STRATEGIC APPROACH TO ENSURE PROCESS SAFETY IN APPAREL MANUFACTURING INDUSTRY USING TOTAL PRODUCTIVE MAINTENANCE (TPM)

H.W.S.N. Denipitiya*, Nayanthara De Silva, S.D.A. Soorige and H.W.N. Madhusanka

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Accidents in the apparel manufacturing process lead to huge monetary and productivity loses. Total Productive Maintenance (TPM) can be identified as a rapidly spreading process improvement tool which is targeting zero defects, zero breakdowns and zero accidents. The aim of this research was to explore the suitability of TPM to ensure Process Safety (PS) in the apparel industry. An extensive literature review was carried out to identify process safety, process accidents and relationship between process safety TPM in the apparel industry. Accordingly set of accidents and existing Occupational Safety and Health (OSH) practices were identified in the apparel manufacturing process.

Both qualitative and quantitative approaches were used for the effective fulfilment of research aim. During first phase of data collection questionnaire survey and document survey were carried out with support of OSH experts to gather knowledge regarding process related accidents. Second phase of data collection was conducted using semi structured interviews and observations to identify TPM approaches used to enhance the PS in apparel manufacturing process.

Findings of the study revealed that implementing TPM led to improve the process safety in the apparel manufacturing process up to some extent. But 90% of the identified TPM approaches focused to ensure the production and quality systems. Therefore, process safety was not adequately addressed by identified TPM approaches in both cases. Hence after implementing TPM, still there were accidents in the apparel manufacturing process. Since the research highlighted the importance of paying adequate attention to process safety when implementing TPM otherwise achieving zero accidents remains as a challenge.

Keywords: *Apparel Manufacturing Process; Process Safety (PS); Total Productive Maintenance (TPM); Safety Health and Environment (SHE).*

1. INTRODUCTION

Apparel industry in Si Lanka acts as the major contributor in Sri Lankan economy among the other different types of manufacturing industries and exports garments to many leading buyers in the world. Quality of garments manufactured in the country is a key contributor to retain in the international market. Therefore, it is vital to maintain the quality of the garments along with the productivity (Kapuge and Smith, 2007). There are different mechanisms available to improve the product quality and the productivity of the process and among that Total Productive Maintenance (TPM) can be identified as one of the key contributor.

TPM is a resource based management tool which directly influences to the worker-subsystem and machine-subsystem in the manufacturing process (McKone *et al*., 2001). The core TPM initiatives can be classified into eight TPM pillars or activities to accomplish the manufacturing performance improvements which includes Autonomous Maintenance, Focused Maintenance, Planned Maintenance, Quality Maintenance, Education and Training, Office TPM, Early Management and Safety Health and Environment (SHE) (Ahuja and Khamba, 2008). Considering the different pillars of the TPM SHE pillar directly relates to improve the process safety by minimising the accidents.

*Corresponding Author: E-mail - sahandeni@gmail.com

SHE pillar focuses on creating a safe workplace and a surrounding area that is not damaged by production process or procedures. This pillar plays an active role integrating each of the other pillars on a regular basis. SHE pillar targets are zero accident, zero health damage, and zero fires (Wakjira and Singh, 2012).

Apparel manufacturing industry is more labour intensive and therefore, number of potential accidents are higher in the process. According to a research done by Calvin and Joseph (2006) physical, chemical, biological and ergonomics hazards are the major hazards allied with the apparel industry. Both minor and major, accidents are frequently occurred in the apparel industry and minor accidents include falls, cutting and bruising, major accidents include fingers can get caught in the machines, puncture, incise wound, blunt injury, pinch points, amputation and injuries due to chemical splashes (Basso *et al*.,2004).

