TOTAL PRODUCTIVE MAINTENANCE FRAMEWORK

FOR AUTOMOTIVE COMPANIES IN MALAYSIA

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Mechanical Engineering)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

NOVEMBER 2015

DEDICATION

To my beloved wife, Roslinda and all of my children: Nabil Irsyad, Nureen Najihah, Muhammad Nabil Ikhwan, Nureen Batrisyia and Nureen Faezatul Sofea, for the doa, love and endless support.

..And to the memory of my late parents who will forever be my inspiration.

ACKNOWLEDGEMENT

In the name of Allah, the Most Beneficent and the Most Merciful. It is with deepest sense of gratitude to the Almighty that gives me strength and ability to complete this thesis. Throughout the journey, I was in contact with many people, researchers, academicians and practitioners. They have contributed significantly towards my understanding and thoughts in this research.

In particular, I would like to take this opportunity to express my solemn thanks and greatest gratitude to my respected supervisor, Assoc. Professor Dr. Abd. Rahman bin Abdul Rahim, and to my co-supervisor, Professor Dr. Noordin bin Mohd Yusof for their invaluable advice, guidance, encouragement, support and motivation throughout the entire course of this research. My next appreciation goes to the honorable panel of experts, Professor Dr. Nooh bin Abu Bakar (internal examiner), Assoc. Professor Dr. Mohd. Nizam bin Abd. Rahman (external examiner) and Professor Ir. Dr. Sha'ri bin Mohd. Yusof (Chairman of the viva-voce). They have ensured the "validity" of my research to follow the utmost standard of UTM "The Research University"...JAZAKUMULLAHU KHAIRAN KATHIRA…The completion of this thesis could not have been accomplished without your support and guidance.

Lastly, I would also like to convey my gratitude to all of my colleagues and friends from Universiti Teknologi Malaysia (UTM), University Kuala Lumpur (UniKL) and automotive companies, who assisted me throughout the research journey. Their invaluable views, supports and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

ABSTRACT

Total productive maintenance (TPM) is an extensive maintenance management approach aimed towards improving the overall equipment effectiveness (OEE). A review on literature revealed that current TPM frameworks are generic and have inadequate coverage on the critical success factors (CSFs) constructs in its structure. These frameworks do not address the operational context particularly in providing the guideline for implementation, thus make it incomplete to be used in adopting TPM methodology. This research aims to provide a more comprehensive TPM framework with a set of significant CSFs and guideline for implementation. First, a conceptual framework (*denoted as TPM Framework I*) was developed with seven significant CSFs constructs as its main components, namely: management commitment and leadership; employee participation; training and education; effective communication; strategic planning; structured implementation approach, and; monitoring and evaluation. It was used for data collection through a mixed method research approach which integrates single-embedded (in-depth) design case study and survey. A methodological triangulation utilizing both qualitative and quantitative methods has been used throughout the research, which includes: semi-structured interview; document analysis; direct and participant observation; analysis of artifacts, and; exploratory survey. The case study aims at providing an insight of how the largest automotive company and six of its subsidiaries implement TPM by exploring "what" and "how" the CSFs constructs are emphasized. Multiple unit of analysis were explored individually and results are drawn together to yield an overall picture of the actual TPM practice. Cross-case analysis and descriptive statistics was used for data analysis. Findings and feedbacks from the case study were synthesized to develop the improved conceptual framework (*denoted as TPM Framework II*) which was then validated through expert validation involving eight respondents from other automotive companies. The inputs from expert validation were analyzed and incorporated for the development of final conceptual framework (*denoted as Final TPM Framework III*). It filled the gap of previous research by integrating most aspects of CSFs constructs from both human and operational context. Another novelty of Final TPM Framework III is the inclusion of extensive implementation plan and introduction of new additional structures of CSFs such as: address all eight pillars of TPM; holistic involvement of business stakeholders, and; employees' skill development linking with equipment life cycle. Such new characteristics have not been addressed in previous TPM framework. Final TPM Framework III can be generalized to automotive companies since it was synthesized from intensive case study and incorporated other automotive companies' input mainly through expert validation exercises. Final TPM Framework III enables the management of automotive companies to take effective actions in handling issues related to TPM implementation.

