Impact of TPM on Productivity Improvement
Case Study of Unilever Sri Lanka

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Declaration

I here by certify that this research is my effort and that to the best of my knowledge and belief, it contains neither materials previously published or written by another person nor material which, to a substantial extent, has been accepted for the award of any other degree or diploma of a university or other institute of higher studies expect where due reference is made in the text.

.... 30/01/2009

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Abstract

It is understood that the most of the traditional manufacturing organizations in Sri Lanka are very low in productivity. This is a main draw back of Sri Lankan industries in competing with international markets. There are several reasons for this low productivity. Especially in manufacturing sector plant maintenance play a major role on efficiency of the process. Traditional maintenance systems focus only on machine maintenance and production process is considered as a separate affaire. Thus maintenance of the plant is carried out by a separate group without much involvement of the plant operators.

But the world accepted Japanese systems such as Toyota Production System (TPS), Total Productive Maintenance (TPM) and Total Quality Maintenance (TQM) are based on team effect with every one's involvement in plant breakdowns, Production Planning, Quality, Safety, new investments, changes on improvements. The main barrier to implement these systems in local manufacturing industry is the cultural barriers and the poor management approach. Unilever Sri Lanka is a leading fast moving consumer goods manufacturing company implemented TQM and TPM by now. This dissertation outlines how the key pillars of TPM which have impacted on the productivity improvement of the company.

List of Abbreviations

TPM- Total Productive Maintenance

OEE- Overall Equipment Efficiency

Seiri- Organization

Seiton- Tidiness

Seiso - Purity

Seiketsu-Cleanliness

Shitsuke - Discipline

MTBF- Mean time between failure

MTTR – Mean time to repair

MP- Maintenance Prevention

QDI- Quality De-merit Index

LTA- Loss time accidents

OPL-One point lessons

JIT-Just In Time

TPS- Toyota Production System

TQM- Total Quality Management

WWBLA- Why Why Because logic Analysis

CBM- Condition Based Maintenance

TBM-Time Based Maintenance

CM- Corrective Maintenance

BM- Breakdown Maintenance

PM- Planned Maintenance

AM- Autonomous Maintenance

KK-Kobetsu Kaizen

E&T-Education and Training

QM-Quality Maintenance

EEM-Early Equipment Management

SHE-Safety, Health and Environment

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Chapter 1

1.0 Introduction

1.1 Background

Total Productive Maintenance (TPM) represents a potential source of productivity improvement in manufacturing organizations. TPM is a program for the fundamental improvement of the maintenance function in an organization, which involves its entire human resources including top management to shop floor workers.

TPM is productive maintenance carried out by all employees through well planned small group activities for example, "In TPM the machine operator is responsible for the maintenance of the machine as well as its operations". The main challenge is to change the attitude of the workforce when implementing this new concept. The implementation of TPM can generate considerable cost saving through increased productivity of the plants. One of the main aims of TPM is to increase the productivity of plant and equipment in such a way as to achieve maximum productivity with only a modest investment in maintenance. This is done by improving and maintaining equipment and facilities at an optimal performance level in order to reduce their life cycle costs. TPM has a double goal in "Zero break down" and "Zero defects" Nakajima (1991) which would help organizations deliver what they have promised.

There are four main reasons for implementing TPM in an organization.

(a). The economic environment surrounding corporations become severe, and total elimination of waste is required for the survival of the corporation. Therefore, waste generated due to the failure shutdown of facilities which have been built with huge investment and wastes such as defective products should be absolutely eliminated.

(b). Requirement for product quality become stringent, and not even one defective product would be allowed. Quality-assured delivery of total quantity is now taken for granted.

(c).The small-lot production of various kinds of products and shortening of production lead time has been strongly required to meet diversified customer needs, so that TPM to reduce the 8 major equipment losses to zero has been recognized as necessary for corporate survival.

(d). Avoidance of the three Ds (Difficult, Dirty and Dangerous), worker preference for employment in the service industry and shorter working hours can be seen as a spreading tendency, making the acquisition of a sufficient work force more difficult. Increases of the aged and higher educated in our society have also contributed to making the maintenance of conventional production facilities difficult.

1.2 The Management Problem

Unilever Sri Lanka (USL) formerly Lever Brothers is one of the most successful multi-national companies in Sri-Lanka. As a leader in the FMCG business, it manufactures and markets high quality consumer goods.

The factory at Grandpass site is the main source for supplying products to the local market. 95% of the Unilever products are manufactured in the factory. For Unilever business in Sri-Lanka, the factory operations are vital. Specially, flexibility, conversion cost and productivity of the local manufacturing operations are important factors for survival of local manufacturing operations in the 70 year old factory in Grandpass.

During 2000, it was revealed that the efficient manufacturing operations in the main factory in Sri-Lanka was critical due to the reduction of import duties from Sri-Lankan government, benchmarking the performance of factory operations with other Unilever regional sites and effects due to the globalization. As a multi-national company, the Unilever compared all performance parameters of the factory operations with other similar sites in the region and it has been observed that productivity of the factory operations were not up to the satisfactory level. Then the Unilever Company had given warning signals to the factory management to take corrective actions for survival of the local manufacturing operations in Sri-Lanka.

This low efficiency was a major problem to achieve their company vision of doubling the business within 5 years (2001-2005)and as well as to be competitive among other manufacturing sites in the region hence, company wanted to drastically improve the efficiencies and become least cost manufacturing unit for the survival of Sri Lankan manufacturing facility. The four manufacturing plants are Personal Products, Edible Fats, Hard Soaps Drying and Toilet Soaps are located in Grandpass site. TPM was a tool well accepted by allover Unilever to improve the performance, hence Unilever Sri Lanka also decided to launch TPM to address this issue.

Thereafter a senior manager was appointed as the full time TPM coordinator and another junior manager was allocated as an assistant to him First they have selected few production lines (one from each plant) to launch TPM. They were called as TPM Model Lines. Then it was launched in those model lines with a kick off ceremony in end 2002. Thereafter it was gradually replicated to the other lines in 2003. Three years after implementation of TPM there was a 7%-8% increase in OEE of the factory. In implementing TPM few activities of key pillars were started on the model lines. The pillars like Autonomous Maintenance and Planned Maintenance ware launched first and Kobetzu Kaizen and Early Equipment Management pillars were started later. The company got the support of Japanese Institute of Plant Management (JIPM) in implementing the TPM concept. The consultants of JIPM regularly visited to the factory and under their guidance TPM was rolled out in the factory.

The seven pillars of TPM were led by seven pillar leaders. They were carried out that task in addition to their core job. These seven pillars were progressed in varying degree and impact of each pillar on the OEE improvement was not analyzed. Hence the company has no idea on what and what pillars contributed more on this improvement and what and what pillars have not or less contributed to this improvement

1.3 Research Problem

Unilever globally has started implementing productivity improvement tool called TPM (Total Productive Maintenance) in their factories during this period. South Asia region of Unilever to which Unilever Sri Lanka (USL) is belongs to is also started implementing this tool in most of their factories during this period. Unilever Sri Lanka also decided to implement TPM to improve their productivity as their Grandpas factory overall equipment efficiency (OEE) was low as 57%.Then Unilever Sri Lanka kicked off implementing TPM in 2002.

Initially TPM was implemented in selected production lines of the factory and they were called as model lines, but later it was replicated to other production lines as well. When we consider the period of 2000 to 2005 there is a significant OEE improvement in the factory but there is no any study carried out to find out how the seven pillars of TPM effected towards this improvement. Thus in this research the attempt is being made to find the relationship between OEE improvement and the different TPM pillar activities carried out.

1.4 Objectives

This research project is undertaken to understand how the following TPM seven pillar activities contributed to improve the efficiency of the different production lines and the key learning's.

- Planned Maintenance Pillar.
- Autonomous Maintenance Pillar.
- Education and Training Pillar.
- Quality pillar.
- SHE (Safety Health and Environment) pillar.
- Kobetzu Kaizen Pillar.
- Early Equipment Management pillar.

Even though JIPM recommends a certain sequence of pillar activities to kick off TPM, based on the results to identify the most effective sequence of pillars to start with by considering the contribution of each pillar towards OEE.

Also to identify the other contributing factors on OEE improvement in the most significantly improved line Out of the selected 13 production lines, by carrying out a detailed analysis on those line performances.

1.5 Significance

In today's business environment of rapid change, social, political and economic volatility, globalization trends and technological advances most of the companies are adopting number of tools to remain competitive in the market. TPM is a well known Japanese tool used by worldwide to re-engineer organizations. There are only very few companies in Sri Lanka even tried to start implementing this TPM concept, but out of that Unilever is the first to implement it and obtained the level one certification, hence there is no any study was carried out to analyze the effectiveness of this tool to improve the efficiency of the operation in Sri Lankan Industry. This research is aimed at identifying whether there is a significant productivity improvement by implementing TPM in Unilever Sri Lanka Grandpass factory. Out of three production departments (Personal Products, Edible Fats and Toilet Soaps) thirteen key production lines were selected for the analysis. The findings of the research will help to other manufacturing companies and Unilever policy makers to decide whether TPM is the right tool to address their inefficiencies and if so out of the seven pillars what pillars have significantly contributed to that change. In addition, the learning's of USL can be used to plan other companies' implementation strategy. Also this study would help to identify whether there is a cultural change happened among the workforce of this old factory due to TPM implementation since TPM involves people of the production floor in most of the activities.

1.6 Scope and Limitations

In order to bring the research to a manageable size only 13 production lines in three key departments were selected for the detailed analysis. The selected production lines were selected as follows, 3 lines from Toilet Soaps, five lines from Personal Products and five lines from Edible Fats. TPM implementation at USL happened from 2002 end to 2003 end hence, the data from 2000 to 2005 was considered for the study. Even though several sub activities carried out under each TPM pillar, only the key one or two criteria's were selected for the each pillar due to the complexity. Also some of the information such as production volumes and expenditure on maintenance cannot be revealed and considered for the study due to the competitive business environment. The following are some key limitations,

- Reliability of data
    - All the line efficiencies are carried out based on the production log sheets which is a document filled by each line leader manually. So there can be some human errors.
    - Before implementing TPM the data collection was not under the TPM method hence calculation of some losses is not possible.
- There can be some other programs which influences OEE other than TPM
    - As example the production target achievement incentive scheme was revised during this period.
    - Voluntary retirement scheme introduced during this period was taken up by most of the senior operators.

- Only the quantifiable pillar activities were considered for the analysis
    - When considering Education and Training Pillar analysis only the training hours given is considered but the actual knowledge improvement was not considered.

Chapter 2

2.0 Literature Review

2.1 Introduction

This chapter aims to build a theoretical foundation upon which the research is based, by reviewing the relevant text books and research findings on TPM related areas. It also covers the TPM related other tools commonly used in the industry such as TQM, JIT, TPS, 5S etc. and its influence to the TPM.

2.2 General Maintenance

Organizations are continuously looking for strategies to improve operations and gain competitive advantage. Tracking the performance of maintenance is a key management issue for many organizations. TPM is one of the key performance improvement tools although it requires commitment for training, resources and integration (Nakano, 1999).

