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Critical Success Factors Maintenance Strategy in Industry for Technical Vocational Education Training Institute

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Abstract

Critical success factors in maintenance strategy for many industries have been identified in many previous studies. Since many industrial activities also are operated in TVET although in small scale, therefore these critical success factors could be adopted for TVET institutions. In many cases, TVET institutions have not implemented yet a specific maintenance strategy for their student workshops. This could reduce equipment readiness and overall equipment effectiveness (OEE). This study aims to establish the critical success factors maintenance strategy for TVET institution in Malaysia. These strategic factors were initially determined by previous industry case studies. Then, these critical factors will be verified by TVET and industrial expert using the Delphi method. After the process of assessment, some of the critical factors from the industry will be discarded and a few other new factors will be included. In the end, seven critical success factors have been qualitatively deducted from the Delphi method. Four out of seven factors selected achieved more than 85% of Kendall's W scale and the other three factors also gained more than 70% of Kendall's W scale. This indicates that all seven critical success factors are considerably significant for TVET maintenance strategy.

1. Introduction

An overview of the situation in TVET, every maintenance carried out depends only on the allocation provided The existing maintenance strategy on TVET is dependent on external suppliers. The strategy of maintenance implemented at TVET are corrective maintenance and preventive maintenance. However, if the provisions are insufficient, most machines requiring preventive maintenance are not feasible because they are channelled to machines requiring corrective maintenance. As a result of inadequate provisions, not all equipment can be maintained periodically. This is further complicated when the machines used in TVET are rather old and used. Machine malfunctions or breakdown in TVET centres disrupt and impact the learning and teaching process. Low overall equipment effectiveness performance indicates machine capabilities and visualization of machine operations, teaching and learning process at TVET. Meanwhile, most of the OEE's performance for the old machine is not very encouraging. This machine is exposed to various damage and problem. This has indirectly affected the efficiency of machine operation. The best way to measure the

efficiency of a machine to operate is through OEE's achievement.

Table 1. OEE performance of 30 lathe machines in a mechanical TVET workshop.

	Availability (Total Time / Running Time)	Performance (Total Count/ Target counters)	Quality (Good workpiece/ Total count)	*OEE (A x P x Q)*
M1-M30	0.864	0.533	0.80	0.368

Maintenance activity in TVET also depends on the provision of the acquired assets. If no provision means no maintenance is implemented. It's very hard to accept but the reality that is happening at TVET institute. Every organization has a variety of cost increases every year. Cost is a challenge faced by every organization. For TVET, challenges need to be addressed in the best way to launch TVET operations across Malaysia. Looking at existing space, equipment maintenance costs need to be reduced by practicing maintenance management strategy adopted from in industry. Therefore, it is important in this study to identify what is critical success factor strategy management in the industry can be applied into the TVET situation before forming a maintenance strategy framework. This study aims to establish the critical success factors maintenance strategy for TVET institution in Malaysia. These strategic factors were initially determined from previous industry case studies. These critical factors will be verified by TVET and industrial expert using Delphi method.

2. Maintenance strategy in industry

Maintenance is a business application that uses and upholds a company's primary process. It determines as a blend of all technological and linked organizational measures built to maintain or rebuild a product, a state where it can perform its necessary purpose [1]. The operation of maintenance management can be separated into two sections: strategic planning definition and execution of the approach. The first part, defining the maintenance strategic plan, involves determining the maintenance objectives as an input specifically extracted from the business strategy. The second part of the system, the execution of the chosen approach, has a different degree of importance [2]. Impactful maintenance management needs a variety of approaches in which maintenance is interpreted from a strategic perspective[3]. As a result, many different strategies have been built up over the years to promote the execution of maintenance management in the industrial sector [4]. Maintenance of the industry is a significant financial contribution. Nevertheless, if the maintenance of production equipment is managed strategically, it leads to the company's economic strength [5]. A suitable maintenance strategy not just to minimizes

the probability of system failure, but also enhances asset working environment, leading to lower cost of maintenance or greater reliability and quality of the products. On the other hand, unsuitable strategies can influence the maintenance cost and thus decrease efficiency and revenue growth [6]. The maintenance objective is not only to maintain plant equipment and facilities to avoid breakdowns and failures, increase performance, ease of maintenance and accessibility of the operating system to optimize manufacturing, but also to improve quality and increase greater productivity by enhancing potential, quicker and more effective performance, decreasing stock and decreasing operating capacity [7].

