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Maintenance Strategy for the Old Lathe Machine in Teaching Workshops at Technical Vocational Education Training Institutes

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Abstract
The TVET workshop equipments for machining should be in a state of high readiness. However, due to inadequate machine care and maintenance procedures, the performance and readiness of this training equipment fall short of industry standards. This study aims to develop a framework strategy for Total Productive Maintenance (TPM) for TVET institutions. The critical success factors of maintenance strategy were identified using the Delphi and Analytical Hierarchy Process (AHP) methodologies. Subsequently, Interpretive Structural Modelling (ISM) was utilised to develop a new maintenance framework strategy. The use of Overall Equipment Effectiveness (OEE) to evaluate maintenance strategy performance indicates a significant improvement.

Keywords: TVET, TPM, OEE, Strategy

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1.0 Introduction

Machine maintenance is an important component of Technical and Vocational Education and Training (TVET), particularly in terms of guaranteeing the functionality of machinery used in practical training. However, there are several challenges directly impacting machine maintenance in TVET institutions. This situation persists due to a poor comprehension of the significance of maintenance management, and there is no effective remedy in place (Eghan, 2014). They rely on the supplier, and onsite maintenance is performed using fundamental preventative and corrective techniques. However, TVET institutions often face budget constraints, making it difficult to allocate adequate funds for regular machine maintenance, repair, and replacement. As a result, machines are more likely to break down unexpectedly, disrupting training schedules. According to Jayaswal et al. (2008), machine failure brought on by progressive deterioration is related to wear and tear, stress fatigue, corrosion, and other factors. Exercises and projects related to teaching and learning will be impacted by this, and the assessment process itself may be delayed or stopped. The study concludes with the development of a framework for maintenance strategy. But first, the critical success factors maintenance strategy for TVET institutions must be identified. Then, the optimal maintenance strategy must be selected. Once the framework has been developed, it must be validated to ensure that the management strategy is being implemented successfully.

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2.0 Literature Review

Total Productive Maintenance (TPM) is an important strategy for increasing the operational efficiency of machinery and equipment while reducing downtime. While TPM has been widely embraced in industry, its use in TVET) institutions necessitates some unique considerations. Without depending on the suppliers, TPM is one of the most popular and beneficial tactics in the sector (Korgal et al., 2019). TPM promotes the idea of maximising equipment performance, preventing unforeseen damage, minimising faults, and avoiding defects that arise throughout the work process (Abhishek et al., 2014, Hernadewita et al., 2019, Caleb & Deebom, 2023). Although the TPM framework has been around for a while, TVET institutions have yet to adopt it. Aspects such as tailoring TPM to student learning, using digital tools, improving collaboration with industries, maintenance management and assuring safety are critical areas that require additional investigation. Additionally, offering personalized training for instructors, establishing effective maintenance schedules, and assuring cost-effectiveness are all necessary to make TPM a viable and successful strategy in TVET. As Joseph (2019) pointed out, there is no one-size-fits-all maintenance plan for all circumstances or sectors. TVET institutions, due to varying conditions and requirements, also follow distinct maintenance procedures.

3.0 Methodology

The current study employed the Delphi Method to determine the critical success factors of maintenance strategy for TVET institutions. A series of in-person interviews and a standardised, open-ended questionnaire were administered to the selected TVET and industries maintenance experts. The experts included lecturers, top management of TVET agencies and industries in Malaysia. These respondents are selected based on work experience, education, position and expertise in related fields. The survey questions were verified by academicians and industry professionals. The survey was typically completed in two or three rounds. The description of the original identified criteria was derived in the last round of the structured interview session, as outlined in Delphi. Next, a number of analytical hierarchy process (AHP) techniques were used to identify the best maintenance practices for TVET institutions. AHP can assist decision-makers in arranging a problem's crucial elements into a hierarchical structure resembling a family tree, which will facilitate handling the decision-making process (Wang et al. 2007). The recommended maintenance strategy framework was then created using Interpretive Structure Modelling (ISM) software. The ISM approach is employed to ascertain and enumerate the correlation between specific factors and a problem or issue (Yadav & Barve, 2015). Out of all the solutions, this study indicates that Total Productive Maintenance (TPM) is the most efficient. After one year of implementation, this novel approach was reviewed. One measure of how well a strategy is being implemented is the overall equipment effectiveness (OEE). Following the effective deployment of TPM, it was discovered that OEE improved (Nallusamy, 2016).