Further, in an analysis of process accidents in Sri Lanka by Gunasekara and De Alwis (2008), categorise the stage of accident taken place as processing, loading/unloading, maintenance/repair, transportation (onsite/offsite), storage and unknown. Among these stages most of the accidents occur, due to human failures and technical failures, occurred during the manufacturing process. Since the apparel industry is highly labour intensive, the risk is applicable to the industry up to a greater extent. In mitigating such accidental risk various standards are implemented, such as Occupational Safety and Health Assessment System (OHSAS) 18001, Ethical Trading Initiative (ETI), Worldwide Responsible Accredited Production (WRAP), CT-PAT, other international safety standards and buyer’s standards.

Even though such standards, audit systems, precautionary methods and commitment exist still workplace accidents are often occurred in apparel industry. Therefore, the need has risen to improve the occupational safety and health. TPM can be identified as a tool to improve the processes and also it can be applied to improve the process safety of the apparel industry. According to Gunasekara and De Alwis (2008) also the stage where the accidental risk is higher also during the manufacturing process/stage. Therefore, to improve the process safety TPM can be applied specially concerning the SHE pillar. Based on the factors the research problem was how TPM can ensure the process safety in apparel manufacturing. The research was aimed to explore the suitability of TPM to ensure Process Safety in the apparel industry and to achieve such aim, following objectives were set.

- Identify process related accidents in apparel industry
- Review the approach of promoting TPM to ensure process safety
- Evaluate the reduction in process accidents by implementing TPM

2. LITERATURE SYNTHESIS

According to Howard (1993), apparel manufacturing is an assembly oriented production process with a great range of raw materials, product types, production volumes, supply chains, retail markets and associated technologies. Production process of apparel manufacturing includes number of functions such as cutting, sewing, quality checking, washing, finishing, inspection and packing (Park-Poaps, 2009).

In the production process proper safety precautions should be taken to minimise or eliminate the accidents. According to Langerman (2015), process safety can be achieved in several ways such as proper designing, engineering techniques and operating and maintenance practices. Process safety leads to prevent and control the events with potential to create hazardous activity. When it comes to the Sri Lankan context Ministry of Health estimates that nearly 15% of the total admissions due to injuries at the Colombo National Hospital in 2011 were work-related (Madurawala, 2015). Therefore, the process safety has become a factor to be considered by the organizations.

2.1. PROCESS RELATED ACCIDENTS

On the other hand, in Sri Lankan context, compensation paid by employers to the victims of work related accidents in 2007 is Rs.65,417,100.00 and in 2012 is Rs.77,119,389.57 (Central Bank of Sri Lanka and Ministry of Labour and Labour Relations, 2009; Central Bank of Sri Lanka and Ministry of Labour and Labour Relations, 2012). Nevertheless, these amounts are only in respect of cases notified to the Commissioner for Workmen’s compensation. However the total cost of occupational injuries mainly consists of non-financial human costs, costs of the lost production, medical costs, compensation for lost wages, production disturbance and administrative and legal overheads and it is not only the employers, workers and the governments who bear the costs of occupational injuries and diseases (Rao, 2007).

In cutting and sewing processes there are different types of machines used and some are used to knit and weave, sew or cut patterns and cloth, some press or steam, and others transport apparel pieces on the factory floor (Czarnecki, 2000). These large number of different machines can cause major accidents, such as puncture, incise wound, blunt injury, pinch points, and amputation (Aneziris *et al*., 2013).

2.2. SIGNIFICANCE OF TPM FOR PROCESS SAFETY

TPM which is an equipment management approach and the methodical application of maintenance interact all workers company wide, allowing organisations to accomplish their objectives of zero breakdowns, zero defects and zero accidents (Nakajima, 1989). In other words, according to Poduval *et al*. (2013), the passion of TPM is incorporated in the three words. "Total" means the whole workforce from top management to the machine operator, "Productive" means how to get greater excellence work out of employees and finally, "Maintenance" is the encouragement of sense of possession in operators.