3. Critical success factor maintenance strategy in industry

Before implementation strategy in TVET, the success factor of the implementation strategy in the industry should be identified. Many of the success factors of the industry's maintenance strategies have been noted in the past study. This element is a guide to researcher to develop such strategies at TVET institute. Top management involvement, training and education, benchmarking, effective communication and cultural change developed in maintenance strategy procedures are among these critical success factors [8]. Most of the time, without full and real encouragement for top management results, leads to failure either in the panning process or in the maintenance strategy implementation phase [9]. Many literatures have often highlighted the function of the commitment and leadership of top management to have a resolute impact on the successful implementation of maintenance strategy [10]. Failure to implement maintenance strategy such as lack of senior management support, lack of budget or investment, pressure of workload, conflict of management initiatives, inefficient use of maintenance staff and poor performance tolerance of senior management [11]. Supreme management commitment and leadership have a positive role to play in improving maintenance strategy performance in organizations [12]. The maintenance strategy calls on the shop floor operators to be involved in the ongoing improvements, cross-functional teamwork and proposals [10].

In fact, the overall participation of employees is a prerequisite to effective maintenance strategy execution and can be ensured by expanding workers ' knowledge and skills in relation to jobs, modifying the worker's machinery workplace, worker consulting, union buy-in, reliable appropriate guidelines schemes and the execution of a enabling and secure working environment for organizations [13]. How top and medium level management is dedicated to the operation of the plan by offering it the correct primary responsibility [14].]. Training and education for employees at all levels is a key factor in adopting maintenance strategy such as TPM [15]. The maintenance strategy like TPM programme is very closely connected to the participation, direct involvement and continuous improvement of workers, education and training programmes at all levels through small but continuous moves. A failed or partial maintenance strategy like TPM process needs considerable recognition and management commitment would do it all over again [16].

All the factors of critical success factors, Top Management Commitment, Resource Management, Performance

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Measurement System, Continuous Improvement System, Training and Education and Work Culture and Involvement, are acknowledged as essential and should be enforced in order to make sure the successful execution of maintenance strategy such as TPM [17]. The organization needs to change the culture of all workers in managing the change in operational strategies during and before the integration of maintenance strategy like TPM[18]. In order to become more efficient, the maintenance strategy should be included in the global production and business strategy [15]. Operators and maintenance workers must achieve common understanding and share machinery responsibility[19]. Bi-way communication between the organization and its internal and external stakeholders for successful execution and maintenance is a basic foundation [20]

Table 2. Critical success factor maintenance strategy in industry

		Critical Success Factor Maintenance Strategy													
No.	Author	The support of top management	The involvement all employee	Ownership.	integrated into the strategic and business plans	Skill, training and education	Empowerment and encouragement	Maintenance performance evaluation	Cultural change	Coordination	Communication	Cooperation	Motivation	Resource Management	Continuous Improvement
1	[9]	x	x	x	x										
2	[21]	x	x		x	x		x							
3	[13]	x	x		x	x	x		x	x	x	x			
4	[8]	x	x	x		x		x							
5	[18]	x	x	x	x	x			x	x	x	x	x		x
6	[22]	x		x		x									
7	[17]	x	x			x		x	x					x	x
8	[16]	x	x			x						x			x
9	[11]	x	x	x		x	x								x
10	[14]	x			x				x					x	
11	[19]	x	x		x	x			x						x
12	[15]	x	x		x	x		x	x		x	x			
13	[12]	x	x		x	x	x		x			x			
14	[10]	x	x			x									