4.0 Findings

4.1 Delphi Method

Based onthe literature, the researcher created this collection of Delphi surveys. The purpose of this questionnaire was to gather quantitative information for the framework's development. The standards stated in the first round were reiterated by all experts (Barrios et al., 2021). The requirements and conditions for applying the Delphi technique, to get expert agreement, were met by questionnaires. Only the elements required to create structures of maintenance strategy were suggested by the researcher. Nevertheless, the validation and selection were made by the designated experts. As indicated in Table 2, the critical success factors of maintenance strategy were divided into seven (7) parts from ten (10) that were assessed by a panel of experts.

4.2 Analytical Hierarchy Process (AHP)

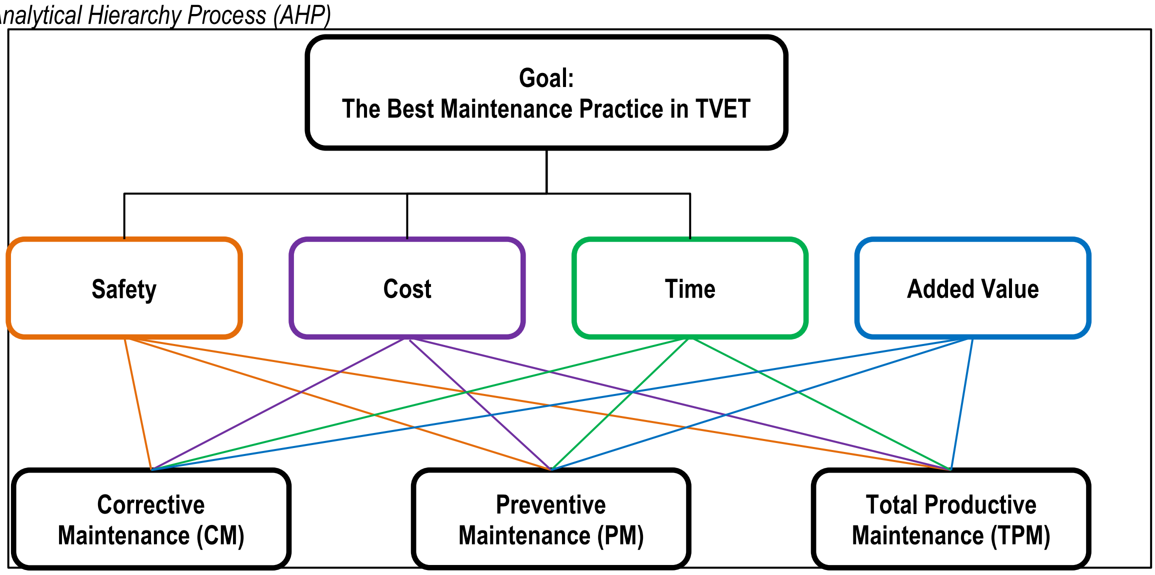

Fig. 1: Hierarchy process based on the criteria

Numerous decision-making problems with various criteria are supported by AHP. It is especially used in group decision-making and has recently gained popularity worldwide in a wide range of policy contexts, including government policy, business, industry, healthcare, construction, and education (Jana et al., 2022). The AHP technique facilitates the process of determining the relative importance and priority of various possibilities (Motaki & Oualid, 2017). Generally, AHP involves three phases (Hong et al., 2022). The first step is to organise the problem into a hierarchical framework with several options, prospects, and subspecific and general criteria. The lowest level is represented by the alternatives or the chosen items (Ali & Wedley, 2004). Combining the comparisons simplifies the process of judging and calculating (Taherdoost, 2017). Decision indications and decision options are components of decision-making process. In accordance with Figure 1, the group created a hierarchy that ought to take the understudy's issue into account.

4.2.1 AHP Result

The industry-wide maintenance strategy is the best approach and has been shown to address a wide range of maintenance-related issues. This study determines whether the limited plan for maintenance should be applied in a Technical and Vocational Education and Training (TVET) institution. It is evident from Table 1 that Total Productive Maintenance (TPM) is suitable for TVET institutions, as found through the present study. Machine operators can be encouraged to undertake maintenance on their own by using this TPM-based technique, which offers a practical framework. The framework needs to direct TPM implementation. In TVET institutions, the next step is the creation of the TPM framework.