ABSTRAK

Kaedah *total productive maintenance* (TPM) merupakan kaedah pengurusan penyelenggaraan yang menekankan kepada peningkatan dalam *overall equipment effectiveness* (OEE) sesuatu mesin. Analisa dari literatur menunjukkan kerangka konseptual TPM yang sedia ada tidak mempunyai konstruk *critical success factors* (CSFs) yang lengkap dan tidak menyediakan pelan pelaksanaan, menjadikannnya tidak sesuai untuk digunakan sebagai sumber rujukan dalam melaksanaan TPM. Kajian ini bertujuan untuk menghasilkan satu kerangka konseptual TPM yang lebih holistik, dengan penekanan kepada konstruk CSFs yang signifikan dan penyediaan panduan untuk pelaksanaan. Untuk tujuan itu, kerangka konseptual (*TPM Framework I*) telah diolah dengan tujuh komponen utamanya: kesungguhan dan kepimpinan pihak pengurusan; penglibatan pekerja; latihan dan pendidikan; keberkesanan komunikasi; perancangan strategik; pelaksanaan secara terancang, dan; pemantauan dan penilaian. Kerangka konseptual ini telah digunakan sebagai asas kepada pengumpulan data bagi kajian melalui kaedah metod campuran yang mengintegrasikan kajian kes (*single-embedded design case study*) dan kaedah soal selidik. Pendekatan triangulasi dengan penggunaan kaedah kualitatif dan kuantitatif telah digunakan sepanjang proses kajian melibatkan: temu bual soalan terbuka; analisis kandungan dokumen; pemerhatian; analisis artifak, dan; soal selidik. Kajian kes bermatlamat untuk meneroka "bagaimana" dan "apakah" konstruk CSFs yang ditekankan oleh syarikat automotif utama dan tujuh anak syarikatnya dalam melaksanakan TPM. Segala maklumat dari kajian kes telah dikumpul dan dianalisis menggunakan kaedah *cross-case analysis* dan *descriptive statistics* kearah perumusan kerangka konseptual TPM II (*TPM Framework II*). Kerangka konseptual TPM II ini kemudiannya telah dirujuk kepada lapan pakar dari industri automotif untuk disahkan. Komen dari pakar-pakar tersebut kemudiannya telah digunakan untuk merumuskan kerangka konseptual TPM III (*Final TPM Framework III*). Kerangka konseptual TPM III ini telah memenuhi lompang dalam kajian-kajian lepas dengan mengintegrasikan hampir keseluruhan konstruk CSFs dari konteks kemanusiaan dan operasi (*human and operational context*). Ianya juga telah dilengkapi dengan plan pelaksanaan dan penekanan terhadap konstruk tambahan dalam CSFs: penekanan terhadap lapan asas TPM; penglibatan menyeluruh *business stakeholders*, dan; kemahiran pekerja selari dengan *machine life cyle*. Ciri-ciri khas ini belum pernah diperkenalkan dalam kerangka konseptual TPM yang sedia ada. Kerangka konseptual TPM III ini boleh digunakan pada semua kilang automotif kerana ianya telah diolah hasil kajian kes secara intensif di kilang automotif utama dan anak-anak syarikatnya. Input dan pandangan pakar-pakar dari kilang-kilang automotif lain juga telah memperkasakan lagi kerangka ini. Kerangka konseptual TPM III ini adalah bermatlamat untuk dijadikan sumber rujukan bagi pihak pengurusan kilang automotif bagi mengambil langkah penambahbaikan dalam menangani masalah yang berkaitan dengan pelaksanaan TPM.