Safety, Health and Environment (SHE) is the last TPM pillar and carryout a procedure to initiative in the direction of the accomplishment of zero accidents (Tsang and Chan, 2000). Even though made known as the last pillar of TPM, the TPM Safety and Environmental pillar is in the same way, if not more, vital than the seven other pillars (Wireman, 2004). The application of SHE approaches take place during the TPM setting out process and SHE activities are at no time complete (Ahuja and Kumar, 2009).

SHE pillar initiatives aim to reactively remove the root causes of occurrences that have happened, to avoid reoccurrence, and proactively decrease the risk of future probable occurrences by aiming near misses and potential hazards (Cooke, 2000).

Suzuki (1994), delivers illustrations of how TPM expands safety and environmental protection,

- Defective or unreliable equipment is a source of danger to the operator and the environment. The TPM objective of Zero-failure and Zero-defects directly supports Zero-accidents.
- Autonomous Maintenance teaches equipment operators how to properly operate equipment and maintain a clean and organized workstation. 5S activity eliminates unsafe conditions in the work area.
- TPM-trained operators have a better understanding of their equipment and processes and are able to quickly detect and resolve abnormalities that might result in unsafe conditions.

The immediate benefits of implementing the SHE pillar are to prevent reoccurrence of lost time accidents and reduce the number of minor accidents as well as preventing environmental system failure. This has a direct financial saving in the cost of containment, investigation and compensation as well as reputational impact (Sharma *et al*., 2006).

3. RESEARCH METHODOLOGY

Initially, an extensive literature review was conducted to primarily identify the importance of apparel sector to Sri Lanka, occupational safety and health issues in apparel sector and TPM concept. Then data collected through two phases.

Phase I was used to validate the accidents determined through the literature survey. Two professionals were contributed to the survey to specifically identify the process related accidents in apparel sector. The professionals were selected mainly based on their experience, rank and responsibilities within the department. All the respondents had experience in the department for more than 2 years. Twelve identified accidents were presented for the phase I data collection to search for actually existing process related accidents. Additionally, document surveys were conducted to collect the numerical values regarding accidents occurred before and after implementing TPM. Further, respondents were requested to recommend some additional accidents that take place in their premises which was not identified in the literature review. Final Interview guideline was developed with the findings of literature review and phase I data collection. The Interview guideline was consisted with accidents identified in literature review and phase I data collection. Phase II data collection was done to identify TPM process improvements which ensure the process safety in apparel manufacturing process. TPM pillars and accident root causes were presented to find most appropriate TPM technique to avoid those accidents. Respondents are requested to give their recommendations in line with the implemented techniques and as well as from theoretical background.

Multiple case study approach was identified as a suitable method because TPM implementation in process wise and plant wise different to each other. Therefore, two case studies were selected considering the number of years plant occupied, number of employees and number of phases of TPM implemented.

Hence all plants were occupied more than 10 years in industry. Furthermore 1,000 exceeds employees were working daily in selected plants. For an example 1,750 direct employees were engaged in the production lines of case study A. With all the other departments it will be 2,200 total employees in case study A. In the same way all plants were in second phase of the TPM implementation. It means they have done TPM implementation to production process and support services also. Therefore, it was easy to gather data which relevant to achieve the aim and objectives

Data analysis was carried out as statistical analysis and content analysis. Accordingly, in the statistical analysis significant accidents were identified by using the number of occurrences and lost time creation due to the accidents. Lost time was measured by using man-days. In addition, three equations were used to compare, the number of occurrences and lost man-days produce, before and after TPM implementation, namely annual man days lost rate, standardised lost man days per employee and rate of reduction in annual man days lost rate. Annual man days lost rate was calculated using the following formula:

$$\text{Annual man days lost rate} = \frac{\sum_{i=1}^{n} lt \text{ i}}{W \times d} \qquad \text{(Eq: 01)}$$

Where, *lt* = Lost time, *w* = Number of workers, *d* = Number of working days per year, *i* = Particular accident and *n* = Annual number of occurrences in particular accident.

Annual man-days lost rate represent ratio between lost man-days due to particular accidents to total number of man-days per year. Hence, identified annual lost rate of particular accidents separately. Furthermore, most lost man days created accidents were identified and included to the semi structured interview and then expert opinions were gartered for the same.

