MAINTENANCE STRATEGY FOR OLD LATHE MACHINE IN TECHNICAL VOCATIONAL EDUCATION TRAINING INSTITUTION

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DEDICATION

This dissertation is dedicated to my late mother, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my late father, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Technical vocational education training (TVET) institutions in Malaysia provide competent and skilful future workers in line with the industrial requirement. Therefore, the facility where the students regularly doing practical such as workshop equipment should be at satisfactory condition and performance. However, due to poor machine care and maintenance, the condition and performance of the training equipment are not satisfactory. Most TVET institutions practice preventive and corrective maintenance, and all maintenance activities are done by suppliers. The current practice on maintenance has many issues such as high cost, delay, and sub-standard equipment maintenance quality. This situation is exacerbated when most machines especially the lathe machines have been used more than a decade. This situation has caused interruptions in teaching and learning. Therefore, the current practice of maintenance strategies needed to be reviewed. This study aims to develop a reliable maintenance strategy framework for TVET institutions. A case study in one TVET institution to examine critical success factors in maintenance strategy was conducted. The institution has 30 lathe machines. A total of 20 maintenance experts from TVET institutions and industries participated in the interviews. The Delphi method was used to gather the data from the experts. The findings on critical success factors revealed support of top management, involvement of all employees, skill training and education, recognition, enforcement, and continuous improvement should be integrated into the strategic and business plans. Next, the existing maintenance strategy, corrective and preventive maintenance together with total productive maintenance were analysed. The analyses were done using a combination of analytical hierarchy process (AHP) and Delphi method. The findings indicated that Total Productive Maintenance (TPM) is the most appropriate strategy to be implemented in the TVET institution. Then, the TPM strategy framework was developed using Interpretive Structural Modelling software. All the identified critical success factors of maintenance strategies were used as variables in the conception of the TPM framework. In addition, the group of experts involved in determining the relationship of the variables in the framework development. Finally, the TPM was evaluated on the 30 lathe machines in that institution. The performance of the TPM was then evaluated based on overall equipment effectiveness (OEE) formula, cost comparison and number of machine breakdown. The condition before TPM was introduced showed that the OEE performance of the machine was 58.2%. After a year of the implementation of TPM, the performance of OEE increased to 62.3% in the first semester and subsequently 64.1%. The result has exceeded the average OEE performance rate of 60% even though the machines have been in used more than a decade, which such a result is of a standard in the manufacturing industry. Also, the developed TPM framework has shown a reduction in maintenance cost and an improvement in the readiness of machine operation. Therefore, the framework is practical and proposed to be used as equipment maintenance strategy in TVET institutions.

ABSTRAK

Institusi latihan pendidikan vokasional (TVET) di Malaysia menyediakan pekerja yang kompeten dan mahir di masa hadapan untuk memenuhi keperluan industri. Oleh itu, kemudahan di mana pelajar melakukan praktikal seperti peralatan bengkel mestilah berada dalam keadaan dan prestasi yang memuaskan. Namun, kerana kurangnya penjagaan dan penyelenggaraan tersebut, maka keadaan dan prestasi peralatan untuk praktikal adalah tidak memuaskan. Sebilangan besar institusi TVET mengamalkan penyelenggaraan pencegahan dan pembetulan, dan semua aktiviti penyelenggaraan dilakukan oleh pembekal. Amalan penyelenggaraan yang sedia ada mempunyai pelbagai masalah seperti kos yang tinggi, kelewatan, dan kualiti penyelenggaraan peralatan yang rendah. Keadaan ini diburukkan lagi apabila kebanyakan mesin terutamanya mesin larik telah digunakan lebih daripada satu dekad. Keadaan ini telah menyebabkan gangguan dalam pengajaran dan pembelajaran. Oleh itu, amalan strategi penyelenggaraan semasa perlu dikaji. Kajian ini bertujuan untuk membangunkan rangka kerja strategi penyelenggaraan yang boleh dipercayai di institusi TVET. Kajian kes di salah sebuah institusi TVET telah dilaksanakan untuk mengkaji faktor kejayaan kritikal dalam strategi penyelenggaraan. Institusi yang dipilih ini mempunyai 30 mesin larik. Manakala sejumlah 20 orang pakar penyelenggaraan daripada beberapa institusi TVET dan daripada industri mengambil bahagian dalam sesi temu bual yang telah dijalankan. Kaedah Delphi digunakan untuk mendapatkan data daripada pakar berkenaan. Hasil kajian menunjukkan faktor kejayaan kritikal iaitu, sokongan pengurusan atasan, penglibatan semua pekerja, latihan dan pendidikan kemahiran, pengiktirafan, penguatkuasaan, dan peningkatan berterusan hendaklah disepadukan ke dalam perancangan strategik dan perniagaan tersebut. Seterusnya, strategi penyelenggaraan semasa, penyelenggaraan pembetulan dan pencegahan bersama dengan penyelenggaraan produktif keseluruhan (TPM) telah dianalisis. Analisis telah dilakukan dengan menggunakan gabungan proses hierarki analitik (AHP) dan kaedah Delphi. Hasil kajian menunjukkan bahawa penyelenggaraan produktif keseluruhan (TPM) adalah strategi yang paling tepat untuk dilaksanakan di institusi TVET. Kemudian, kerangka kerja strategi TPM dibangunkan dengan menggunakan perisian *Interpretive Structural Modelling*. Semua faktor kejayaan kritikal strategi penyelenggaraan yang telah dikenal pasti, digunakan sebagai pemboleh ubah dalam konsep kerangka TPM. Di samping itu, kumpulan pakar yang terlibat menentukan hubungan pemboleh ubah dalam pembangunan kerangka kerja tersebut. Akhirnya, TPM dinilai terhadap 30 buah mesin larik di institusi tersebut. Prestasi TPM kemudian dinilai menggunakan formula keberkesanan peralatan keseluruhan (OEE), perbandingan kos dan jumlah kerosakan mesin. Keadaan sebelum TPM diperkenalkan menunjukkan bahawa prestasi OEE mesin ialah 58.2%. Setelah setahun pelaksanaan TPM, prestasi OEE meningkat kepada 62.3% pada semester pertama dan seterusnya 64.1% pada semester berikutnya. Keputusannya telah melebihi kadar prestasi OEE purata 60% walaupun mesin telah digunakan lebih dari satu dekad, dan dapatan ini telah mencapai piawaian industri pembuatan. Rangka kerja TPM yang dibangunkan juga telah menunjukkan pengurangan kos penyelenggaraan dan peningkatan kesediaan operasi mesin. Oleh itu, kerangka kerja ini praktikal dan dicadangkan untuk digunakan sebagai strategi penyelenggaraan peralatan di institusi TVET.

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LIST OF ABBREVIATIONS

AHP	-	Analytical Hierarchy Process
ANP	-	Analytic Network Process
BD	-	Breakdown
CBM	-	Conditions Base Maintenance
CM	-	Corrective Maintenance
CODAS	-	Combinative Distance-Based Assessment
CSF	-	Critical Success Factors
FMCDM	-	Fuzzy Multiple Criteria Decision Making
ISM	-	Interpretive Structure Modelling
MARA	-	Majlis Amanah Rakyat
OEE	-	Overall Equipment Effectiveness
OM	-	Opportunistic Maintenance
PdM	-	Predictive Maintenance
PM	-	Preventive Maintenance
RCM	-	Reliable Centre Maintenance
RMCGPG	-	Revise Multi Choice Goal Programming
SM	-	Schedule Maintenance
TOPSIS	-	Technique for Order Preference by Similarity to Ideal Solution
TPM	-	Total Productive Maintenance
TVET	-	Technical Vocational Education Training

LIST OF SYMBOLS

λ	-	Lambda
A	-	Availability
P	-	Performance
Q	-	Quality

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Majlis Amanah Rakyat is an agency under the Ministry of Urban Development. MARA through the Technical and Vocational Division has 24 technical vocational education training institutions. There are 11 MARA Higher Skills College (KKTM) and 13 MARA Skills Institute (IKM) which conduct various fields of certification and diploma programmes. All these institutions are known as MARA TVET institution. MARA TVET's mission is to be a superior and blessed trust organization to uplift the dignity of the nation. While MARA TVET's vision is to form a holistic TVET human capital based on entrepreneurial values, objective of the establishment of MARA TVET are to be a superior higher education institution based on institutions and technopreneurs, forming a holistic and balanced TVET human capital based on R.I.S.E (Religious, Innovative, Skills and Entrepreneurship), be a catalyst in the technological revolution to increase competitiveness, to form a sustainable and dynamic MARA TVET corporate governance and to be an internationally recognized TVET educational institution. Each centre has workshops and equipment to facilitate the teaching and learning process. Through data obtained in 3 years from 2015 to 2017 in Figure 1.1, maintenance allocation experienced a dramatic drop while the number of applications increased from year to year. The projected trend of this expenditure is expected to be sustained next year and also it is likely that the allocation of maintenance will be deducted. The figure shows that the approved maintenance allocation decreased from 2015 to 2017. According to Figure 1.2, the difference is more pronounced, when the amount of application is higher than the approved allocation. Increased application of the allocation was due to the fact that the warranty period of equipment and machines had expired in the documents contract.

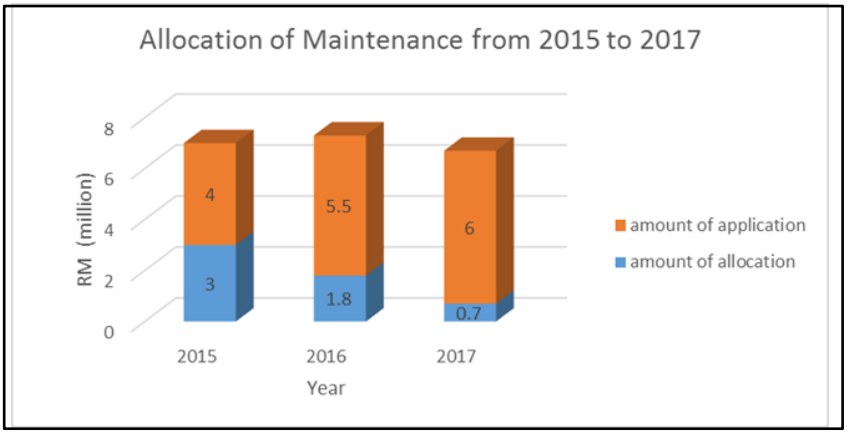

Figure 1.1 The comparison of allocation amount and application within three years' duration (Procurement and Maintenance Department, 2020)

Every year, the average equipment requiring maintenance is 5000 unit (Procurement and Maintenance Department,2020). Therefore, TVET institution gives priority to certain machines that require maintenance and repair immediately. The types of maintenance strategies implemented in TVET institution are corrective maintenance and preventive maintenance in which they rely 100% on contractors to carry out maintenance activities. However, if allocation is insufficient, most machines requiring preventive maintenance are not feasible because they are channelled to machines requiring corrective maintenance. Provision of maintenance allocations in minimum conditions does not reflect long-term solutions, coupled with lack of knowledge in maintenance management and the problem persists, there is no solution (Eghan, 2013).

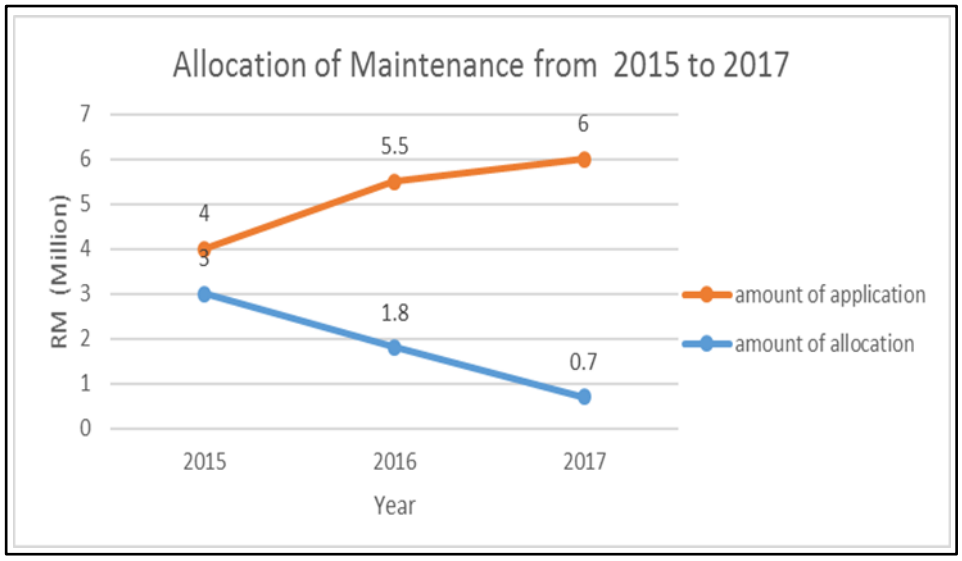

Figure 1.2 The trend of allocation amount and application amount within three years' duration (Procurement and Maintenance Department, 2020)

These equipment and machines will definitely be exposed to failure or damage. This problem contributes to greater damage and repeated issues every year. MNSE, Province, and Pascal (2009) notes TVET institution also has problems related to periodic maintenance and preventive maintenance without solution. Referring to past journal, the cost of maintenance is becoming increasingly critical with the increasing competition in the business environment. The competition led to more focus on cost reduction in operations and maintenance. Cost reduction may immediately be reflected on pricing and hence, gaining edge over competitors. Maintenance cost constitutes a major portion of total operations cost and hence is central to most cost reduction programs (Audu, Musta'amal, Kamin, & Saud, 2013). The equipment available at TVET institution not only embraces intensive training, but the operation of this equipment requires costly maintenance. Meanwhile, maintenance work performed by external suppliers does not meet established procedures. The quality of the work is dubious as it ignores safety factors. The external supplier has misinterpreted the type of damage to the machine. These factors have contributed to the maintenance costs where the kind of failure that should be preventive maintenance was changed to corrective maintenance. Therefore, TVET institution needs to find a solution to reduce maintenance costs by not relying on suppliers in managing maintenance activities.

Gedel and Gablah (2014) conclude that, every operator should be given training on usage technology, maintenance and simple handling. Autonomous

maintenance aims to train operators to keep the machine in place of the machine in the early stages without relying on maintenance personnel. This action can help solve the problem of impairment that occurs on the machine where the prefix action will be quickly taken before the failure spreads to greater (Attri, Grover, Dev, & Kumar, 2013). This method of maintenance strategy can reduce the dependence on suppliers as well as reduce maintenance costs. This situation is exacerbated when existing equipment and machinery in institution have a long period of operation and are getting old. Equipment and machinery will be prone to various failures if not properly cared and maintained. TVET institution needs to act more drastically and wisely to manage the existing equipment despite some challenges and limited resources.

1.2 Problem Statement

Questions have been raised about the maintenance management in TVET institution. The situation in TVET institutions is that most of the equipment and machines used are over 15 years and above. These machines and equipment are very vulnerable to gradual deterioration. In general, the result of the deterioration is due to the factors that can be avoided without any heavy maintenance. Machine failure caused by gradual deterioration is a failure associated with to wear, tear, stress fatigue, corrosion, and so forth (Jayaswal, Wadhwani, & Mulchandani, 2008). Table 1.1 shows an example of a list of lathe machines and years of purchase.

Table 1.1 Lathe machine list in a TVET institute (Procurement and Maintenance Department, 2020)

No.	Brand	Quantity	Year
1.	P&G	60	1993
2.	Pinacho	88	1995
3.	Colchester	98	2001
4.	Knuth	33	2004

When these old machines are not well-maintained and there is no efficient maintenance strategy, problems will result in non-optimal use of machines. This situation disturbs learning processes because the machine's readiness and availability will affect the quality of teaching and learning process. For example, the practical class or practical exam was delayed, and sometimes student cannot complete their task because of machine failure. This situation affects the quality of students, teaching and learning process. Next becomes an obstacle to the vision, mission and objectives of the establishment of TVET institution. Kamau (2013) points out that the major challenge to their lecturers, most of the equipment at the institute in minimal care, and it has been used for quite some time. The equipment condition will affect learning then abolish their chances of competitiveness to get a spell after graduation. Machines need careful care to last long. In addition, this maintenance requires a well-organized and practical maintenance management to maintain the performance of the machine operated. Other researcher, who have looked maintenance management at TVET institution, Maino (2013) have found that the instructors at TVET institution complains about the state of the many equipment on TVET institution is outdated and in need of maintenance. TVET institution is experiencing the same situation as described by previous researchers. However, to confirm the description of the situation, overall equipment effectiveness studies have been conducted on several lathe machines as shown in Table 1.1. The result obtained 58.2 % indicates that the situation is unfolding on TVET institution. Most of the OEE's performance for the old machine is not very encouraging. The OEE benchmark value is at a good level and accepted within the industry when it is 85% and above. So any OEE performance score below 85% is recommended to improve the performance (Elevli & Elevli, 2010).