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LIST OF ABBREVIATIONS

4M1E	-	Man-Machine-Method-Material-Environment
5S	-	Shop Floor Control
AM	-	Autonomous Maintenance
BM	-	Breakdown Maintenance
CAPD	-	Check-Act-Plan-Do
CBM	-	Condition Based Maintenance
CLTM	-	Cleaning-Lubrication-Tightening-Minor repair
CMMS	-	Computerised Maintenance Management System
CQI	-	Continual Quality Improvement
CSFs	-	Critical Success Factors
DIY	-	Do-it-yourself
DOE	-	Design of Experiment
DOSH	-	Department of Safety and Health
EIT	-	Equipment Improvement Team
EM	-	Early Management
ETM	-	Engine Transmission Manufacturing
FI	-	Focused Improvement
FMEA	-	Failure Mode and Effect Analysis
FMECA	-	Failure Mode and Effect Critical Analysis
FTA	-	Fault Tree Analysis
GRR	-	Gauge Repeatibility and Reproducibility
HAZOP	-	Hazard and Operability Analysis
HOQ	-	House of Quality
ICC	-	Innovative and Creavitivty Circle
ICT	-	Information and Communication Technology
IID	-	Innovation and Improvement Department

JIPM	-	Japan Institute of Plant Maintenance
JIT	-	Just-In-Time
KPI	-	Key Performance Index
K-T	-	Kepner-Tregoe
Lean	-	Lean Manufacturing
MAI	-	Malaysia Automotive Institute
MAJAICO	-	Malaysia-Japan Automotive Industries Corporation
MCSA	-	Motor Current Signature Analysis
MIDA	-	Malaysia Industrial Development Authority
MITI	-	Ministry of International Trade and Industry
MMC	-	Mitsubishi Motors of Japan
MPC	-	Malaysian Productivity Corporation
MPV	-	Multi Purpose Vehicle
MSA	-	Measurement System Analysis
MVF	-	Multi-Vehicle Factory
NAP	-	National Automotive Policy
OA	-	Organizational Achievement
OEE	-	Overall Equipment Effectiveness
OEM	-	Ecology Oriented Manufacturing
OSHA	-	Occupational Safety and Health Act
PQCDSM	-	Productivity, Quality, Cost, Delivery, Safety, Morale
PDCA	-	Plan-Do-Check-Action
PdM	-	Predictive Maintenance
PM	-	Planned Maintenance
PrM	-	Preventive Maintenance
P-M	-	Phenomenon-Mechanism
PPAP	-	Production Part Approval Process
QI	-	Quality improvement
QFD	-	Quality Function Deployment
QM	-	Quality Maintenance
RCA	-	Root Cause Analysis
RCM	-	Reliability Centered Maintenance
RO	-	Research Objective

RQ	-	Research Question
SGA	-	Small Group Activity
SHEM	-	Safety, Health and Environment Managerment
SIRIM	-	Standards and Industrial Research Institute of Malaysia
SMIs	-	Small-Medium Industries
SOP	-	Standard Operation Procedure
SPC	-	Statistical Process Control
SWOT	-	Strength-Weakness-Opportunity-Threat Analysis
TE	-	Training and Education
TPM	-	Total Productive Maintenance
TPMAS	-	TPM in Administrative and Support Department
TPMC	-	TPM Coordination
TPS	-	Toyota Production System
TQM	-	Total Quality Management

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CHAPTER 1

INTRODUCTION TO THE RESEARCH

1.1 Background of the Research

In order to face intense competition in the borderless world, manufacturing organizations must be supported by efficient maintenance and effective manufacturing strategies (Dogra *et al*., 2011; Ahuja and Khamba, 2008; Marquez and Gupta, 2006). Reliable manufacturing equipment has been considered as significant contributor to organizational competitiveness (Dogra *et al*., 2011; Sharma *et al*., 2006; Kutucuoglu *et al*., 2001). With growing dependence on automation and mechanization, maintenance of manufacturing equipment is becoming more complex and critical (Pophaley and Vyas, 2010; Ben-Daya and Duffuaa, 1995). Due to such characteristic, manufacturing industry players are under enormous pressure to minimize downtime for their business survival (Rolfsen and Langeland, 2012).