4. Industry maintenance strategy approaches in TVET institute

Research on industry-oriented maintenance strategies adopted into the TVET institute is not so much and relatively limited. There has been some research done on the maintenance strategy into TVET such as Total Productive Maintenance, but there are constraints but there is also valuable information from the research. Having learned the industry-oriented approach into the TVET environment, in the last study, only two researchers focused on the TPM approach in managing maintenance, teaching and learning at TVET. According to first researcher [23] study, the researcher paid attention to the implementation of Autonomous Maintenance of the Grinding Machine. In the study, the researcher used the Fuguai method where the method was to identify the abnormal cause of the machine. The researcher mentioned that it was difficult to run the Autonomous Maintenance program on the machine as the machine users were different every week. besides that, another challenge is that he states that Autonomous Maintenance requires high levels of skills and knowledge to carry out such maintenance. there are constraints in the implementation of Autonomous Maintenance as the machine users at the study centre are different each week, making it difficult for Autonomous Maintenance applied at the centre of study. It can be explained that in order to implement the TPM program at TVET it is necessary to thorough planning not only focus on one element in TPM. The results of this information support the critical success factor of maintenance management in the industry as discussed earlier. From this is the factor that has become a space or thing that needs to be emphasized in practicing the industry-wide TPM strategy to be applied to TVET. According to second researcher [24]. The researcher has analysed OEE's performance of lathe machine at an Educational Institute Workshop. In the study only focused on calculating OEE for a lathe machine of the study centre. The researcher analysed the results, the current results of the OEE's performance for the lathe machine at the centre of study were 72%. The study shows that OEE calculations for machines in the education centre are well-known that the production system and the use of machines in the industry and in the study centre are different. This information is important and valuable for further research to implement the TPM approach at TVET.

5. Delphi Method

In this Delphi process requires expert information from industry and TVET. This information is important to determine the Critical Success Factor related to the maintenance strategy. They are comprised of groups based on maintenance technology in the industry and faculty or lecturers involved with the use and maintenance of the TVET institute. The first process is to identify the factors contributing to the success of maintenance strategies in industry and TVET. In this first round is more to brainstorming experts. Generally, Delphi begins with an open survey during the first round [25]. These factors can be identified as variables. Generally, these variables are identified through a survey process that will be directed to industry experts and TVET to support the initial information contained in literature review. Then the second process is for confirmation to the predefined variable. A survey will be returned to the specialist for the validation of the predetermined variable. After that discussion will be more focused in which the scale of discussion is narrowed. After confirmation is done, the raking setting will be done through the calculation process. This ranking process can help researchers to make a conclusion to the identification of which variables are more important. Information obtained after going through the first to last process will determine the Critical Success Factor in the maintenance strategy applied in the industry which will then be applied to the TVET institute.

