Total Productive Maintenance and Manufacturing Performance: Does Technical Complexity in the Production Process Matter?

Halim Mad Lazim, Mohamed Najib Salleh, Chandrakantan Subramaniam, and Siti Norezam Othman

Abstract—This paper intends to discuss some findings from a study of TPM practices in manufacturing organizations in Malaysia. Total productive maintenance (TPM), a resource-emphasized approach moves the paradigm of maintenance by putting emphasis on total employee involvement in the maintenance activities. We studied the relationship between TPM practices and manufacturing performance. We investigated the moderating effect of the level of technical complexity in the production process in the TPM practices and manufacturing performance relationships as well. Significant relationships were found between TPM practices and cost. We also found the moderating effect of technical complexity in the production process on the relationship between TPM practices and manufacturing performance.

Index Terms—Cost, manufacturing, total productive maintenance.

I. INTRODUCTION

Total productive maintenance (TPM), a resource-emphasized approach moves the paradigm of maintenance by putting emphasis on total employee involvement in the maintenance activities. Operators and all employees should be actively involved in a maintenance programme that enable to avoid any disruptions, breakdowns, stoppages, failures, and so forth in order to improve manufacturing performance. Therefore, in the highly competitive manufacturing industries, the ability and reliability of equipment that well-maintained is very important in order to achieve desired manufacturing performance namely cost reduction, high quality products, on-time delivery, and flexibility. Furthermore, several studies in the literature argue that further research is required in the area of maintenance and operations management. In order to address this need, the study investigates the extent of TPM practices in the Malaysian manufacturing companies, to investigate the relationship between TPM practices and manufacturing performance and to investigate the moderating effect of the level of technical complexity in the production process in the TPM practices and manufacturing performance relationships. The study uses data collected from 106 manufacturing companies from various types of industries.

II. LITERATURE REVIEW

A. Total Productive Maintenance

Undeniably, new technologies and advanced equipment need more attention from manufacturing companies especially when there are strong demands and pressure from customers. Therefore, manufacturing companies need to respond quickly to ensure smooth daily operations and manage adjustments to uncertainties in the market place. The ability to produce products through lean production, for instance, requires an extraordinary workforce who is capable of dealing with various challenges. Through proper and suitable maintenance programmes, major losses due to breakdowns and defects can be avoided. Even though these maintenance program will cost money, but the lack of maintenance will cost even more [1]. The goal of the any TPM program is to improve productivity and quality along with increased employee morale and job satisfaction. [2]. TPM has become more popular not only due to its ability to improve performance but also due to the emphasis it places on human capital resources. There are many recent worldwide studies (in the form of case studies and surveys) related to TPM, for example, [3]-[11].

B. Technical Complexity in Production Process

There are few researches being conducted to investigate the relationship between maintenance and technical complexity. Technical complexity has many definitions. In production process, it can be defined as the extent to which human effort is replaced by machines [12]. [13] claimed that increased technical complexity lead to greater control over the flow of processes and more predictable results for production. However, increased automation also means that equipment is more intricate making the diagnosis of equipment problems more difficult. In a highly automated plant, the limitations of computer controls, the integrated nature of the equipment, and the increased knowledge requirements all make it more difficult to diagnose and solve equipment problems [14]. Type of production process in manufacturing can be divided into five categories; project, job shop, batch, assembly line and continuous flow [15]. However, in real manufacturing process, the effects of the different levels of technical complexity can be made plain by describing the characteristics of the end points of the scale, job-shop technology and continuous flow technology [16].

III. METHODOLOGY

We have surveyed Malaysian manufacturing companies...
using scientific approach. The sampling frame was taken from Federation of Malaysian Manufacturers (FMM) 2010 directory. The measures of this study were from various sources after thorough reviewed of articles. The sample selection was chosen systematically. The main objective of the study was to analyze the moderating effect of the level of technical complexity in the production process in the relationship between TPM practices and manufacturing performance. Then, the research hypothesis was tested using hierarchical regression analysis accordingly.