The TPM programme is a proactive and cost effective approach to equipment maintenance. It is an integrated process requiring the support of all levels of the organization. It maximizes equipment effectiveness by establishing a comprehensive productive maintenance system covering the entire life of the equipment and spanning all equipment –related fields. TPM improves business performance in many aspects such as operations performance, safety and cleanliness, employee morale and customer satisfaction. All these aspects usually lead to a significant improvement in the company's bottom line.

2.3 TPM/TQM/5S

There are 16 major losses related to equipment, manpower, material, die, jig, tool and energy utilization is identified under TPM. The main of TPM is to address them and make them zero for corporation survival (Kosu, 2003).

The 16 major losses are categorized into 8 categories as per Table 2.1

Table 2.1: 16 Major Losses

	Type Of Loss	**Loss Category**
1.	Equipment failure loss	Equipment Down time Loss
2.	Set-up & adjustment loss	
3.	Cutting blade and jig change loss	
4.	Start up loss	
5.	Minor stoppage and idle loss	Equipment Performance Loss
6.	Speed loss	
7.	Defect and rework loss	Defect Loss
8.	Shut Down Loss	Losses in Equipment Loading Time
9.	Management Loss- Waiting for Instructions or material	Obstructing Man Power Loss
10.	Operating motions loss	
11.	Line Organization Loss- Automation Failure Loss	Line Organization man hour Loss
12.	Logistics Loss	
13.	Measurement and Adjustment Loss	Defect Quality Loss
14.	Material Yield Loss	Losses obstructing efficiency of material and energy utilization
15.	Energy Loss	
16.	Die and Tool Loss	

Source: Kosu, K.K. (2003) Total Productive Maintenance.p4

Out of the 16 losses only the first seven losses are effecting the overall equipment efficiency (OEE) calculations (Appendix i) OEE is the key measure of TPM which is the product of availability rate, performance rate and quality product rate. Refer Table 2.2.

Availability Rate- the first 4 losses are affecting in calculating this
Performance Rate- the 5 th and 6 th losses are the components of performance rate
Quality Product Rate- Defect and rework loss is the contributor for this.

Table 2.2: OEE calculating formula

Availability Rate	$\frac{\text{Loading Time – Down Time}}{\text{Loading Time}}$	$\frac{L-D}{L}$
Performance Rate	$\frac{\text{Operating Time-Performance Loss}}{\text{Operating Time}}$	$\frac{O-S}{O}$
Quality Product Rate	$\frac{\text{Net Operating time – Defect Loss Time}}{\text{Net Operating time}}$	$\frac{N-Q}{N}$
OEE	Availability X Performance Rate X Quality Product Rate	$\frac{V}{L}$

Source: Kosu, K.K. (2003) Total Productive Maintenance.p18

2.3.1 History of TPM

TPM is a unique Japanese system which has been developed from PM concept (Preventive maintenance or productive maintenance) which was introduced from USA (Nakajima, 1988)

PM originated and was developed in USA as follows

(1). Preventive Maintenance (PM: 1951) – It is a kind of physical check up of equipment, and also kind of preventive medicine for the equipment. Just as the human life expectancy can be expanded by the progress in preventive medicine to human suffering from disease, the pant equipment service life can be prolonged by preventive equipment failure (disease) beforehand.

(2). Corrective Maintenance (CM:1957) – is a system in which the concept to prevent equipment failures has been further expanded to be applied to the improvement of equipment so that equipment failure can be eliminated (improving the reliability) or equipment can be easily maintained (improving maintainability).

(3). Maintenance Prevention (MP: 1960) – is an activity to design the equipment and line to be maintenance free. As the ultimate goal of the equipment and line is to keep them completely maintenance free, every effort should be made to try to achieve the ultimate ideal condition of "what the equipment and the line must be". All these activities to improve equipment productivity by performing MP,PM and CM through the life cycle of equipment is generally called productive maintenance (PM).

In 1971, Nippon Denso Company first introduced and successfully implemented TPM in Japan. This automobile parts manufacturer introduced TPM concepts from its inception. They won the PM Excellent Plant Award also during 1970's. This was the beginning of TPM in Japan. Since then, TPM has spread throughout Japan, especially in the Toyota group.

However, TPM has made a gradual change and the tendency to implement Condition Based Maintenance (CBM) can be seen from the early 80's

TPM aims at

1. Establishing a corporate culture that will maximize production system effectiveness,
2. Organizing a "genba-genbetsu" system to prevent losses and achieve zero losses
3. Involving all functions of an organization including production, development, sales and management,
4. Involving every member of an organization, from top management to front line operators and
5. TPM is defined as aiming at forming a corporate culture which can pursue the maximum possible efficiency of the overall production system.

2.3.2 Definitions of TPM

The definition of TPM was determined in 1971, when TPM was first put in to forward. At that time, TPM was strictly within the purview of the production departments. The definition for production sector is as follows

1. TPM aims to minimize equipment efficiency (OEE)

2. TPM aims to establish a total system of PM, designed for the entire life of equipment.

3. TPM operates in all sectors involved with equipment, including the planning, using, and maintenance sector.

4. TPM is based on the participation of all members, from top management to frontline staff members.

5. TPM carries out PM through motivation management, i.e. small group activities

However, in line with the spread and development of TPM, it became clear that, to improve the efficiency of the production sector were not enough. TPM was introduced to all the departments in company wide scale, with all sectors, including development, sales and administration. A new definition was developed to reflect the real state of affaires of all the sectors and it is as follows.

1. TPM aims to create a corporate system that maximizes the efficiency of the production system

2. TPM creates systems for preventing the occurrence of all losses on the front line and is focused on the end product. This includes sytems for realizing "zero accidents, zero defects, and zero failures" in the entire life cycle of the production system.

3. TPM is applied in all sectors, including the production, development, and administration departments.

4. TPM is bases on the participation of all members, ranging from the top management to frontline employees.

5. TPM achieves zero losses through overlapping small group activities.

It can also be considered as the medical science of machines. Total productive maintenance (TPM) is a maintenance program which involves a newly defined concept for maintaining plants and equipments. The goal of the TPM program is to increase production while, at the same time, increasing employee moral and job satisfaction.

TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a noon profit activity. Down time for maintenance is scheduled as a part of the manufacturing day and in some cases as an integral part of the manufacturing process. The goal is to hold emergency and un scheduled maintenance to a minimum.

2.4 Seven Pillars or Principles of TPM

1. Planned Maintenance
2. Autonomous Maintenance (Jishu – Hozen)
3. Kobetzu Kaizen (Focused Improvement)
4. Education and Training
5. Quality Maintenance
6. Early Equipment Management (Initial Flow control)
7. Safety Health and Environment (SHE)

And in addition to Office TPM is known as the eighth pillar in administration departments.

2.4.1 Planned Maintenance Pillar

Planned maintenance should establish and maintain optimal equipment and process conditions, it should also be efficient and cost effective-Suzuki (1994). In a TPM development program, planned maintenance is the deliberate, methodical activity of building and continuously improving such a maintenance system. An efficient planned maintenance program combines time based maintenance (TBM), condition based maintenance (CBM), and break down maintenance (BM) as rationally as possible.

Time based maintenance (TBM) consists of periodically inspecting, servicing, and cleaning equipment and replacing parts to prevent sudden failures and process problems. It should be part of both autonomous maintenance and specialized maintenance activities.

Conditioned based maintenance (CBM) uses equipment diagnostics to monitor and diagnose moving machinery conditions continuously or intermittently during operation and on stream inspection (OSI-checking the condition of static equipment and monitoring signs of change by nondestructive inspection techniques). As its name implies, condition-based maintenance is triggered by actual equipment conditions rather than the elapsing of a predetermined interval of time. Breakdown maintenance (BM) means waiting until equipment fails to repair it. Breakdown maintenance is used when failure does not significantly affect operation or production or generate any financial losses other than repair costs.

Preventive maintenance (PM) combines time based and condition- based methods to keep equipment functioning by controlling equipment components, assemblies, accessories, attachments and so on. It also maintains the performance of structural materials and prevents corrosion, fatigue and other forms of deterioration from weakening them.

Corrective maintenance (CM) improves equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness can be redesigned.

The purpose of planned maintenance (PM) system in the factory is to ensure the equipment conditions at their best with the minimum maintenance cost, enabling equipment to function at an optimal level whenever operation is required. It is aimed to have trouble free machines and equipment's producing defect free products for total customer satisfaction.

Types of maintenance

1 Break down maintenance
2 Preventive maintenance
3 Corrective maintenance
4 Maintenance prevention

With planned maintenance we evolve our efforts from a reactive to a proactive method and use trained maintenance staff to help train the operators to better maintain their equipment (Annexture 3).

Breakdown maintenance

It means that people waits until equipment fails and repair it.. Such a thing could be used when the equipment failure does not significantly affect the operation or production or generate any significant loss other than repair cost.

Preventive maintenance

It is a daily maintenance (cleaning, inspection, oiling and re – tightening), design to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection equipment condition diagnosis, to measure deterioration. It is further divided in to periodic maintenance and predictive maintenance. Just like human life is extended by preventive medicine, the equipment service life can be prolonged by doing preventive maintenance

Periodic maintenance (Time based maintenance- TBM)

Time based maintenance consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems.

Predictive maintenance (CMB)

This is a method in which the service life of important part is predicted based on inspection or diagnosis, in order to use the parts to the limit of their service life. Compared to Periodic maintenance, predictive maintenance is conditioned based Predictive maintenance. It manages trend values, by measuring and analyzing data about deterioration and employs a surveillance system, designed to monitor conditions through an on- line system. McKone and Weiss (2002).were developed Guidelines for Implementing Predictive Maintenance. They evaluated the use of continuous monitoring predictive tools and the traditional periodic maintenance tools. It revealed that carrying out predictive maintenance with traditional periodic maintenance will result in low failure rate and reduce premature break downs of equipment. Also they analyze the effectiveness of the predictive tolls and technologies and it helps to select the best technology for a particular maintenance solution.

Corrective maintenance (CM)

It improves equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be redesigned to improve reliability or improving maintainability.

Maintenance prevention (MP)

It indicates the design of new equipment. Weakness of current machines are sufficiently studied (on site information leading to failure prevention, easier maintenance and prevents of defects, satisfy and ease of manufacturing) and are incorporated before commissioning a new equipment. The advantages of MP were broadly discussed by Thun, (2006) and analyzed the dynamic implications of Total Productive Maintenance in his study on Maintaining preventive maintenance and maintenance prevention. He also identified the interrelations between the different pillars of TPM.

2.4.2 Autonomous Maintenance (Jishu – Hozen)

Autonomous maintenance aims to create a scenario where all operators look after their own equipment, carrying out routine checks, oiling and greasing, replacing parts, doing simple repairs, spotting problems at an early stage, checking precision and so on. Autonomous maintenance can only be carried out by operators who are thoroughly conversant with their equipment, Tajiri and Gotoh(1999). There is a seven stem Autonomous maintenance plan developed to work this concept properly in the shop floor. This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activity and technical repairs. The operators are responsible for up keep of their equipments to prevent it from deteriorating.

