational model involves reducing the number of layers from five to three in the organisation (i.e. director, manager, department manager, supervisor and director) (i.e. factory management team, factory team, and shift teams (i.e. cells) respectively. The factory management team is responsible for the strategic plans, policies, procedures and know-how, as well as external communication and internal co-ordination. It is the team's responsibility to ensure standardisation and consistency of application throughout the factories. The factories have their own manager and a team of support staff in maintenance, quality, process efficiency and planning. The shift teams are self-managed work teams whose cell leaders have expertise in coaching, communication, team working and problem solving.

Company B

The company specialises exclusively in packaging, it has a global network spanning 30 countries in Europe, Asia, Africa and America and there are over 30,000 people employed at its 160 factories world-wide. The plant at the focus of the study was first opened in the 1950s.

In 1990 the plant was heading towards closure, and as a consequence, decided in 1991 to implement total quality management (TQM) and followed this with TPM in 1994; TPM projects were focussed around a bottleneck analysis undertaken on the factory. By 1996, 16 successful projects had been completed, but senior management wished to accelerate the pace of improvements, so it set the goal of achieving the JIPM award by 1998; the "TPM Excellence First Category" was achieved by this date.

The company has used the seven TPM pillars (i.e. focused improvements; autonomous maintenance; planned maintenance; quality maintenance;

education and training; early equipment management, and safety and environment) in its implementation of TPM. Each pillar has seven steps which are oriented around the plan-do-check-act cycle and have allocated pillar champions.

In the last three years for which data are available the following improvements have been made: the percentage of the workforce involved in TPM has increased from 10 per cent to 85 per cent; customer complaints have reduced to 20 per cent of their value in 1995; production volumes have increased by 40 per cent with the same number of employees; overtime costs were reduced by 40 per cent; absenteeism has been reduced by 43 per cent; and the output per employee has increased by 46 per cent.

TPM process

A TPM organisational structure was established, termed world class performance (WCP) promotion organisation see Figure 1. The factory was divided into three modules and each of these was managed by module leaders. There were no specific TPM facilitators/co-ordinators employed, instead the overall TPM process was managed by the WCP manager with the support of the module leaders, their teams and the pillar champions.

The company's TPM policy was:

> Achieve World Class Status through awareness and improvement of the complete workforce. Training and involvement in continuous improvement activities, providing the tools and techniques to attach and eliminate all known losses, to impact on our quality, productivity and profitability.

Cost and volume deployment techniques were used to identify areas where focussed improvements were carried out and to help identify what techniques were applicable. Nakajima's (1988) seven steps of autonomous maintenance were followed by Company B and they also introduced planned maintenance. Quality maintenance was used to eliminate defects by the setting and control of

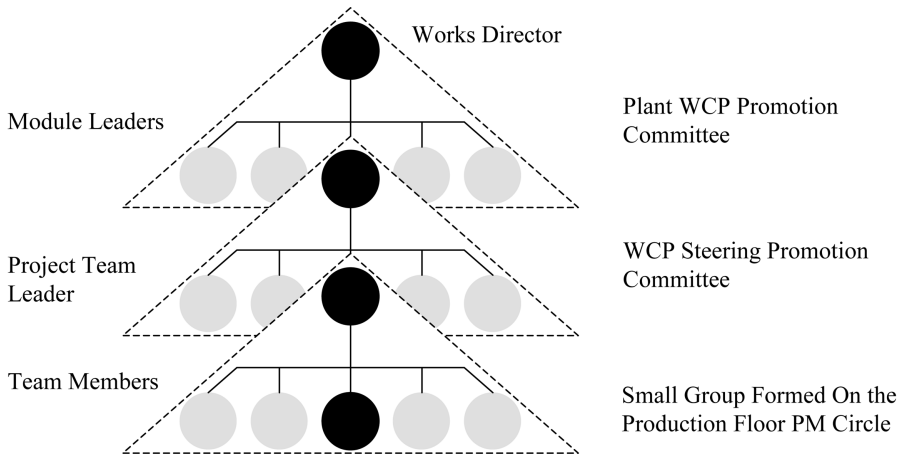

Figure 1.
WCP promotion organisation

equipment conditions. The process was carried out by first determining the relationship between key product characteristics and the production process. The optimum operating conditions, which eliminate defect products, were determined and the machine restored to these conditions, then the machines were modified to sustain these optimal settings. For education and training purposes the company focussed on developing multi-skilled employees so that they could achieve all the other TPM pillars.

Nakajima's (1988) early equipment management approach was used as a structured process between the production plant and those responsible for purchasing and/or designing new equipment. With this the product and process manufacturing experience was gathered and documented, then new equipment was developed. The company used tools and techniques such as QA Matrix, Process FMEA, Cm/Cmk and Cp/Cpk for this purpose.

The company's safety and environment objectives were also linked directly to TPM, they were to:

- create a safe working environment;
- comply with legal constraints; and
- reduce costs, by reducing the number of accidents.

Strategic objectives

The company have set themselves the following targets for improvement:

- the percentage of the workforce involved in TPM;
- customer complaints;
- production quantities;
- overtime costs;
- absenteeism; and
- output per employee.

For each of the seven TPM pillars, written plans have been developed, for example the planned maintenance plan is:

- expand breakdown successes to the rest of the department;
- continue to support autonomous maintenance;
- expand the development of computerised systems;
- continue with stock reduction;
- expand zone maintenance systems to other machines;
- develop thermal imaging systems to incorporate mechanical parts;
- communicate with suppliers for other systems (e.g. vibration analysis);
- continue the development of systems for tighter budget control; and
- review maintenance costs.