1.3 Research Objectives

The objectives of the research are:

(a) To determine critical factor affecting maintenance strategy for TVET institution

What is the critical factor affecting maintenance strategy in TVET institution?

(b) To suggest the suitable maintenance strategy for TVET institution.

What are the criteria influence the maintenance strategy in TVET institution?

Which is the best of maintenance strategy appropriate for TVET institution?

(c) To develop a framework of maintenance strategy for TVET institution.

What is the maintenance strategy framework applied to TVET institution?

(d) To verify the framework of maintenance strategy for TVET institution.

What is the result of Overall Equipment Effectiveness for the machine after apply the maintenance strategy?

How much the maintenance cost after applies the maintenance strategy?

How many numbers of machines breakdown after apply the maintenance strategy?

1.4 Significance of the Research

This study develops a reliable maintenance strategy framework for TVET institution. Although the maintenance strategy is adopted from the industry, however the methodology implemented in this study is limited specifically for MARA TVET institution. This maintenance strategy framework can be used by any TVET institution in Malaysia. TVET institution is the largest producer of skilled manpower to the industry. With the existence of total productive maintenance strategies in TVET institution, will affect the quality of students in line with the needs of the industry demands. The efficiency of TVET management in use, machine maintenance and storage equipment will continue to build confidence and influence learning in workshops and practical training (Etuk & Usoro, 2016).

The study outcomes highlight a new approach for maintenance management in TVET institution. TPM maintenance strategy has long been established in the industry, but not in TVET institution. The use of this maintenance strategy has improved OEE performance 5.9%, reduced the annual cost of machine maintenance 39.3% and reduced the number of machines breakdown 73.3%. All these outcomes that have been described gave a positive impact and made TVET institution on the right track to achieve the overall mission, vision and objectives that have been set.

1.5 Scope and Limitation of the Research

This study focused on total productive maintenance strategy applied in one of MARA TVET institution. TPM is the most appropriate maintenance strategy to study its implementation in MARA TVET institution base on three factors:

i. MARA TVET institution already has a strong site implementing TPM maintenance strategy because of 5s program has long been established.
ii. Base on two studies Kalpande (2014) and W. Mahmood et al. (2008), already has some hints and guidelines need to be improved in term of TPM implementation in education sector.
iii. MARA TVET institution has the strength of skilled manpower to perform autonomous maintenance.

TPM maintenance strategy is implemented on a lathe machine. Lathe machine is also one of the main and common machines in MARA TVET institution. Therefore, this study uses lathe machines as the main study material in identifying frequently damaged machines in MARA TVET institutions. This study focuses on a total of 30 students from Certificate of Industrial Mechanic Technology Certificate and 30 lathe machines at IKM Kuala Lumpur. The selection of IKM Kuala Lumpur as the location and study material is due to several factors as follow:

i. IKM Kuala Lumpur runs the Industrial Mechanic Certificate Program, where the students, technicians and lecturers have knowledge in machine maintenance. In accordance with the TPM strategy, requires basic knowledge in machine maintenance.

ii. IKM Kuala Lumpur has been recognized by Malaysia Productivity Corporation in running the 5s Program.
iii. The institute has 30 lathe machines that are over 20 years old.
iv. The ratio of machine to student is 1:1

1.6 Organization of Thesis

Overall, this research is comprised of five chapters to achieve the desired goal.

Chapter 1 - Introduction offers a brief overview of the problem statement for this research, the objectives that are aimed to be achieved, as well as the significance and scope of research.

Chapter 2 - Literature Review presents a brief overview of maintenance, including its definition, management, strategies, industry sector and TVET sector. This chapter introduces the research gaps identified from the recently highlighted issues and outlines some indications for the proposed solution. In maintenance management have been described various strategies and concepts that have been applied in the industry. A specific study to analyze the selection of maintenance strategies should be conducted specifically at TVET institution to determine which maintenance strategies are appropriate to the situation and criteria at the institute. After knowing the maintenance strategy in the industry and the criteria that influence the selection of the maintenance strategy, the success factors of implementing the maintenance strategy in the industry need to be identified. Meanwhile, the development of the TPM framework in TVET institution should be based on the critical success factors of maintenance strategies in the industry. This will cause the process of adoption the maintenance strategy from the industry to TVET institution run smoothly and achieve the objectives of the study. Once the framework is developed, the implementation of the maintenance strategy needs to be evaluated for its effectiveness. This study focuses on OEE performance, maintenance cost and number of machines breakdown. The positive effect on the three elements mentioned will confirm that the maintenance strategy is successful at TVET institution.

Chapter 3 - Research Methodology describes the quantitative and qualitative approach based on four research objectives (ROs) subject to the wide use of Delphi Methods, Interpretive Structural Modelling, Analytical Hierarchy Process, the outcomes of OEE performance, cost comparison and number of machine breakdowns which forms the main part of this study. In RO 1, the emphasis and opinion on critical success factors that has been listed in the industry provides guidance to evaluate which factors can be applied into the TVET institution. Therefore, the determination of critical success factor maintenance strategies for TVET institution should be carried out using Delphi Methods. In RO 2, each sector involved has different maintenance strategies. This includes TVET institution also has different maintenance strategies due to different situations and criteria. A specific study to analyze the selection of maintenance strategies should be conducted using combination of Delphi Methods and Analytical Hierarchy Process. In RO 3, maintenance strategy implementation must have a complete framework from start until the end process. The findings of RO1 and RO2 will assists for the development of maintenance strategy framework using Interpretive Structural Modelling. Lastly, in RO 4, a verification process is established to portray the potential of maintenance strategy to benefit the OEE performance, maintenance cost and number machine of machine breakdowns.

Chapter 4 - Results and Discussion presents the result from the outlined ROs, the determination of critical success factors maintenance strategy, the most suitable maintenance strategy in TVET institution, the development maintenance strategy framework. The effectiveness of the end results is validated via potential increase of OEE performance, the reduction of maintenance cost and number of machine breakdowns.

Chapter 5 – Conclusion highlights the contribution, the achievement of the research objectives, and the proposal for future endeavors. This chapter describes the significance of critical success factors, maintenance strategy analysis, maintenance strategy framework and OEE application in TVET institution.

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Appendix A – List of respondents

No	Name	Age	Position	Industry / TVET	Address	Working Experience	Field	Education
1	Mohammad Nizam Bin Arf	38	Senior Engineer	Inokom Corporation Sdn Bhd	Lot 38, Mukim Padang Meha Padang Serai, Kulim 09400 Kedah Darul Aman	14 years	Automotive Man	Diploma Automated System & Maintenance Technology Degree in Automatyion & Robotic Master in Tech. & Industrial Management
2	Mohammad Ashran Bin Gl	40	Senior Production Engir	AVP Engineering Sdn Bhd	Lot 4, Jalan Waja 16, Kawasan Perindustrian Telok Panglima Garang, 42500 Telok Panglima	15 years	Product Manufa	Degree in Mechanical Eng. Diploma Tool and Die Cert in Mechanic Industry
3	Muhammad Shahir Bin Mo	35	Quality Engineer	Toa Paint Products Sdn Bhd	B3A-30 (FLOOR 3A), 10 BOULEVARD, PJU 6A, Lebuhraya SPRINT, Kampung Sungai Kayu Ara, 47400 Petaling Jaya,	10 years	Product Manufa	Degree in Mechanical Eng.
4	Shah Johan Bin Md Shah	43	Treatment Executive	Indah Water Consortium	C-G-8, Block C, Greentown Square, Jalan Dato' Seri Ahmad Said, 30450, Ipoh, Perak, Kampung Kastam Greentown,	15 years	Treatment Proce	Diploma in Automated System & Maintenance Tech.
5	Mohammad Hafizuddin Bi	38	Operation Supervisor	Nur Power Plant	Lot 30, Jalan Hi-tech 4, Kulim Hi-tech Park, 09000 Kulim, Kedah	15 years	Power Plant	Certificate in Mechanical Eng Diploma in Mechanical Eng Competence Skill Cert
6	Mohd Syadzry Bin Ramli	38	Senior Engineer	Sony EMCS	Lot 5, Persiaran Kemajuan, Kawasan Perindustrian Bangi, 43650 Bandar Baru	10 years	Production	Degree in Electrical Eng. Master in Tech. & Industrial Management
7	Mohd Shabuddin Bin Mat	45	Director	Indsys Engineering Sdn Bhd	No.9 Jalan Kelumpang Satu 27/41A, Seksyen 27, 40400 Shah Alam,	19 years	Machine Tools M	Degree in Electrical.

7	Mohd Shabuddin Bin Ma	45	Director	Indsys Engineering Sdn Bhd	No.9 Jalan Kelumpang Satu 27/41A, Seksyen 27, 40400 Shah Alam,	19 years	Machine Tools	Degree in Electrical.
8	Shahril Reza Bin Suffian	38	Supervisor	Perodua Manufactring Sdn B	48200 Rawang, Selang	16 years	Machine mainte	Diploma Automated System & Maintenance Tech
9	Syed Mahdzar Bin Syed	54	Project Director	RK Elevator Sdn Bhd	A, RK HQ (PUCHONG). A-02-05, Block, Persiaran Prima Utama, 5, Jalan Prima 5/5, Taman	28 years	Elevator & Lift	Degree in Mechanical Eng. Master in Industrial and Tech.
10	Nazmi Bin Khalid	40	Manager	Semperit Engineering & Tech	Lot 18374, Jalan Perusahaan 3, Kamunting Industrial Estate, 34600 Kamunting, Perak Darul Ridzuan,	13 years	Machine Manuf	Degree in Mechatronics
11	Syahril Izwan Bin Abdul	38	Lecturer	Politeknik TSB, Kulim	Kulim Hi-tech Park, 09	12 years	TVET	Degree in Electrical Eng
12	Mohamed Nazeeb Bin Mohammed Naina	40	Lecturer	IKBN, Sepang	Bandar Baru Salak Tinggi, 43900	15 years	TVET	Diploma in Tool & Die Tech
13	Noorismaliana Binti Isma	39	Lecturer	CIAST	Seksyen 19, 40300 Sh	15 years	TVET	Diploma in Mechanical Eng.
14	Abdul Halim Bin Kling	57	Technical Training Officer Principle	German Malaysian Institute	Jalan Ilmiah, Taman Universiti, 43000 Kajang, Selangor	30 years	TVET	Master in Manufacturing System
15	Mustafa Amin Bin Khairu	39	Technical Officer	UNIKL MFI	Section 14, Jalan Damai, Seksyen 14, 43650 Bandar Baru	15 years	TVET	Diploma in Tool & Die Tech Degree in Tech Mngt Master in Industrial
16	Khairol Nizam Bin Azmi	41	Asst.Vocational Traini	ILP Ipoh	Kawasan Perindustrian, Taman	17 years	TVET	Diploma in Fabrication Tech.
17	Affendi Bin Ahmad Daha	47	Lecturer	Vocational College Sungai	Lot 82, Kampong Sungai Tukang: 08000, Sungai Petani	26 years	TVET	Degree in Mechanical Eng.
18	Ismail Bin Yunus	33	Asst Vocational Traini	KKTM Balik Pulau	Jalan Pondok Upih, 11000 Balik Pulau,	15 years	TVET	Diploma in Mechanical Eng.
19	Humaizee Bin Misman	42	Asst Vocational Traini	IKM Kuala Lumpur	Jalan Belangkas, Kampung Pandan, 55100 Kuala Lumpur, Wilayah Persekutuan	19 years	TVET	Diploma in Mechatronics Eng.
20	Mohd Fadzil Bin Mohd S	44	Asst Vocational Traini	IKM Johor Bahru	848, Jalan Taruka, Kawasan Perindustrian Tampoi,	18 years	TVET	Diploma in Machine Bulding & Maintenance Tech
21	Ir. Asymal Wajdi Bin Mohd Akhir@Mokhtar	40	Vocational Training Of	MARA HQ	Ibupejabat MARA, Jalan MARA, 50609	15 years	TVET	Master in Electrical Eng Profesional Engineer

No	Name	Position	Working Experienc	Designation	Education	Points
1	Mohammad Nizam Bin Arffin	Senior Engineer	14 years	Automotive Manufacturing & Maintenance	Diploma Automated System & Maintenance Technology Degree in Automatyion & Robotic Master in Tech. & Industrial Management	
Score		5	3	5	5	18/20
2	Mohammad Ashran Bin Ghazali	Senior Production Engineer	15 years	Product Manufacturing	Degree in Mechanical Eng. Diploma Tool and Die Cert in Mechanic Industry	
Score		5	5	5	5	16/20
3	Muhammad Shahir Bin Mohd Noor	Quality Engineer	10 years	Product Manufacturing	Degree in Mechanical Eng.	
Score		3	3	5	5	16/20
4	Shah Johan Bin Md Shahriff	Treatment Executive	15 years	Treatment Process & Control	Diploma in Automated System & Maintenance Tech.	
Score		3	5	5	3	16/20
5	Mohammad Hafizuddin Bin Ahma	Operation Supervisor	15 years	Power Plant	Certificate in Mechanical Eng Diploma in Mechanical Eng Competence Skill Cert	
Score		3	5	5	3	16/20
6	Mohd Syadzry Bin Ramli	Senior Engineer	10 years	Production	Degree in Electrical Eng. Master in Tech. & Industrial Management	
Score		5	3	5	5	18/20
7	Mohd Shabuddin Bin Mat Hasan	Director	19 years	Machine Tools Maintenance	Degree in Electrical.	
Score		5	5	5	5	20/20
8	Shahril Reza Bin Suffian	Supervisor	16 years	Machine maintenance	Diploma Automated System & Maintenance Tech	
Score		3	5	5	3	16/20
9	Syed Mahdzar Bin Syed Mohamed	Project Director	28 years	Elevator & Lift Installation	Degree in Mechanical Eng. Master in Industrial and Tech.	
Score		5	5	3	5	18/20
10	Nazmi Bin Khalid	Manager	13 years	Machine Manufacturing	Degree in Mechatronics	

Score		5	3	5	5	18/20
11	Syahril Izwan Bin Abdul Yamin	Lecturer	12 years	TVET	Degree in Electrical Eng	
Score		3	3	5	5	16/20
12	Mohamed Nazeeb Bin Mohammed Naina Marican	Lecturer	15 years	TVET	Diploma in Tool & Die Tech	
Score		3	5	5	3	16/20
13	Noorismaliana Binti Ismail	Lecturer	15 years	TVET	Diploma in Mechanical Eng.	
Score		3	5	5	3	16/20
14	Abdul Halim Bin Kling	Technical Training Officer Principle	30 years	TVET	Master in Manufacturing System	
Score		5	5	5	5	20/20
15	Mustafa Amin Bin Khairuddin	Technical Officer	15 years	TVET	Diploma in Tool & Die Tech Degree in Tech. Mngt. Master in Industrial	
Score		3	5	5	5	18/20
16	Khairol Nizam Bin Azmi	Asst.Vocational Training Office	17 years	TVET	Diploma in Fabrication Tech.	
Score		3	5	5	3	16/20
17	Affendi Bin Ahmad Dahalan	Lecturer	20 years	TVET	Degree in Mechanical Eng.	
Score		3	5	5	5	18/20
18	Ismail Bin Yunus	Asst Vocational Training Officer	15 years	TVET	Diploma in Mechanical Eng.	
Score		3	5	5	3	16/20
19	Humaizee Bin Misman	Asst Vocational Training Officer	19 years	TVET	Diploma in Mechatronics Eng.	
Score		3	5	5	3	16/20
20	Mohd Fadzil Bin Mohd Said	Asst Vocational Training Officer	18 years	TVET	Diploma in Machine Bulding & Maintenance Tech	
Score		3	5	5	3	16/20
21	Ir. Asymal Wajdi Bin Mohd Akhir@Mokhtar	Vocational Training Officer	15 years	TVET	Master in Electrical Eng Profesional Engineer	
Score		3	5	5	5	18/20

Appendix B – Validation of research instruments

Validation of the Research Instruments

It is confirmed that the research instrument developed by researcher Razni Bin Khalid from Razak Faculty of Technology and Informatics consists of:

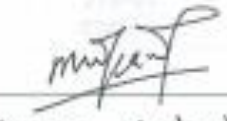
i) Research Objective Questionnaire 1

ii) Research Objective Questionnaire 2

has been reviewed and found to be in line with the research objectives. The reviews are as follows:

The questions developed are well suited to the study

Thank you.