Standardised lost man-days per employee calculated using the following formula,

$$\text{Standardised lost man days per employee} = \frac{\sum_{i=1}^{n} lt}{w} \qquad \text{(Eq: 02)}$$

Where, *lt* = lost time, *i* = accident type and *w* = number of workers.

Standardised lost man days per employee represents ratio between lost man days due to particular accidents to total number of employees. The standardised lost man days per employee was calculated separately for each and every accident, which helped to further identify the accidents which had most impact to the productivity of the organization. Moreover, accident comparison between before and after implementation of TPM could be done using figures from these equations.

Rate of reduction in annual man days lost rate calculated using following formula,

$$\text{Rate of reduction in annual lost rate} = \frac{X1-X}{X1} \times 100\% \qquad \text{(Eq: 03)}$$

Where, *X1* =annual lost rate before implementing TPM and *X* = annual lost rate after implementing TPM.

Rate of reduction in annual lost rate represent the reduction of the accidents after implementing TPM compared to before implementing the TPM. Most TPM approaches addressed accidents could be identified by the rate of reduction in annual lost rate.

Content analysis was carried out by analysing the responses of each interviewee. Respondents were requested to elaborate how TPM techniques were used to avoid listed accidents and how they have overcome the root causes in their places. Findings of semi structured interviews, was comprehensively discussed in this section. The section also contains a detailed discussion on improved and possible improvement strategies of TPM.

4. DATA ANALYSIS AND FINDINGS

Twelve types of accidents were identified in apparel manufacturing process in both cases. Number of accidents and lost time created by particular accidents were collected in phase I data collection. Incise wound accident was the mostly occurred accident in both cases before implementing TPM and the total of both cases amounted to 161 times (Case A - 80 times and Case B - 71 times). After implementing TPM, only 59 times incise wound accidents were occurred in both cases (refer Table 1).

When considering the prick injury accidents, it was identified as the second highest number of accidents which were occurred before implementing TPM in both cases. In total 135 accidents which distributed as 75 and 60 in cases A and B respectively before implementing TPM. After implementing TPM, prick injury accidents were occurred only 42 times in both cases, as 22 accidents in Case A and 20 accidents in Case B (refer Table 1). Third highest number of accidents count was recorded from contusion accidents before implementing TPM in both cases. In total 99 contusion accidents were occurred in both cases before implementing TPM and respectively 45 accidents in Case A and 34 accidents in Case B. After implementing TPM total contusion accidents reduced to 41 accidents, as 24 accidents in Case A and 17 accidents in Case B (refer Table 1).

Laceration injury accident was occurred 96 times before implementing TPM in both cases as 49 accidents and 47 accidents were occurred in the Case A and Case B respectively. However, after implementing TPM total laceration injury accidents have reduced to 33 accidents (refer Table 1).

Furthermore, irritation of eyes accidents occurred 79 times in both cases before implementing TPM. Respectively, 47 accidents and 32 accidents was happened in case A and case B. After implementing TPM total number of irritation of eyes accident was reduced to 26 times (refer Table 1).

Table 1: Number of Accidents Before and After Implementing TPM

Accident Type	Case A		Case B		Total	Case A		Case B		Total
	2011	2012	2011	2012		2013	2014	2013	2014	
Prick Injury	43	32	25	35	135	12	10	9	11	42
Sprain	20	13	10	14	57	25	30	20	17	92
Blunt Injury	1	1	2	1	5	1	2	0	4	7
Pinch points	0	1	1	0	2	0	2	1	1	4
Contusion	43	22	15	19	99	14	10	10	7	41
Laceration injury	30	19	18	29	96	9	7	11	6	33
Electrical shock	2	0	2	1	5	0	1	3	1	5
Irritation of eyes	30	17	12	20	79	5	8	9	4	26
Incise wound	48	32	34	47	161	21	12	16	10	59
Hair stuck	1	0	0	0	1	1	1	1	0	3
Compound fracture	3	0	3	2	8	3	2	1	2	8
Soft tissue injury	1	2	1	2	6	3	2	1	1	7

