Identification of the Success Factors for the Implementation of Total Productive Maintenance in an Organisation Using Interpretive Structural Modeling(ISM)

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Abstract

Business today is in a constantly changing and evolving world. To keep pace with the competition and drive growth in a sustainable and profitable manner, it is imperative that the organisations adopt world class manufacturing. One major pillar of world class manufacturing is Total Productive Maintenance or TPM(Ahuja and Khamba, 2007).Through this paper we aim to study the factors that affect the successful implementation of TPM in an organisation.Wehave derived relationships among the various factors using the ISM modeling approach and topped it off by applying MICMAC analysis on the result to obtain a comprehensive relationship among the variables. The analysis of the driving power and dependence power of these variables is carried out using these methods(Kant and Singh, 2009). Our study here tells us that the top management's commitment is the major force behind the successful implementation of TPM in any organisation.

Keywords: TPM, ISM, MICMAC, OEE, HSE, SSIM

1. Research Objective

For organisations to compete in today's dynamic market they need to be constantly evolving and give the best of available products to the customer in the least possible time with the least possible effort. The only way this can be done is by being frugal with respect to the operating costs. One of the methods that can help us achieve this is Total Productive Maintenance or TPM(Nachiappan and Anantharaman, 2006). The implementation of TPM in an organisation is driven by a lot of factors. We in our study have gone through an exhaustive amount of research literature on implementation of TPM in various organisations in different parts of the world. Based on our study we have zeroed in eleven factors that significantly drive the implementation of TPM in organisations. These factors are listed down in Table 1.

Table 1. Factors driving implementation of TPM

1	Health, Safety andEnvironment
2	Top Management Commitment
3	Autonomous Maintenance
4	Cross-functional Training
5	Employee Morale
6	Size of Organisation
7	Work culture
8	5S
9	Employee involvement
10	Focused improvements
11	Quality maintenance in management

Our study involved deriving of the contextual relationship between these factors for the successful implementation

of TPM. For this purpose Interpretive Structural Modeling (ISM) was used and the variables have been classified on the basis of their driving and dependent powers. To enhance the model we have also applied MICMAC analysis so that a comprehensive view of the relationships can be obtained.

2. Literature Review

Total Productive Maintenance advocates shifting the maintenance of the equipment and material from the maintenance team to the process and production owners(Prabhuswamy*et al.*,2013). In such scenario, several apprehensions may arise among various entities involved in the process. Organisational and functional changes necessary for the implementation of TPM can be vindicated with the help of mathematical models. With the changing demand in productivity, quality, availability, and complexity, the traditional approach needs to be revisited and perhaps modified. TPM works upon three basic principles of highest level of equipment performance, highest level of equipment maintenance and procurement of new equipments with high performance and low life cycle costs. This is measured using the parameter OEE (overall equipment efficiency). Based on our study from research articles we have constructed a literature review.

From the study of various relevant research literatures the following factors that affect the successful implementation of TPM has been identified(Exhibit 8):

2.1. Health, Safety,and Environment (HSE)

In any modern day organisation, HSE forms an unavoidable factor. The health of an employee, safety of the plant, and the environmental impacts that they cause are at the forefront of any innovation or reengineering that takes place in the present day organisations. They form a major impact on the decision making policy of an industry/organisation.

2.2. Top Management Commitment

Top management is the decision making body of any organisation. So any change that needs to be done, need to be driven by them. Without their initiation and support it is almost impossible for any reengineering or revamps to rollout. They are responsible for all the activities in an organisation. They are responsible for conceptualizing a vision for the successful implementation for the required and proposed changes.

2.3. Autonomous Maintenance

It is the process by which equipment operators accept and share the responsibility of the maintenance of the machines. This includes the performance and health factors of the machines. An operator is in day to day contact with the machines. So he is in the best position to identify when and where a machine requires maintenance. By adopting this philosophy, an organisation can considerably reduce its maintenance expenses while at the same time increase the life of the machine thereby bringing about cost savings.

2.4. Cross-functional Training

Employee training is the main medium of employee skill enhancement. Along with theiralready known skills, it is imperative that the employees are trained in other areas of expertise also. By doing this we increase the replace ability of a worker and reduce the overdependence on the worker. On a personal front the employee becomes better equipped to face the challenges ahead of him. The financial gain that the organisation stands to earn from this philosophy is manifold compared to the cost involved.