Automotive industry is one of the most important manufacturing industries in Malaysia (Salleh *et al*., 2012; MIDA, 2012; Wad and Govindaraju, 2011; Mahidin and Kanageswary, 2004). Economic contribution by the automotive industry to the overall Malaysian economy by providing employment and attracting capital investment cannot be neglected (Salleh *et al*., 2012; Johnson *et al*., 2007). Rapid growth in automotive industry has boosted and stimulated the development of auto-related industry from materials supply to production, sales, service and other auto-related operations (Rosli, 2006; Chand and Shirvani, 2000; Simpson *et al*., 1998). Such development has also contributed to the skill development and advancement of technological and engineering capabilities in Malaysia (MITI, 2012; Johnson *et al*.,

2007; Rosli, 2006; Mahidin and Kanageswary, 2004; Chand and Shirvani, 2000). The automotive industry has a linkage with a wide range of related industries such as: iron and steel, chemical, rubber and plastic, electrical and electronics industry (MIDA, 2012; Rosli, 2006; Simpson *et al*., 1998). All those industries have formed a huge supply chain within the automotive industry (Chong *et al*., 2012; Johnson *et al*., 2007). Of significance, the automotive industry requires an innovative approach to optimize the maintenance of manufacturing equipment to ensure the product supplies to the end customer have superior, competitive and reliable quality (Sharma *et al*., 2012; Dogra *et al*., 2011; Pophaley and Vyas, 2010; Tsang and Chan, 2000; Ben-Daya and Duffuaa, 1995). The continuous fascination of the automotive industry and its significant impact on the global industry growth has attracted many researchers to contribute the idea and explore potential opportunity for the continual improvement, particularly in maintenance management (Aspinwall and Elgharib, 2013; Chong *et al*., 2012; Rolfsen and Langeland, 2012; Salleh *et al*., 2011; Harsej and Yusof, 2011; Pophaley and Vyas, 2010; Lazim *et al*., 2008; Rosli, 2006; Bamber *et al*., 1999; Bohoris *et al*., 1995).

The automotive industries in the West have adopted total productive maintenance (TPM) as an effective maintenance strategy for world class performance beside other branch in maintenance management such as reliability centered-maintenance (RCM), condition-based maintenance (CBM) and computerized maintenance management system (CMMS) (Irajpour *et al*., 2014; Aspinwall and Elgharib, 2013; Bamber *et al*., 1999). The adoption of TPM methodology by a careful consideration on the critical success factors (CSFs) constructs in those automotive industries has proven to improve the maintenance efficiency (Gates, 2010; Meibodi and Monavvarian, 2010; Deros, 2004). The effective and efficient equipment maintenance through TPM methodology would made a significant contribution to the profitability of the organization through an increased in the production efficiency, improved in product quality, lower operating cost, timely delivery to customers, ensured safety of the workplace and improved morale of the employees (Sharma *et al*., 2012; Ahuja and Khamba, 2008; Tsahouras, 2007). Such impressive findings in the West have motivated the researcher to further investigate the extensiveness of TPM implementation within the Malaysian automotive industry.

1.2 Problem Statement

1.2.1 The Need of In-depth Study in TPM

A review on TPM literature revealed that there was insignificant research done to address the TPM implementation in Malaysian context. Based on the 91 journals reviewed, it was found that there were only 15.4 percent of journals contributed by Malaysian researchers. Therefore the TPM research in Malaysia is considered still in its infancy and relatively unsaturated (Chong *et al*., 2012). Most of the available TPM researches in Malaysia focus on general review (14.3 percent) and survey study (50 percent) instead of reporting the actual implementation using case study approach. Only 35.7 percent of Malaysian researchers employ case study methodology in their research (Chong *et al*., 2012; Norddin *et al*., 2012; Bon and Karim, 2011; Lazim *et al*., 2008; Ahmed *et al*., 2005). The general review and survey study were mainly aimed at addressing the overall scenario of TPM practice and obtaining generic empirical evidence on the effect of independent variables towards successful TPM implementation. The empirical evidences provided by previous studies are useful as a starting point for further exploration in TPM research. Each of the variables identified could be further investigated by applying a case study methodology for an in-depth study (Yin, 2009). This has created a research gap in investigating in depth various issues in TPM implementation.