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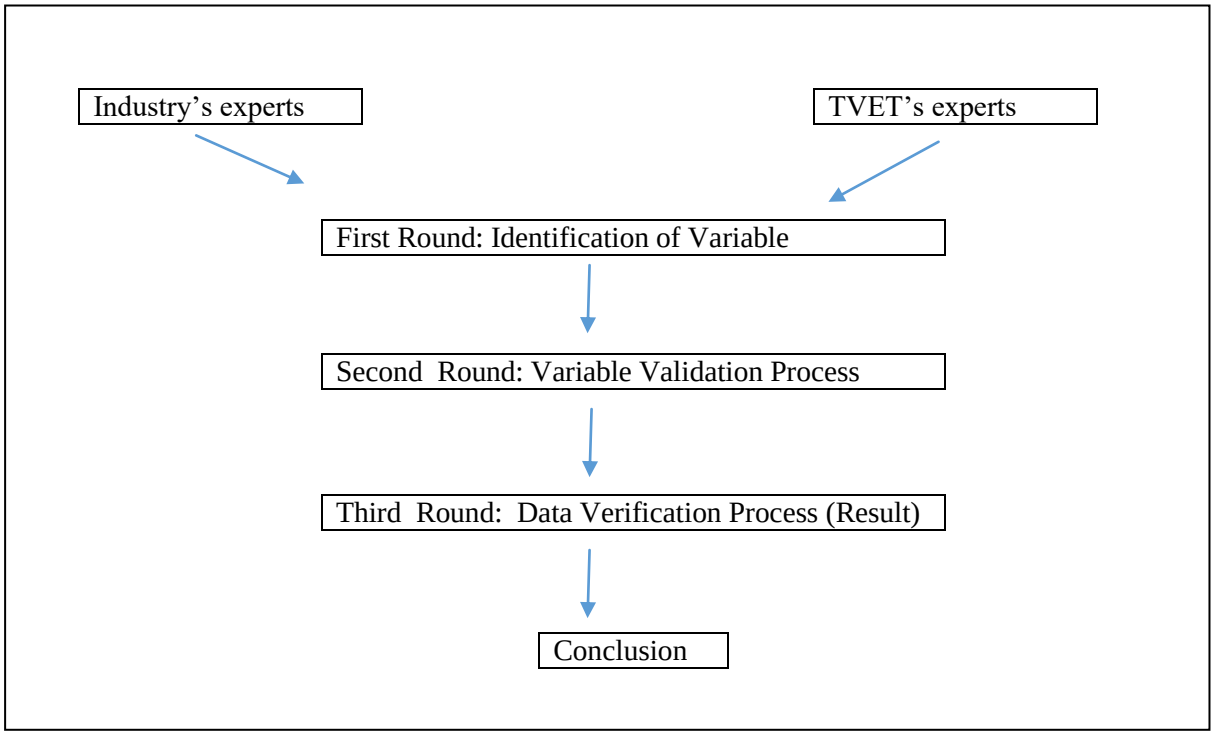

Figure 1. Delphi Method Process for Identification of Maintenance Strategy in Industry for TVET Institue.

For the first round in Table 3, the questionnaire was distributed to 20 expert groups involved in the maintenance industry and TVET. 10 of them are from the industry and 10 others are coming from the TVET group. The group size is dependent on the group dynamics to reach consensus among professionals rather than on the statistical power. So, 10 to 18 experts on a Delphi panel are recommended by literature [26]. The findings show that some variables identified as Critical Success Factor for industry-oriented strategies will then be implemented in TVET. There are 15 variables identified in the first round as shown in table 1. The findings in the first round also indicate that there are two variables specified by TVET expert groups different from industry expert groups. The variables are Recognition V14 and Enforcement V15. The rest of Variable 1 to Variable 13 has the same view expressed by both expert groups industry and TVET institute.

Table 3. First Round: Identification of Variable

No.	Variable	Indicator
1	The support of top management	V1
2	The involvement all employee	V2
3	Integrated into the strategic and business plans	V3
4	Skill, training and education	V4
5	Empowerment and encouragement	V5
6	Maintenance performance evaluation	V6
7	Cultural change	V7
8	Coordination	V8
9	Cooperation	V9
10	Communication	V10
11	Motivation	V11
12	Resource Management	V12
13	Continuous Improvement	V13

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14	**Recognition**	**V14**
15	**Enforcement**	**V15**

After identifying the critical factors in the implementation strategy, the second round in Table 4 is a definitive process of validation process. In this second round, only a group of experts is involved in this process. For each panel more than 50 percent of specialists maintain chosen factors [26]. They are five of the industry groups and the other five are from the TVET group. Results from the second round of this Variable have been shortlisted. The variables are V1 to V4 and V13 to V15. While Variables 14 and Variable 15 are still available as expert group options. All experts reaffirmed the variable mentioned in the first round. Experts determined which variables are the priority After going through the second round as stated in table 4. The result of this validation is that only 7 variables are selected. The variables are V1, V2, V3, V4, V13, V14, and V15.

Table 4. Second Round: Variable Validation Process

No.	Variable	Indicator
1	**The support of top management**	**V1**
2	**The involvement all employee**	**V2**
3	**Integrated into the strategic and business plans**	**V3**
4	**Skill, training and education**	**V4**
5	**Continuous Improvement**	**V13**
6	**Recognition**	**V14**
7	**Enforcement**	**V15**

In the table 5, the seven variables will be revalued by giving points from 1 to 10 by the same 10 experts, five of the industry and the other five from TVET. All experts will rate these seven variables by a maximum of 10 in the Table 5. They were needed to use full figures, to use all 10 points and not more than 10 points, and were asked to allocate their points but chose the most important for a powerful assessment in AFG of the 10 statements they felt were [27].