Table 2: Number of Loss Man-days Before and After Implementing TPM

Accident Type	Case A				Case B				Case A				Case B			
	Man days lost 2011	Man days lost 2012	Annual man days lost rate	Standardized lost man days per employee	Man days lost 2011	Man days lost 2012	Annual man days lost rate	Standardized lost man days per employee	Man days lost 2013	Man days lost 2014	Annual man days lost rate	Standardized lost man days per employee	Man days lost 2013	Man days lost 2014	Annual man days lost rate	Standardized lost man days per employee
Prick Injury	15	25	0.00877193	0 .021053	20	27	0.00783333	0.018800	9	8	0.0037281	0.0089474	7	9	0.00266667	0.006400
Sprain	47	30	0.01688596	0.040526	23	33	0.00933333	0.022400	58	70	0.0280702	0.0673684	46	39	0.01416667	0.034000
Blunt Injury	3	3	0.00131579	0.003158	6	2	0.00133333	0.003200	3	6	0.0019737	0.0047368	0	10	0.00166667	0.004000
Pinch points	0	5	0.00109649	0.002632	5	0	0.00083333	0.002000	0	8	0.0017544	0.0042105	4	3	0.00116667	0.002800
Contusion	89	45	0.02938596	0.070526	31	39	0.01166667	0.028000	31	22	0.0116228	0.0278947	22	14	0.00600000	0.014400
Laceration injury	38	24	0.01359649	0.032632	23	37	0.01000000	0.024000	11	8	0.0041667	0.0100000	14	7	0.00350000	0.008400
Electrical shock	4	0	0.00087719	0.002105	4	2	0.00100000	0.002400	0	2	0.0004386	0.0010526	7	2	0.00150000	0.003600
Irritation of eyes	68	39	0.02346491	0.056316	27	46	0.01216667	0.029200	11	18	0.0063596	0.0152632	20	9	0.00483333	0.011600
Incise wound	63	42	0.02302632	0.055263	44	61	0.01750000	0.042000	27	15	0.0092105	0.0221053	20	13	0.00550000	0.013200
Hair stuck	3	0	0.00065789	0.001579	0	0	0.00000000	0.000000	2	3	0.0010965	0.0026316	3	0	0.00050000	0.001200
Compound fracture	3	0	0.00065789	0.001579	3	2	0.00083333	0.002000	4	2	0.0013158	0.0031579	2	3	0.00083333	0.002000
Soft tissue injury	2	2	0.00087719	0.002105	4	2	0.00100000	0.002400	4	2	0.0013158	0.0031579	5	1	0.00100000	0.002400

Considering the number of accidents, most significant impact for the business was lost time created by those accidents. The production was considerably affected due to those accidents. Lost time related to accidents occurred before and after implementing TPM was further elaborated using annual man days lost rate and standardized lost man days per employee (refer Table 2).

Man day lose before and after can be shown by taking one accident as an example. Comparing all the accidents, highest loss man days were created by incise wound accidents before implementing TPM. It was 210 man-days in both cases and each case amount to 105 man days (refer Table 2). These 210 loss days were created due to 161 accidents in both cases. Hence average loss man days per accidents was 1.5 man days. After implementing TPM in both cases number of lost days due to incise wound accidents were reduced to 75 man days. It was average of 1.2 man days was loss due to incise wound accidents after implementing TPM in both cases. However, after implementing TPM still incise wound accident was the highest in loss man-days.

When consider about the annual man-days loss rate before implementing TPM, in Case A it was 0. 02302632. Even though the calculated figure was a very smaller value since it has considered the total man days of two years. This value can be used to compare and identify the rate of lost man-days reduction.