Signature : 

Name : Muzam Shah bin Kamra

Position : Head of Corporate office

Experience : 28 years

Education Background : Chemical Engineering

Company/Agency : PRASS N

Official stamp :

Date : 8/8/2019

Validation of the Research Instruments

It is confirmed that the research instrument developed by researcher Razni Bin Khalid from Razak Faculty of Technology and Informatics consists of:

i) Research Objective Questionnaire 1

ii) Research Objective Questionnaire 2

has been reviewed and found to be in line with the research objectives. The reviews are as follows:

The questions are in line with the objectives of the study. A few improvement need to be revised based on the discussion.

Thank you.

Signature : _____

Name : DR. SUZILAWATI AKMAR BT AHMAD

Position : Timbalan Pengarah 3 (Cawangan Penyelidikan Dan Maklumat) Bahagian Kemahiran dan Pendidikan MARA

Experience : 16 tahun

Education Background : Civil Engineering and Tech. and Vocational Education

Company/Agency : Majlis Amanah Rakyat (MARA)

Official stamp : MAJLIS AMANAH RAKYAT

Date : 30/7/2019

Validation of the Research Instruments

It is confirmed that the research instrument developed by researcher Razni Bin Khalid from Razak Faculty of Technology and Informatics consists of:

i) Research Objective Questionnaire 1

ii) Research Objective Questionnaire 2

has been reviewed and found to be in line with the research objectives. The reviews are as follows:

The questionnaire 1 & 2 are suitable to meet the objective research objectives 1 & 2.

Thank you.

Signature :

Name : Ir. MAHZAN BIN TEH
Pengarah
Bahagian Kemahiran dan Teknikal
MARA

Position :

Experience : 28 years

Education Background : Master in TVET (Electrical & Electronics)

Company/Agency : MARA

Official stamp :

Date : 29/4/2019

Appendix C – Research question (Delphi Methods) & AHP application

ROUND 1

This survey for a group of industry experts and TVET experts. You are required to answer all the questions below. There is no right or wrong in the answer given. The answers provided should be clear and precise

1) Respondent Background

Name: Mohammad Nizam Bin Arffin Age: 38

Gender: Male Company: Inokom Corporation Sdn Bhd

Position: Senior Engineer Working Experience: 14 years

Field of Expertise: Automotive Manufacturing & Maintenace Education: Degree in Industrial Robotics Tech.

2) Does your company/TVET institution have a Maintenance Department?
Yes

3) What are the types of maintenance strategies used in your company/TVET institution?
TPM

4) Is the maintenance strategy practiced in your company/TVET institution successful?
(if NO, please answer the question no. 5 only. If YES, please answer the question no.6 only)

Yes, so far successful but the strategy needs to be updated

5) What are the obstacles to maintenance strategies in your company/TVET institution?
Null

6) What are the success factors maintenance strategy in your company / TVET institution?

- **staff training**
- **top management commitment**
- **strategic plan**
- **work culture**
- **always want to improve the performance**
- **employee cooperation**

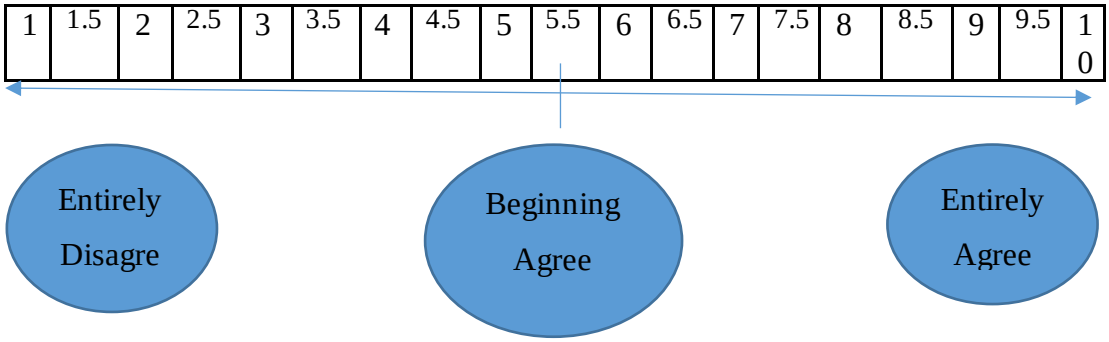
ROUND 2

You are required to choose the Critical Success Factors which are important within the TVET institute. Please tick (√) in the space provided.

No.	Variable	Please tick (√)
1	**The support of top management**	√
2	**The involvement all employee**	√
3	**Integrated into the strategic and business plans**	√
4	**Skill, training and education**	√
5	**Empowerment and encouragement**	√
6	**Maintenance performance evaluation**	√
7	**Cultural change**	√
8	**Coordination**	
9	**Cooperation**	√
10	**Communication**	√
11	**Motivation**	
12	**Resource Management**	
13	**Continuous Improvement**	√
14	**Recognition**	√
15	**Enforcement**	√

ROUND 3

You are required to choose the points between 1 until 10 and fill in the table given for selected Critical Success Factors.



No.	Critical Success Factors	Points
1.	The support of top management	8
2.	The involvement all employee	8.5
3.	Integrated into the strategic and business plans	7
4.	Skill, training and education	9
5.	Continuous Improvement	8.5
6.	Recognition	7.5
7.	Enforcement	9

Table 5.1 Industrial expert no. 1 answer for the first round

Respondent Background.	**Question 2.**
Name: Nizam Bin Arffin	Yes
Gender: Male	**Question 3**
Postion : Senior Engineer	TPM
Age: 38	**Question 4**
Working Experience: 14 years	Yes, so far successful but the strategy needs to be updated
Company: Inokom Corporation Sdn Bhd	**Question 5**
Designation: Automotive Manufacturing & Maintenace	Null
Education: Bachelor in Industrial Robotics Technology	**Question 6** - staff training - top management commitment - strategic plan - work culture - always want to improve the performance - employee cooperation

Table 5.2 Industrial expert no. 2 answer for the first round

Respondent Background.	**Question 2.**
Name: Mohammad Ashran Bin Ghazali	Yes
Age: 40	**Question 3**
Gender: Male	TPM & CM
Company: AVP Engineering Sdn Bhd	**Question 4**
Position: Senior Production Engineer	Yes
Working Experience: 15 years	**Question 5**
Designation: Product Manufacturing	Null
Education: Bachelor in Mechanical Eng.	**Question 6** - motivation - staff communication - business objective - staff encouragement - always want to improve performance - top management commitment - staff gratitude

Table 5.3 Industrial expert no. 3 answer for the first round

Respondent Background.	**Question 2.**
Name: Muhammad Shahir Bin Mohd Noor	Yes
Age: 35	**Question 3** TPM & CM
Gender: Male	**Question 4** Yes
Company: Toa Paint Products Sdn Bhd	**Question 5**
Position: Quality Engineer	Null
Working Experience: 10 years	**Question 6**
Designation: Product Manufacturing	- training & education - work coordination
Education: Bachelor in Mechanical Eng.	- strategic plan - continuous improvement - always want to improve performance - management cooperation - enforcement for autonomous maintenance

Table 5.4 Industrial expert no. 4 answer for the first round

Respondent Background.	**Question 2.**
Name: Shah Johan Bin Md Shahriff	Yes
Age: 43	**Question 3** Preventive Maintenance & Corrective Maintenance
Gender: Male	**Question 4**
Company: Indah Water Consortium	Yes, almost done.
Position: Treatment Executive	**Question 5**
Working Experience: 15 years	**Question 6**
Designation: Treatment Process & Control	- training & education - business plan
Education: Diploma in Automated System & Maintenance Tech.	- well organized from top management - skill competency - resource management - recognition

Table 5.5 Industrial expert no. 5 answer for the first round

Respondent Background.	**Question 2.**
Name: Mohammad Hafizuddin Bin Ahmad	Yes **Question 3** Preventive Maintenance & Corrective Maintenance
Age: 38	
Gender: Male	**Question 4** Yes, almost done.
Company: Nur Power Plant	**Question 5**
Position: Operation Technician	Null
Working Experience: 10 years	**Question 6** - the involvement all employee - performance evaluation - well organized from top management - skill competency - resource management - enforcement by top management
Designation: Power Plant	
Education: Certificate in Mechanical Eng	

Table 5.6 Industrial expert no. 6 answer for the first round

Respondent Background.	**Question 2.**
Name: Mohd Syadzry Bin Ramlias	Yes **Question 3**
Age: 38	TPM, PM & CM
Gender: Male	**Question 4** Yes, based on the maintenance record
Company: Sony EMCS	**Question 5**
Position: Senior Engineer	Null
Working Experience: 10 years	**Question 6** - the involvement all employee - performance evaluation - well organized from top management - skill and training - resource management - Recognition (tournament inter production line for maintenance program)
Designation: Production	
Education: Bachelor in Electrical Eng. Master in Industrial and Tech.	

Table 5.7 Industrial expert no. 7 answer for the first round

Respondent Background.	Question 2. Yes
Name: Mohd Shabuddin Bin Mat Hasan Age: 45 Gender: Male Company: Indsys Engineering Sdn Bhd Position: Director Working Experience: 19 years Designation: Machine Tools Maintenance Education: Bachelor in Electrical Eng	Question 3 Breakdown Maintenance, PM, CM & Retrofitting Question 4 Yes, 85% machine in good condition Question 5 Null Question 6 - Staff involvement - Staff competency and cooperation - Well organized from top management - Education and training - Empowerment - Encouragement

Table 5.8 Industrial expert no. 8 answer for the first round

Respondent Background.	**Question 2.** Yes
Name: Nazmi Bin Khalid Age: 40 Gender: Male Company: Semperit Engineering & Tech. Position: Mechanical Design Manager Working Experience: 13 years Designation: Machine Manufacturing Education: Bachelor in Mechatronics	**Question 3** TPM, PM & CM **Question 4** Yes, based on evaluation of the OEE **Question 5** Null **Question 6** - Top management involvement - Employee skill - Work culture - Education and training - Company enforcement - Kaizen

Table 5.9 Industrial expert no. 9 answer for the first round

Respondent Background.	**Question 2.** Yes
Name: Shahril Reza Bin Suffian Age: 38 Gender: Male Company: Perodua Manufacturing Sdn Bhd Position: Senior Technician Working Experience: 16 years Designation: Machine Maintenance Education: Diploma Automated System & Maintenance Tech.	**Question 3** TPM, PM & CM **Question 4** Yes, production running on schedule **Question 5** Null **Question 6** - Cooperation among staff - Maintenance evaluation - Management involvement - Skill and knowledge - Communication from top to down

Table 5.10 Industrial expert no. 10 answer for the first round

Respondent Background.	**Question 2.** Yes
Name: Syed Mahdzar Bin Syed Mohamed Age: 54 Gender: Male Company: RK Elevator Sdn Bhd Position: Project Director Working Experience: 28 years Designation: Elevator & Lift Installation Education: Bachelor on Mechanical Eng. Master in Industrial and Tech.	**Question 3** PM & CM **Question 4** Yes, lack of complaint **Question 5** Null **Question 6** - Strategic plan - Business objective - Top management responsibility - Motivation & encouragement form staff - Continuous improvement

Table 5.11 TVET expert no. 1 answer for the first round

Respondent Background. Name: Syahril Izwan Bin Abdul Yamin Age: 38 Gender: Male Company/TVET: Politeknik TSB, Kulim Position: Lecturer Working Experience: 12 years Designation: TVET Education Education: Bachelor in Electrical Eng	**Question 2.** Yes, in the HQ. **Question 3** Corrective Maintenance (outsource) & Preventive Maintenance depends on technician/lab personel. **Question 4** less satisfying **Question 5** - Lack of knowledge about maintenance management - No enforcement - Budget constraint **Question 6** Null

Table 5.12 TVET expert no. 2 answer for the first round

Respondent Background. Name: Mohamed Nazeeb Bin Mohammed Naina Marican Age: 40 Gender: Male Company/TVET: IKBN, Sepang Position: Lecturer Working Experience: 14 years Designation: TVET Education Education: Diploma in Tool & Die Tech	**Question 2.** Yes, in the HQ. **Question 3** In the past, they did use internal flap for maintenance. Due to lack of students, they outsource all activities (PM & CM) **Question 4** No, not all equipment repaired because of budget constraint. **Question 5** - Lack of student to apply autonomous maintenance - Not include in strategic plan - No enforcement **Question 6** Null

Table 5.13 TVET expert no. 3 answer for the first round

Respondent Background.	**Question 2.**
Name: Noorismaliana Binti Ismail	Yes, in the HQ.
Age: 39	**Question 3** PM depends on technician and lecturers & CM (outsource)
Gender: Female	
Company/TVET: CIAST	**Question 4** Not all equipment maintained and depends on budget
Position: Lecturer	
Working Experience: 10 years	**Question 5** - No enforcement about equipment maintenance management - Lack of student
Designation: TVET Education	- Not include in strategic plan
Education: Diploma in Mechanical Eng.	**Question 6** Null

Table 5.14 TVET expert no. 4 answer for the first round

Respondent Background.	**Question 2.**
Name: Abdul Halim Bin Kling	Yes,
Age: 57	**Question 3** Preventive Maintenance & Corrective Maintenance
Gender: Male	**Question 4** Almost done but still have issue.
Company/TVET: German Malaysian Institute	**Question 5** - the employee involvement - lack of focus from top management according to the budget.
Position: Technical Training Officer Principle	- spares part management
Working Experience: 30 years	**Question 6** - Training & education
Designation: TVET Education	- Strategic business plan - Skill competency
Education: Bachelor in Manufacturing Eng Master in Manufacturing System	- Resource management

Table 5.15 TVET expert no. 5 answer for the first round

Respondent Background.	**Question 2.**
Name: Mustafa Amin Bin Khairuddin	Yes,
Age: 39	**Question 3** Preventive Maintenance (depends on technician and lecturers) & Corrective Maintenance (outsource)
Gender: Male	
Company/TVET: UNIKL MFI	**Question 4** 50-50, Not all equipment maintained
Position: Technical Officer	**Question 5** - Lack of budget
Working Experience: 15 years	
Designation: TVET Education	**Question 6** Null
Education: SKM Level 3 Bachelor in Tech. Mngmt	

Table 5.16 TVET expert no. 6 answer for the first round

Respondent Background.	**Question 2.**
Name: Khairol Nizam Bin Azmi	Yes, in the HQ
Age: 41	**Question 3** Preventive Maintenance (depends on technician and lecturers) & Corrective Maintenance (outsource)
Gender: Male	
Company/TVET: ILP Ipoh	**Question 4** Almost done but still have issue depends on budget
Position: Asst.Vocational Training Officer	
Working Experience: 17 years	**Question 5** Null
Designation: TVET Education	
Education: Diploma in Fabrication Tech.	**Question 6** - The involvement all employee - Training and education - Well organized from top management - Skill competency - Resource management

Table 5.17 TVET expert no. 7 answer for the first round

Respondent Background.	**Question 2.**
Name: Affendi Bin Ahmad Dahalan Age: 47 Gender: Male Company/TVET: Vocational College Position: Lecturer Working Experience: 26 years Designation: TVET Education Education: Bachelor in Mechanical Eng.	Yes, in the HQ **Question 3** Preventive Maintenance & Corrective Maintenance (outsource) **Question 4** Still have issue depends on budget. Not all equipment will be repaired **Question 5** - lack of involvement all employee - lack of knowledge - no enforcement **Question 6** Null

Table 5.18 TVET expert no. 8 answer for the first round

Respondent Background.	**Question 2.**
Name: Ismail Bin Yunus Age: 33 Gender: Male Company/TVET: KKTM Balik Pulau Position: Asst Vocational Training Officer Working Experience: 10 years Designation: TVET Education Education: Diploma in Mechanical Eng.	Yes, in the HQ **Question 3** Preventive Maintenance & Corrective Maintenance (outsource) **Question 4** No, machine breakdown frequently **Question 5** - No continue improvement - Lack of knowledge and training - No enforcement **Question 6** Null

Table 5.19 TVET expert no. 9 answer for the first round

Respondent Background. Name: Humaizee Bin Misman Age: 42 Gender: Male Company/TVET: IKM Kuala Lumpur Position: Asst Vocational Training Officer Working Experience: 19 years Designation: TVET Education Education: Diploma in Mechatronics Eng	**Question 2.** Yes, in the HQ **Question 3** Preventive Maintenance (depends on technician and lecturers) & Corrective Maintenance (outsource) **Question 4** 50-50, machine breakdown frequently and disrupt learning process **Question 5** - No continue improvement - Lack of training - No enforcement - No support tools like heavy industrial vacuum **Question 6** Null

Respondent Background. Name: Mohd Fadzil Bin Mohd Said Age: 44 Gender: Male Company/TVET: IKM Johor Bahru Position: Asst Vocational Training Officer Working Experience: 18 years Designation: TVET Education Education: Diploma in Mechanical Eng.	**Question 2.** Yes, in the HQ **Question 3** Preventive Maintenance (depends on technician and lecturers) & Corrective Maintenance (outsource) **Question 4** 50-50, still machine breakdown frequently **Question 5** - No continue improvement - Serviced provided by supplier not quality - No enforcement - Not integrate into strategic plan - Lack of recognition **Question 6** Null

ROUND 1 RESEARCH OBJECTIVE 2

This survey for a group of TVET experts. You are required to answer all the questions below. There is no right or wrong in the answer given. The answers provided should be clear and precise.