Table 1. AHP Result of Maintenance Strategy

Maintenance Strategies	Score
CM	0.1203
PM	0.2920
TPM	0.5876

4.3 Interpretive Structural Modelling

Building a framework for a TPM maintenance strategy is the next stage. Interpreting structural modelling (ISM) was used in the creation of this framework. ISM uses an interpretive method since the group determines whether and how the different components are related to one another (Fathi et al., 2019). A knowledgeable and problem-aware expert group will accurately identify variables through research or group idea-generation techniques like Delphi Method Process, Nominal Group technology, brainstorming, etc. (Poduval et al., 2015). It is necessary to identify a group of experts before beginning the ISM technique. All of the experts are knowledgeable about the issue and have held upper- or mid-level managerial or teaching positions (Faisal &Talib, 2016). Nine experts from TVET institutions and industry participated in this study. Compared to other methods like Delphi and structural equation modelling (SEM), the ISM requires fewer expertise (Yadav & Sharma, 2017).

4.3.1 Identification of TPM framework elements description

The next stage is to use a brainstorming session to establish the fundamental components that will make up the TPM framework. It is feasible to identify crucial components of the problem or difficulties by using a group problem-solving technique or literature analysis. ISM's basic concept is to use the user's experience and expertise to break down complex systems into a number of smaller subsystems, or components, and then organise those elements into a hierarchical, linear structural model with several layers (Chen, 2012 and Guofeng et al., 2019). The aspects of the TPM framework were identified as shown in Table 2.

Table 2. Identification of TPM Framework Elements

No.	Elements	Description
1.	Skill, training and education	• Machine Selection • Identify the root cause of the failure. • Maintenance training to overcome the failure
2.	The involvement of all employees (lecturers, technician and student)	• Machine ownership • Autonomous maintenance implementation • Conduct routine maintenance according to the schedule
3.	The support of top management	• TPM Campaign • Buy the support equipment (heavy duty vacuum) • Form the TPM team
4.	Enforcement	• Routine checking • Monthly audit
5.	Continuous Improvement	• TPM meeting • TPM evaluation • OEE Performance
6.	Integration into strategic and business plans	• TPM objective • Integrate into curriculum/syllabus
7.	Recognition	• Make a TPM award • Conduct inter-programme tournaments