IV. RESULTS AND ANALYSIS

There were 167 questionnaires returned back and usable responses were only 106 (10.07%) and data was analyzed accordingly. In order to increase the response rate, efforts have been taken as suggested by [17] and [18]. We received 71 (67%) responses from big companies and 35 (33%) from small/medium companies. Most of the companies were operated more than 10 years. We also ran the factor analysis accordingly. All independent variables loadings were recorded more than 0.66 and Eigenvalues were more than 1.4. Meanwhile, the dependent variable, cost, recorded loadings of more than 0.7 and the Eigenvalue recorded were 8.56. Table I depicted the descriptive analysis for all variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<tbody>
<tr>
<td>TPM team</td>
<td>3.81</td>
<td>0.76</td>
</tr>
<tr>
<td>TPM strategy</td>
<td>3.93</td>
<td>0.61</td>
</tr>
<tr>
<td>Autonomous</td>
<td>3.91</td>
<td>0.63</td>
</tr>
<tr>
<td>maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned maintenance</td>
<td>3.70</td>
<td>0.72</td>
</tr>
<tr>
<td>Technology Complexity</td>
<td>3.53</td>
<td>0.78</td>
</tr>
<tr>
<td>Cost</td>
<td>3.54</td>
<td>0.80</td>
</tr>
</tbody>
</table>

The inter correlation of TPM team, TPM strategy, autonomous maintenance and planned maintenance indicated that there was a significant positive relationship with cost. The perceived reduction of manufacturing costs included production costs, manpower costs, overhead costs, material costs and unit costs. Thus, TPM team \( r = 0.34, p<0.01 \), TPM strategy \( r = 0.62, p<0.01 \), autonomous maintenance \( r = 0.55, p<0.001 \) and planned maintenance \( r = 0.57, p<0.01 \). Higher practices were associated with higher reduction of costs.

In order to examine the hypotheses of this study, 3-Step hierarchical regression was utilised. Various authors recommend using Hierarchical Regression in research concerned with moderator variable detection [19]-[21]. In addition, [22] suggest that moderating effect can be tested using multiple regressions. In step 1, the 4 independent variables were regressed with the dependent variable. However, before further analysis could proceed, multiple regression assumptions were tested accordingly. Multiple regressions rely on four main assumptions to be fulfilled. Normality, linearity, independence of residuals and homoscedasticity [23] and these were tested consequently.

The hierarchical regression showed TPM strategy \( \beta = 0.272, p<0.05 \) and planned maintenance \( \beta = 0.437, p<0.01 \) were positively related to cost. Therefore, TPM strategy has a stronger prediction power of cost compared to planned maintenance. The significant interaction is between technical complexity and TPM strategy \( \beta = 5.373, p<0.01 \) and between technical complexity and planned maintenance \( \beta = -2.011, p<0.05 \).

Fig. 1 showed that the relationship between TPM strategy and cost is strongest in the case of high technical complexity and weakest in the case of low technical complexity.

![Fig. 1. The moderating effect of technical complexity in the relationship between Total Productive Maintenance (TPM) strategy and cost.](image)

Meanwhile, Fig. 2 showed that technical complexity significantly moderates the relationship between planned maintenance and cost.

![Fig. 2. The moderating effect of technical complexity in the relationship between Planned Maintenance and Cost.](image)
V. CONCLUSION AND RECOMMENDATION

TPM tries to ensure equipment related losses are minimized and more effort is made to reduce equipment-related losses or defects. TPM could essentially help to minimize the deterioration of equipment, hence improving performance as highlighted by various researchers, for instance, [4], [5], [24], [25], and [26]. Meanwhile TPM team usage in the plant being low as shown by the standardized beta value of -0.05 for cost. Furthermore, the vicariate analysis showed a moderate positive low correlation between TPM team and manufacturing performance, $r=0.34$, for cost. This relationship may not be strong enough to have held up in the multivariate analysis. As noted by [27] based on their case study, work habits and communication especially for production lines and different shifts could affect the morale of TPM team development. The possible assumptions to be drawn from this study are that the communication and leadership of TPM team are not clearly perceived by those at operator level and other departments. The TPM team has been perceived as unable to formulate actions that can effectively help to reduce costs. TPM strategy which focuses on overall equipment effectiveness (OEE) tries to demonstrate that using all related information and the production line status, operators and maintenance staff can work closely to ensure more improvement suggestions and to ensure well-functioning equipment, performance efficiency and availability of equipment. An overall OEE of 85% is considered as world class performance [28]. In order to achieve an OEE of 85%, therefore, performance efficiency must achieve 95%, availability must achieve 95% and quality must achieve 99%. The results indicated that TPM strategy and planned maintenance found to be related to cost.

Future research can be expanded further by analyzing other factors contributed to manufacturing performance. For instance, product characteristics, vertical integration, model mix, automation level and market requirements might possibly affect manufacturing performance [29], [30] and [31].

ACKNOWLEDGMENT

H. M. Lazim, M. N. Salleh, C. Subramaniam, and S. N. Othman would like to express our grateful to the Ministry of Higher Education (MOHE), Research and Innovation Management Centre (RIMC) Universiti Utara Malaysia (UUM) and the Vice Chancellor of Universiti Utara Malaysia (UUM) in providing us the opportunity to conduct and finish this research.

REFERENCES

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