Likewise standardized lost man days per employee in incise wound accidents before implementing TPM in Case A was 0.05526316. As same in above calculations this figure can be interpreted as follows,

$$\text{Standardized lost man days per employee} = \frac{\text{Total loss man days per partcular accident}}{\text{Number of employee}} \qquad \text{(Eq: 04)}$$

Hence, standardized lost man days per employee give the figure as a ratio to total number of employees. Therefore 0.05526316 can be interpret as,

$$\text{Man days lost per employee out of total man days per two years} = \text{Standardize lost man days per employee} \times \text{Total number of employee} \qquad \text{(Eq: 05)}$$

$$= 0.05526316 \text{ x } 950$$

$$= 52.5 \text{ man days}$$

It indicates there was a possibility of losing 52.5 man days from an employee out of total working man days in a year. So in a year, from an employee 52.5 man days were lost due to incise wound accidents in Case A. After implementing TPM this figure was dropped to 21.5 man days from an employee. Similarly, before implementing TPM in Case B standardised lost man days per employee due to incise wound accidents was 52.5 man days in a year. After implementing TPM this figure was reduced to 16.5 man days in a year. Accordingly, these figures can be calculated based on the data available in Table 2.

The empirical findings highlighted a different influence of TPM implementation four different types of accidents based on the above calculations incise wound, price injury, irritation of eye, contusion and laceration injury were reduced and sprain, electrical shock, blunt injury, pinch points, hair stuck, soft tissue injury and compound fracture accidents did not show any influence to reduce number of accidents even after implementing TPM.

5. CONCLUSIONS

The empirical study was focussed on studying the TPM implementation in the apparel industry and the relationship of TPM and the process safety. The literature review was focussed on identifying the different types of accidents available in the garment manufacturing process. Then the accidents identified through the literature were reviewed for the adequacy and availability through the industry survey.

Based on the statistical analysis it was revealed most significant accidents by cross checking the lost time created due to those accidents. Further, aforesaid statistical analysis used to compare accident count before and after TPM implementation and to identify the accidents that have been mostly addressed through TPM. The results showed a reduction of the number of occurrences of some accidents and lost time produced by accidents after implementation of the TPM. Nevertheless, there were accidents still remained same as before or increased after implementing TPM too. Based on the perceptions of experts and the observation of the process also revealed that process safety of the manufacturing process was increasing through TPM implementation. However, the reduction of accidents was not applicable for all types of accidents since there were accidents which were reduced after TPM implementations also according to the expert perceptions which confirmed the results of the statistical analysis. It was revealed that there is a gap between the expected level and actual level in process safety improvement using TPM since the zero accident level was not achieved in any of the selected cases.

6. REFERENCES

Ahuja, I.P. and Khamba, J.S., 2008. Total productive maintenance: literature review and directions. *International Journal of Quality & Reliability Management,* 25(7), 709-750.

Ahuja, I.P. and Kumar, P., 2009. A case study of total productive maintenance implementation at precision tube mills. *Journal of Quality in Maintenance Engineering*, 15(3), 241-258.

Aneziris, O.N., Papazoglou, I.A., Konstandinidou, M., Baksteen, H., Mud, M., Damen, M. and Oh, J., 2013. Quantification of occupational risk owing to contact with moving parts of machines. *Safety Science,* 51(1), 382-396.

Basso, B., Carpegna, C., Dibitonto, C., Gaido, G., Robotto, A. and Zonato, C., 2004. Reviewing the safety management system by incident investigation and performance indicators. *Journal of Lost Prevention in the Process Industries,* 17(17), 225-231.

Calvin, S. and Joseph, B., 2006. Occupation related accidents in selected garment industries in Bangalore city. *Indian Journal of Community Medicine*, 31(3), 150-152.

Central bank of Sri Lanka and Ministry of Labour and Labour Relations, 2009. *Sri Lanka Labour Gazettes*. Colombo: Ministry of Labour and Labour Relations.