1) Respondent Background

Name: Syahril Izwan bin Abdul Yamin Age: 38

Gender: Male Company/ Institution: Politeknik TSB, Kulim

Position: Lecturer Working Experience: 12 years

Field of Expertise: TVET Education Education: Degree in Electrical Eng

2) Explain briefly the definition of maintenance strategy as below:

- Corrective Maintenance
  - **Repair when the parts damage**
  - **Change the failure parts**

- Preventive Maintenance
  - **Follow the schedule**
  - **to prevent the machine from getting worse**

- Total Productive maintenance
  - **Apply the autonomous maintenance**
  - **Have eight pillars**

3) What are the criteria that might influence the maintenance strategies (as above) for the equipment in TVET institution?
Duration, Price, Supplier, Safety

ROUND 2 RESEARCH OBJECTIVE 2

You are required to choose the criteria that might influence the maintenance strategies, which are important within the TVET institution. Please tick (√) in the space provided.

No.	Criteria	Please tick (√)
1	**Safety**	√
2	**Cost**	√
3	**Added Value**	
4	**Supplier**	√
5	**Type of Machine**	
6	**Time**	√
7	**Technology**	

ROUND 3 RESEARCH OBJECTIVE 2

1) Explain briefly the advantages and disadvantages of the criteria regarding to the maintenance strategies in TVET institution below:

Criteria	CM		PM		TPM	
	Advantages	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Safety	The risk lies on the supplier	Might be high risk because of the failure greater than PM	The risk lies the supplier	Still have the because of poor quality job done by supplier	The risk of poor-quality job determined by technician and lecturers	The risk lies on the TVET institute but minimum scale
Cost	**Advantages** No regular charge as PM	**Disadvantages** High Charge	**Advantages** Low Charge	**Disadvantages** Sometime the activities can manage by TVET	**Advantages** No Charge because done by TVET	**Disadvantages** Needs more budget to train the staff
Time	**Advantages** No schedule to stop the machine operation	**Disadvantages** Need a long time to repair	**Advantages** The time is short	**Disadvantages** Short but depend on the supplier and budget some time they not follow the schedule.	**Advantages** Can do anytime and arrange the maintenance time table at the appropriate time	**Disadvantages** Must have the enforcement to do these activities
Added Value	**Advantages** The machine is used until failure occur. Sometime good because the not frequent stop for the maintenance	**Disadvantages** Sometime the machine getting worse because no PM	**Advantages** Do the maintenance weekly or monthly	**Disadvantages** The PM schedule still Depends on budget	**Advantages** The quality of job controlled by TVET	**Disadvantages** Must have a proper program to do these activities

ROUND 4 RESEARCH OBJECTIVE 2

You are required to write Agree or disagree corresponding to the statement given in table below.

Corrective Maintenance

Criteria	No.	Statements	Agree / Disagree
Safety	S1	The risk lies on the supplier but might be high risk because of the failure greater than PM and the supplier ignore the safety	Agree
Cost	C1	Repair costs are probably less than the expense of preventive maintenance where investment is needed for prevention of breakdowns and problems, no regular charge but once the machine get failure the charge will be higher from supplier	Agree
	C2	Very little to do after purchasing of a resource and before a problem	Disagree
	C3	Expensive but satisfy match with the work	Disagree
Time	T1	No schedule, specific time to stop machine operation for repair but need a long time to repair and disturb the availability of machine	Agree
	T2	Spend more time if not apply the PM but the downtime machine will increase because the failure	Agree
Added Value	A1	Sometime can reduce the cost if the TVET focus on CM strategy but increased long-term costs	Agree
	A2	The machine is used until failure occur. Sometime good because the not frequent stop for the maintenance but sometime the machine getting worse because no PM	Agree
	A3	Consists of very targeted action on specific components but leading to more failures in components that are highly unpredictable	Agree

ROUND 4 RESEARCH OBJECTIVE 2

You are required to write Agree or disagree corresponding to the statement given in table below.

Preventive Maintenance

Criteria	No.	Statements	Agree / Disagree
Safety	S1	The risk lies the supplier but still have the risk because of poor quality job done by supplier	Agree
Cost	C1	Overall, very cost effective but sometime become loss to do preventive maintenance for machine in good condition and can be done by TVET staff	Agree
	C2	Cheap and satisfy with the work done by supplier	Agree
	C3	More efficiently and smoothly their equipment performs, the more profit they can make but risk of damage and increase cost when conducting unneeded maintenance done by supplier	Agree
Time	T1	The duration is short but depend on the supplier and budget, sometime they did not follow the schedule.	Agree
	T2	Enhances the performance of assets by increasing uptime but teaching and learning process disrupt	Agree
Added Value	A1	Do the maintenance weekly or monthly but the PM schedule still depends on budget	Disagree
	A2	Equipment downtime is decreased but still depends on the quality of job done supplier	Agree

ROUND 4 RESEARCH OBJECTIVE 2

You are required to write Agree or disagree corresponding to the statement given in table below.

Total Productive Maintenance

Criteria	No.	Statements	Agree / Disagree
Safety	S1	The risk of poor-quality job determined by technician and lecturers but the risk lies on the TVET institute but minimum scale	Agree
	S2	TVET can improve safety environment and evaluate the safety aspects but difficult to implement but lack of knowledge and manpower	Disagree
Cost	C1	No Charge because done by TVET but needs more budget to train the staff	Agree
	C2	Can reduce the maintenance cost TVET for the long term but need an investment for start up the program	Agree
	C3	Minimize waste but lack of knowledge	Disagree
Time	T1	Can do anytime and arrange the maintenance time table at the appropriate time and must have the enforcement to do these activities	Agree
	T2	The maintenance schedule controlled by TVET but need the framework of maintenance strategy	Agree
	T3	Manage in student time table but difficult to obey if no enforcement	Agree
Added Value	A1	The quality of job controlled by TVET but must have a proper program to do these activities	Agree
	A2	Increase skill and knowledge for staff and student but the quality is questionable if the job done by TVET	Disagree

AHP Criteria and Maintenance Strategy Ranking Proses

Importance scale	Defination of impotance scale
1	Equally Important Preferred
2	Equally to Moderately Important Preferred
3	Moderately Important Preferred
4	Moderately to Strongly Important Preferred
5	Strongly Important Preferred
6	Strongly to Very Strongly Important Preferred
7	Very Strongly Important Preferred
8	Very Strongly to Extremely Important Preferred
9	Extremely Important Preferred

Cost Added

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Value

Cost Time

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Cost Safety

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Time Added Value

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Time Safety

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Safety Added value

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Added Value

PM CM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

TPM CM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

TPM PM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Cost

PM CM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

TPM CM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

TPM PM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Time

PM CM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

TPM CM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

TPM PM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Safety

PM CM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

TPM CM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

TPM PM

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Table 5.20 TVET expert no. 1 answer for the first round

Respondent Background.	**Question 2.**
Name: Syahril Izwan Bin Abdul Yamin Age: 38 Gender: Male Company/TVET: Politeknik TSB, Kulim Position: Lecturer Working Experience: 12 years Designation: TVET Education Education: Bachelor in Electrical Eng	**Corrective Maintenance** Repair when the parts damage Change the failure parts **Preventive Maintenance** Follow the schedule To prevent the machine from getting worse **Total Productive maintenance** Apply the autonomous maintenance Have eight pillars **Question 3.** Duration, Price, Supplier,

Table 5.21 TVET expert no. 2 answer for the first round

Respondent Background.	**Question 2.**
Name: Mohamed Nazeeb Bin Mohammed Naina Marican Age: 40 Gender: Male Company/TVET: IKBN, Sepang Position: Lecturer Working Experience: 14 years Designation: TVET Education Education: Diploma in Tool & Die Tech	**Corrective Maintenance** Rectify a fault so that the failed equipment **Preventive Maintenance** Regularly performed on the machine **Total Productive maintenance** A holistic approach to equipment maintenance that strives to achieve perfect production **Question 3** Duration, Added Value, Cost, Type of Machine

Table 5.22 TVET expert no. 3 answer for the first round

Respondent Background.	**Question 2.**
Name: Noorismaliana Binti Ismail Age: 39 Gender: Female Company/TVET: CIAST Position: Lecturer Working Experience: 10 years Designation: TVET Education Education: Diploma in Mechanical Eng.	**Corrective Maintenance** The maintenance that is required when an item has failed or worn out, to bring it back to working order **Preventive Maintenance** Comprises the care and servicing of machines **Total Productive Maintenance** Increase production while, at the same time, increasing employee morale and job satisfaction. **Question 3.** Safety, Cost, Time, Added Value

Table 5.23 TVET expert no. 4 answer for the first round

Respondent Background.	**Question 2.**
Name: Ir. Asymal Wajdi Bin Mohd Akhir@Mokhtar Age: 40 Gender: Male Company/TVET: MARA Position: Vocational Training Officer Working Experience: 14 years Designation: TVET Education Education: SKM Level 4 Bachelor in Electrical Eng Master in Electrical Eng Professional Engineer	**Corrective Maintenance** Carried out after failure detection and is aimed at restoring an asset to a condition in which it can perform its intended function **Preventive Maintenance** The purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects. **Total Productive Maintenance** A lean manufacturing philosophy that centers on achieving near-perfect production. The aims of TPM are high: no breakdowns, no small stops or slow running, no defects, and no accidents. **Question 3** Added Value, Time, Machine, Cost

Table 5.24 TVET expert no. 5 answer for the first round

Respondent Background.	**Question 2.**
Name: Mustafa Amin Bin Khairuddin Age: 39 Gender: Male Company/TVET: UNIKL MFI Position: Technical Officer Working Experience: 15 years Designation: TVET Education Education: SKM Level 3 Bachelor in Tech. Management	Corrective Maintenance the technical activity carried out after a failure has occurred **Preventive Maintenance** improve equipment life and avoid any unplanned maintenance activity **Total Productive Maintenance** Operators are the owners of the machines to take responsibility for the day-to-day maintenance of their machines **Question 3** Safety, Cost, Time

Table 5.25 TVET expert no. 6 answer for the first round

Respondent Background.	**Question 2.**
Name: Khairol Nizam Bin Azmi Age: 41 Gender: Male Company/TVET: ILP Ipoh Position: Asst.Vocational Training Officer Working Experience: 17 years Designation: TVET Education Education: Diploma in Fabrication Tech.	**Corrective Maintenance** To correct the defects of equipment **Preventive Maintenance** Regularly scheduled inspections, tests, servicing, repairs, replacements **Total Productive Maintenance** Self-directed maintenance, wherein machine operators are responsible for the routine maintenance and operations of their machines **Question 3** Added Value When Use the Maintenance Strategy, Cost, Duration

Table 5.26 TVET expert no. 7 answer for the first round

Respondent Background. Name: Affendi Bin Ahmad Dahalan Age: 47 Gender: Male Company/TVET: Vocational College Position: Lecturer Working Experience: 26 years Designation: TVET Education Education: Bachelor in Mechanical Eng.	**Question 2.** **Corrective Maintenance** Implemented right after a defect has been detected **Preventive Maintenance** To maintain a level of certain service on equipment **Total Productive Maintenance** An approach to equipment maintenance that aims to achieve a perfect production process **Question 3** Safety, Machine, Cost, Machine Technology

Table 5.27 TVET expert no. 8 answer for the first round

Respondent Background. Name: Ismail Bin Yunus Age: 33 Gender: Male Company/TVET: KKTM Balik Pulau Position: Asst Vocational Training Officer Working Experience: 10 years Designation: TVET Education Education: Diploma in Mechanical Eng.	**Question 2.** **Corrective Maintenance** Done after problem **Preventive Maintenance** Done before problem **Total Productive Maintenance** Autonomous Maintenance **Question 3.** Safety, Cost, Time, Added Value, Technology

Table 5.28 TVET expert no. 9 answer for the first round

Respondent Background.	**Question 2.**
Name: Humaizee Bin Misman Age: 42 Gender: Male Company/TVET: IKM Kuala Lumpur Position: Asst Vocational Training Officer Working Experience: 19 years Designation: TVET Education Education: Diploma in Mechatronics Eng	**Corrective Maintenance** Corrective will maximize the preventive actions. **Preventive Maintenance** Preventive maintenance will minimize the need of corrective **Total Productive Maintenance** Process of using machines, equipment, employees and supporting processes to maintain and improve the integrity of production and the quality of systems. **Question 3.** Equipment, Safety, Added Value After Apply the Strategy, Price

Table 4.35 TVET expert no. 10 answer for the first round

Respondent Background.	**Question 2.**
Name: Mohd Fadzil Bin Mohd Said Age: 44 Gender: Male Company/TVET: IKM Johor Bahru Position: Asst Vocational Training Officer Working Experience: 18 years Designation: TVET Education Education: Diploma in Mechanical Eng.	**Corrective Maintenance** Maintenance actions carried out to restore a defective item **Preventive Maintenance** Schedule of planned maintenance actions **Total Productive Maintenance** A method to maximize the overall equipment effectiveness **Question 3.** Assets Will Be Maintain, Maintenance Cost, Duration Maintenance Activities

Table 5.29 Expert no.1 answer in the third round

Criteria	CM		PM		TPM	
Safety	**Advantages** The risk lies on the supplier	**Disadvantages** Might be high risk because of the failure greater than PM	**Advantages** The risk lies the supplier	**Disadvantages** Still have the because of poor quality job done by supplier	**Advantages** The risk of poor-quality job determined by technician and lecturers	**Disadvantages** The risk lies on the TVET institute but minimum scale
Cost	**Advantages** No regular charge as PM	**Disadvantages** High Charge	**Advantages** Low Charge	**Disadvantages** Sometime the activities can manage by TVET	**Advantages** No Charge because done by TVET	**Disadvantages** Needs more budget to train the staff
Time	**Advantages** No schedule to stop the machine operation	**Disadvantages** Need a long time to repair	**Advantages** The time is short	**Disadvantages** Short but depend on the supplier and budget some time they not follow the schedule.	**Advantages** Can do anytime and arrange the maintenance time table at the appropriate time	**Disadvantages** Must have the enforcement to do this activity
Added Value	**Advantages** The machine is used until failure occur. Sometime good because the not frequent stop for the maintenance	**Disadvantages** Sometime the machine getting worse because no PM	**Advantages** Do the maintenance weekly or monthly	**Disadvantages** The PM schedule still depends on budget	**Advantages** The quality of job controlled by TVET	**Disadvantages** Must have a proper program to do this activity