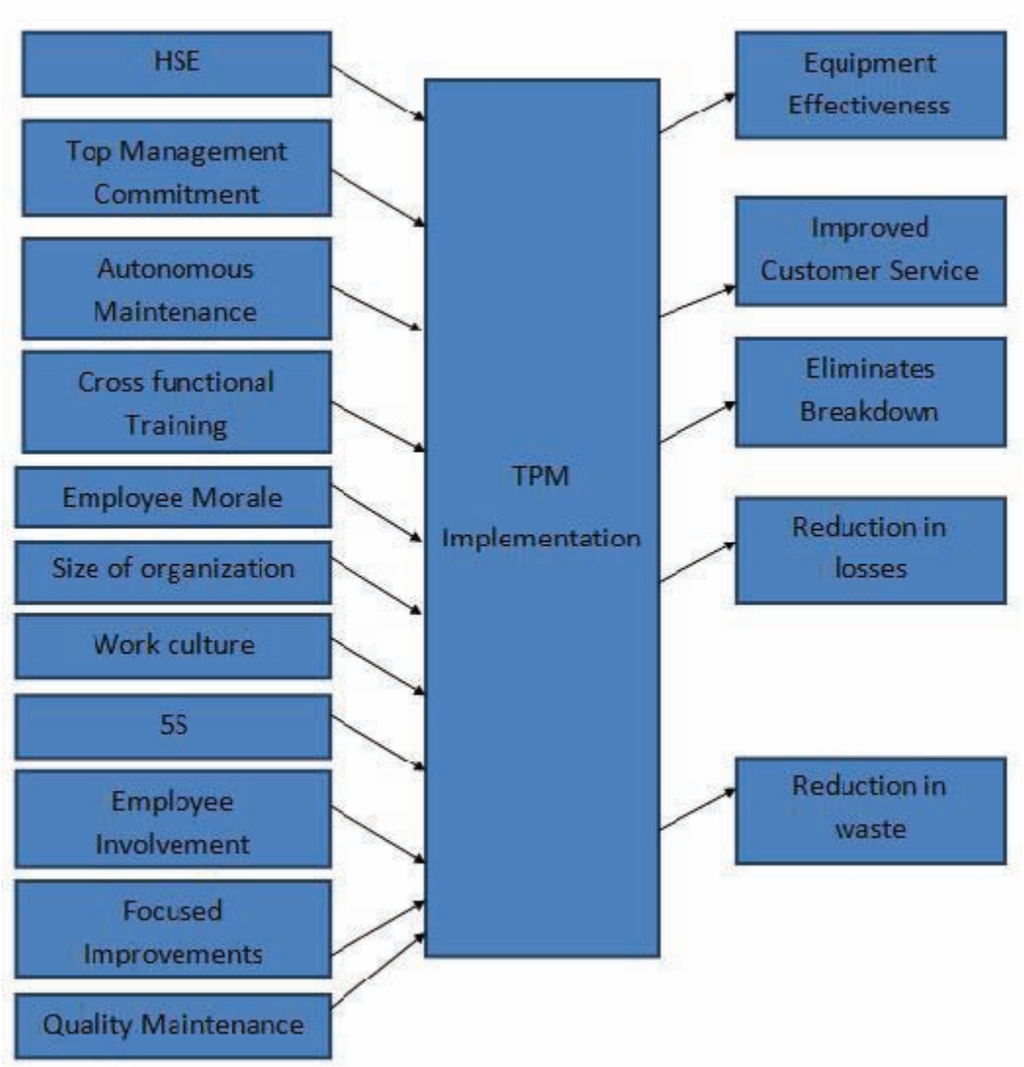
2.5. Employee Morale

Employee morale is an indication of how determined an employee is to achieve his stated goals and objectives. For any change to happen, the morale of the employee is utmost important. It is the single factor that tilts the scale in favor of any new process implementation.

2.6. Size of Organisation

Organisations are of various types. They can be small, medium or large. The various processes that need to be followed vary with the size of an organisation. The process that is used for a small organisation may not be the same for a large organisation. The classification of the organisation may be on the basis of the number of the employees, the product range or the annual turnover of the organisation. For a process like TPM, organisation size is a very important factor and needs to be carefully analyzed and studied.

Figure 1. Theoretical framework



2.7. Work culture

Work culture is an important indicator for the employee. It helps in bringing out the best from an employee. It helps the organisation to retain their employees. It is an indicator of the beliefs, thought process and attitude of the employees. The work culture is defined by the ideologies and principles of an organisation. It also defines how the employees interact with each other as well as how they respond to the demands of the organisation.

2.8. 5S

This philosophy is based on the 5 Japanese principles of *seiri, seiton, seiketsu, seiso* and *shitsuke*. It defines how to organise a work space both effectively and efficiently. It brings about a standardization that is build out of a healthy discussion with the employees. The positive changes that they bring about in streamlining a process and increasing the efficiency, is a valuable asset to any organisation.

2.9. Employee Involvement

Employees are the lifeline of any organisation. For organisations to grow, the employees need to be actively involved. Employee involvement shows the level of confidence that the employee has in the policies and practices of the organisation. No process can be introduced into an organisation without considering the levels of employee involvement needed.

Table 2: SSIM model showing relationship between variables

Variables	1	2	3	4	5	6	7	8	9	10	11
1	1										
2	A	1									
3	A	V	1								
4	A	V	O	1							
5	V	V	O	V	1						
6	O	O	O	O	O	1					
7	A	V	O	V	X	O	1				
8	A	V	V	V	A	V	A	1			
9	A	V	A	A	X	O	X	A	1		
10	A	V	V	V	A	O	A	A	V	1	
11	O	V	V	V	A	O	A	V	V	X	1

A : Variable j leads to variablei
V : Variable i leads to variable j
X : Variable i leads to variable j and variable i leads to variable j
O : No relationship between i and j

2.10. Focused Improvements

Improvements to be carried out in an organisation need to be identified first. These improvements should be focused and prioritized in the most important and relevant areas. Pinpointing the areas that need improvement and then focusing on them to bring about improvements in your process is the idea entrapped in the whole gamut of focused improvements.

2.11. Quality Maintenance in Management

Quality is the distinguishing feature of the products in the coming generation. To achieve this objective it is necessary that quality maintenance be decided at the management level itself. The main focus of this philosophy is to focus on tasks that keep the machines producing error free quality products.

2.12. Research Methodology

Every theory or conclusion is supported by the rigorous research that has been put behind it. The study is supported by the literature review of various research papers on implementation of Total Productive Maintenance in various countries such as India, Malaysia and China. After the extensive study of the research literature, research variables (dependent and independent) were identified. A theoretical framework, incorporating these variables is suggested. Theoretical framework is shownin Figure 1.