AM Policy

1. Uninterrupted operation of equipment
2. Flexible operators to operate and maintain other equipments
3. Eliminating the defects at source through active employee participation
4. Stepwise implementation of JH activities

The seven Autonomous Maintenance Steps;

1. Initial Cleaning – eliminate dust and dirt from main body of equipment, lubricate and tighten, expose and deal with equipment problems,

2. Tackling contamination sources and hard to access areas- Reduce housekeeping time by eliminating or containing sources of dust, dirt or other contamination, and improving places that are hard to clean, lubricate, tighten or check.

3. Provisional Autonomous Maintenance standards- Formulate provisional standards to enable cleaning, lubricating, tightening and checking to be sustained dependably with minimal time and effort (this will mean establishing time slots for routine and periodic maintenance)

4. General inspection-Train operators in inspection, procedures using inspection manuals, enabling them to expose and correct equipment defects by performing comprehensive equipment inspection.

5. Autonomous Checking- Formulate definitive cleaning, lubrication and inspection standards that can be followed efficiently and dependably; draw up autonomous inspection checklists and put them into use

6. Standardization – Develop a comprehensive house keeping system by devising additional standards for items such as

- Movement of materials around the shop floor
- Data recording
- Control of moulds, jigs, tools etc.
- Quality assurance data on the process.

7. Full self management- Roll out and implement company policies and objectives, and continually improve the equipment by keeping accurate MTBF and other maintenance records, analyzing the data captured, and doing improvements as a routing part of the job

2.4.3 Kobetzu Kaizen Pillar (Focused Improvement Pillar)

Focus improvement activity is a priority in any TPM development program and is at the top of the list of the eight fundamentals of TPM development. It is one of the major activities in the TPM master plan, and its implementation begins simultaneously with the TPM kick-off, Suzuki (1992). Focused improvement includes all activities that maximize the overall effectiveness of equipment, processes, and plants through uncompromising elimination of losses and improvement of performance. It is implemented systematically and the following procedure is extremely effective for breaking out of the vicious cycle that prevents improvements and locking them firmly into place.

Step 0: Select a topic

Step 1: Understand Situation

Step 2: Expose and eliminate abnormalities

Step 3: Analyze Causes

Step 4: Plan Improvement

Step 5: Implement Improvement

Step 6: Check Results

Step 7: Consolidate gains

2.4.4 Education and Training Pillar

In TPM, the two basic approaches to training are on the job training and Self development. Fundamentally, improving the abilities of individuals not only helps the company's bottom line, but also increases people's morale. To achieve this, all line managers and supervisors must be dedicated to educating the people in their department. They must devote a considerable portion of their energy to develop equipment –competent personnel through TPM, Shirose (1992).

What is skill?

Skill is the ability to do one's job, to apply knowledge and experience correctly and reflexively in all kinds of events over and extended period. Systematically accumulating training, experience, and information enables a person to exercise good judgment and act appropriately. Skill is the product of personal motivation and through training.

There are four skill levels,

Level 1: Lack both theory and practical ability (need to be taught)

Level 2: Knows in theory but not in practice (needs practical training)

Level 3: Has mastered practice but not theory. (can not teach to others)

Level 4: Has mastered both theory and practice (can teach others)

Training should be designed to meet all of these needs. Much training is ineffective, either because the content or timing is inappropriate. Training should be thorough and practical, and it should be clearly understood the needs one step at a time. Finally the aim should be develop equipment-competent operators, that is, operators coping with automation, pneumatics, drives, electronic control and other technologies. To facilitate extensive training it is required to carry out a skill evaluation of each member on required skill areas. In order to effectively promote operation and maintenance skill development, it is recommended that activities be systematically executed in accordance with the following six steps.

Step 1: Setting of principles and priority measures based on confirmation of the skill gaps

Step 2: Establishment of a training system for operation and maintenance skill development.

Step 3: Execution of operation and maintenance skill development

Step 4: Establishment and evolution of a system for developing and nurturing capabilities.

Step 5: Creation of self-enlightening environment.

Final objective is to improve the normal operators to equipment-competent operators and they should be able to

- Detect equipment abnormalities and effect improvements.
-Understand equipment structure and functions and are able to discover the cause of abnormalities.
-Understand the relationship between equipment and quality and can predict quality abnormalities and discover their causes.
-Repair equipment by replacing components

2.4.5 Quality Maintenance Pillar

Quality maintenance pillar consists of activities that establish equipment conditions that do not produce quality defects, with a goal of maintaining equipment in perfect condition to produce perfect products. Quality defects are prevented by checking and measuring equipment conditions periodically and verifying that the measured values lie within the specified range. Potential quality defects are predicted examining trends in the measured values and prevented by taking measures in advance.

Rather than controlling results by inspecting product and acting against defects that have already occurred, quality maintenance in TPM aims to prevent quality defects from occurring. This is accomplished by identified checkpoints for process and equipment conditions that affect quality, measuring these periodically, and taking appropriate action (Figure1).

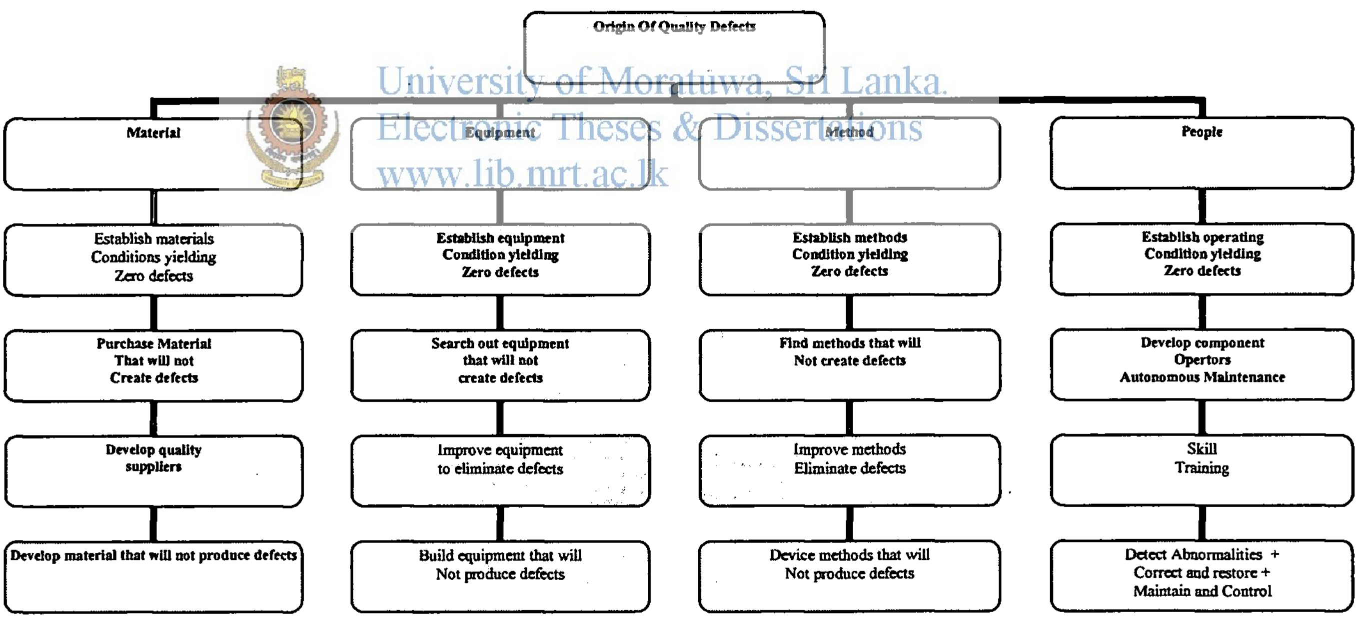


Figure 1: Basic Philosophy of Zero Defects.

Source: Suzuki, T. (1992), TPM in Process Industries, p237.

The approach illustrated in Figure 1 focuses on the four production inputs (equipment, material, people, and methods) as a sources of quality defects.

A quality maintenance program builds upon gains achieved through fundamental TPM activities such as autonomous maintenance, focused improvement, planned maintenance, and operation and maintenance skill training. There are several pre-conditions for successful quality maintenance program, however: abolish accelerated deterioration, eliminate process problems, and develop competent operators. The relationship between equipment and quality is analyzed by considering each component of the equipment which governs the quality of the product. Finally a matrix is developed which is called QA matrix which has the relationship between plant and quality characteristics.

McAdam and Duffner (1996) carried out a study on Implementation of Total Productive Maintenance in support of an established total quality programme. This study discussed in detail how TPM can be effectively implemented within an organization that has an established TQ (total quality) programme in place. Case study data of Harris Ireland Ltd. (part of Harris Corporation) are analyzed and discussed in detail. The data used includes questionnaire and interview data. The paper also shows how TPM implementation in Harris has been driven by the results of Baldrige –based audits.

It was highlighted that the TQM implementation was to survive the business and not to reducing workforce. There is a belief of among all groups of the company that they contribute to achieve company's objectives. Also team working is very prominent in Harris. Overall skills and training was improved in the organization while implementing TPM. TQM was seen as a management led initiative focusing on continuous improvement in all aspects of the business to increase the competitiveness of the organization. The culture in which TPM is implemented has a large impact on whether or not it will be successful. It is perceived by all groups within the organization that everyone is responsible for quality, and majority of employees within the group feel ownership for their jobs.

Quality Demerit Index is the formula which is the quality measure that Unilever globally use to asses the overall packed quality of the finished goods. The defects are classified in to four categories as follows.

"A" Defect (Critical defects)

Defects in this category would be readily recognized by the customer /consumer and would result in refusal to purchase the product and /or the defects which violates the statutory requirement.

"B" Defect (Major defects)

Defects in this category would result in hesitancy by the customer /consumer and would result in refusal to purchase the product if discovered immediately or dissatisfaction if discovered later.

"C" Defect (Minor defects)

Defects in this category would not affect the customer /consumer to purchase the product but would influence the overall perception of product quality, which may affect purchase decision after repeated incidences.

"D" Defect (Very Minor defects)

Defects in this category would only be recognized by a trained person .Cumulatively this will lead to a less favorable impression.

The QDI value is obtained through this formula.

$$QDI = 1\ \%\ A\ defect + 0.65\ \%\ B\ defect + 0.3\ \%\ C\ defect + D\ defect$$

2.4.6 Early Equipment Management (Initial Flow control)

As customers' requirements continue to diversify, product life cycles become ever shorter and the competition to develop new products grows more and more intense. It has become vitally important to beat the competition to market with new products, even if only by a little. A company's success in reducing product launch times by simultaneously developing the equipment needed to produce them (instead of waiting until the product has been developed before starting to develop the equipment) can make or break it.

Having safe, loss- free, reliable, maintenance friendly and operator- friendly equipment right from the outset will make it possible for the production department to do a far better job. In Early Equipment Management helps to eliminate design flaws in new or remodeled equipment at the planning, development and design stages, practicing MP design with the aim of achieving immediate, problem-free startup (Vertical start up). In Early Product Management, we try to shorten development lead times as well as achieving vertical startup. In both cases, it is important to design –in solutions to actual problems experienced in the past as well as conceivable future problems.

The following procedure ensures that early management of products and equipment evolves comprehensively and effectively.

Step1: Investigate and analyze the existing situation.

Step2: Establish an early management system.

Step3: Debug the new system and provide training.

Step4: Apply the new system comprehensively.