Table 5.30 Expert no.2 answer in the third round

Criteria	CM		PM		TPM	
	Advantages	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Safety	TVET does not have to be thought of as the risk lies with the supplier	Still have the risk if the supplier ignore safety	TVET does not have to be thought of as the risk lies with the supplier	Still have the risk if the supplier ignore safety	TVET can evaluate the risk and solve it	Difficult to implement and the risk lies on the TVET institute but minimum scale
Cost	**Advantages** Expensive but satisfy match with the work	**Disadvantages** Expensive	**Advantages** Cheap and satisfy with the work	**Disadvantages** None	**Advantages** Can reduce the maintenance cost	**Disadvantages** TVET have to spend more for at the beginning
Time	**Advantages** Do not have specific time to repair the machine	**Disadvantages** Disturb the availability of machine	**Advantages** Not too long	**Disadvantage** Disturbing student timetable	**Advantages** The maintenance schedule controlled by TVET	**Disadvantages** Need the framework of maintenance strategy
Added Value	**Advantages** Sometime can reduce the cost if the TVET focus on CM strategy	**Disadvantages** Increased long-term costs	**Advantages** Equipment downtime is decreased	**Disadvantages** But still depends on the quality of job done supplier	**Advantages** Increase skill and knowledge for staff and student	**Disadvantages** The quality is questionable if the job done by TVET

Table 5.31 Expert no.3 answer in the third round

Criteria	CM		PM		TPM	
Safety	**Advantages** All the risk lies on the supplier	**Disadvantages** A few jobs have done not follow the procedure	**Advantages** All the risk lies on the supplier	**Disadvantages** A few jobs have done not follow the procedure	**Advantages** Improve safety environment.	**Disadvantages** Difficult to implement and the risk lies on the TVET institute but minimum scale
Cost	**Advantages** Less than the investment required for planned maintenance	**Disadvantages** The cost higher when the machine breakdowns	**Advantages** overall, very cost effective	**Disadvantages** Sometime become loss to do preventive maintenance for machine in good condition	**Advantages** Minimize waste	**Disadvantages** Lack of knowledge
Time	**Advantages** Good availability of machine	**Disadvantages** Need more time when do the activities	**Advantages** Enhances the performance of assets by increasing uptime	**Disadvantage** Teaching and learning process disrupt	**Advantages** Manage in student time table	**Disadvantages** Difficult to obey if no enforcement
Added Value	**Advantages** Consists of very targeted action on specific components	**Disadvantages** Leading to more failures that are highly unpredictable	**Advantages** Fewer interruptions to critical operations	**Disadvantages** But still depends on the quality of job done supplier	**Advantages** Getting TVET involved in maintaining their own equipment	**Disadvantages** The quality is questionable if the job done by TVET

Table 5.32 Expert no.4 answer in the third round

Criteria	CM		PM		TPM	
Safety	**Advantages** The risk depends on the failure and the supplier	**Disadvantages** **If** the supplier ignore safety Effect the TVET students and staff	**Advantages** The risk depends on the failure and the supplier	**Disadvantages** If the supplier ignore safety Effect the TVET students and staff	**Advantages** Increase the quality of safety	**Disadvantages** Difficult to implement
Cost	**Advantages** Very little to do after purchasing of a resource and before a problem actually occurs	**Disadvantages** It will expensive for long term	**Advantages** Cheaper than CM	**Disadvantages** keeping equipment regularly maintained requires a bit of an investment	**Advantages** Can reduce the maintenance cost for the long term	**Disadvantages** Need an investment for start up the program
Time	**Advantages** Spend more time if not apply the PM	**Disadvantages** unplanned equipment downtime	**Advantages** Less equipment downtime	**Disadvantage** Disturbing student timetable	**Advantages** The maintenance schedule controlled by TVET	**Disadvantages** Difficult to implement
Added Value	**Advantages** Consists of very targeted action on specific components	**Disadvantages** Leading to more failures that are highly unpredictable	**Advantages** Fewer interruptions to critical operations	**Disadvantages** But still depends on the quality of job done supplier	**Advantages** Getting TVET involved in maintaining their own equipment	**Disadvantages** The quality is questionable if the job done by TVET

Table 5.33 Expert no.5 answer in the third round

Criteria	CM		PM		TPM	
	Advantages	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Safety	The risk liability under supplier	maintenance may be rushed, leading to a higher risk of unsafe or improper work	The risk liability under supplier	If the supplier ignore safety Effect the TVET students and staff	TVET can evaluate the safety aspects	Lack of knowledge and manpower
Cost	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
	Repair costs are less than the expense of preventive maintenance where investment is needed for prevention of breakdowns and problems	Higher long-term costs	More efficiently and smoothly their equipment performs, the more profit they can make.	Risk of damage and increase cost when conducting unneeded maintenance	Increase the OEE and at same time reduce the cost	Need another budget for training and education
Time	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantage**	**Advantages**	**Disadvantages**
	The machine is used until failure occur so the machine availability is good	Maintenance work is put on hold until the problem is resolved.	can decrease and optimize that downtime	Disturbing student timetable	TVET can manage the schedule	Difficult to implement
Added Value	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
	Sometime good because the not frequent stop for the maintenance	Leading to more failures that are highly unpredictable	Help equipment to run much more efficiently	But still depends on the quality of job done supplier	Apply the Autonomous Maintenance	The quality is questionable if the job done by TVET

AHP application using Microsoft Excel for normalized score

Safety	CM	PM	TPM		
CM	1	0.5	0.3333		
PM	2	1	0.5		
TPM	3	2	1		
COL.TOTAL	6	3.5	1.8333		
NORMALIZED SCORE TABLE					
CM	0.166666667	0.142857	0.181803	0.163776	16.4
PM	0.333333333	0.285714	0.272732	0.29726	29.7
TPM	0.5	0.571429	0.545464	0.58964	53.9
COL.TOTAL	1	1	1	1	

Based on the evaluations of previous step, build the pairwise comparison matrix according to the following rule:

$a_{ij} > 0,\ a_{ji} = \frac{1}{a_{ij}}, a_{ii} = 1$

$\lambda \max = \frac{\sum ajwj - n}{wl}$

Consistency Index (CI) = $\frac{\lambda \max - n}{n-1}$

Consistency Ratio (CR) = $\frac{Consistency\ Index\ (CI)}{Random\ Index\ (RI)}$

Table 5.34 Calculation of λ max for Added Value

Weightage sum value	Weightage criteria	Ratio= WSV/WC
0.2565	0.0853	3.0070
0.6444	0.2132	3.0225
2.1513	0.7014	3.0671

$$\lambda max = \frac{3.0070 + 3.0225 + 3.0671}{3}$$

$$\lambda max = 3.0322$$

After getting the max λ value, the next step is to find the value in the Consistency Index (CI) as shown in the calculation.

Calculation of Consistency Index and Consistency Ratio

$$\text{Consistency Index (CI)} = \frac{\lambda max - n}{n-1}$$

$$= \frac{3.0322 - 3}{3 - 1}$$

$$= 0.0161$$

$$\text{Consistency Ratio (CR)} = \frac{Consistency\ Index\ (CI)}{Random\ Index\ (RI)}$$

$$= \frac{0.0161}{0.58}$$

$$= 0.027 < 0.10$$

Table 5.35 Calculation of λ max for Cost

Weightage sum value	Weightage criteria	Ratio= WSV/WC
0.3287	0.1095	3.0018
0.9282	0.3091	3.0029
1.7469	0.5812	3.0056

$$\lambda\, max = \frac{3.0018 + 3.0029 + 3.0056}{3}$$

$$\lambda\, max = 3.0034$$

After getting the max λ value, the next step is to find the value in the Consistency Index (CI) as shown in the calculation.

Calculation of Consistency Index and Consistency Ratio

$$\text{Consistency Index (CI)} = \frac{\lambda\, max - n}{n-1}$$

$$= \frac{3.0034 - 3}{3 - 1}$$

$$= 0.0034$$

$$\text{Consistency Ratio (CR)} = \frac{Consistency\ Index\ (CI)}{Random\ Index\ (RI)}$$

$$= \frac{0.0034}{0.58}$$

$$= 0.0058 < 0.10$$

Table 5.36 Calculation of λ max for time

Weightage sum value	Weightage criteria	Ratio= WSV/WC
0.3629	0.1210	2.9991
0.8335	0.2664	3.1287
1.8956	0.6124	3.0953

$$\lambda\, max = \frac{2.9991 + 3.1287 + 3.0953}{3}$$

$$\lambda\, max = 3.0034$$

After getting the max λ value, the next step is to find the value in the Consistency Index (CI) as shown in the calculation.

Calculation of Consistency Index and Consistency Ratio

$$\text{Consistency Index (CI)} = \frac{\lambda\, max - n}{n-1}$$

$$= \frac{3.0743 - 3}{3 - 1}$$

$$= 0.0037$$

$$\text{Consistency Ratio (CR)} = \frac{Consistency\ Index\ (CI)}{Random\ Index\ (RI)}$$

$$= \frac{0.0034}{0.58}$$

$$= 0.0063 \lessdot 0.10$$

Table 5.37 Calculation of λ max for safety

Weightage sum value	Weightage criteria	Ratio= WSV/WC
0.4919	0.1637	3.0048
0.894	0.2972	3.008
1.6244	0.5389	3.0142

$$\lambda\, max = \frac{3.0048 + 3.008 + 3.0142}{3}$$

$$\lambda\, max = 3.009$$

After getting the max λ value, the next step is to find the value in the Consistency Index (CI) as shown in the calculation.

Calculation of Consistency Index and Consistency Ratio

Consistency Index (CI) $= \frac{\lambda\, max - n}{n-1}$

$= \frac{3.009 - 3}{3 - 1}$

$= 0.009$

Consistency Ratio (CR) $= \frac{Consistency\ Index\ (CI)}{Random\ Index\ (RI)}$

$= \frac{0.009}{0.58}$

$= 0.0155 < 0.10$

$$\begin{bmatrix} 0.0853 & 0.1095 & 0.1210 & 0.1637 \\ 0.2132 & 0.3091 & 0.2664 & 0.2989 \\ 0.7014 & 0.5812 & 0.6124 & 0.5423 \end{bmatrix} \begin{bmatrix} 0.0516 \\ 0.5050 \\ 0.2748 \\ 0.1685 \end{bmatrix}$$

Figure 5.1 The matrix multiplied by the weight vector

CM Score $= (0.0853\ x\ 0.0516)\ +\ (0.1095\ x\ 0.5050)\ +\ (0.1210\ x\ 0.2748)\ +\ (0.1637\ x\ 0.1685)$

$PM\ Score = (0.2132\ x\ 0.0516)\ +\ (0.3091\ x\ 0.5050)\ +\ (0.2664\ x\ 0.2748)\ +\ (0.2989\ x\ 0.1685)$

$TPM\ Score = (0.7014\ x\ 0.0516)\ +\ (0.5812\ x\ 0.5050)\ +\ (0.6124\ x\ 0.2748)\ +\ (0.5423\ x\ 0.1685)$

$$0.1199 = 0.0040\ +\ 0.0552\ +\ 0.0332\ +\ 0.0275$$

$$0.2905 = 0.011\ +\ 0.156\ +\ 0.0732\ +\ 0.0503$$

$$0.5566 = 0.00361\ +\ 0.2935\ +\ 0.1682\ +\ 0.0913$$

Appendix D – ISM Application

MINIT MESYUARAT JAWATANKUASA
PROGRAM PEMBANGUNAN RANGKA KERJA *TOTAL PRODUCTIVE MAINTENANCE* DI INSTITUTSI TVET MARA
BIL. 1/2020

Tarikh : 4 Februari 2020

Masa : 9.00 pagi hingga 5.00 petang

Tempat : Bilik Kaizen 3, Tingkat 20, BKT, Ibu Pejabat MARA

SENARAI KEHADIRAN

1. **Ir. Asymal Wajdi B. Muhd Akhir@Mokhtar - PENGERUSI**
   Bahagian Kemahiran dan Teknikal , MARA
2. **Saifolnizam Bin Hashim**
   KKTM Kuantan
3. **Humaizee Bin Misman**
   IKM Kuala Lumpur
4. **Mohammad Nizam Bin Arffin**
   Inokom Corporation Sdn Bhd
5. **Mohd Syadzry Bin Ramli**
   Sony EMCS
6. **Muhammad Shahir Bin Mohd Noor**
   Toa Paint Products Sdn Bhd
7. **Mohammad Ashran Bin Ghazali**
   AVP Engineering Sdn Bhd
8. **Ismail Bin Yunus**
   KKTM Balik Pulau
9. **Mohd Fadzil Bin Mohd Said**
   IKM Johor Bahru
10. **Razni Bin Khalid**
    Bahagian Kemahiran dan Teknikal, MARA – **URUS SETIA**

MAJLIS AMANAH RAKYAT (MARA)
Ibu Pejabat MARA
21, Jalan MARA
50609 KUALA LUMPUR
MALAYSIA

Tel: 603-2613 2000
Faks: 603-2691 3620
Laman Web: www.mara.gov.my

Ruj. Tuan :
Bil MARA :
Ruj. Kami : BKT: 1/142 Jilid 6 ( )
Tarikh : 15 JAN 2020

Mohammad Nizam Bin Arffin
Inokom Corporation Sdn Bhd
Lot 38, Mukim Padang Meha
Padang Serai, Kulim
09400 Kedah Darul Aman
Malaysia

Tuan/Puan,

PERLANTIKAN SEBAGAI AHLI PANEL PEMBANGUNAN RANGKA KERJA *TOTAL PRODUCTIVE MAINTENANCE* DI INSTITUTSI TVET MARA

Dengan segala hormatnya perkara di atas adalah dirujuk.

2. Bahagian Kemahiran Dan Teknikal MARA menganjurkan sesi pembangunan rangka kerja Total Productive Maintenance di institutsi TVET MARA pada ketetapan berikut:

Tarikh : 4 Februari 2020
Tempat : Bilik Kaizen 3, Tingkat 20, Bahagian Kemahiran dan Teknikal, Ibu Pejabat MARA
Masa : 9.00 pagi hingga 5.00 petang

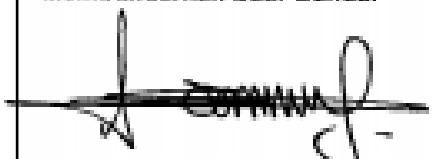
3. Sehubungan itu, pihak MARA bersetuju untuk melantik tuan sebagai salah seorang ahli panel pembangunan rangka kerja TPM di institutsi TVET MARA.

Pemilihan pihak tuan sebagai ahli panel adalah berdasarkan latar belakang dan kepakaran yang dimiliki oleh pihak tuan berkaitan dengan perlaksanaan TPM di industry.