The framework depicts the research variables that drive implementation of TPM resulting into equipment effectiveness, improved customer service, eliminating breakdown, and reduction in losses and waste. Interpretive structure modeling analyses the research variables and MICMAC analysis derived the driving variables among the given. The use of ISM and MICMAC simplified the relationship among the variables. The specific relationship between variables is depicted in the reachability matrix and SSIM model. The overall structure is derived using the digraph model. The digraph model is constructed using the lower triangular matrix derived from the reachability matrix(Mandal and Deshmukh, 1994).

2.13. Structural Self Interaction Matrix (SSIM)

For analysing the contextual relationship between the identified variables we have constructed a SSIM model as shown in Table 2.

2.14. Reachability Matrix (Mandal and Deshmukh, 1994)

The initial reachability matrix is constructed from the SSIM by substituting the V,A,X,O entries with 1 and 0,

as shown in Exhibit 1. Then this matrix is put through transitivity check i.e. if element *i*leads to element *j* and element *j* leads to element *k*, then element *i*should lead to element *k*[9]. The modified reachability matrix is obtained as shown in Exhibit 2.

2.15. MICMAC Analysis(Mandal and Deshmukh, 1994)

Different variables have been classified into four quadrants, namely autonomous,dependent, linkage and driving variables, based on their driving power and dependence power which we have calculated during the transitivity test. It has been presented in Exhibit 3. We have also constructed a directed graph using MICMAC analysis and the reachability matrix (Exhibit 7).

2.16. Level Partitioning (Mandal and Deshmukh, 1994)

From the reachability matrix, the reachability set and antecedent set (Exhibit 4)for eachvariable is identified. The reachability set consists of the variable itself and all the othervariables to which it may reach, and the antecedent set consists of thevariable itself and the other variables which may reach to it. Theintersection of these sets is derived for all variables. The variable for which the reachability and intersection sets are the same is the top-level variable. Once the top-level variable is identified, it is separated out from the other variables and various iterations, based on the above methodology are carried out to identify the other levels which need to be assigned to the remaining variables. This has been shown in Exhibit 4 [9].

2.17. Lower Triangular Matrix and Digraph (ISM model)

From the reachability matrix we have constructed a lower triangular matrix (Exhibit 5). Each variable is arranged as per the levels assigned and entries are filled with 1's and 0's as per the reachability matrix. From this matrix we have constructed a digraph model (Exhibit 6) where we have marked the relationship between the variables using arrows. If there exists a relationship between i and j, then this is shown using an arrow pointing from i to j(Mandal and Deshmukh, 1994). This is a refined digraph over the one constructed using MICMAC analysis and reachability matrix. This is the ISM model.

3. Findings of the Study

1. From the analysis of the modified reachability matrix and MICMAC analysis it is found that commitment of top management is the key factor in the implementation of TPM. Followed by cross-functional training and employee involvement.
2. From the MICMAC Analysis it can also be inferred that size of the organisation is an autonomous variable as far as the implementation of TPM is concerned.
3. Variables like Health, Safety and Environment (HSE) and Quality maintenance are dependent variables. They are weak drivers but strongly dependent.
4. Employee morale, work culture, autonomous maintenance, employee involvement, 5S and focused improvement are found to be the linkage variables.

4. Conclusion

For successful implementation of TPM activities in the organisation the key factor is the commitment of the top management in pursuing the TPM philosophy, though the criterions like employee morale and work culture share strong dependency on all the other variables.

A culture of cross-functional training programs also enhances the culture of autonomous maintenance in the organisation.

The size of the organisation dictates, to some extent the level of 5S practices in an organisation. Focused improvements drive the variables like employee morale and work culture. 5S also participates as a strong linkage variable in the TPM implementation process.

From a manager's perspective, autonomous maintenance and focused improvements are very crucial for an organisation's growth. These can be achieved by improvingthe work culture in the organisation, boosting employee morale and increasing their involvement at work place. The manager, thus, must focus to better the work environment of the employees, motivate them to perform their best, provide cross-functional training to improve their employability and even address their grievances. While considering these factors, the management must also consider the cost benefit ratio that these processes

carry along with them. The cost factor has not been extensively dealt with in our research. The whole gambit of considering the cost of each of the identified factors and the economic benefit that these factors contributes towards the overall economic state of the organisation post implementation of TPM based on the recommendations of our research requires further study and research.

The size of the organisation is a double edged sword in the context of our research. We see that while we consider a large organisation, the economies of scale with respect to the investment that is needed for the successful implementation of TPM practices act in its favour, the complexity of the process that is needed for the changes to trickle down to the desired level act as a huge deterrent. This fact acts vice-versa for a small organisation. This fact makes it necessary that the decision to implement TPM becomes a strategic one thereby further enhancing our research study that top management commitment is the key philosophy for a successful implementation of TPM. This relationship is a novel concept that requires further exploration and can be a basis for a full-fledged research in itself.