4.3.2 Development of framework

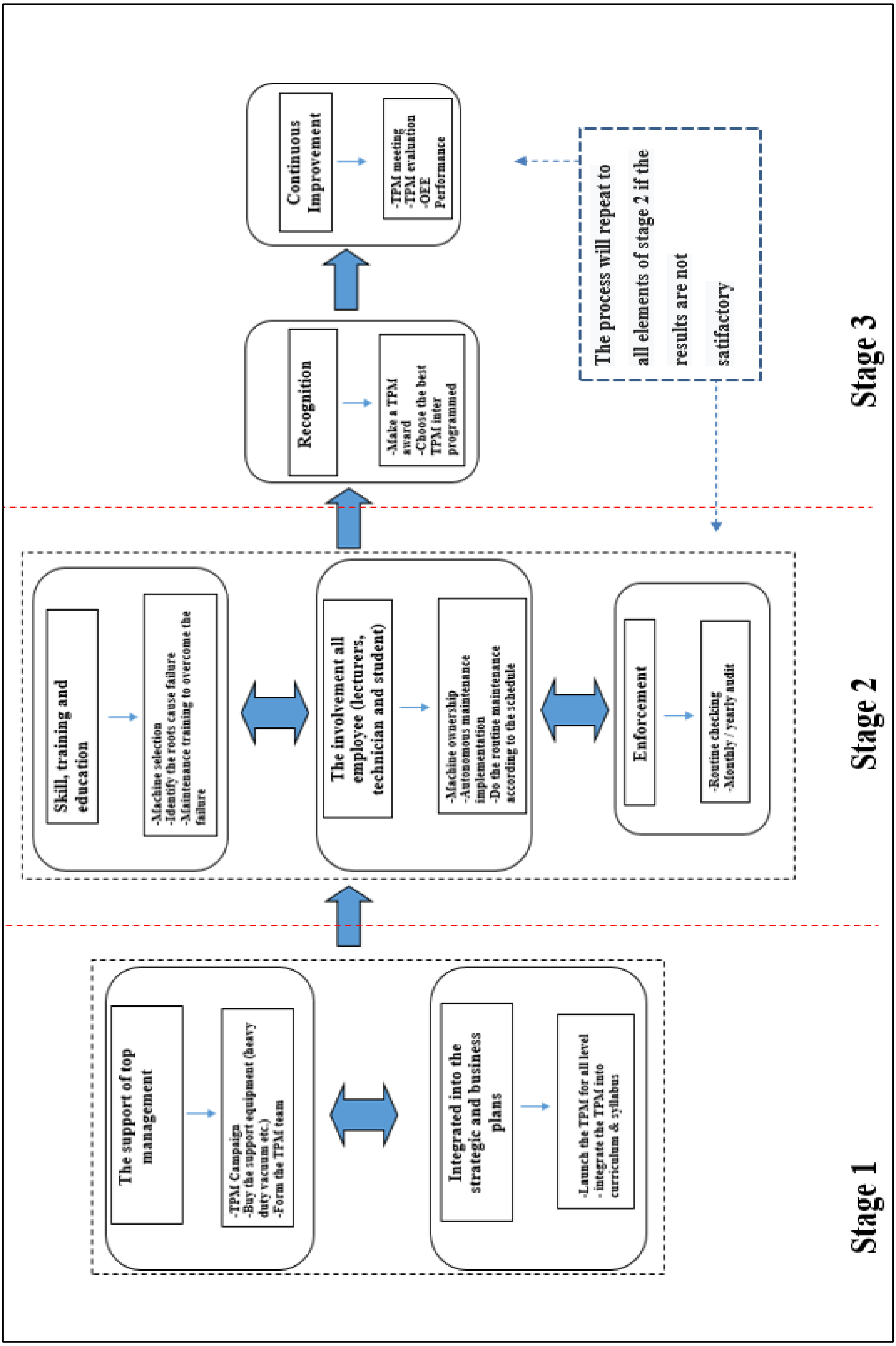

Fig. 2: TPM Framework for TVET Institution

Using ISM software, the expert voting procedure was carried out concurrently. Simultaneously, modelling in the ISM software transformed the object system into a representational and well-defined system made up of directed graphs (digraph). Every fundamental structural component of the framework is explained in detail. In conclusion, as shown in Figure 2, the TVET institutes TPM framework was completed and made available to all TVET institutes. The TPM framework for TVET institutes essentially consists of seven essential components that need to be strictly followed. The first step in implementing TPM strategy is integrating top management support into the strategic and business and end with an element recognition.

4.4 Overall Equipment Effectiveness

Regular monitoring is necessary to prevent decline in performance, and most machines are advised to rely on frequent unification to avoid machine failure (Gurbeta et al., 2017). This technique addresses a comprehensive approach in which improving OEE performance cannot be achieved by the maintenance method alone (Shyamkumar, 2014). However, TPM deployment will lead to higher OEE while lowering failure, damage, waste, and accidents (Patel et al., 2016). In a recent study, OEE for lathe machines was successfully enhanced from 75% to 78% as a result of the deployment of TPM through autonomous maintenance (Kapuyanyika & Suthar, 2018). OEE is made up of three parts: performance, quality, and availability. The Application of OEE formula is as follows (Patel et al., 2016).

$$OEE = Availability \times Performance \times Quality$$

Table 3. OEE Performance of 30 Lathe Machines (M30) in a Mechanical TVET Workshop on July-December Session 2017 Before TPM Implementation

Availability (Total Time / Running Time)	Performance (Total Count/ Target Counters)	Quality (Good workpiece/ Total Count)	*OEE* *(A x P x Q)*
M30 0.921	0.791	0.80	0.582 58.2%

As shown in Table 3, OEE performance from July through December 2017 was 58.2% before TPM Implementation.

Table 4. OEE Performance of 30 Lathe Machines in a Mechanical TVET Workshop on January – June 2019 Session After TPM Implementation

	Availability (Total Time / Running Time)	Performance (Total Count/ Target counters)	Quality (Good workpiece/ Total count)	*OEE* *(A x P x Q)*
M1- M30	(Average) 27.82/30 = 0.927 92.7%	97/120= 0.808 80.8%	25/30 = 0.833 83.3%	0.623 62.3%

For availability performance, the result in Table 4 was 92.7% . The quality improved to 83.3%, and performance grew by 80.8%. The overall OEE performance is 5.2% better than it was previously.