4. Diharap pembabitan pihak tuan sebagai ahli panel pembangunan rangka kerja TPM memberi impak positif di dalam perlaksanaan TPM di institutsi TVET MARA. Segala kerjasama dan perhatian pihak tuan/puan amat diharapkan.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
"Membandarkan Luar Bandar"



AHMAD MARZUKI BIN MAHAT
Timbalan Pengarah II
b.p.: Pengarah
Bahagian Kemahiran dan Teknikal
MARA

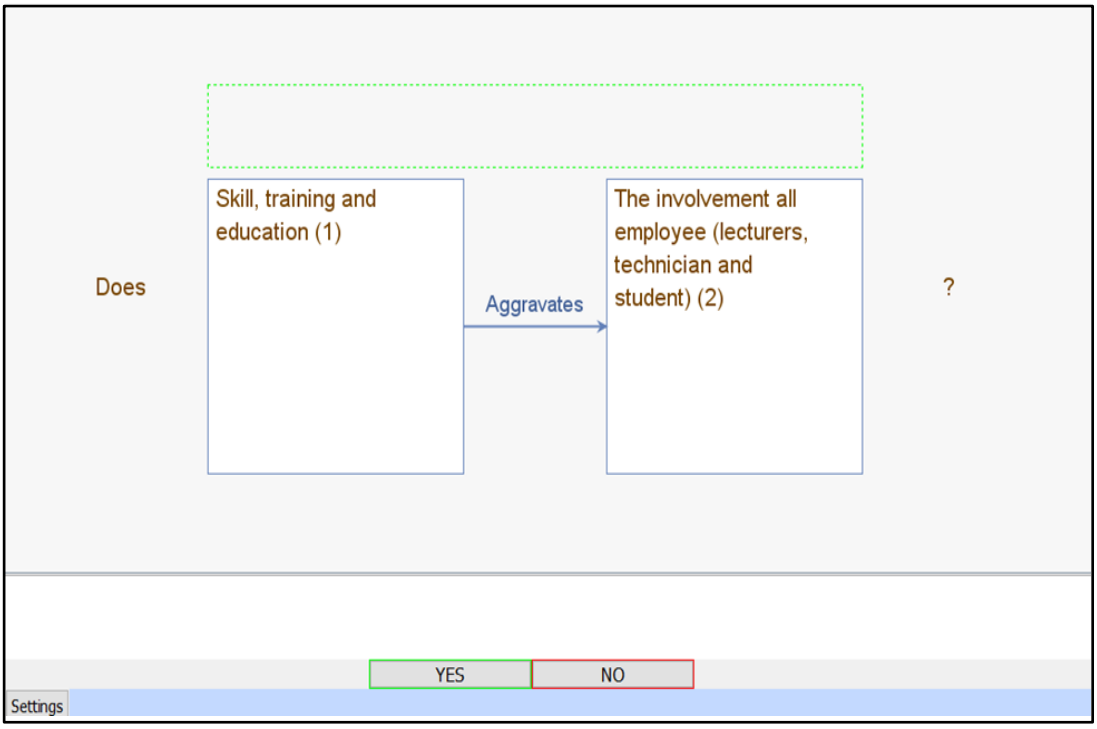


Figure 4.10 The element 2 aggravates the element 1

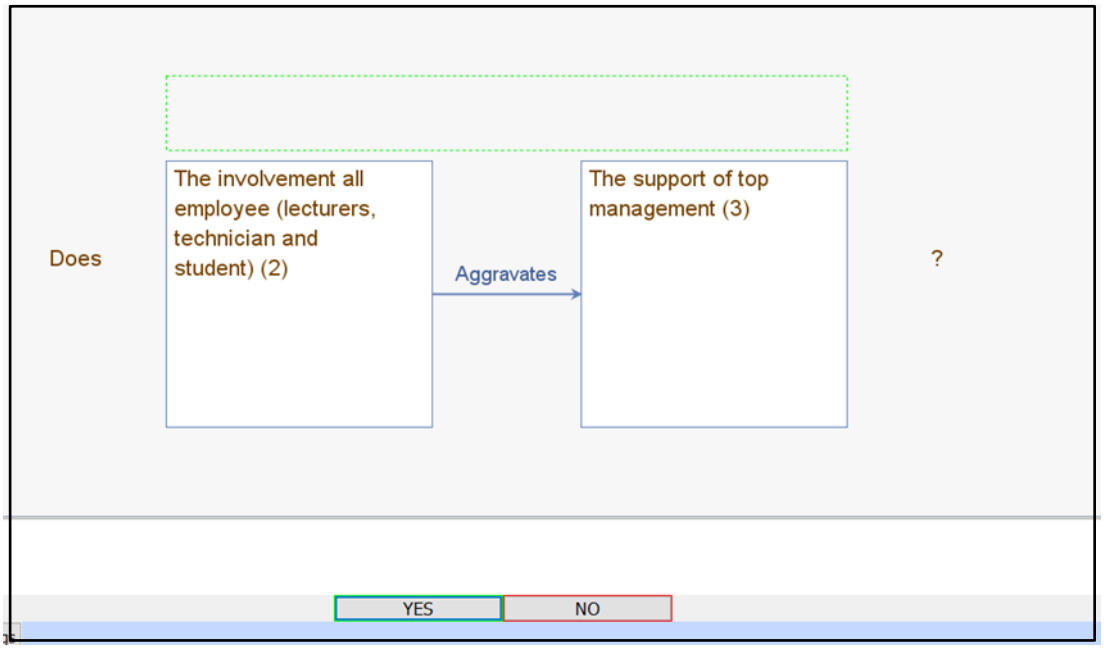


Figure 4.11 The element 2 aggravates the element 3

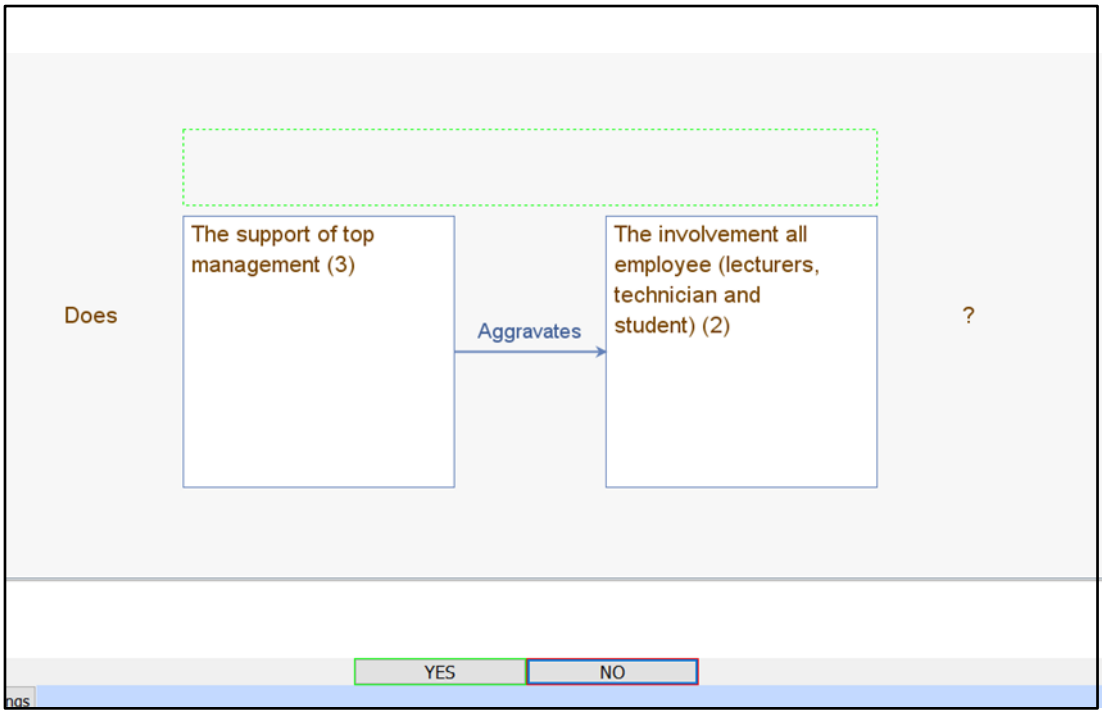


Figure 4.12 The element 3 aggravates the element 2

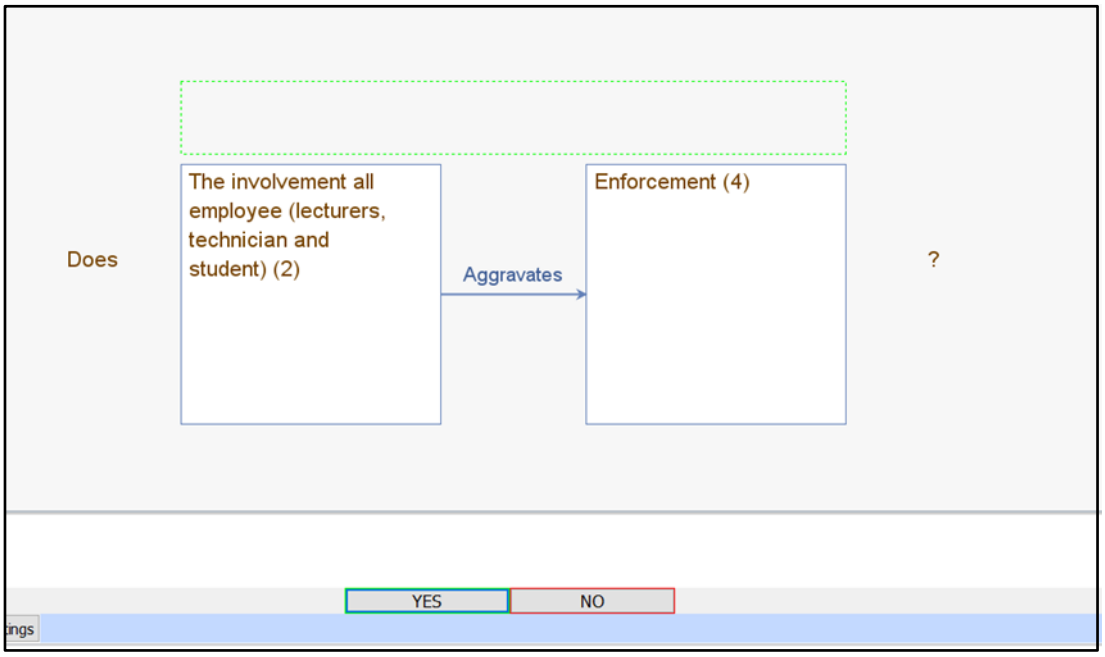


Figure 4.13 The element 2 aggravates the element 4

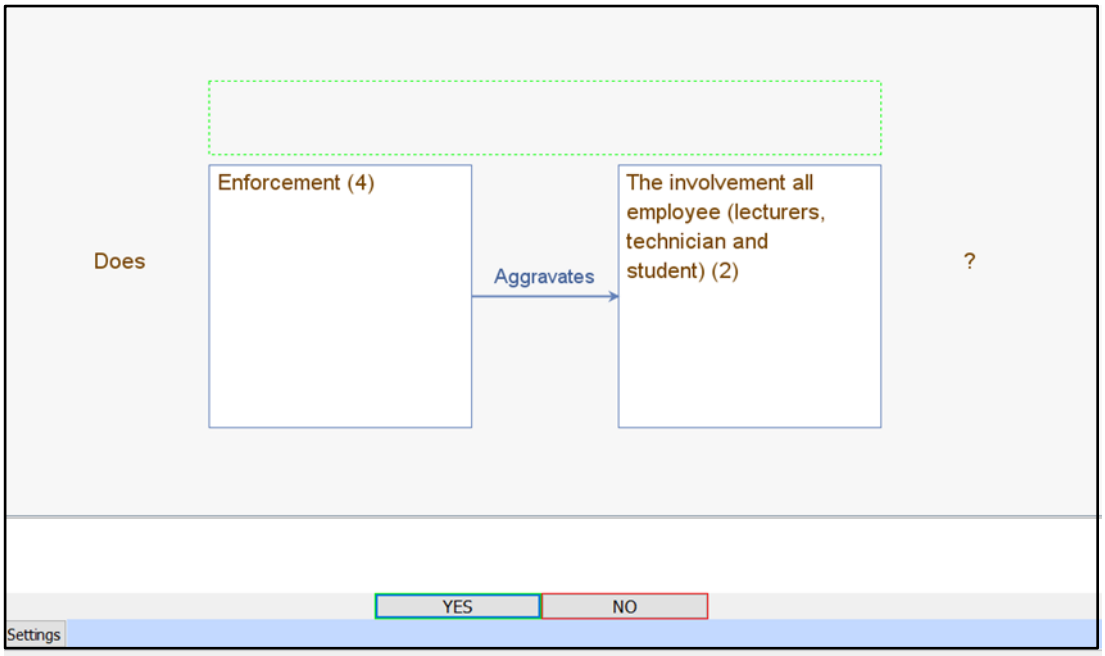


Figure 4.14 The element 4 aggravates the element 2

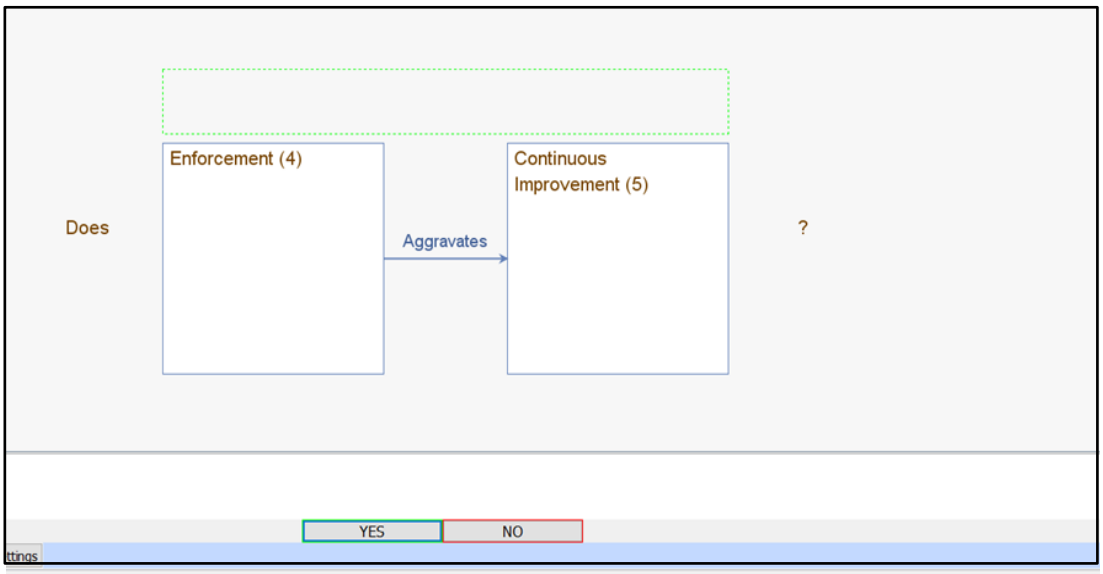


Figure 4.15 The element 4 aggravates the element 5

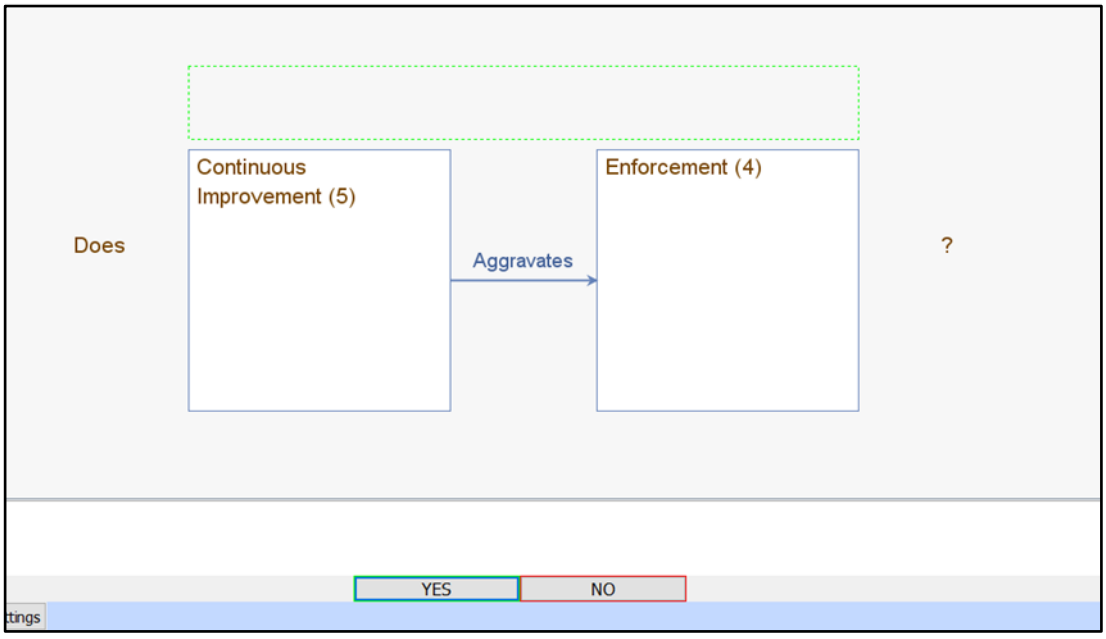


Figure 4.16 The element 5 aggravates the element 4

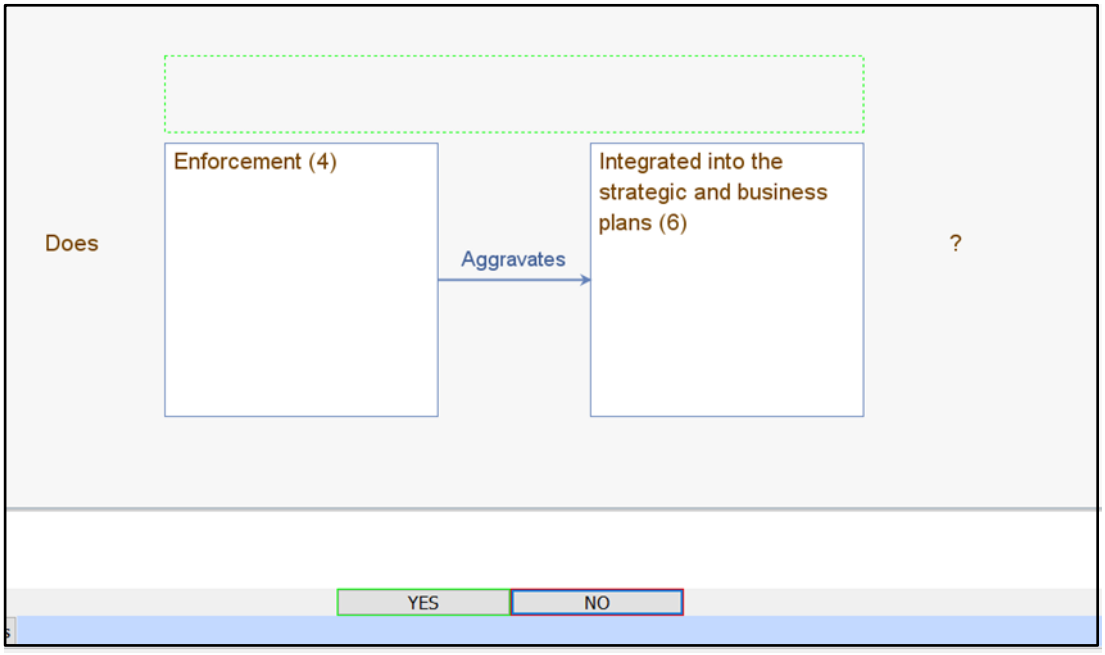


Figure 4.17 The element 4 aggravates the element 6

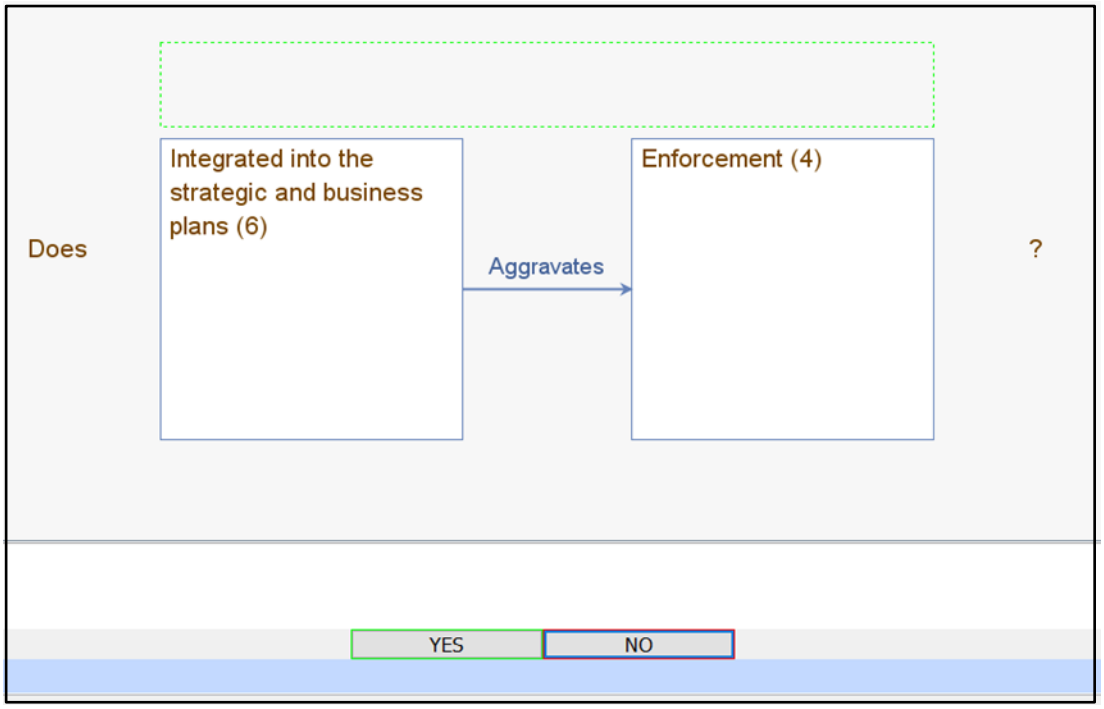


Figure 4.18 The element 6 aggravates the element 4

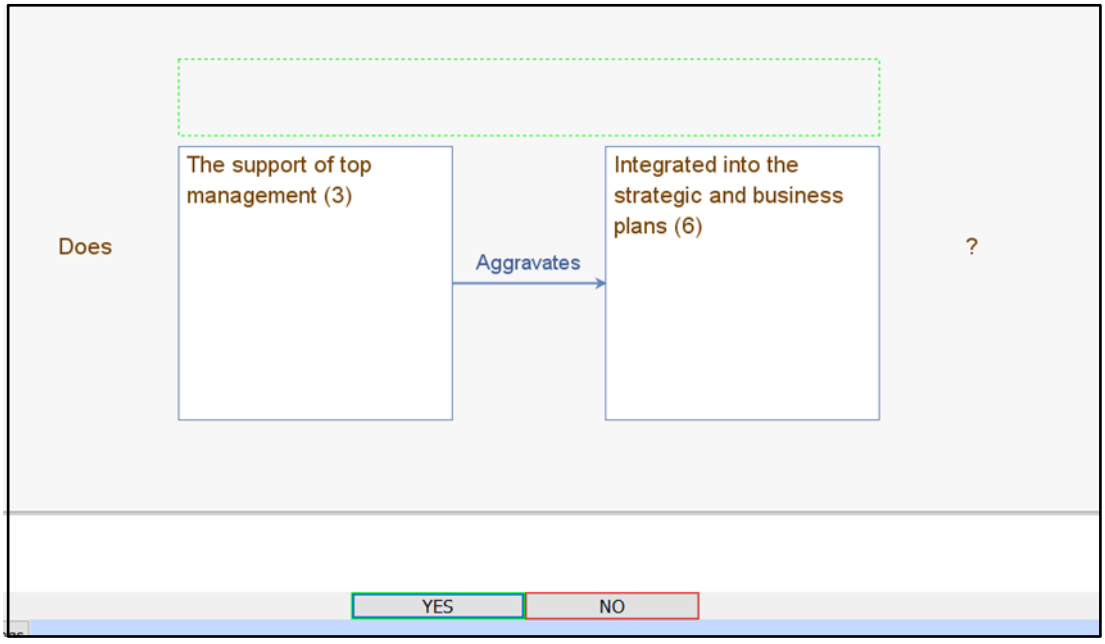


Figure 4.19 The element 3 aggravates the element 6

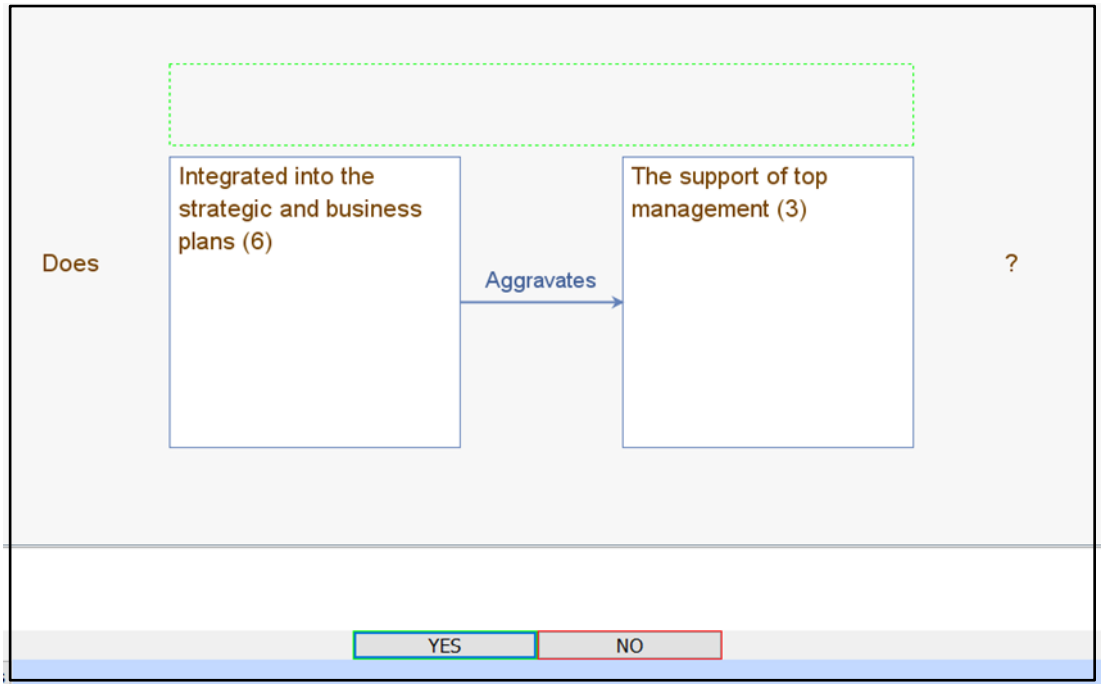


Figure 4.20 The element 6 aggravates the element 3

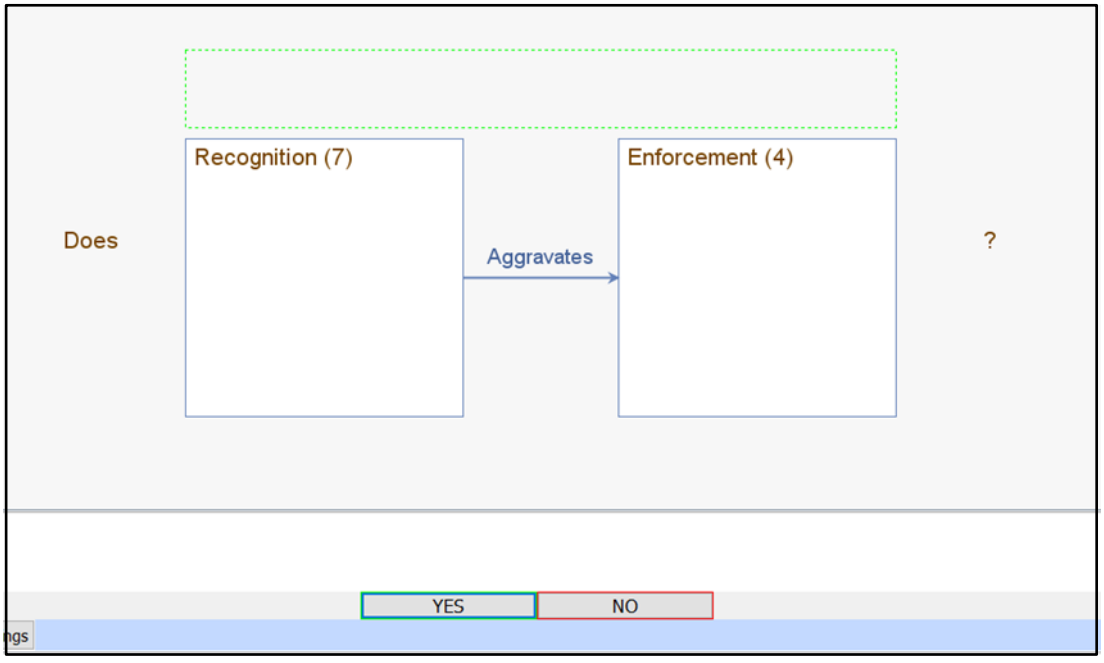


Figure 4.21 The element 7 aggravates the element 4

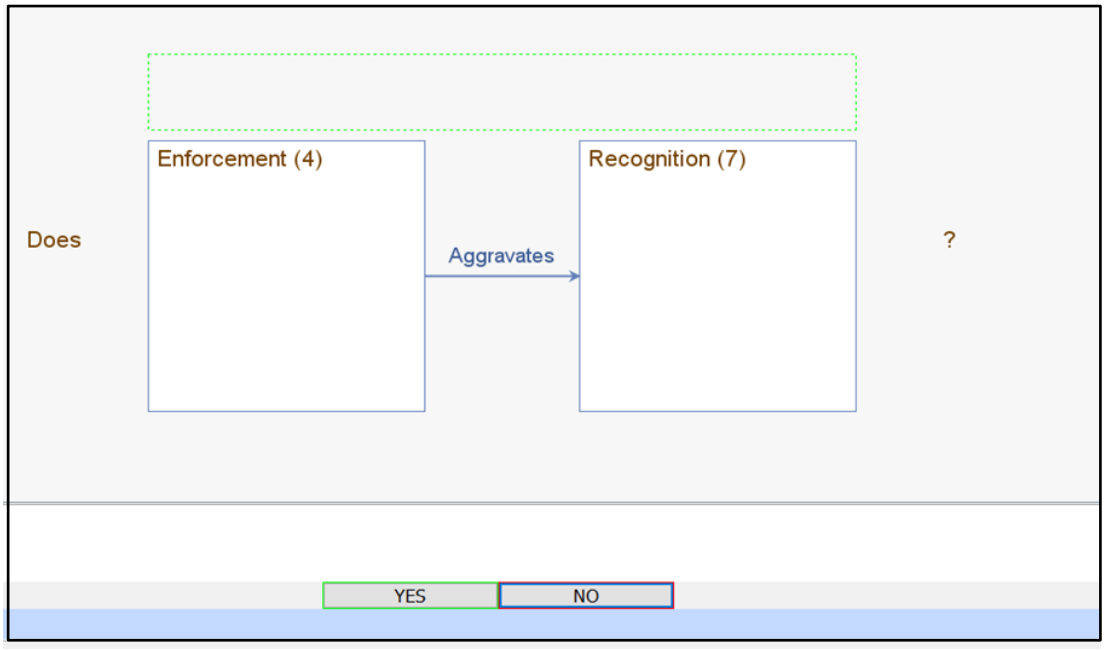


Figure 4.22 The element 4 aggravates the element 7

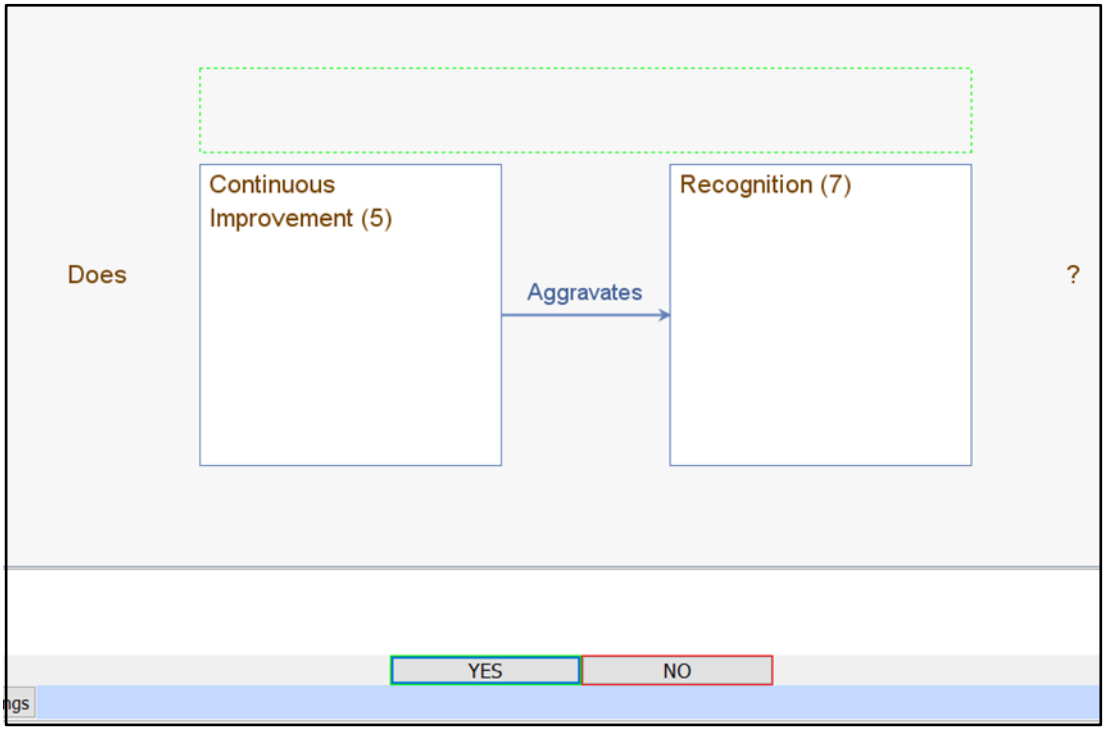


Figure 4.23 The element 5 aggravates the element 7

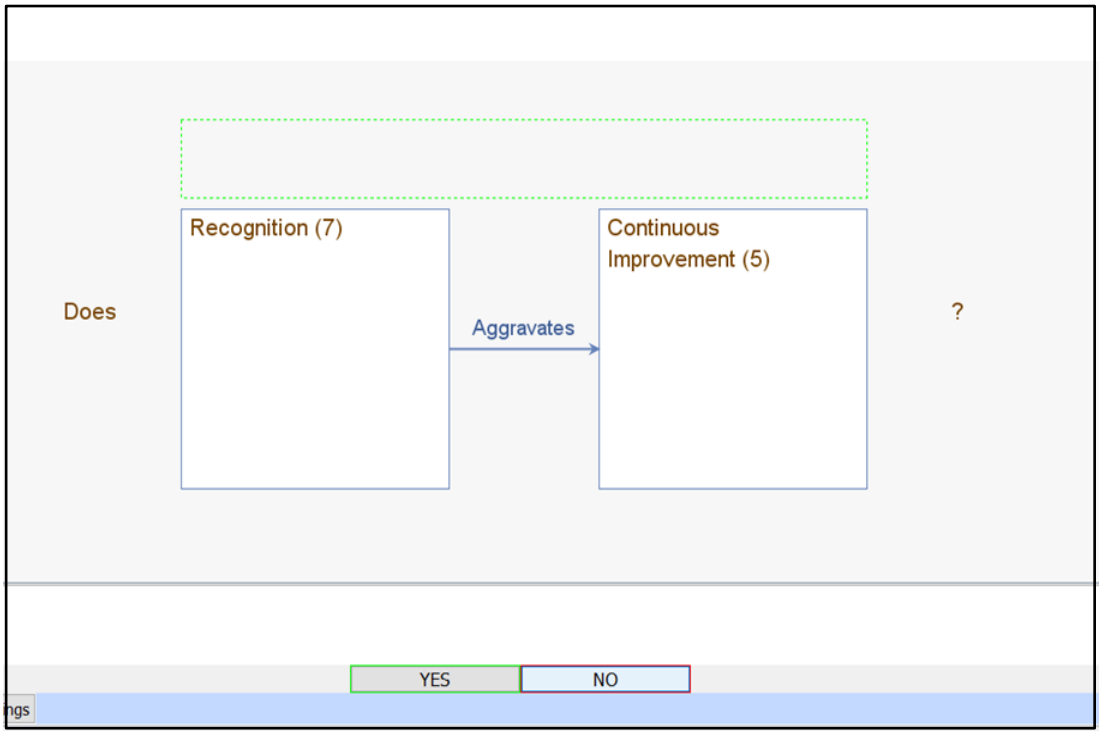


Figure 4.24 The element 5 aggravates the element 7

Appendix E – OEE formula application

Before TPM Implementation	After TPM Implementation
	
	
	
	
	

Availability

Jul-Dec 2017 session			
No. machine	Total hours	Actual hours	availability
Machine 1	126	126	1
Machine 2	126	126	1
Machine 3	126	126	1
Machine 4	126	119	0.94
Machine 5	126	98	0.77
Machine 6	126	119	0.94
Machine 7	126	126	1
Machine 8	126	112	0.88
Machine 9	126	119	0.94
Machine 10	126	119	0.94
Machine 11	126	119	0.94
Machine 12	126	126	1
Machine 13	126	126	1
Machine 14	126	112	0.88
Machine 15	126	98	0.77
Machine 16	126	126	1
Machine 17	126	126	1
Machine 18	126	126	1
Machine 19	126	98	0.77
Machine 20	126	98	0.77
Machine 21	126	105	0.83
Machine 22	126	119	0.94
Machine 23	126	105	0.83
Machine 24	126	126	1
Machine 25	126	126	1
Machine 26	126	126	1
Machine 27	126	126	1
Machine 28	126	126	1
Machine 29	126	91	0.72
Machine 30	126	98	0.77
Total running time			27.63

1 week= 7 hours

1 semester = 18 weeks

Jan-June 2019 session			
No. machine	Total hours	Actual hours	availability
Machine 1	126	126	1
Machine 2	126	119	0.94
Machine 3	126	126	1
Machine 4	126	119	0.94
Machine 5	126	126	1
Machine 6	126	119	0.77
Machine 7	126	126	1
Machine 8	126	126	1
Machine 9	126	98	0.77
Machine 10	126	126	1
Machine 11	126	126	1
Machine 12	126	126	1
Machine 13	126	126	1
Machine 14	126	98	0.77
Machine 15	126	126	1
Machine 16	126	98	0.77
Machine 17	126	126	1
Machine 18	126	91	0.72
Machine 19	126	126	1
Machine 20	126	112	0.88
Machine 21	126	112	0.88
Machine 22	126	126	1
Machine 23	126	119	0.94
Machine 24	126	126	1