2.4.7 Safety and Environment (SHE) Pillar

Assuring safety and preventing adverse environmental impacts are important issues in process industries. Operability studies combined with accident prevention training and near-miss analysis are effective ways of addressing these concerns. Safety is promoted systematically as part of TPM activities. As with all TPM activities, safety activities are implemented step by step. Certain issues are of particular importance in the process environment. For example, it is particularly important to incorporate fail-safe mechanisms that is, to design equipment that will remain safe even when people do not take the proper precautions. Assuring safety during shutdown maintenance is also important. In process industries, shutdown maintenance requires considerable assistance from outside subcontractors, as do operations such as cleaning. This makes it doubly important to ensure safety during such operations. Need to check the skills and qualifications of subcontract workers well in advance whenever possible. Take every practical step to assure safety, including giving rigorous safety training and carefully supervising the work itself.

There are two step approach to build up of safer human-machine system.

a. Making the equipment safe=Preventing equipment disaster.

Promotion of five TPM pillar (AM, PM, E&T, QM, IFC) implementation and thorough eradication of losses that cause failures, quality problems and unstable conditions, such as minor stoppages in particular, are effective in preventing equipment disaster.

b. Fostering personnel skillful in ensuring safety=preventing motion disaster.

To prevent motion disaster, changing people's awareness is important.

Brah and Chong (2004) have completed a study on Relationship between TPM and performance which found out that there is a positive correlation between TPM and business performance in Singapore organizations .They have selected 600 Singapore companies (80% manufacturing and 20 & service sector) for the study. From the analysis of data it was proved that there is a significant difference in performance between firms that adopt TPM and those do not, experienced and inexperienced TPM firms and small and large TPM firms.

Kodali and Chandra (2001) have completed a study on Analytical Hierarchy Process for Justification of TPM. This study attempted to examine the suitability of TPM for Indian

Industries. A analytical hierarchy process was used to justify TPM and confer adequacy of TPM implementation.

Carannante et al.(1996) have carried out a study on Implementing TPM in foundry industries of UK and Japan. They have considered five pillars of TPM and compared the status of both the countries. These five pillars are Attack Losses , Set up PM (Planned Maintenance) Autonomous Maintenance, Training and Education and Improvement Prevention. The comparison was done under nine main categories and each main category has been sub divided into 4-6 sub elements. The points were given out of 100 for each element.

Miyake et al.(1995) have completed a study on Improving manufacturing systems performance by complementary application of just in time, total quality control and TPM paradigms. They first describe the three paradigms in a tabular manner, thus facilitating their comparison and grasping of similarities and particularities. The study revealed that most of the Japanese companies under review were adopted at least two of the above systems.

Lycke (2003) has completed a study on Team development when implementing TPM. This study was carried out with the data of a Sweden medium scale company where TPM teams, or improvement teams have been established all over the company. It reveals that the bond between the worker teams and the supervisors and their corporation towards improvement. Also explains the initial barriers for smooth functioning of teams and how it was overcome with TPM implementation.

Al-Hassan et al.(2000) have carried out a study on The role of TPM in business excellence. This study explains how the different pillars of TPM influence the business excellence. It has categorized the seven pillars as enablers and results oriented in a model developed. It concludes that the in today's highly competitive markets TPM could be the only philosophy that makes the difference between success and failure for some organizations. It also talks about related strategies such as six sigma, JIT, Kaizens. TQM

TQM is a comprehensive approach to improve competitiveness, effectiveness and flexibility through planning, organizing and understanding of each activity and involving each individual at each level Oakland (1993). TQM ensures that management adopt a strategic overview of quality and focus on prevention, not detection of problems. It often requires a mind-set change to break down existing barriers. The core of TQM is the customer-supplier relationship, where the processes must be managed,

Recent Trend in the Japanese productivity-enhancement movement high lighted that the many of the manufacturing practices developed in Japan in 1970's and 1980's emphasize bottom up decision processes characterized by teams, the empowerment of multi-skilled workers on the shop floor and demand pull, Nakamura (1997). These practices includes, JIT, TQM while they continue to be effective under appropriate circumstances. Unlike the above systems implementing TPM requires a top down approach. TPM provides direct connection between corporate wide objectives such as the overall cost reduction and shop floor practices.

The impact on competitiveness and a framework for successful implementation were discussed in the study carried out by Park and Han (2001) on Total Productive Maintenance:. It describes that TPM has a relationship among all organizational functions, but particularly between production and maintenance, for continuous improvement of product quality, operational efficiency, capacity assurance and safety. This article also provides the key factors that are critical to the successful implementation of TPM. This research concludes that long term benefits of TPM are the results of considerable investment in human resource development and management.

2.5 Why TPM ?

There are three main reasons why TPM has spread so rapidly throughout Japanese industry as well as in other parts of the world (Suzuki, 1992).

It guarantees dramatic results.

Visibly transforms the workplace.

Raise the level of knowledge and skill in production and maintenance workers.

The objectives by implementing TPM can be broadly categorized as follows.

- Avoid wastage in a quickly changing economic environment.
- Producing goods with out reducing product quality
- Reduce cost
- Produce a low batch quantity at the earliest possible time
- Goods send to the customers must be non defective.

The advantageous of TPM can be direct and indirect hence by implementing TPM in a workplace it gives enormous results, Refer Table 03.

Table 2.3: Why TPM

Motives of TPM	1 Adoption of life cycle approach for improving the overall performance of production equipment 2 Improving productivity by highly motivated workers which is achieved by job enlargement. 3 The use of voluntary small group activities for identifying the cause of failure , possible plant and equipment modification.
Uniqueness of TPM	The major difference between TPM and other concepts is that the operators are also made to involve in the maintenance process. The concept of " I (Production operators) Operate ,You (Maintenance department) Fix " is not followed.
TPM Objectives	1 Achieve Zero defects ,Zero break down and Zero accidents in all functional areas of the organization 2 Involve people in all levels of organization. 3 From different terms to reduce defects and self Maintenance
Direct benefits of TPM	1 Increase productivity and OPE (overall plant efficiency) by 1.5 or 2 times 2 Rectify customer complains 3 Reduce the manufacturing cost by 30% 4 Satisfy the customer needs by 100% (delivering the right quantity at the right time in the required quality) 5 Reduce accidents 6 Follow pollution control measures.
Indirect benefits of TPM	1 Higher confidence level among the employees 2 Keep the work place clean , neat and attractive 3 Favorable change in the attitudes of the operators 4 Achieve goals by working as team 5 Horizontal development of a new concept in all areas of the organization 6 Share knowledge and experience 7 The workers get a feeling of owning the machine

Source: Suzuki, T. (1992), TPM in Process Industries. p21.

2.6 JIT and TPM

JIT and TPM are very closely related concepts. Shirose 1996, in order to achieve so called JIT production which calls for " Producing the necessary volume of necessary item at the necessary time" it is necessary to reduce the sporadic failures, minor stoppages, and defects to zero, and to minimize the set up and adjustment time for the realization of multi- item, small volume production. TPM can be said to enable the necessary conditions for and to support the complete enforcement of JIT. Ohno (1996) has revealed that the following five basic concepts are common to JIT and TPM

1. Company-wide manufacturing technology directly linked to management
2. Through elimination of waste
3. Prevention of malfunction occurrence in advance
4. On-site (or on the spot), actual goods focus
5. Participatory management and respect for people

2.7 Toyota Production System (TPS) and TPM

TPS is closely linked to TPM. TPS is down to earth elimination of waste. Just-in-time (JIT) delivery and automation are two major concepts incorporated into TPS.

For the JIT system to function properly, defective products should be kept to the minimum, aiming at a zero level of processed product inventory. Toyota has achieved this by tightening their quality standards and improving the quality of their part suppliers as well. They keep minimum stocks of raw material as well. Through QM pillar in TPM addresses the quality issues to get zero defect status.

For the automation to function properly, the equipment failure rate should also be kept to the zero level. Mainly through AM and PM pillars they achieve zero break down status, hence TPM is essential in achieving the zero level of defect products, processed product inventory and equipment failures.

Chapter 3

3.0 Methodology

This chapter explains the research model developed for this research study which is drawn from the conceptualization of literature review. Also explain the key variables identified to analyze this concept. Further it also discusses the research methodology to be used for this research study.

3.1 Conceptualization

After a detailed literature review on TPM text books, journals and previous research works on TPM and Productivity improvement, it was revealed that the seven pillars of TPM impacts productivity in numerous ways. Also it is evident that overall equipment efficiency (OEE) is the most reasonable parameter to measure the productivity in manufacturing industries. The critical activities of each pillar were selected for the analysis, Refer Table 05.

Autonomous Maintenance Pillar-

Two criteria were considered to identify the impact of AM pillar towards OEE are

a. Number of Fuguais identified is an initial activity started by the line team. Fuguais are abnormalities identified by the operator on each line. These Fuguais are two types namely Green and Red. Green are the ones can be rectified by the line operator itself. Red ones are the one needs maintenance crew's help to rectify. These Fuguais are tags filled in duplicate and original is hanged on the machine and the copy is filed to follow up the tag completion.
b. Current state of the AM Step – out of the 7 AM steps the each line is in different stages of AM, hence, it was another good measure of AM status of the line.

Planned maintenance pillar-

The two criteria identified to measure the impact of PM pillar towards OEE are

a. Number of Why Why analysis carried out for major breakdowns.

Why Why analisis is a TPM tool to analise a problem to identify the root cuase of a problem. If Why Why analisis fails to identify the root cuase WWBLA (Why Why Because Logic Analysis) tool can be used to analyse the problem more deeper. This analysis is carried out by a team consist with line operators, technicians and supervisers.

b. Number of CBM (Condition Based Maintenance) schedules available

CBM is a key activity in PM pillar to prevent break downs and to reduce maintenance cost. The equipment are ranked as ABC on their criticality towards the operation and introduced different CBM techniques. Most common techniques are vibration analysis, laser alignment checking, Thermography, Non distructive testing of welds structures.

Kobetsu Kaizen pillar-

This pillar activities are measured by the number of implemented Kobetsu Kaizens in each line. These Kaizens are carried out by a team consists with line operators and maintenance team. Most of these Kaizen ideas came from the operators in the line. When a Kaizen is carried out in a particular line it is replicated to all the similar lines in the factory. Some Kaizens carried out by regional factories also replicated in the local company. There is a annual Kaizen competition and rewarding system based on the impact to the busyness.

Education and Training Pillar-

The impact of this pillar is measured by the no of training hours carried out on different topics. These training were held in house with external and internal resource personnel. Initially a skill gap analysis was carried out for each and every member of the workforce to identify the skill gaps.

SHE pillar-

The impact is measured by the number of loss time accidents (LTA) occurred and the safety one point lessons (OPL) identified in each line.