Exhibit 1

Table 3. Reachability matrix

Variable	1	2	3	4	5	6	7	8	9	10	11
1	1	0	0	0	1	0	0	0	0	0	0
2	1	1	1	1	1	0	1	1	1	1	1
3	1	0	1	0	0	0	0	1	0	1	1
4	1	0	0	1	1	0	1	1	0	1	1
5	0	0	0	0	1	0	1	0	1	0	0
6	0	0	0	0	0	1	0	1	0	0	0
7	1	0	0	0	1	0	1	0	1	0	0
8	1	0	0	0	1	0	1	1	0	0	1
9	1	0	1	1	1	0	1	1	1	1	1
10	1	0	0	0	1	0	1	1	0	1	1
11	0	0	0	0	1	0	1	0	0	1	1

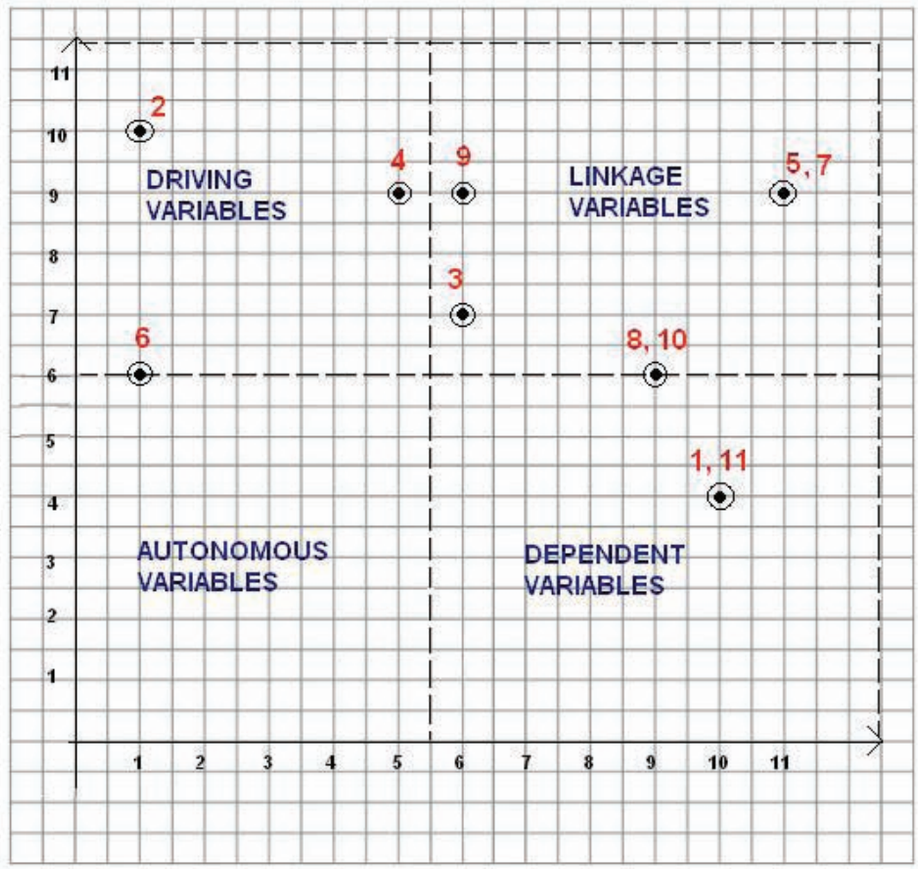
Exhibit 2

Table 4. Modified Reachability Matrix, after transitivity test

Variables	1	2	3	4	5	6	7	8	9	10	11	Driving
1	1	0	0	0	1	0	1	0	1	0	0	4
2	1	1	1	1	1	0	1	1	1	1	1	10
3	1	0	1	0	1	0	1	1	0	1	1	7
4	1	0	1	1	1	0	1	1	1	1	1	9
5	1	0	1	1	1	0	1	1	1	1	1	9
6	1	0	0	0	1	1	1	1	0	0	1	6
7	1	0	1	1	1	0	1	1	1	1	1	9
8	1	0	0	0	1	0	1	1	0	1	1	6
9	1	0	1	1	1	0	1	1	1	1	1	9
10	1	0	0	0	1	0	1	1	0	1	1	6
11	0	0	0	0	1	0	1	0	0	1	1	4
Dependence	10	1	6	5	11	1	11	9	6	9	10	

Exhibit 3

Figure 2. MIC MAC ANALYSIS



X –Axis: Dependence rank
Y-Axis: Driving power

<B level>Exhibit 4

Table 5. Level partition, with all iterations

Level Partioning : Iteration Level - 1				
Variables	**Reachability Set (R)**	**Antecedent Set (A)**	**R^A**	**Level**
1	1,5,7,9	1,2,3,4,5,6,7,8,9,10	1,5,7,9	1
2	1,2,3,4,5,7,8,9,10,11	2	2	
3	1,3,5,7,8,10,11	2,3,4,5,7,9	3,5,7	
4	1,3,4,5,7,8,9,10,11	2,4,5,7,9	4,5,7,9	
5	1,3,4,5,7,8,9,10,11	1,2,3,4,5,6,7,8,9,10,11	1,3,4,5,7,8,9,10,11	1
6	1,5,6,7,8,11	6	6	
7	1,3,4,5,7,8,9,10,11	1,2,3,4,5,6,7,8,9,10,11	1,3,4,5,7,8,9,10,11	1
8	1,5,7,8,10,11	2,3,4,5,6,7,8,9,10	5,7,8,10	
9	1,3,4,5,7,8,9,10,11	1,2,4,5,7,9	1,4,5,7,9	
10	1,5,7,8,10,11	2,4,5,7,8,9,10,11	5,7,8,10,11	
11	5,7,10,11	2,3,4,5,6,7,8,9,10,11	5,7,10,11	

Level Partioning : Iteration Level – 2				
Variables	**Reachability Set (R)**	**Antecedent Set (A)**	**R^A**	**Level**
2	2,3,4,,8,9,10,11	2	2	
3	3,8,10,11	2,3,4,9	3	
4	3,4,8,9,10,11	2,4,9	4,9	
6	6,8,11	6	6	
8	8,10,11	2,3,4,6,8,9,10	8,10	
9	3,4,8,9,10,11	1,2,4,9	4,9	
10	8,10,11	2,4,8,9,10,11	8,10,11	2
11	10,11	2,3,4,6,8,9,10,11	10,11	2