Machine 25	126	126	1
Machine 26	126	91	0.72
Machine 27	126	126	1
Machine 28	126	126	1
Machine 29	126	91	0.72
Machine 30	126	126	1
Total running time			27.82

Jul- Dec 2019 session			
No. machine	Total hours	Actual hours	availability
Machine 1	126	98	0.77
Machine 2	126	126	1
Machine 3	126	126	1
Machine 4	126	126	1
Machine 5	126	126	1
Machine 6	126	126	1
Machine 7	126	126	1
Machine 8	126	126	1
Machine 9	126	126	1
Machine 10	126	98	0.77
Machine 11	126	126	1
Machine 12	126	126	1
Machine 13	126	126	1
Machine 14	126	98	0.77
Machine 15	126	126	1
Machine 16	126	98	0.77
Machine 17	126	126	1
Machine 18	126	98	0.77
Machine 19	126	126	1
Machine 20	126	98	0.77
Machine 21	126	126	1
Machine 22	126	126	1
Machine 23	126	126	1
Machine 24	126	126	1
Machine 25	126	98	0.77
Machine 26	126	126	1
Machine 27	126	126	1
Machine 28	126	126	1
Machine 29	126	126	1
Machine 30	126	119	0.94
Total running time			28.33

Performance

June-Dec 2017 session						
No of student	A1	A2	A3	A4	Total	notes
Student 1	1	1	1	1	4	
Student 2	1	0	1	0	2	need extra class /Time
Student 3	1	1	0	0	2	need extra class /Time
Student 4	1	1	1	1	4	need extra class /Time
Student 5	1	1	1	1	4	
Student 6	0	0	1	1	2	need extra class /Time
Student 7	1	1	1	1	4	
Student 8	1	1	1	1	4	
Student 9	0	1	1	1	3	need extra class /Time
Student 10	0	1	1	1	3	need extra class /Time
Student 11	1	1	1	1	4	
Student 12	0	1	1	1	3	need extra class /Time
Student 13	1	1	1	1	4	
Student 14	0	1	1	1	3	need extra class /Time
Student 15	1	1	1	1	4	need extra class /Time
Student 16	1	0	1	1	3	need extra class /Time
Student 17	1	1	1	1	4	
Student 18	1	0	0	1	2	need extra class /Time
Student 19	0	1	0	1	2	
Student 20	1	0	1	0	2	need extra class /Time
Student 21	1	1	1	0	3	need extra class /Time
Student 22	1	0	1	1	3	need extra class /Time
Student 23	1	1	0	1	3	need extra class /Time
Student 24	1	1	1	1	4	
Student 25	0	0	1	1	2	need extra class /Time
Student 26	1	1	1	1	4	
Student 27	1	1	1	1	4	
Student 28	1	1	0	1	3	need extra class /Time
Student 29	0	1	1	1	3	need extra class /Time
Student 30	0	1	1	1	3	need extra class /Time
Total actual work project				95/120	95	

Jan-June 2019 session						
No of student	A1	A2	A3	A4	Total	notes
Student 1	1	1	0	1	3	
Student 2	1	1	1	1	4	need extra class /Time
Student 3	1	1	0	0	2	need extra class /Time
Student 4	1	1	1	1	4	need extra class /Time
Student 5	1	1	1	1	4	
Student 6	0	1	1	1	3	need extra class /Time
Student 7	1	1	1	1	4	
Student 8	1	0	0	1	2	
Student 9	0	1	0	1	2	need extra class /Time
Student 10	1	1	1	1	4	need extra class /Time
Student 11	0	1	1	1	3	
Student 12	1	1	1	1	4	need extra class /Time
Student 13	1	1	1	1	4	
Student 14	0	1	1	1	3	need extra class /Time
Student 15	0	1	1	1	3	need extra class /Time
Student 16	1	0	1	1	3	need extra class /Time
Student 17	1	1	1	1	4	
Student 18	1	1	1	1	4	need extra class /Time
Student 19	1	1	0	1	3	
Student 20	1	0	1	1	3	need extra class /Time
Student 21	1	1	1	1	4	need extra class /Time
Student 22	1	0	1	1	3	need extra class /Time
Student 23	1	1	0	1	3	need extra class /Time
Student 24	1	0	1	1	3	
Student 25	0	1	1	0	2	need extra class /Time
Student 26	1	1	1	1	4	
Student 27	1	1	0	1	3	
Student 28	1	1	0	1	3	need extra class /Time
Student 29	0	1	1	1	3	need extra class /Time
Student 30	0	1	1	1	3	need extra class /Time
Total actual work project				97/120	97	

Jul-Dec 2019 session						
No of studen	A1	A2	A3	A4	Total	notes
Student 1	1	1	1	1	4	