Company C

The company manufactures motorised vehicles. In the mid 1980s a Japanese company bought a 60 per cent share in the company and by the late 1980s this had increased to 99 per cent. The Japanese company brought with them the TPM process and stability for the factory by guaranteeing everyone's job for three years. By the late 1980s the company was using three pillars of TPM – 5S, OEE and motivation – the focus being to eliminate losses in quality, cost and delivery. From 1992 to 1994 company C developed its TPM approach to cover offices, autonomous maintenance and planned maintenance. In 1994 it was awarded the JIPM (TPM) Level 1 Award. Using the pillars of: improvements; autonomous maintenance; planned maintenance; education; preliminary maintenance; quality maintenance; TPM in the offices; safety and environment, the company is aiming to achieve JIPM Level 2 by 2001.

TPM process

When TPM was launched the company appointed a TPM team of 12 facilitators/co-ordinators reporting directly to the factory president. They used cost deployment to identify improvement areas. Their main focus was to increase productivity and reduce the work space, resulting in an increase in the quantity of products they manufacture on their site and hence increasing market share. An example of this is that in 1989 it took 35 days to manufacture a motorcycle, currently it takes seven days. The company is now focussing on how to achieve the optimum in line balancing and one-piece flow.

The company follows Nakajima's (1988) seven steps of autonomous maintenance. After each of Nakajima's (1988) seven steps has been implemented on a machine an audit is undertaken. The team's managers check the audit and if satisfactory, give the team a small award so they can progress to the next level. The company's success is demonstrated by the fact in 1999 only 877 breakdowns of more than five minutes duration were experienced on their 1,123 machines and the average time between breakdowns was 1.3 years. The measurements are made by using a combination of OEE and line balancing, and this results in an ABC classification system that prioritises machines for production and maintenance. For example, an A class machine is one which is a bottleneck on a particular production line and there is no replacement equipment if it breaks down; "A" class machines are therefore the first to be repaired, planned maintenance is a priority and they are operated continuously. OEE is measured on all "A" class machines to help focus improvement activities: currently Company C only measures OEE on 30 per cent of its machines.

The key focus of Company C is its people and their training; at the time of this study about 2.5 per cent of its annual sales turnover was spent on training. The increase in operators' skill levels means that there are now no setters or inspectors. The number of maintenance staff has also reduced (e.g. there are only four maintenance staff in the machine shop to attend to 350 machines). There is also a strong focus on the team, with each TPM team generating their

own three-year business plan and they then manage their TPM board to help communicate the progress made. The teams also have an improvement engineer who, if a member of staff identifies an improvement, will assist with its development. An indication of the commitment to the workforce is that 300 operators were sent to Japan for three months to work with their counterparts. Company C has also focussed on flattening its organisational structure and currently has four layers: operators; improvement engineers/assistant; team leaders; and factory director.

TPM is not only utilised on the factory floor, but also in the office environment, where 30 per cent of the administrative activities have been removed.

TPM co-ordinators

When TPM was first launched, a TPM team of 12 facilitators/co-ordinators was appointed, and at the time it supported 1,400 employees. The size of this team has reduced with increased ownership of TPM on the shop floor; currently it has four TPM facilitators/co-ordinators. The importance of TPM is emphasised by the fact that the TPM team reports direct to the factory president.

Strategic objectives

The goal is to achieve the JIPM Level 2 award by 2001; this involves improving all areas by a further 50 per cent, and the aim is to increase their market share for all products.

Summary

The three companies are large global companies exporting to international markets, and have been located on existing sites for more than 30 years. All three companies implemented TPM because they were exhibiting considerable business difficulties (e.g. reduction of business in traditional markets and facing plant closure). As Steinbacher and Steinbacher (1993) state, you "need dissatisfaction with the way things are to initiate the need for change . . .". Davis (1996) supports this by stating that one of the main reasons companies fail with TPM is because the ". . . company is not serious about change . . .", as do Maggard and Rhyne (1992). "At least 2 to 3 years, most likely 5 years are required for a total TPM implementation, but if there is no urgency for change this could take longer."

All three companies had TPM organisational structures, where the TPM manager reported directly to senior management. TPM implementation was facilitated by the small number of management layers in each company. They also followed Nakajima's (1988) seven steps of autonomous maintenance and employed the JIPM recommended approach. Company A attained the JIPM award in 1995, Company B in 1998 and Company C in 1994. Even though different TPM pillars were adopted by the three companies, they all employed improvements; autonomous maintenance; education and training; safety, and

quality maintenance. They also used cost deployment to help focus improvement activities to the areas where the greatest benefits would be achieved. To help with this and to support the specific goals each company set itself: Company A used Pareto analysis, Company B volume deployment and Company C line balancing. A strong focus on training of all personnel was evident in all three companies.

There are a small number of differences in how TPM was implemented: the different pillars adopted; the use of the ABC machine classification system; and the role of facilitators. Companies A and C have 329 and 1,123 machines respectively in comparison to Company B which has less than 50. This is the main reason why they utilised the ABC machine classification system to help them decide on priorities for improvements and maintenance. Company B, on the other hand, used bottleneck analysis to determine areas for focussed improvements.

Companies A and C have used TPM co-ordinators/facilitators to help implement TPM in their factories. Company A employed three TPM co-ordinators for their 700 employees and Company C 12 for their 1,400 employees. On the other hand, Company B, with only 130 employees, had only their world class performance manager to implement TPM.

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