Quality Maintenance Pillar-

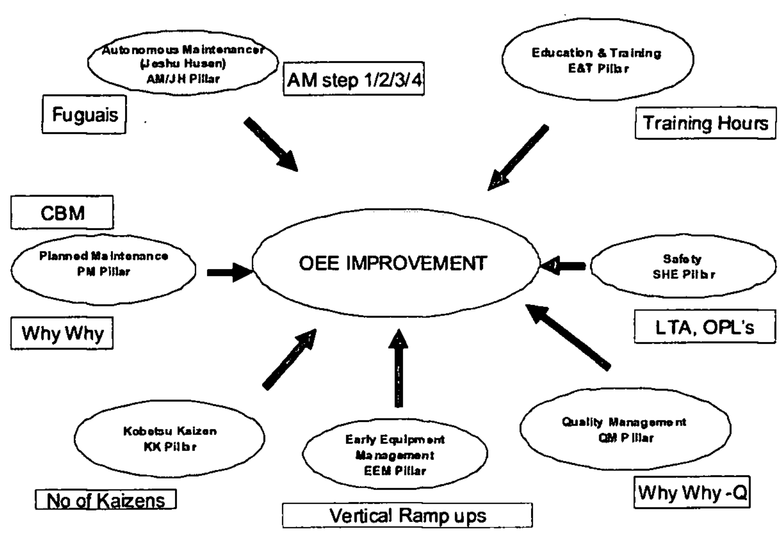
The impact of QM pillar is measured by the number of Why Why analysis carried out on quality issues.

Early Equipment Management Pillar-

The impact is mainly linked with new technology introduction. Vertical Ramp up is a measure of post commissioning efficiency of new equipment and it was the measure of EEM pillar.

Table 3.1 List of activities considered under each pillar

TPM Pillar	Measuring Criteria
Autonomous Maintenance –AM	1.No. of Fuguais identified 2. AM level Step1/2/3/4
Planned Maintenance-PM	1.No. of Why Why analysis carried out for equipment break downs 2.No of Condition Based Maintenance Schedules (CBM)
Kobetsu Kaizen –KK	1.No. of Kobetsu Kaizens completed
Education and Training- E&T	1.No. of skill upgrade training hours completed per person
Early Equipment Management-EEM	1.No of Vertical ramp up new projects
Safety Health and Environment-SHE	1.No. of Loss Time Accidents (LTA) 2.No of Kaisens on safety improvements
Quality Maintenance QM	1.No. of quality improving Kaisens 2.No of Why Why analysis on Quality issues



The conceptual framework as depicted in figure 2 was developed based on the selected activities of seven TPM pillars.

Figure 2: Conceptual frame work

3.2 Case Study Method

This research was carried out in both quantitatively and qualitatively. A case study method was adopted to carry out this study since, Unilever Sri Lanka, Grandpass factory has implemented TPM and has all the supporting data and evidences.

Case study research excels at bringing us to an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research. Case studies emphasize detailed contextual analysis of a limited number of events or conditions and their relationships. Researchers have used the case study research method for many years across a variety of disciplines.

Social scientists, in particular, have made wide use of this qualitative research method to examine contemporary real-life situations and provide the basis for the application of ideas and extension of methods. Researcher Robert K. Yin defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used (Yin, 1984, p. 23).

Critics of the case study method believe that the study of a small number of cases can offer no grounds for establishing reliability or generality of findings. Others feel that the intense exposure to study of the case biases the findings. Some dismiss case study research as useful only as an exploratory tool. Yet researchers continue to use the case study research method with success in carefully planned and crafted studies of real-life situations, issues, and problems. Reports on case studies from many disciplines are widely available in the literature.

3.3 Selection of Sample Lines

Out of the 3 production departments (Toilet Soaps, Personal Products and Edible Fats) in Grandpass factory 13 production lines were selected for this analysis. The other lines in the manufacturing plants were not considered since they do not produce finished products, hence clear efficiency measurement is not happening. Out of these 13 lines there is a TPM model line in each department where TPM was initially implemented.

3.4 Data Collection Method

First the research is carried out through quantitative approach by analyzing the data available on TPM activities and line efficiencies. These line data is obtained from the central data base in the TPM secretariat. Unilever central data base on line performance is maintained at TPM secretariat. All the production lines enter their line production and the losses in the production log sheet referring the defect number. These log sheets are collated and data is fed to line performance data base by the data entry operator at the TPM secretariat. The previous days log sheets are certified by the plant management and send to the data entry operator by 8 a.m. The TPM secretariat enter these data in to the central data base and daily circulate the daily, weekly, monthly YTD performances of each line.

The line defects are categorized under six major losses, Break downs, set up adjustments, idling , minor stoppages (less than 10 mts. Break downs) reduced speed losses, quality defects and start up losses. This data base has the option of generating trend graphs on any defect of each line which enables to analyze the line losses and find out major losses of the line.

All the TPM pillar activity data also gathered by TPM secretariat and keep records, hence all the TPM activity data and the line performance data is available at a single location. Each pillar leader is monitoring their pillar progress and they ensure that the all the TPM activities happening on each line is being captured.

Finally the significantly improved line and the line which was not shown any improvement are further analysed by interviewing key stakeholders of those lines. A Questionnaire (Annexture 3) was prepared to interview them and gather information. The Plant Manager, The Plant Engineer, Line leader or operator of each line and TPM Coordinator are the key people to be interviewed. All three shift crews were covered when selecting line leaders and operators of the lines.

Chapter 4

4.0 Observations and Data Analysis

4.1 Observations

Unilever Sri Lanka who manufacture fast moving consumer goods has its main manufacturing unit in Grandpass. It has seven departments out of which 3 departments Edible Fats, Toilet Soaps and Personal Products departments has produce finished goods and others produce semi finished goods or provide services Refer Table 4.1.

Table 4.1: Summary of activity of each key manufacturing plant

Plant	Description	Product/ Brand	Manning level	OEE Before	OEE After
Edible Fats	The plant comprises of an oil refinery and five packing lines	Astra, Flora and bakery fats	140	54	65
Personal Products	Toothpaste, shampoos, creams and lotions are produced at this plant on ten packing lines	Signal, Sunsilk, Lifebuoy, Pears, Ponds	145	64	65
Toilet Soaps	The plant comprises of drying plant and three packing lines to produce all the toilets soaps requirement of Sri Lanka	Lux, Lifebuoy, Pears	80	56	71
Hard Soaps Drying	The plant consists of three drying plants used for the manufacture of soaps chips that are sent to a third party packing plant at LINDEL site	Chips for Sunlight and Lifebuoy	40	N/A	N/A
Soapery	The base soap used for the toilet soaps and hard soaps is manufactured in this plant. It also comprises of a glycerine extraction facility. Glycerine is a key by-product .	Base soap for toilet and hard soaps	45	N/A	N/A
Bulk Materials Storage	The vegetable oils that are a major ingredient in soaps and margarines is stored and blended in this plant	Oils for soaps and margarines	10	N/A	N/A
Central Engineering Services	Provides the utility (power, water, steam and compressed air) needs to the other manufacturing facilities.		55	N/A	N/A

Source: Factory Passport, Unilever Sri Lanka

4.1.1 Central Data Base

Unilever Sri Lanka has implemented TPM starting from 2002 in all their production lines, hence the period from 2000 to 2005 was considered as the analysis period to gather data. The data required for this analysis is of two folds, one is line efficiency data the other is the TPM activity data. The Industrial Engineering department of the company collated and compiled the line performance data before implementing TPM. But after TPM implementation TPM secretariat started collating all line performance data with more detail defect classification. The overall equipment efficiency (OEE) of each line was collected from central data base data.

The table 4.2 below shows the OEE of each line during the considered 5 years.

Table 4.2: OEE of the selected lines from 2000-2005

Dept	OEE						OEE Imp. %
	2000	2001	2002	2003	2004	2005	
Toilet Soaps L1	60	58	61	68	71	72	19
Toilet Soaps L2	58	54	59	69	69	70	20
Toilet Soaps L3	52	52	53	59	67	71	33
Toilet Soaps Dept	56	55	58	66	69	71	25
PP NM 700	62	59	58	71	75	74	20
PP AM 1000	62	66	61	66	69	72	14
PP8 Lane					57	59	
PP Sh Hassia	59	76	71	79	73	62	14
PP TP Hassia	66	65	65	65	65	60	-5
PP Dept	64	69	66	72	70	65	5
Edible 45g	55	56	49	60	70	75	32
Edible 100g	47	53	50	50	64	66	38
Edible 250g	51	54	52	60	59	65	22
Edible 500g		50	41	46	50	54	4
Edible PMG	63	59	61	59	57	56	-10
Edible Dept	54	55	52	57	62	65	10

Source: Loss Tree Data Base, Unilever Sri Lanka

TPM pillar activity information also collated by the TPM secretariat. In addition to the full time TPM Coordinator each pillar has a pillar leader who monitors the progress of each pillar by the number of activities carried out. Out of the several activities carried out under each pillar maximum to activities were selected under a one pillar. But in some cases like KK and E& T pillars only one criterion is selected for the analysis. Altogether 10 activities were selected under the seven pillars as depicted in Table 3.1.

This table indicates the total number of activities carried out on each line during the 5 years but the number of activities carried out in each year is used for the analysis. Some activities such as Training hours per person and loss time accidents are not line specific since workmen are not fully dedicated to a line hence in those cases departmental values are considered. Under EEM pillar the measuring criteria vertical ramp up data is available only for Toilet Soaps and Edibles Department because there was no innovation project happened in Personal Products department during this period. Under Education and Training pillar the data available is the no of training hours conducted on each area for each person hence the training hours per person is measured for each department for the analysis.

Table 4.3: Pillar activities.

Pillar	Measuring Criteria	TS			PP					EDIBLE				
		L1	L2	L3	NM 700	NM 1000	8 Lane	SH Hassia	TP Hassia	45g	100g	250g	500g	PMG
AM	Fuguais	884	404	391	469	359	55	117	81	199	262	987	148	264
	AM level	4	4	4	3	4	3	3	4	3	4	4	3	3
PM	WW	7	10	7	70	23	1	3	5	2	5	2	0	3
	CBM Schedules	1	1	1	1	1	0	0	0	1	1	1	1	0
KK	Kaizens	0	3	3	1	1	2	2	2	3	2	3	2	0
E&T	Training Hrs/Person	34			29					20				
EEM	Vertical Ramp Up's	89%										68%		
SHE	LTA's	1			1					3				
	Kaizen-Safety	13	12	6	4	8	2	1	0	2	6	0	0	0
QM	WW-Quality	3	4	1	70	45	1	11	26	3	4	2	1	1

Source: TPM Data base, Unilever Sri Lanka

4.1.2. Through Interviews

A total of fifteen interviews ranging from 15 to 30 minutes conducted with key personal like TPM coordinator, factory manager, Union leader, Plant managers, Plant Engineers, line managers and operators were carried out covering the most significantly improved line and the non improved line, out of the thirteen production lines. Toilet Soaps line number 3 was selected as the most significantly improved line and the Personal Products Toothpaste Hassia line was taken as the non improved line. All the interviews were based on the sample set of questions (Annexure 2). When selecting the interviewees from the line, people from 3 different shifts were selected considered to get the feedback all shifts.

The answers were noted down and at the end the summary was re-presented to the interviewee to get the confirmation from them. A friendly general conversation was carried out with line members before get into the questions to ensure that they will openly express their views on TPM.

4.2 Data Analysis

During this five year period all 13 production lines TPM activity data as well as the line OEE data is available, in this case OEE is the dependent variable and the all other TPM activities are independent variables, hence to analyze the relationship between these variables, regression analysis is the most appropriate statistical technique.