Level Partioning : Iteration Level – 3				
Variables	**Reachability Set (R)**	**Antecedent Set (A)**	**R^A**	**Level**
2	2,3,4,,8,9	2	2	
3	3,8	2,3,4,9	3	
4	3,4,8,9	2,4,9	4,9	
6	6,8	6	6	
8	8	2,3,4,6,8,9	8	3
9	3,4,8,9	1,2,4,9	4,9	

Level Partioning : Iteration Level - 4				
Variables	**Reachability Set (R)**	**Antecedent Set (A)**	**R^A**	**Level**
2	2,3,4,9	2	2	
3	3	2,3,4,9	3	4
4	3,4,9	2,4,9	4,9	
6	6	6	6	4
9	3,4,9	1,2,4,9	4,9	

Level Partioning : Iteration Level - 5 and 6				
Variables	**Reachability set (R)**	**Antecedent Set (A)**	**R^A**	**Level**
2	2,4,9	2	2	6
4	4,9	2,4,9	4,9	5
9	4,9	1,2,4,9	4,9	5

NOTE: R^A means intersection of R set and A set

Exhibit 5

Table 6. Lower triangular matrix

Variables	1	5	7	10	11	8	3	6	4	9	2
1	1	1	1	0	0	0	0	0	0	1	0
5	1	1	1	1	1	1	1	0	1	1	0
7	1	1	1	1	1	1	1	0	1	1	0
10	1	1	1	1	1	1	0	0	0	0	0
11	0	1	1	1	1	0	0	0	0	0	0

8	1	1	1	1	1	1	0	0	0	0	0
3	1	1	1	1	1	1	1	0	0	0	0
6	1	1	1	0	1	1	0	1	0	0	0
4	1	1	1	1	1	1	1	0	1	1	0
9	1	1	1	1	1	1	1	0	1	1	0
2	1	1	1	1	1	1	1	0	1	1	1