1.2.2 TPM Research in Automotive Industry

About 50 percent of TPM researches in Malaysia were conducted in non-specific industry (Lazim and Ramayah, 2010; Batumalay and Santhapparaj, 2009; Seng *et al*., 2006; Ahmed *et al*., 2004; Ramayah *et al*., 2002). Another 28.6 percent of the research portion was conducted in a specific manufacturing industry such as fertilizer, electrical and electronic industry. The number of research focuses specifically in automotive industry was 21.4 percent. Apparently there is a lot of research opportunity related to TPM implementation in Malaysian automotive industry. The automotive industry has also gained the attention of this research since

it is considered as one of the important industries to support the vision of Malaysian government to be a developed nation by year 2020 (MIDA, 2012; Salleh *et al*., 2011; Putri, 2011). This research is expected to provide an insight of the actual practices on how a Malaysian automotive company adopts TPM methodology.

1.2.3 TPM Research on CSFs Constructs

Previous studies in the West have highlighted the importance of emphasizing CSFs constructs to ensure the success in TPM implementation. Emphasis on CSFs would shorten the learning curve in adopting TPM methodology (Poduval *et al*., 2013; Majumdar and Manohar, 2012; Ahuja and Khamba, 2008; Bamber *et al*., 1999). However a review on the literature revealed that the CSFs constructs have not been adequately addressed by researchers. Most of the present research in Malaysia focused on obtaining a broad status of TPM implementation (Ahmed *et al*., 2004); investigating the factors that could further improve the overall equipment effectiveness (OEE) in manufacturing industries (Batumalay and Santhapparaj, 2009); general review on feasibility of integrating TPM with Six Sigma (Harsej and Yusof, 2011) and study on the possibility of transferring TPM practices to supply chain (Chong *et al*., 2012). There was an effort to study the CSFs constructs of TPM in Malaysian context by Lazim and Ramayah (2010), Seng *et al*. (2006) and Ramayah *et al*. (2002). However those studies were done with incomprehensive coverage of CSFs constructs. Furthermore, they were conducted through a survey and in a non-specific industry. Therefore, the questions of "how" the Malaysian automotive company adopted TPM methodology, "what" are the constructs of CSFs being emphasized and "what" is the level of its emphasis remained unanswered and requires an in-depth study. As such, this research aims to close those gaps by exploring actual practices on how Malaysian automotive company utilize or apply the CSFs constructs while implementing TPM.

1.2.4 Absence of Comprehensive TPM Framework

There have been many frameworks suggested to guide TPM implementation (Lazim and Ramayah, 2010; Batumalay and Santhapparaj, 2009; Ahuja and Khamba, 2008; Seng *et al*., 2006; Ahmed *et al*., 2004; Park and Han, 2001; McKone *et al*., 1999). However, a comparative analysis on the published TPM frameworks uncovered that none of them have an adequate coverage on the CSFs constructs in their structure, thus make it incomprehensive to be used as a guide in adopting TPM methodology. A review of literature also revealed that, as of to date, there is no integrated TPM framework developed for automotive company that address all constructs of CSFs. This research is aimed to close the gaps by providing a comprehensive conceptual framework as a guide for TPM implementation in automotive company.

1.3 Research Questions

The main focus of this research is related to TPM implementation in Malaysian automotive company. To address that concern, four research questions were identified and formulated as listed:

1. How the company adopts TPM methodology and what is the adoption level?
2. What are the constructs of CSFs being emphasized and their level of emphasis?
3. How CSFs constructs are emphasized? Is there any framework used by the company in emphasizing the CSFs constructs?
4. What are the areas that can be further improved in TPM implementation?