Student 2	1	1	1	1	4	need extra class /Time
Student 3	1	1	0	0	2	need extra class /Time
Student 4	1	0	1	1	3	need extra class /Time
Student 5	1	1	1	0	3	
Student 6	1	0	1	1	3	need extra class /Time
Student 7	1	1	1	1	4	
Student 8	1	1	0	1	3	
Student 9	1	1	1	1	4	need extra class /Time
Student 10	0	1	1	1	3	need extra class /Time
Student 11	1	1	1	1	4	
Student 12	0	1	1	1	3	need extra class /Time
Student 13	1	1	1	1	4	
Student 14	0	1	1	0	2	need extra class /Time
Student 15	1	1	1	1	4	need extra class /Time
Student 16	1	0	1	1	3	need extra class /Time
Student 17	1	1	1	1	4	
Student 18	1	0	0	1	2	need extra class /Time
Student 19	0	1	0	1	2	
Student 20	1	0	1	1	3	need extra class /Time
Student 21	0	1	1	0	2	need extra class /Time
Student 22	1	1	1	1	4	need extra class /Time
Student 23	1	1	0	1	3	need extra class /Time
Student 24	1	1	1	1	4	
Student 25	1	0	1	1	3	need extra class /Time
Student 26	1	1	1	1	4	
Student 27	1	1	1	1	4	
Student 28	1	1	0	1	3	need extra class /Time
Student 29	1	1	1	1	4	need extra class /Time
Student 30	1	1	1	0	3	need extra class /Time
Total actual work project				98/120	98	

Quality

INSTITUT KEMAHIRAN MARA

KEPUTUSAN PENILAIAN SUBJEK

KOD & SUBJEK :KMM 2113 INTERMEDIATE TURNING PRACTICES | KURSUS : SIJIL TEKNOLOGI KEJURUTERAAN PEMBUATAN

SEMESTER : 2 | KELAS : A | SESI : JUL - DIS 2019

BIL	NAMA	NO.K/P	PENILAIAN												JUMLAH MARKAH 100%	% HADIR	GRED	CATATAN LULUS (L) / GAGAL (G)
			A1(P)		A2(P)		A3(F)		T1(T)									
			WAJARAN															
			/100	25%	/100	25%	/100	40%	/100	10%								
1			**21.6**	5.4	**85.6**	21.4	**86.9**	34.8	**39.0**	3.9					65.5	100%	B-	LULUS
2			**88.8**	22.2	**88.0**	22.0	**83.1**	33.2	**38.0**	3.8					81.2	100%	A-	LULUS
3			**92.4**	23.1	**94.6**	23.7	**88.5**	35.4	**36.0**	3.6					85.8	100%	A	LULUS
4			**89.7**	22.4	**93.1**	23.3	**90.4**	36.2	**26.0**	2.6					84.5	100%	A-	LULUS
5			**87.2**	21.8	**88.8**	22.2	**76.9**	30.8	**48.0**	4.8					79.6	100%	A-	LULUS
6			**82.9**	20.7	**92.5**	23.1	**92.8**	37.1	**47.0**	4.7					85.7	100%	A	LULUS
7			**27.2**	6.8	**87.2**	21.8	**83.7**	33.5	**63.0**	6.3					68.4	100%	B-	LULUS
8			**91.1**	22.8	**94.1**	23.5	**92.6**	37.0	**41.0**	4.1					87.4	100%	A	LULUS
9			**86.8**	21.7	**89.4**	22.4	**82.8**	33.1	**43.0**	4.3					81.5	100%	A-	LULUS
10			**97.1**	24.3	**96.4**	24.1	**94.1**	37.6	**33.0**	3.3					89.3	100%	A	LULUS
11			**22.6**	5.7	**80.6**	20.2	**87.9**	35.2	**39.0**	3.9					64.9	100%	B-	LULUS
12			**90.0**	22.5	**87.0**	21.8	**82.1**	32.8	**38.0**	3.8					80.9	100%	A-	LULUS
13			**91.4**	22.9	**95.0**	23.8	**86.5**	34.6	**37.0**	3.7					84.9	100%	A	LULUS
14			**88.9**	22.2	**92.3**	23.1	**91.4**	36.6	**31.0**	3.1					85.0	100%	A	LULUS
15			**86.7**	21.7	**87.5**	21.9	**80.9**	32.4	**48.0**	4.8					80.7	100%	A-	LULUS

LIST OF PUBLICATIONS

1. Indexed Journals

Razni Khalid, Mohd Yusof Md Daud, Ahmad Jusoh (2019). Critical Success Factors Maintenance Strategy in Industry for Technical Vocational Education Training Institute. Test Engineering and Management, 81(11-12), 679-688.
(Indexed by SCOPUS)

1. Indexed Conference Proceedings

Ir. Mohd Effendi Amran, Ts. Dr. Habibah @ Norehan Binti Haron, Azizi Mohd Noor, **Ts. Razni Khalid**. Supply Chain Strategy for Ayamas Food Cooperation. Proceedings of the International Conference on Industrial Engineering and Operations Management Bangkok, Thailand, March 5 - 7, 2019.