Exhibit 6

Figure 3. Digraph model

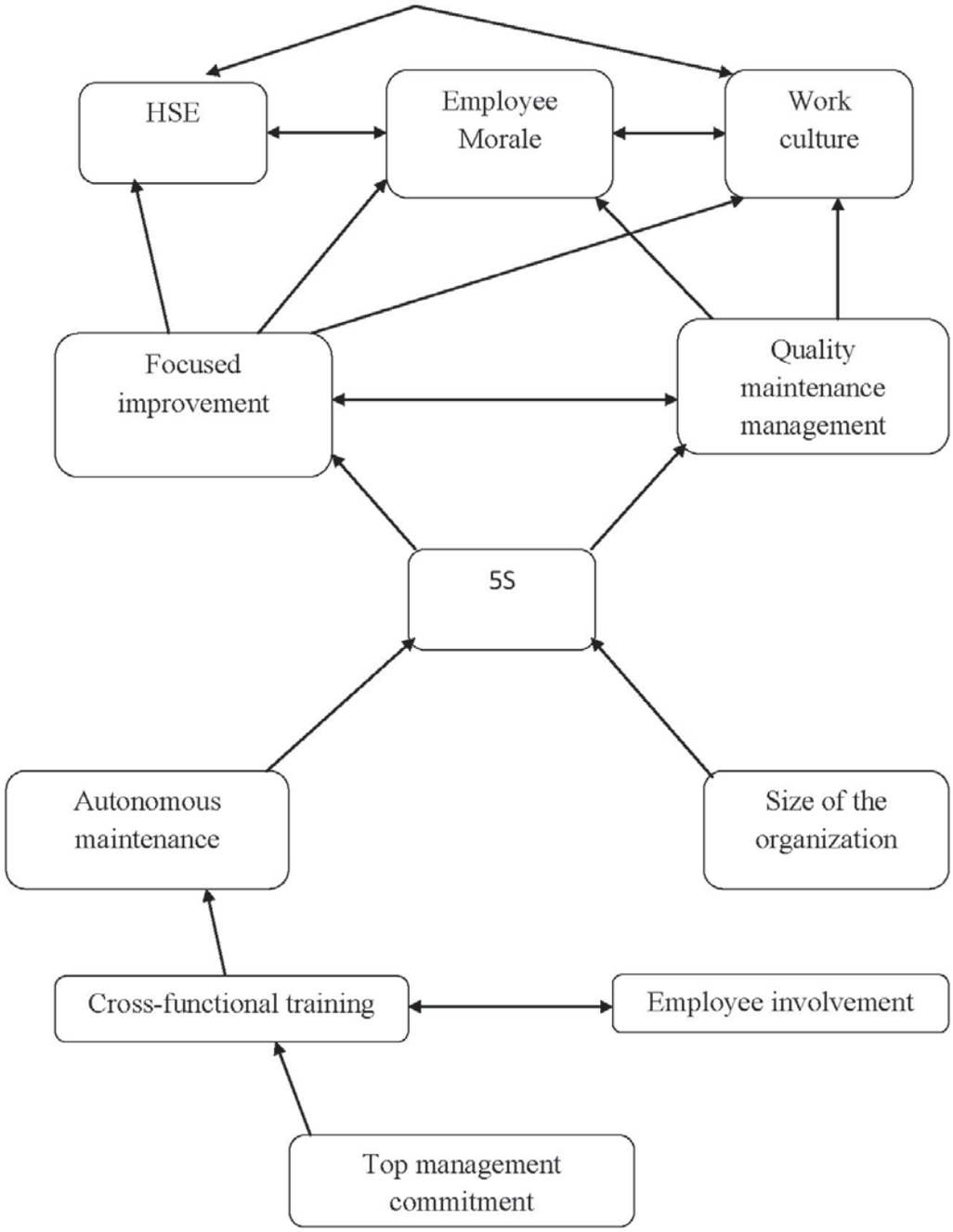


Exhibit 7

Figure 4. Directed graph using MICMAC analysis and reachability matrix

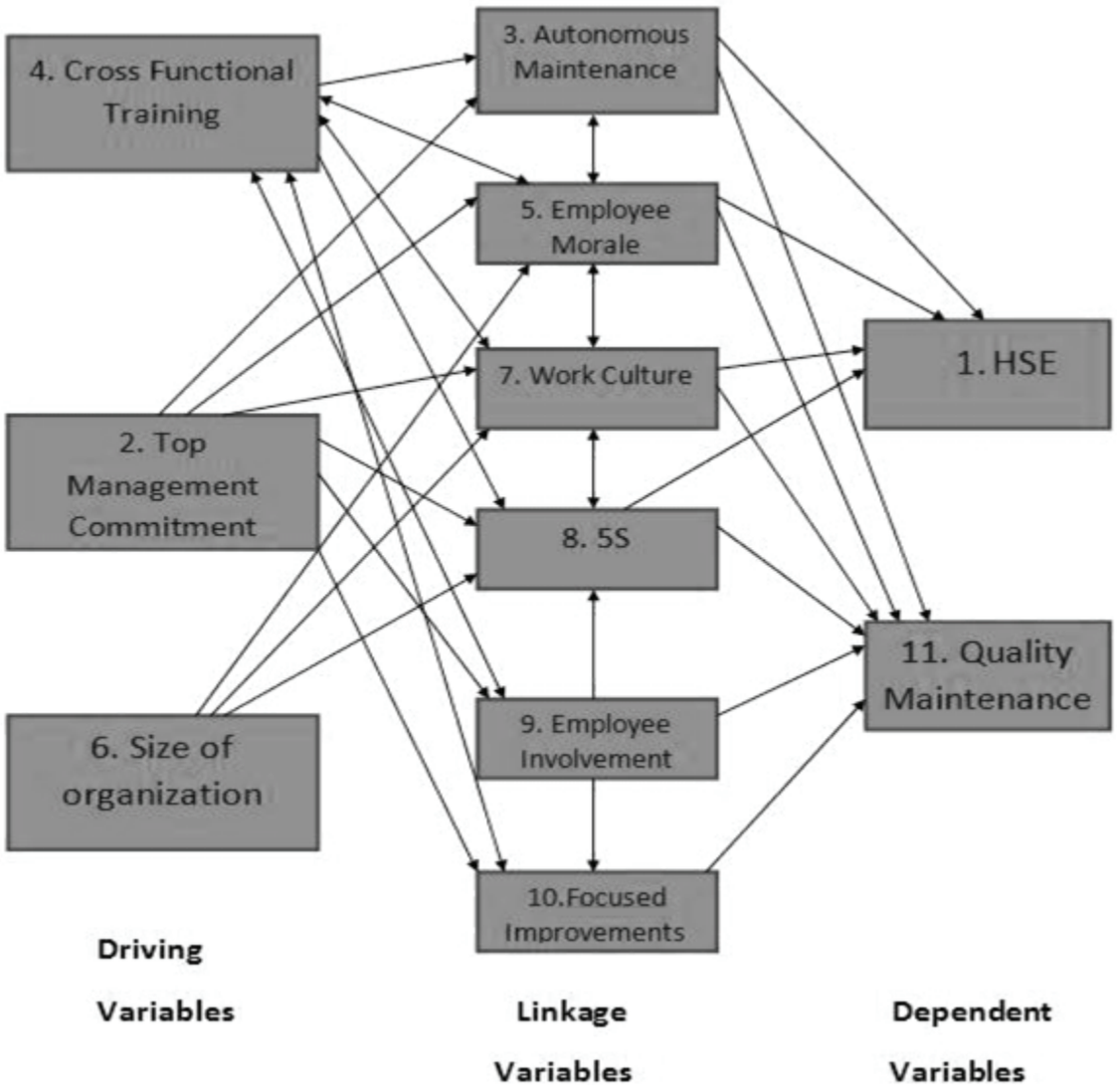


Exhibit 8

Table 7. Summary of literature review

Sr No:	Author/Year	Context	Definition	Variables	Limitations
1	John, 1999	Use of mathematical modeling for understanding the benefits of implementing TPM.	Mathematical models can be used to vindicate the organisational and functional changes necessary to implement TPM.	Planned maintenance and customer performance	The paper discusses on the impact quantization by the model but not on how the models can be developed. Also the modeling is heavily dependent on various sets of assumptions. Different assumptions can give different results and therefore a hint of inconsistency.
2	Bamber*et al*., 1999	Factors that affect the successful implementation of TPM and development of a generic model for the same.	TPM can be based on the 5 Japanese principles as well as the western world's approach to TPM. Factors like Increased equipment effectiveness, training, autonomous maintenance, early equipment management and planned preventive maintenance can be used to determine the effectiveness of TPM implementation. .	Alignment to mission, employee involvement, management commitment, motivation, the existing organisation	The model neither depicts the interdependencies of the sub-factors nor the influence of the various sub-factors on the nine critical factors.
3	Ahuja and Kumar, 2009	Contributions of successful TPM implementation to competitive industries at a Precision Tube Mill in India.	TPM is the strategic tool that helps organisations to achieve efficient and effective maintenance. TPM has evolved into a equipment-centric effort embracing the concept of continuous improvement and total participation by the employees and departments and improvement in employee suggestions and contributions.	Autonomous maintenance, focused maintenance, planned maintenance, quality maintenance, education and training, safety, health and environment, office TPM and development management	The paper mainly deals with the organisational perspective of the advantages of TPM. The employee level impacts have only been crudely captured in the intangible benefits as illustrated. More thought and research has to be done in this regard.
4	Ahmed *et al*., 2004	Understanding the state of TPM in small and medium industries in Malaysia and the effect of the lack of Total Productive Maintenance in the same.	The research paper, through surveys and questionnaires, tries to understand the awareness amongst SMI's in Malaysia regarding TPM, the nature of TPM application in these industries, the limitations faced by SMI's in implementing the same and finally proposes a methodology for its easy implementation	Production volume, safety, quality, cost of production, productivity index, employee morale	The study is limited to only the small and medium industries in Malaysia
5	Van der Wal and Iyan, 2002	Case study regarding the TPM implementation in a paper and pulp company, in South Africa, through interviews and questionnaires.	The research paper investigates the legitimacy of implementation of TPM activities in the company. They floated questionnaires to measure the degree of know how in the field of TPM and through interviews (of the staff exposed to TPM) the legitimacy of the implementation was measured.	Employee involvement, top management support, autonomous maintenance, cross-functional training	Study is limited to the effect of TPM implementation on the productivity of only one South African mill

Sr No:	Author/Year	Context	Definition	Variables	Limitations
6	Ashraf, 1999	Shortcomings in the practical implementation of TPM and devises a more feasible implementation process called Appropriate Productive Maintenance [APM].	TPM works upon three basic principles of highest level of equipment performance, maintaining equipment at the highest level and procuring new equipment's of high performance and low life cycle costs. The author proposes a revised approach focusing on specific results, management thought process and to account for the differences from the ideal case. The new model is called as APM and is a strategic and operational model.	Autonomous maintenance, employee involvement, TPM group	The paper does not explore the possible weaknesses of the newly proposed APM methodology. A rigorous study in this respect will be needed to explore if the methodology is correct or not.
7	Ireland and Dale, 2001	Implementation of TPM in 3 different companies based on Nakajima's seven principles of autonomous maintenance.	The paper delves into the TPM implementation process of 3 companies. TPM was their path to overcome their shortcomings.	Focused improvement, autonomous maintenance, planned maintenance, quality maintenance, education and training, early equipment maintenance and safety and the environment.	The paper mentions about the use of ABC classification and other process like FMEA and Quality matrix, but the results of these have not been listed in the paper.