Central bank of Sri Lanka and Ministry of Labour and Labour Relations, 2012. *Sri Lanka Labour Gazettes*. Colombo: Ministry of Labour and Labour Relations.

Cooke, F.L., 2000. Implementing TPM in plant maintenance: some organizational barriers. *International Journal of Quality & Reliability Management*, 17(9), 1003-1016.

Czarnecki, C., 2000. Integrating the cutting and sewing room of garment manufacture using mechatronic techniques. *Mechatronics*, 5(2), 295-308.

Gunasekera, M.Y. and De Alwis, A.A., 2008. Process industry accidents in Sri Lanka: Analysis and basic lessons learnt. *Process Safety and Environment Protection,* 86(6), 421-426.

Howard, D.J., 1993. "Reinforcement: origin, dynamics, and fate of an evolutionary hypothesis", In Harrison, R.G. (ed.), Hybrid zones and the evolutionary process, Oxford University Press, Oxford.

Kapuge, A.M. and Smith, M., 2007. Management practices and performance reporting in the Sri Lankan apparel sector. *Managerial Auditing Journal*, 22(3), 303-318.

Langerman, N., 2015. Expand Process Safety Management. *Journal of Lost Prevention in the Process Industries*, 22(2), 99-113.

Madurawala, S., (2015). *Dying to Work? Why Health and Safety in the Work Place is an Important Economic Issue for Sri Lanka* [online]. Colombo, Institute of Policy Studies. Available from: http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=90097 [Accessed 5 July 2015].

McKone, K.E., Schroeder, R.G. and Cua, K.O., 2001. The impact of total productive maintenance practices on manufacturing performance. *Journal of Operations Management*, 19(1), 39-58.

Nakajima, S., 1989. *TPM Development Program: Implementing Total Productive Maintenance*. Productivity Press.

Park-Poaps, V.V., 2009. Technology adoption by apparel manufacturers in Tirupur town. *Journal of Fashion Marketing and Management,* 13(2), 201-214.

Poduval, P.S., Pramod, V.R. and Raj, J.V., 2013. Barriers in TPM Implementation in Industries. *International Journal of Scientific & Technology*, 2(5), 28-33.

Rao, S., 2007. Safety culture and accident analysis - a socio-management approach based on organizational safety social capital. *Journal of Hazardous Materials*, 142(3), 730-740.

Sharma, R.K., Kumar, D. and Kumar, P., 2006. Manufacturing excellence through TPM implementation: a practical analysis. *Management & Data Systems*, 106(2), 256-280.

Suzuki, T., 1994. *TPM in Process Industries* [online]. New York, Productivity press. Available from: https://books.google.lk/books?id=yFP5DCKG4MEC&pg=PR13&lpg=PR13&dq=tpm+in+process+industries&source=bl&ots=KTMIrk5KbI&sig=zdXJJsUNAp6AOgQyLxCN6ILWYW0&hl=en&sa=X&ei=cmqbVeW5JcvQ0ASNroOQDQ&ved=0CCcQ6AEwAg#v=onepage&q=tpm%20in%20process%20industries&f=false [Accessed 7 January 2015].

Tsang, A.H. and Chan, P.K., 2000. TPM implementation in China: a case study. *International Journal of Quality & Reliability Management*, 17(2), 144-157.

Wakjira, M.W. and Singh, A.P., 2012. Total Productive Maintenance: A Case Study in Manufacturing. *Global Journal of researches in engineering, Industrial Engineering*, 12(1).

Wireman, T., 2004. *Total Productive Maintenance* [online]. New York, Industrial Press Inc. Available from https://books.google.lk/books?id=UfKRG56P1QC&pg=PA198&lpg=PA198&dq=wireman+TPM&source=bl&ots=sjvnMfjHg&sig=q6airhjpBxigBBLekBqpbqjLuk&hl=en&sa=X&ei=tnubVbv3GdDkuQTgo7boDQ&ved=0CC0Q6AEwBA#v=onepage&q=wireman%20TPM&f=false [Accessed 9 July 2015].