4.2.1 Simple Linear Regression

Simple linear regression is a good method to develop a relationship between two variables from which one is a dependent variable and the other is an independent variable. In this case OEE is the dependent variable and the measuring parameter no of Kaizens, no of Why Whys etc. would be the independent variable in each case.

The model we use is a straight line relationship between independent variable X and dependent variable Y.

$$Y = b_o + b_1X_1 + \epsilon$$

b_o: is the Y intercept of straight line,

b1: is the slope of the line,

ϵ: is the random error and assumes that it is normally distributed with mean zero.

To minimize the error component most commonly used regression line is with minimum sum of the squared errors (SSE).

4.2.2 Correlation

The relationship between the two variables is called as correlation analysis. The correlation between two variables is a measure of linear relationship between them. Correlation coefficient is ρ for population and r for sample. If r is large (closer to 1) and positive, then there is a high correlation between the two variables. Once we have determined that a linear relationship exists between the two variables to identify how strong that relation ship is also important. It is measured by the r^2 which is called as the coefficient of determination.

The higher the r^2 is, better the fit and higher our confidence in the regression. But when r^2 is exceptionally high, such as 0.999 or 0.99 then there must be some thing wrong. There is no clear answer on how high should be the coefficient of determination to predict the results with confident, but higher the r^2 the more accurate will be our predictions. The r^2 value of 0.9 or more is very good. A value greater than 0.8 is good, and a value of 0.6 or more may be satisfactory in some applications, although we must be aware of that, in such cases, errors in prediction may be relatively high. When the r^2 value is 0.5 or less, the regression explains only 50% or less of the variation in the data, therefore, predictions may be poor.

T test and F test are another two tests carried out to identify the significance of the relationship between the two variables.

4.2.3 Multiple Regression

In regression analysis when there are more than one independent variable then the model is called as multiple regression model.

$Y=b_0+b_1X_1+b_2X_2+\ldots\ldots+b_kX_k+\epsilon$

(Y is the dependent variable, X_1, X_2 ……. are the independent and ϵ is the random error.)

By using the F test we can find out the whether there is a relationship between dependent variable with at least one independent variable. Once we conclude that separate tests need to be carried out to determine the relationship of each sub set.

Similar to simple linear correlation in multiple regression the multiple coefficient of determination - R^2 is a measure of how well the regression equation fits the data. Also by considering the degrees of freedom of k variables an adjusted multiple coefficient of determination is computed.

When analyzing the relationship between Y and X_1, X_2 … there is a problem of correlations among

X_1, X_2 … i.e. independent variables which is termed as multicollinearity. However we do not want independent variables to be correlated with one another. When this happens, the independent variables rob one another of explanatory power.

Statistical Package for Social Sciences (SPSS) software package was used to analyze the above data. Compared to other data analysis packages SPSS statistics is easier to use as well as very advance in analysis features available. Simple and multiple linear regression analysis is used to analyze the relationship between the independent variable and dependent variables of this data set.

First using the linear regression relationship between each independent variable (TPM activity) and OEE of a production line (dependent variable) were identified. By comparing the results (beeta and $r^{2)}$ the most significant TPM activities can be identified. Also by using the multiple regression the impact of multiple TPM activities on OEE of the production lines were identified. From this we can find the impact of different TPM pillars on OEE. Also multiple regression can be used to find the lines which were having a significant OEE improvement due to the all the TPM activities or vice versa.

There were 11 independent variables (Refer Table 3) to measure the activities of 7 TPM pillars and those variables were fed to the SPSS first. The dependent variable OEE also entered. There are 12x 13 variables since each line has 12 variables.

The data for the above variables were gathered from 2000 to 2005 for all 13 lines and fed to the SPSS data base. Linear Regression was then carried out for the every activity on each line and obtained a report (Annexture 4). From the SPSS regression report, Beta and r^2 were used to compare the relationship between each TPM activity and OEE. The table 4 contains the OEE of each line during this period and the percentage change within this five years. The summary of SPSS analysis reports is in the tables below. Also the significance of each individual regression parameter is also tested using this software.

4.3 Results

The key results obtained from simple linear regression are the gradient-Beeta, coefficient of determination -R^2 and the significance. First those results of each sub activity are tabulated in department wise. Then the total pillar effect is analyzed using multiple regression for all the 13 lines. Finally the interview data results were analyzed on the most significantly improved line and the poorly performed line.

Toilet Soaps Department

Table 4.4: Pillar activities vs OEE relationship of Toilet Soaps lines

Pillar	TPM Activity	TS L1			TS L2			TS L3		
		B	R^2	Sig	B	R^2	Sig	B	R^2	Sig
AM	Fuguais	0.20	0.39	0.01	0.73	0.54	0.04	0.83	0.69	0.01
	AM level	0.93	0.86	0.01	0.93	0.87	0.02	0.98	0.96	0.03
PM	WW	0.61	0.37	0.03	0.52	0.27	0.06	0.73	0.54	0.04
	CBM Sch.	0.76	0.57	0.01	0.97	0.94	0.02	0.87	0.76	0.03
KK	Kaizens	*	*	*	0.63	0.40	0.04	0.80	0.63	0.03
E&T	Training Hrs/Person	0.801/0.64/0.04**								
EEM	Vertical Ramp Up's	0.428/0.18/0.03**								
SHE	LTA's	0.428/0.18/0.07**								
	OPL's	0.61	0.37	0.0.4	0.52	0.27	0.06	0.73	0.54	0.04
QM	WW-Quality	0.81	0.66	0.05	0.66	0.43	0.15	0.93	0.87	0.006

(* no activity carried out , hence not analyzed)

(** Data available only for department hence line wise results are not available)

As depicted in Table 4.4, it is clear that in the toilet soaps 3 lines only AM, PM and E&T pillar activities have significantly contributed to the OEE. The other pillars do not show strong relationship on OEE improvement of any of the lines. When further analyzed the AM,PM and E&T pillar sub activities contribution, AM level is the most significant contributor and Why Why analysis (WW) is the less effective out of the 5 sub activities. But OPL's under SHE pillar and Why Why on Quality defects under QM pillar also shown a marginal relationship towards OEE.KK pillar contribution in line 2 and 3 are significant and no relationship in line 1 since there is no Kaizen carried out in line 1.

The line 3 which was significantly improved line (33% OEE improvement) during this period shows a significant relationship between pillar activities and OEE compared to other 2 lines. This line's OEE was at 52% which was the lowest among the 3 lines when implementing TPM in 2002 and it was also among the 3 lowest OEE lines of the factory (13 lines). The performance of this line is further discussed below with the interview data.

Personal Products Department

Table 4.5: Relationship between pillar activities vs. OEE of PP lines

Pillar	TPM Activity	PP NM 700			PP NM1000			PP 8 Lane			PP SH Hassia			PP TP Hassia		
		B	R^2	Sig	B	R^2	Sig	B	R^2	Sig	B	R^2	Sig	B	R^2	Sig
AM	Fuguais	0.67	0.45	0.04	0.63	0.40	0.60	-0.45	0.20	0.08	-0.19	0.04	0.60	0.66	0.44	0.80
	AM level	0.79	0.62	0.03	0.53	0.28	0.40	-0.53	0.28	0.06	-0.01	0.00	0.50	-0.06	0.00	0.60
PM	WW	0.65	0.42	0.04	*	*	*	-0.43	0.18	0.04	-0.24	0.06	0.47	0.40	0.16	0.86
	CBM Sch.	0.51	0.26	0.07	0.71	0.50	0.50	*	*	*	*	*	*	*	*	*
KK	Kaizens	*	*	*	*	*	*	-0.43	0.18	0.06	-0.03	0.00	0.40	0.71	0.50	0.08
E&T	Training Hrs/Person	0.751/0.56/0.08**														
EEM	Vertical Ramp Up's	*														
SHE	LTA's	0.676,0.46/0.78**														
	OPL's	0.50	0.25	0.20	*	*	*	-0.25	0.06	0.00	-0.43	0.19	0.04	*	*	*
QM	WW-Quality	0.73	0.54	0.10	*	*	*	-0.42	0.18	0.39	-0.36	0.13	0.47	-0.23	0.05	0.66

(* no activity carried out, hence not analyzed)

(** Data available only for department hence line wise results are not available)

As depicted in Table 4.5, Personal Products department lines' OEE does not show any significant relation ship between any of the pillar activities vs. OEE. Even though NM 700 line's OEE increased by 20% during this 5 years it shows only a moderate relationship to AM and PM pillars. When compared with 5 lines in this department only NM 700 line has completed both the sub activities of PM pillar.

In general PM and KK activities were not carried out in all the lines in Personal Products Department. Only one PM pillar activity i.e. break down why why analysis was carried out in the 3 sachet lines and no CBM schedules were implemented. KK pillar was active only on 3 sachet lines but the impact on OEE in those lines also very poor or negative.

The other significant point is the there are some negative Beeta's for some activities in sachet lines such as 8 lane and two Hussia lines. Out of the 3 lines, 8 lane machine which was installed in 2004 has a significant negative relationship to all the activities during the two years span.

But the two Hassia lines has some negative impact from few activities such as AM, PM and QM still the significance is very low.

Out of the 13 lines, toothpaste Hassia is one of the lines dropped OEE during this period and the results also shows that there was no impact from any of the pillar activities towards its OEE.

When implementing TPM this line's OEE was at 66% and which was the most efficient line out of the 13 lines in year 2000 and it maintained its OEE at 65% till 2004. But in 2005 it was dropped to 60%.This is further analyzed with the help of interview results.

The other specialty in Personal Products Department activities is that there was no any innovation project carried out in any of the lines during this period. Hence EEM pillar activities were not happened.

Edible Fats Department

Table 4.6: Relationship between pillar activities vs. OEE of Edible lines

Pillar	TPM Activity	EDIBLE 45g			EDIBLE 100g			EDIBLE 250g			EDIBLE 500g			EDIBLE PMG		
		B	R^2	Sig	B	R^2	Sig	B	R^2	Sig	B	R^2	Sig	B	R^2	Sig
AM	Fuguais	0.77	0.60	0.03	0.92	0.85	0.04	0.22	0.05	0.03	0.14	0.02	0.06	-0.66	0.43	0.04
	AM level	0.83	0.69	0.04	0.87	0.75	0.03	0.86	0.73	0.04	0.47	0.22	0.09	0.00	0.00	0.05
PM	WW	0.74	0.55	0.09	0.72	0.52	0.10	0.77	0.59	0.07	-	-	-	0.23	0.06	0.65
	CBM Sch.	0.65	0.66	0.04	0.76	0.65	0.04	0.85	0.76	0.05	0.54	0.34	0.03	0.23	0.32	0.04
KK	Kaizens	0.42	0.17	0.08	*	*	*	0.17	0.03	*	*	*	*	*	*	*
E&T	Training Hrs/Person	-0.194/0.04/0.04**														
EEM	Vertical Ramp Up's	-0.082 /0.01/.4**														
SHE	LTA's	-0.321 /0.13 /0.03**														
	OPL's	0.74	0.55	0.04	0.72	0.52	0.03	*	*	*	*	*	*	*	*	*
QM	WW-Quality	0.74	0.55	0.09	0.72	0.52	0.10	0.77	0.59	0.07	0.75	0.56	0.15	*	*	*

(* no activity carried out, hence not analyzed)

(** Data available only for department hence line wise results are not available)

Out of the 5 production lines in Edibles Department PMG line is a non priority line which produces industrial margarines and marketed by a different company. Hence TPM activities were not progressed in this line to a considerable level.