Table 5. Third Round: Data Verification Process (Result)

Experts	V1	V2	V3	V4	V13	V14	V15	Total
1	8	8.5	7	9	8.5	7.5	9	57.5
	0.139	0.147	0.121	0.156	0.147	0.13	0.156	1
2	9	9	7.5	9.5	8	8	8.5	59.5
	0.151	0.151	0.126	0.159	0.134	0.134	0.142	1
3	9.5	9.5	9	8.5	8.5	7	7.5	59.5
	0.159	0.159	0.151	0.142	0.142	0.117	0.126	1
4	8.5	9	9.5	9	8.5	7	7.5	59
	0.142	0.153	0.162	0.153	0.142	0.119	0.127	1
5	9.5	9.5	9.5	9.5	8.5	6	8	60.5
	0.157	0.157	0.157	0.157	0.14	0.099	0.132	1
6	8.5	9.5	7	9	8.5	9	9	60.5
	0.14	0.157	0.115	0.148	0.14	0.148	0.148	1
7	9	9	8	8.5	9	8.5	8.5	60.5
	0.148	0.148	0.132	0.14	0.148	0.14	0.14	1
8	9.5	9	7.5	9.5	8	9	9.5	62

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9	0.153 8	0.145 8.5	0.12 7	0.153 9	0.129 8.5	0.145 8.5	0.153 9	1 58.5
10	0.136 9	0.145 9	0.119 9.5	0.153 9.5	0.145 8	0.145 8	0.153 8.5	1 61.5
	0.146	0.146	0.154	0.154	0.13	0.13	0.138	1
Mean	**0.147**	**0.15**	**0.135**	**0.151**	**0.139**	**0.13**	**0.141**	

At the third round, in the Table 6, Variable 4 gets the highest points of 91% with mean points of 0.151. Followed by Variable 2 got 90.5% points with mean points is 0.150. The third variable is Variable 1 with percentage 88.5% and mean 0.147. Variable 15 gets 85% with average mean of 0.141. The four variables V4, V2, V1, and V15 surpass 85% and show the variable is the most important variable in the Critical Success Factor in the maintenance strategy practiced in the industry to be applied in the TVET. According Kendall's W scale, if the result gets 70% or higher would show a good consensus and the classification stage would be considered finished [26]. For Variables 13, 3 and 14, the percentage points and mean reached are low, however, these three fixed variables exceed 70% and above. This shows that the variable is still accepted in the industry and can be introduced into the TVET.

Table 6. Variable Percentage and Mean

No.	Indicator	Variable	Percentage %	Mean
1	**V4**	**Skill, training and education**	**91**	**0.151**
2	**V2**	**The involvement all employee**	**90.5**	**0.15**
3	**V1**	**The support of top management**	**88.5**	**0.147**
4	**V15**	**Enforcement**	**85**	**0.141**
5	**V13**	**Continuous Improvement**	**84**	**0.139**
6	**V3**	**Integrated into the strategic and business plans**	**81.5**	**0.135**
7	**V14**	**Recognition**	**78.5**	**0.13**

6. Conclusion

After going through the Delphi process, Critical Success Factor for an industry-leading strategy to be implemented into TVET has been identified. It is the support of top management, the involvement all employee, Integrated into the strategic and business plans, Skill, training and education, Continuous Improvement, Recognition and Enforcement. The findings are supported by previous studies as stated in the literature review. Meanwhile, these findings also show two variables identified by the expert group as different variables and an expletive idea. These variables are Recognition and Enforcement that can be further elaborated on future research. In this study there are also variables in parallel with the problems raised in the previous study. According to [23], implementing Autonomous Maintenance strategies at TVET requires high levels of skills and knowledge. So the result shows that Variable 4 Skill, Training and Education gets the highest and most important score in the success factor in the maintenance strategy.

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