Table 5. OEE Performance of 30 Lathe Machines in a Mechanical TVET Workshop on July – December 2019 Session After TPM Implementation

	Availability (Total Time/ Running Time)	Performance (Total Count/ Target counters)	Quality (Good workpiece/ Total count)	*OEE* *(A x P x Q)*
M1-M30	(Average) 28.33/30 = 0.944 94.4%	98/120 = 0.816 81.6%	25/30 = 0.833 83.3%	0.641 64.1%

When examined in accordance with availability performance, OEE performance surged by 64.1%, reaching 94.4%. While quality has remained at 83.3%, performance has grown by 81.6%. The overall OEE performance from July to December 2017 is 5.9% better than the prior performance.

5.0 Discussion

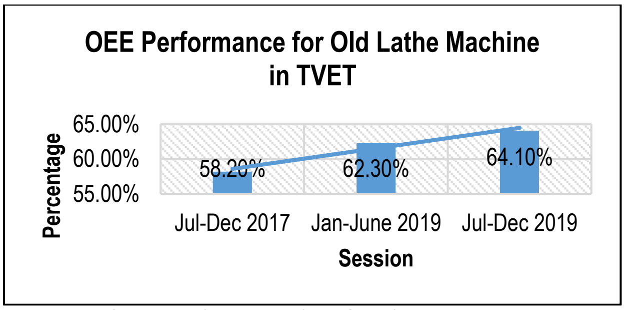

Fig. 3: The Performance of the OEE for Lathe Machines

As shown in Fig. 3, the performance of the OEE for lathe machines has improved following the implementation of the TPM, based on the practical class/exam of the designated session. It shows that prior to the introduction of TPM, the machine's OEE performance was 58.2%. Following the first year of TPM deployment, OEE performance improved to 62.3% and then 64.1%. The machine's operational readiness, the quantity of workpieces finished within the allotted time, and the quantity of workpieces receiving grade A were all factors contributing to this rise. The conclusions following the deployment of TPM were also supported by the study's findings. The use of TPM resulted in a 3% rise in the workshop's OEE for the lathe machine (Kapuyanyika and Suthar, 2018). This data indicated that the introduction of TPM at MARA TVET institution had a beneficial impact, despite the slow progression of the movement. OEE World Class was 85%, and international research indicated that the average OEE rate in the industrial sector was 60% (Taherdoost, 2017). The adoption of a TPM strategy framework in TVET institutions offers profound implications for policy development, training programs, and the broader implementation of TPM across sectors. By influencing policies on equipment maintenance and safety standards, enhancing the quality and relevance of training, and creating a strong link between TVET institutions and industries, TPM can significantly improve the skill sets of TVET graduates. Moreover, by fostering collaboration with industries and promoting digital maintenance tools, TVET institutions can prepare students for the evolving needs of modern industries, making them highly employable and ensuring that maintenance excellence becomes ingrained in TVET.

6.0 Conclusion and Recommendations

The implementation of Total Productive Maintenance (TPM) in TVET institutions requires a systematic, tailored approach to overcome the challenges and gaps identified in previous discussions. By focusing on actionable recommendations like customizing TPM frameworks for educational environments, enhancing funding, integrating digital tools, improving instructor capacity, and fostering collaboration with industry. Furthermore, ensuring safety, continuous improvement, and proper evaluation mechanisms will allow for the long-term success and sustainability of TPM in TVET institutions, ultimately leading to better-prepared graduates and more efficient machinery management. Given the current circumstances in TVET institutions, the study concludes that the TPM maintenance strategy is most suited for adoption, and a framework has been developed. According to the results, TPM has been successfully implemented in TVET institutions only based on the lathe machine. Future study must explore a variety of conventional and CNC machines in order to expand this limitation as much as possible. The results of this study have all been able to address issues pertaining to machine care that have come up within TVET. Still, this study has provided a solid foundation for future research on TVET institution maintenance strategies. The TPM framework's creation and application, as well as the OEE performance in this study, pave the way for the concept of other modern maintenance strategies in TVET institutions, including Condition-Based Maintenance (CBM) and Reliability Centred Maintenance (RCM).

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Paper Contribution to Related Field of Study

This paper contributes to the field of TVET by developing a comprehensive maintenance strategy framework tailored to Malaysian TVET institutions. The TVET institution's machinery and equipment continue to function well with the TPM maintenance approach, as seen by the rise in the OEE percentage.

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