As depicted in Table 4.6 Edibles department also only AM and PM pillar activities shows a moderate relationship to OEE improvement. But the two lines 45g and 100 g shows a strong relationship between AM, PM pillar activities and OEE. These two lines' OEE improvement is also considerably high 32% and 38% respectively. In this department there is a significant impact to OEE from QM pillar activities when compared to other two departments. Also there were 3 loss time accidents reported in Edibles whilst the other two departments had only one each so that this department has had the highest number of LTA's during this period. Moreover unlike in other two departments, Edibles has a negative relationship from E&T pillar activities. Under the SHE pillar OPL's were carried out only in 45g line and 100g lines and there is a significant relationship towards OEE in those lines.

Under EEM pillar vertical ramp up results were available since there was an innovation project implemented in Edibles during this period. It shows a negative Beeta and R^2 and significance is also very low.

The other important point in the above result is that the most activities shows high significance towards the moderate positive relationship towards OEE.

Total Factory

Table 4.7 Relationship between pillars vs. OEE of all lines

<table>
<tr><th>Pillar</th><th></th><th>AM</th><th>PM</th><th>KK</th><th>E&T</th><th>EEM</th><th>SHE</th><th>QM</th></tr>
<tr><td rowspan="2">TS L1</td><td>R^2</td><td>0.90</td><td>0.95</td><td>*</td><td rowspan="6">**
0.641/0.05</td><td rowspan="6">**
0.699/0.038</td><td>0.71</td><td>0.37</td></tr>
<tr><td>Sig</td><td>0.01</td><td>0.01</td><td>*</td><td>0.15</td><td>0.20</td></tr>
<tr><td rowspan="2">TS L2</td><td>R^2</td><td>0.89</td><td>0.84</td><td>0.40</td><td>0.53</td><td>0.27</td></tr>
<tr><td>Sig</td><td>0.03</td><td>0.06</td><td>0.17</td><td>0.32</td><td>0.28</td></tr>
<tr><td rowspan="2">TS L3</td><td>R^2</td><td>0.98</td><td>0.99</td><td>0.63</td><td>0.91</td><td>*</td></tr>
<tr><td>Sig</td><td>0.00</td><td>0.00</td><td>0.06</td><td>0.03</td><td>*</td></tr>
<tr><td rowspan="2">PP NM700</td><td>R^2</td><td>0.81</td><td>0.92</td><td>*</td><td rowspan="10">**
0.564/0.08</td><td rowspan="10">*</td><td>0.40</td><td>0.54</td></tr>
<tr><td>Sig</td><td>0.08</td><td>0.02</td><td>*</td><td>0.05</td><td>0.10</td></tr>
<tr><td rowspan="2">PP NM1000</td><td>R^2</td><td>0.56</td><td>0.55</td><td>*</td><td>0.56</td><td>*</td></tr>
<tr><td>Sig</td><td>0.44</td><td>0.14</td><td>*</td><td>0.70</td><td>*</td></tr>
<tr><td rowspan="2">PP8L</td><td>R^2</td><td>0.62</td><td>*</td><td>0.18</td><td>0.20</td><td>0.18</td></tr>
<tr><td>Sig</td><td>0.51</td><td>*</td><td>0.40</td><td>0.72</td><td>0.39</td></tr>
<tr><td rowspan="2">PPSH H</td><td>R^2</td><td>0.14</td><td>0.13</td><td>0.00</td><td>0.31</td><td>0.13</td></tr>
<tr><td>Sig</td><td>0.80</td><td>0.47</td><td>0.95</td><td>0.57</td><td>0.47</td></tr>
<tr><td rowspan="2">PP TPH</td><td>R^2</td><td>0.09</td><td>0.00</td><td>0.50</td><td>0.06</td><td>0.05</td></tr>
<tr><td>Sig</td><td>0.87</td><td>0.86</td><td>0.12</td><td>0.65</td><td>0.66</td></tr>
<tr><td rowspan="2">ED 45g</td><td>R^2</td><td>0.92</td><td>*</td><td>0.17</td><td rowspan="10">**
0.038/0.71</td><td rowspan="10">**
0.007/0.877</td><td>0.57</td><td>0.55</td></tr>
<tr><td>Sig</td><td>0.02</td><td>*</td><td>0.41</td><td>0.28</td><td>0.09</td></tr>
<tr><td rowspan="2">ED 100g</td><td>R^2</td><td>0.79</td><td>*</td><td>*</td><td>0.58</td><td>0.72</td></tr>
<tr><td>Sig</td><td>0.09</td><td>*</td><td>*</td><td>0.27</td><td>0.52</td></tr>
<tr><td rowspan="2">ED 250g</td><td>R^2</td><td>0.92</td><td>*</td><td>0.03</td><td>0.00</td><td>0.59</td></tr>
<tr><td>Sig</td><td>0.02</td><td>*</td><td>0.75</td><td>0.93</td><td>0.07</td></tr>
<tr><td rowspan="2">ED 500g</td><td>R^2</td><td>0.60</td><td>*</td><td>*</td><td>0.41</td><td>0.56</td></tr>
<tr><td>Sig</td><td>0.39</td><td>*</td><td>*</td><td>0.24</td><td>0.15</td></tr>
<tr><td rowspan="2">ED PMG</td><td>R^2</td><td>0.36</td><td>*</td><td>*</td><td>0.01</td><td>*</td></tr>
<tr><td>Sig</td><td>0.51</td><td>*</td><td>*</td><td>0.83</td><td>*</td></tr>
</table>

(* no activity carried out, hence not analyzed)

(** Data available only for department hence line wise results are not available)

The table 4.7 shows the impact of each pillar towards line OEE. Out of the seven pillars five pillars has more than one activity and the Multiple Regression was used to analyze them. Only the other two pillars results were analyzed using Simple Linear Regression. The two values obtained from these analyses using the SPSS software are R^2 and the significance which gives the dependency of independent variable on independent variables and the significance level of that dependency.

When we analyze the results in Table 4.7 the impact of seven pillars towards OEE improvement AM and PM pillars shows a significant relationship in most of the lines. Other than PP sachet lines and Edibles 500g and PMG lines all the other lines have a R^2 of around 0.9 and a significance less than 0.05 which is a very high significance level.

Only half of the lines have carried out KK pillar activities and as per the results non of them have high impact on OEE. The Education and Training pillar activities in Toilet soaps department and Personal Products department shows strong relationship but the Edibles department results do not show any significance. EEM pillar activities have been carried out in Toilet Soaps and Edibles only and there is only a low impact in Toilet Soaps and there is no significant impact to OEE in Edibles. SHE pillar does not show any significance in any of the lines but there were considerably higher number of LTA's happened in Edibles. QM pillar activities show a marginal impact on some Edible lines but there is no any impact on any other lines.

The above statistical results can be further analyzed with help of the interview data. The interviews mainly focused on Toilet Soaps line 3 which was improved its OEE by 33% and the Personal Products Tooth Paste Hassia line which was dropped its OEE by 5%. The interviews with the TPM Coordinator, Factory Manager, and Factory Engineer were not only on those two lines but also on overall effects as well.

TPM coordinator said that the TPM was kicked off in Unilever with the implementation of AM pillar activities as per the general guidelines of JIPM and that is why AM pillar activities have been implemented better than the other pillars. Also he said that the lines which carried out AM activities well have improved better than the other lines. His other point is that the pillar leader's drive on their pillar is also reflected on the progress of the pillar activities. As a example he mentioned that the AM pillar leader's department has progressed AM pillar activities more than the other departments.

Factory Manager's idea is that the operator's who has a good attitude got involved in TPM activities more and others changed at a very low phase or few did not changed at all. His view is that most of the improvements (Kaizens) were successful in the departments where workers attitude is very positive. Also he mentioned that there should have been more attention towards get people's involvement and changing their attitude through Education and Training Pillar at the beginning of the journey. The other point he mentioned is that only the low efficient lines have been improved by considerable amount but the lines which had a OEE of 70's were improved marginally.

The Factory Engineer who is the PM Pillar leader as well said the PM activities have not happened deep enough on the production lines compared to the services departments such as Boiler plant and Air Compressors. His view is that the two activities considered under PM is, number of Why Why's on break downs and number of CBM schedules implemented are the basic steps of PM. But to get more benefits out of PM, maintenance prevention (MP), detail break down analysis (WWBLA- Why Why Because Logic Analysis) need to be carried out.

From the line specific interviews it was revealed some clear indications on the different performance of the two selected lines,

1. Toilet Soaps Line 3 which was the maximum OEE improved line.
2. 2. Personal Products Toothpaste Hassia Line which was the OEE dropped line.

Toilet Soaps line 3 is a dedicated line for a single product hence, the number of size change overs are zero and only the colour change overs are present. Due to this it does not have change over related losses. TPM was implemented in this line on 2003 after model line implementation in 2002, but lots of Kaizen carried out in model line have been replicated to this line soon after TPM has been introduced to this line. According to the Plant Engineer of Toilet Soaps lot of quality issues were eliminated after introducing these Kaizens to this line. Also the front line management said that they were able to address to the high speed loss of this line due to unaccounted time by convincing the line team since there was a very good relationship between management and the operators in this department. According to the line 3 team they are very keen on carrying out JH activities and they never skipped daily JH cleaning 30 minutes. Plant Engineer further said that PM activities also carried out very vigorously in this line compared to other lines. One fitter was dedicated to complete all the time base and condition base maintenance of this line on every Sunday and they complete all the due tasks with much responsibility. TPM coordinator said "continuously carrying out JH activities is one of the main reasons why Toilet Soaps Department performance increase, also the whole team, managers together with operators performed CLIT (cleaning, lubrication, inspection and tightening) without fail is another key contributor for this achievement." He also mentioned that this line has the advantage of not having frequent change overs which leads to set up and adjustment losses. Factory Managers view is that the Toilet Soaps carried out PM activities methodically than other production departments which also has a higher bearing on L3 better results.

Toothpaste Hassia line in Personal Products Department is the line which dropped it's OEE by 5% over this period. This line produces Toothpaste sachets and compared to other lines it maintained a very high OEE in 2000/02. This line is a very high priority line since this line is the only line which produces Toothpaste Sachets. It is the only line which has completed AM step 4 level out of the 13 lines. According to the line operators they said that the there were lot of recurrent break downs and quality issues in this line which were not analyzed properly to find the root cause of the problems. As per the plant Manager the attitude of the line team also very poor compared to the other lines in the department. And it was a one reason for not initiating in analyzing the line issues. The TPM coordinators view is also that the line team including the line managers were not keen on solving the problems in the line using the TPM tools. This line also has frequent product change overs which also contributed to this poor performance. According to the line leaders they pointed out that there was no dedicated crew to run this line since most of the time toothpaste tube filling lines acquire people from this line to cover the absenteesm since they are much complicated lines. Hence most of the time inexperience people are working in this line which also led to this poor performance. As per the Plant Engineer this line's efficiency started dropping after 2004 since it has undergone a major Kaizen to increase the capacity of the machine during that year. The machine which was designed for 2 lanes was modified to a 4 lane machine by that Kaizen. His view is that there were some teething problems in the machine after this local modification and not totally solved quickly.