8	Ahmed *et al*., 2010	Implementation of the TPM methodology in the pharmaceutical industry.	TPM has been devised to meet the requirements of the highly competitive modern manufacturing economy. It aims at markedly increasing the production while at the same time ensuring increased employee participation and morale.	Loading time, down time, standard cycle time, actual cycle time, unit produced and defective units.	The sample space for the study is restricted to a niche area in a third world country. This may not be a clear indication of the industry standard.
9	Cooke, 2000	Difficulties faced by 4 firms while attempting to implement TPM initiatives.	Various barriers to the successful implementation of TPM are also identified e.g. recruiting procedures, dispute with the joint trade unions on reduction of headcount, inadequate workforce, increase in production - lack of maintenance time, occupational group differences.	Support and commitment from the top management, joint cooperation from the maintenance workers and the operators, higher level of ownership and responsibility from the operators and training	The companies under investigation share similar characteristics in terms of the nature of production.
10	Ahuja and Khamba, 2008	Interrelationship between various TPM success factors and the accruing manufacturing competencies.	The research paper lists the factors that lead to the recent change in the manufacturing industry on a global scale. The strategic TPM factors are identified for the Indian manufacturing sector. Also the accruing manufacturing competencies from the successful implementation of the TPM initiative, that helps an organisation in turbulent and challenging markets, are identified and validated.	Assistance by the top management and manufacturing competencies	The findings of the paper are limited to the Indian manufacturing sector

Sr No:	Author/Year	Context	Definition	Variables	Limitations
11	Singh *et al.*, 2013	TPM implementation phase for an automotive component manufacturer.	The paper discusses the importance of TPM and mentions the 8 pillars of TPM and discusses their phased implementation.	Workers support and support from the top management.	TPM implementation is studied for a machine shop having only CNC machines
12	Almeanazel, 2010	Goals and benefits of implementing Total Productive Maintenance, and calculating the overall equipment effectiveness in one steel company in Jordan.	The research empowered the company with a methodology to calculate their inefficacies in order to improve productivity and concludes by suggesting TPM implementation to improve the waste time and system machines.	Education and training, employee involvement, autonomous maintenance	Study is restricted to only one steel company in Jordan
13	Ahuja and Khamba, 2007	Implementation and evaluation of TPM in Indian manufacturing enterprises.	TPM is an approach for Indian manufacturing enterprises to elevate from traditional way of manufacturing to World class manufacturing.	Focused Improvement, quality maintenance, training and top management commitment	Considering the culture followed in Indian industry, the transformation from reactive maintenance to Total Productive maintenance is difficult. Imbibing motivation and self-belief in workplace is time-taking and rigorous process.
14	Bakri*et al.*, 2012	Study of TPM in crafting Lean Production and integrating them for further research.	TPM shows the path of diversion between Lean and Non-Lean companies	Integration of TPM and Lean Production, JIT , quality, inter department support and employee involvement	A lot of research is required for their fully integration and impact on manufacturing practices.
15	Lazim and Ramayah, 2010	Study of TPM practices followed in Malaysia	In this world of changing business environment, TPM is a tool to adopt the best manufacturing practices and excel in manufacturing segment.	TPM team, TPM strategy, autonomous maintenance, planned maintenance	Apart from TPM, factors such as continuous improvement, customer satisfaction and leadership affect the manufacturing practices. Explanation of these factors is not mentioned. Variables such as complexity of production process, complexity of technology and size of company affect the relation between TPM and manufacturing performance
16	Patra*et al.*, 2005	Implementing office TPM for administration facilities in an organisation.	Office TPM, one of the pillars of TPM, has strengthened mundane IT skills and increased proficiency among administrative people.	Large database, 5S, autonomous maintenance, employee participation and top management support	Office TPM is worthless without training administrative people. Technical skills must be refreshed at regular intervals. Computer skills are needed to carry out the library automation activities and effective information
17	Konecny and Thun, 2010	Combined effect of TPM and TQM in current manufacturing industries.	TQM and TPM, being two different philosophies, havedeveloped compressive and consistent set of manufacturing practices.	Cross-functional training, autonomous maintenance, customer focus	Involvement of HR department needs to be magnified. Only HR people can make these practices to be implemented from top to bottom. Further research is necessary in the analysis of conjoint implementation of TQM and TPM practices.