1.4 Research Objectives

This research will assess the status of TPM implementation based on CSFs constructs. The CSFs constructs emphasized by the case study company will be identified and the way the company emphasized those constructs will be explored. Subsequently, any weakness on the adoption of TPM methodology will be identified and as an outcome, the research will propose improvement areas through the refined framework for TPM implementation. The research outlines five objectives, which are:

1. To assess the status of TPM implementation in an automotive company.
2. To identify the CSFs constructs emphasized in TPM implementation.
3. To explore how CSFs constructs are emphasized.
4. To propose potential improvement areas for TPM implementation.
5. To develop a comprehensive TPM framework for automotive industry.

1.5 Research Scope

In order to ensure the research is effective and manageable within the given timeframe, below are the scopes for this research:

1. The developed conceptual TPM framework can be used by automotive company as a guide or roadmap to improve an existing TPM implementation or to start a new TPM implementation program. The research provides a guideline on the implementation of the framework and the actual implementation in any company is beyond the scope of this research.
2. The expert validation of the framework is done only through experts from potential user company.
3. The case study company was selected because of its position as a premier automotive company and its record of TPM implementation. The findings

and results of the study might be biased towards the situation of the company and might not fully represent the situation of other automotive companies as a whole.

4. The primary data obtained in the research is confined to the data collected from March 2010 to June 2013 within the case study company. The results and findings from the research are considered as a snap shot analysis of the data collected. Thus, it might not precisely reflect the actual situation at other times.

1.6 Significance of the Research

TPM methodology promised to yield efficient support to the organization competiveness, in terms of quality product, reasonable operational cost as well as timely delivery to the customers (Graisa and Al-Habaibeh, 2011; Bamber et *al*., 1999). In order to expand and promote TPM implementation in developing country such as Malaysia, there must be a strategic implementation plan. Further review and analysis of the current TPM implementation methodology in Malaysian companies requires in-depth investigation, in order to get a clear understanding of its implementation status. This research is expected to provide an insight of the current status of TPM implementation particularly in automotive company. From literature, as of to date, there is no integrated TPM framework developed for automotive company that address the entire CSFs constructs. This research will provide a comprehensive conceptual framework to act as guide for TPM implementation in the automotive industry. The framework can assist the management of automotive company to take proactive measure in managing issues related to TPM implementation. The results from the study would also be beneficial for the case study company to assess their implementation status and make necessary measures for continuous quality improvement (CQI). This research can also act as a foundation for further research in TPM. Each construct of the framework can be further studied and validated with the actual implementation. Further improvement in TPM will improve the quality of the product manufactured by the automotive companies.

1.7 Outline of the Thesis

This thesis is organized into six chapters. Chapter One explains the research background, problem statement, research question and research objective. The research scope and the significance of the research concerning TPM implementation in automotive industry were described at the end of the chapter. Chapter Two provides a review of literature on quality improvement initiatives, maintenance management, rationale on the selection of TPM as the research focus, TPM philosophy, TPM implementation methodology, CSFs constructs of TPM, previous study on TPM and comparative study on the existing TPM framework.

Chapter Three outlines the research methodology and procedures. It provides a description on the case study protocol which includes the development of research framework, confirmation on data collection method and data analysis used in this research. Chapter Four explains the development of the research framework (denoted as TPM Framework I) and reports on the results as well as findings of the case study carried out to validate the CSFs constructs embedded in TPM Framework I. Subsequently, Chapter Five discusses the development of the conceptual framework (denoted as TPM Framework II) from the output of case study and literature review. The chapter further explains about validation exercise of TPM Framework II. Chapter Five ended with the explanation on the development of Final TPM Framework III, description of the framework and proposed implementation plan. The conclusion and important implications, limitations and directions for future research are summarized in Chapter Six.

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