Chapter 5

5.0 Conclusion

This chapter aims to recommend the key TPM pillars which influence the efficiency improvement of a manufacturing organization in Sri Lanka. This chapter will also aim at identifying possible areas of further study that can be conducted in order to find the effectiveness of TPM on local industry.

5.1 Key Conclusions

There is a considerable OEE improvement in most of the lines with the implementation of TPM. There is a twenty percent or more improvement in seven lines out of the thirteen production lines of the three departments. Only two lines shows a decrease in OEE during this period and both of them are producing less demand products.

Autonomous Pillar- There is a strong influence from AM activities to the OEE in most of the lines. Especially in significantly improved lines main contributor is AM. Out of the two elements considered in AM activities AM step 1/2/3/4 achievement contributed considerably than Fuguai finding. Also the impact from AM on OEE is very low in Personal Products department compared two other two departments. From the interviews it was revealed that main reason for this is more product changeovers and complexity of the department.

Planed Maintenance Pillar- There is a considerable influence on OEE from this pillar too. But the more weight is shown from the CBM/TBM activities and not from the break down analysis. On the other hand PM is happening on all the lines even though in some lines it is less significant.

Kobetzu Kaizen Pillar- This pillar activities were compared only on department level and only Toilet soaps department shows a significant relationship on OEE. Other two department shows a very low significance on OEE improvement.

Early Equipment Management Pillar- Other than in toilet soaps department any other department has not significantly achieved any results on vertical start ups of new projects. But each department has completed at least a one project during this period.

SHE Pillar- Toilet soaps department shows significance on SHE pillar activities. Edibles department showed a poor SHE performance (high LTA rate) resulted in a negative impact on OEE.

Quality Management Pillar- This pillar activities carried out in Edibles department and Personal Products department shows a marginal impact.

Out of the seven TPM pillars only AM and PM activities indicates a significant relationship to OEE improvement of these production lines. It is obvious that lines operating at less than 70% OEE can be improved by 20%-30% easily by focusing mainly on AM and PM.

From the interviews carried out for the highly improved line and the least improved line it was revealed that the highly demand product line's TPM activities are happening because the management focus is more on those lines. But the TPM activities in less critical lines on plan achievement are relatively less importance was given. On the other hand maximum improved Toilet Soaps line 3 does not have much product change-overs hence its set up and adjustments loss is minimal. Even though the Personal Products toothpaste Hassia line is the first line to achieve JH step 4 in that department, still it is the least improved line in the factory. On the other hand the workforce attitude and the skill level is also significant in these results. The team of the TS L3 which was the best line shows a very good attitude and high skills. There involvement in TPM circle team activities was very high, hence the Education and Training Pillar is played a vital roll even though it was not clearly highlighted in the results.

5.2 Recommendations.

Even though few companies in Sri Lanka started implementing TPM only Unilever has practicing TPM in methodical way and obtained level 1 certification this case study was limited to one company. So this study can be expanded to other companies who are now started practicing TPM.

As per this research Autonomous Maintenance, Planned Maintenance and Education and Training pillars are the key pillars to start TPM, hence a detail study on one of those pillars would be able to find more best manufacturing practices.

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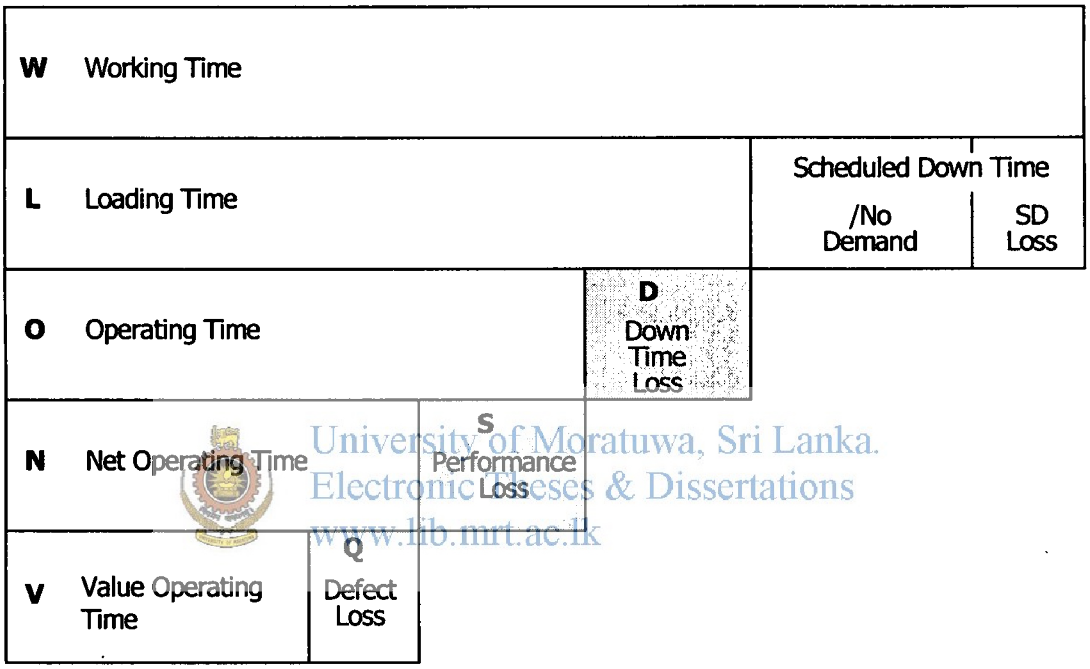
7.0 Annextures

Annexture 1 – OEE definition and method of calculation

TPM	Unilever	A REWARDING WORK STYLE
Overall Equipment Efficiency		



Availability	$\frac{\text{Loading Time - Down Time}}{\text{Loading Time}}$	$\frac{L - D}{L}$
Performance Rate	$\frac{\text{Operating Time - Performance Loss Time}}{\text{Operating Time}}$	$\frac{O - S}{O}$
Quality Product Rate	$\frac{\text{Net Operating Time - Defect loss Time}}{\text{Net Operating Time}}$	$\frac{N - Q}{N}$
OEE	**Availability X Performance Rate X Quality Product Rate**	$\frac{V}{L}$

Working Time	Working Time is the amount of time equipment can operate in a day or month
Loading Time	Loading Time is the amount of time equipment is planned to operate in a day or month excluding the routine down time losses
Operating Time	Operating Time is the amount of time the equipment actually operates excluding failure downtime losses
Net Operating Time	Net Operating Time is the amount of time the equipment actually operates at the designed speed
Value Operating Time	Value Operating Time is the amount of time the equipment actually operates to give the right quality output

Scheduled Down Time	No Demand	The time that the machine idle due to no production plans
	SD Loss	- Planned maintenance - Un avoidable start-up/ Shutdown - No Material (Planning) - No Workmen (Planing) - Plan suspensions
Down Time Loss	Equipment Failure	The time that require part replacement, function stoppage or decline, any repair time more than 10 minutes
	Set-up & Adjustment	The time loss due to prepare for subsequent production - Product/ Pack Change over - date code change
	Cutting Blade & Jig Change	The time loss due to change cutting blades, grinding wheels etc.
	Start-up	The time loss until the start-up, running in and machine conditions of the equipment have been stabilised - after plant shutdown - Monday morning etc.
	Other Down Time	- Cleaning/ Checking, - Awaiting instructions, - Awaiting materials, - Awaiting personnel distribution, - Quality confirmation - no buffer - no workmen (absenteeism)
Performance Loss	Minor Stoppage & Idling	The loss due to minor troubles, Starving, etc.
	Speed Loss	Loss caused by the difference between the designed speed and the actual working speed.
Defect Quality Loss		This caused when defects are found and have to be reworked

Annexure 2 - Questionnaire

Sample questions asked during interviewing for the research of Impact of TPM Implementation on Productivity Improvement.

1. Was this a TPM model line ?
2. If not when did you start doing TPM in this line
3. What pillar activities you started first
4. How old this line is
5. How was the attitude of the people working in this line towards TPM activities
6. How was the worker participation on TPM activities.
7. How was the commitment on TPM activities of the management of your department
8. Were the circle teams were active in your department
9. Did the operators of the line aware of the poor/good performance of the line
10. Did they know that there is a rewarding system based on efficiency of the line
11. Was there a good relationship between machine operators and Engineering fitters
12. How was the support from the central Engineering team on break-downs
13. Were there dedicated line operators.
14. What was the skill level of the operators working in the line
15. Was this line's finished products has a high sales demand

Annexture 3 - TBM /CBM Schedule for AM 1000 Machine

S.No	Name of the equipment	Down time classification	ABC classification	CBM	TBM
1	AM 1000 Filling Machine	Red piston o' ring	A	W	
		Red pusher	A	M	
		Red filling nozzle	A	6M	
		Red filling photocell	A		
		Red filling piston solenoid value - Mech	A		12M
		White filling nozzle	A	12M	
		White filling piston	A	M	
		White pusher bush	A	M	
		White filling piston ring	A	M	
		White pusher rod	A	M	
		White paste filling unit bearing	A		12M
		White filling photocell	A		
		Tube aligning photo cell burned	A		6M
		Cup ring belt	A		12M
		Cup belt bush	A		3M
		Conveyor belt	A	3M	
		Hot air problem (Gas cut)	A	W	
		Filling machine main motor & gear box	A	6M	
		Red filling piston pin	B	M	
		White filling blow off value	B	3M	
		White paste weight adjustment	B	3M	
		White filling photocell burned	B	W	
		White filling piston solenoid value - Mech	B	12M	
		Sealing jaw adjustments	B	W	
		Tube align photo cell	B		

		Tube ejector shaft	B	M	
		Tube feeder – motor	B	6M	
		Tube ejector solenoid value	B	12M	
		Tube feeder pusher alignment	B	6M	
		Tube feeder rocker plate	B	12M	
		Tube feeder motor	B	6M	
		Tube aligning lifting pusher	B	3M	
		Tube aligning lifting pusher holder	B	12M	
		Cutter knife	B	3M	
		Cutter pin	B	M	
		Cup aligning	B	6M	
		Photo cell system pusher	B	3M	
		Hot air blower	B	3M	
		Hot air lifting pusher	B	M	
		Cut- out –electrical	B	W	
		Tube feeder cassette	B	M	
		Data code unit	B	W	
		Cut out – electrical		W	
		Tube feeder cassette	C	M	
		Tube feeder tilter	C	3M	
		Cutter air hose	C	W	
		Data/ batch code impression	C	3M	
		Gum tape machine	C	3M	
2	AM 1000 carton Machine	C/M suction cup	A		3M
		Vacuum pump	A	M	
		Carton box adjustment	B	3M	
		Carton feeding adjustment	B	3M	
		C/M motor coupling pad	B	W	
		Tube feeding pusher	B	M	
		C/M gear box	B	12M	
		Conveyor belt pocket	B	3M	
		Carton m/c spocket chain	B	3M	
		Carton m/c side conveyor belt	B	6M	

W	WEEKLY
M	MONTHLY
3M	THREE MONTHLY
6M	SIX MONTHLY
12M	TWELVE MONTHLY

A Very critical and no major BD

B Critical and few BD's short MTTR

C Not critical