Sr No:	Author/Year	Context	Definition	Variables	Limitations
18	Ferrari *et al.*, 2002	Introduction of TPM in Italian factories.	TPM in Italy have started gaining pace in reducing breakdown losses and motivating employees and contractors through autonomous maintenance.	Preventive maintenance, employee participation, operators and workers involvement, top management support	TPM practices followed by Italian manufacturing companies are more theoretical based. No mathematical research is made. TPM is time consuming method.
19	Yamashina,1995	Strategies being adopted by Japanese industries to counter competition and other economic factors.	Attractive products and strong manufacturing capability through JIT product development and cost reduction with help of TPM are the key factors needed to establish a competitive advantage.	Just in Time, process designing	This study is only about Japanese manufacturing sector
20	Ahuja and Khamba,2008	The contributions of TPM initiatives for achieving core competencies in manufacturing organisation.	TPM implementation is the core competence of organisations over 300 in India.	Inter-relationships between TPM implementation dimension and core competency indicator, realization of strategic core competencies with respect to timeframe of TPM implementation, productive maintenance	Investigation is specially based on Indian organisation and a certain region of India.
21	Ahuja and Khamba,2008	To study on the impact of TPM practices on Indian manufacturing firm.	TPM initiative is the source of competitive advantage.	Focused improvements and quality maintenance in management	The study has been conducted in Indian manufacturing organisations to formulate the critical success factors and enablers for overcoming obstacles to successful TPM implementation with regard to its preparedness to face global challenges.
22	Tsang andchan, 2000	How TPM can be implemented and work flow can be accelerated successfully	TPM is the key factor of cost reduction of the product.	Work culture and work psychology	This case study is carried out a high-precision machining factory in mainland China.
23	Aspinwal and Elgharib,2013	In context to TPM implementation methods and technique in terms of payback return on investment.	Successful TPM implementation is the key factor of company sustaining.	Work culture and difficulties in implementing TPM	The number of companies that were willing to take part in the study was poor, thereby making it difficult to generalize the conclusions. And this study is carried out in UK Companies.
24	Tsarouhas, 2007	In context to implementation of TPM in food industry in general and a bakery in particular.	Implementation of TPM in a bakery/food industry, with an aim to create competitive advantage and maximize exploitation of mechanical equipment.	Support from top management, product design and cross-functional training	i. This paper implementing TPM carries out study for a period of 5 years only. A longitudinal study for this case will be more promising. ii. Also, the study must be extended to all bakery products

Sr No:	Author/Year	Context	Definition	Variables	Limitations
25	Graisa and Al-Habaibeh, 2011	Designing an innovative TPM strategy to address the production challenges of Libyan Cement Industries.	Development of a model which facilitates the implementation of modern TPM through comprehensive productivity and maintenance system.	Productive maintenance, HSE and product design	i. The paper has researched and developed an innovative model that can be used to address the production challenges faced by the Libyan cement industries. However, it does not talk about its implementation practicality.
26	Bohoris*et al*., 1995	Implementation of TPM in Land-Rover – Transmissions using Computerized Maintenance Management System (CMMS).	CMMS is a very important contributor providing prompt and accurate information for the implementation of TPM.	Top management commitment, cross-functional training, planned maintenance	i. This system relies heavily on the input provided by the human resources of LRT, which is a drawback for successful implementation TPM.
27	Sharma *et al*., 2006	Achieving excellence in the manufacturing sector by implementing TPM.	The implementation of TPM leads to maximization of OEE by reducing wastage. Hence, reducing the challenges in becoming a World class manufacturer.	Cross-functional training, strategy formation, consistent management support	i. The study herein deals with implementation of the model in semi-automated cells of company only. There can be integration errors.
28	Ahmed *et al*., 2005	Implementing TPM for more than just maintenance purposes.	A well-conceived TPM is a means for mi minimization of customer complaints, reduction of inventory levels, and increasing the quality.	HSE, quality maintenance and top management support	i. The data should be collected by using a computerized system and not manually. ii. There is scope for further reduction in cycle time
29	Ljungberg, 1998	Considering Overall Equipment Efficiency (OEE) as a base for the effective implementation of TPM.	The study focuses on gathering data for machinery losses, which provide the required base for planning activities in a TPM framework.	Production process, process knowledge, maintenance activities and production conditions	The model adopted in this study needs to be applied and checked for in an organisation/industry and checked for its practicality.

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