IDENTIFICATION AND ANALYSIS OF BARRIERS OF TPM IMPLEMENTATION USING TOTAL INTERPRETIVE STRUCTURAL MODELING APPROACH: A CASE STUDY

by

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Miftahul Jannat Chowdhury

This Work is Dedicated to My Parents and My Beloved Husband

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List of Abbreviations

TPM	: Total Productive Maintenance
TISM	: Total Interpretive Structural Modeling
MICMAC	: Cross-impact Matrix Multiplication Applied to Classification analysis

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ABSTRACT

Bangladesh is already entered in the era of modern industrialization, even preparing to enter the 4IR (4^{th} Industrial Revolution). So, we are becoming more export oriented. Above 80% of our export products are ready-made garments. Now a day's world's manufacturing industries are going through a very competitive time due to Covid-19 situation. Surviving has become quite difficult. Many industries are trying to adapt some globally used tools and techniques, such as TPM (Total Productive Maintenance), to survive in the competitive market. This is a philosophical tool which mainly focused on to start an autonomous system that combine the manufacturing and maintenance which will prevent losses, reduce costs, and develop a system to properly use the capacity of machines. Some industries are trying their heart and soul to implement TPM. However, most of the industries are not being concern about the barriers of implementing; hence, they fail to take the proper countermeasure and fails to implement. The aim of this research is to identify barriers that are impeding TPM implementation. Initially fourteen barriers were identified and then reduced to ten through analysis and which are mostly related to the RMG sector. After that, a structural model of barriers is suggested using Total Interpretive Structural Modeling (TISM) technique. This model will help to understand contextual relationship among barriers and determined their interdependency. Lastly, MICMAC analysis has been done to determine the importance of barriers based on their driving power and dependency. The findings from this research shows that lack of top management's involvement and not implementing pilot-study, are the most important among barriers. Some other barriers like lack of education and training, no SOP, lack of KPI based analysis etc. also considered to be significant. These findings and its visual presentation through TISM model will help industrial managers to concentrate on barriers to prevent failure of TPM implementation. They will easily understand where to focus on and what preventive measure could be taken to effectively implement TPM in RMG sector.

Chapter 1
Introduction

1.1 Introduction

Total Productive Maintenance (TPM) is a systematic approach that enhance an organization's productivity and reduce costs by producing high quality goods and minimizing wastage. The Japanese initiated the concept in the sixties when they realized that increasing demand necessitated more specialized machines, which in turn required maintenance groups dedicated for this purpose. The TPM strategy for improving equipment reliability is to carry out regular daily maintenance by the operators while mandate to carry out specialized maintenance work, upgradation and modification jobs by the maintenance crew to minimize failures thereby increase machine availability, reduce costs and improve profitability of the organization. The concept looks simpler than the practical aspect. Implementation is very complex and it involves various stages each of which required focused attention. Otherwise TPM implementation process would bound to result in failure. Industries all over the world have struggled and failed to implement due to this reason. It's not a quick-fix methodology and requires commitment, dedication and perseverance from management and employees and have to work dedicatedly over the long run (in terms of years) to deliver visible results (Poduval et al., 2013)

In the era of modern manufacturing, organizations must possess both effective and efficient maintenance to be successful and achieve world-class manufacturing. Competition in market increased dramatically and to confront this challenge, company's leaders are benchmarking their organizations' performance and improve processes to catch up the competition. Because of this Total Productive Maintenance (TPM) is the best strategy to improve process (Baluch et al., 2012). It is one of the best strategies to increase availability and reliability of production machines /equipment (Ahmad et al., 2011). By reinforcing corporate structures, TPM activities eliminate all losses through the attainment of zero defects, zero failures, and zero accidents. Amid these, attainment of zero failures has the significant affect because failures directly lead to defective products and a lower equipment operation ratio, which in turn becomes a major factor for accidents (Sharma et al., 2012). For achieving zero defects and zero failures TPM addresses equipment maintenance through a comprehensive productive-maintenance delivery system covering the entire life of the equipment and involving all employees from production and maintenance personnel to top management. Although there are numerous books and case studies that exalt the benefits of TPM (Nakajima, 1988; Ahuja & Khamba, 2008a), some companies have decided that this approach to maintenance will not work for them (Patterson et al., 1995).

It is important to study new programs in details to understand how they actually support manufacturers' improvement efforts. The process of TPM implementation is a journey and not all companies are able to implement it successfully (Badli Shah, 2012). Implementation of any quality management program, especially TPM poses a number of challenges. A great infrastructure and commitment of all personnel from top management to bottom level is required while implementing it. Factors that are adversely affect the success of TPM implementation are known as barriers. The aim of this paper is to develop contextual relationships among the identified barriers using Total Interpretive Structural Modeling (TISM) and classified them depending upon their driving and dependence power. TISM is a well-established methodology for identifying relationships among specific barriers. Experts' opinion are taken to develop relationship matrix which later used to develop TISM model. Barriers are derived theoretically from various literature sources, and expert's discussion (see Table 1). Some barriers are extracted from the work of those who have explored TPM or have addressed a particular barrier in detail (Singh et al., 2014). To remain competitive in the global market, organizations seek to produce better quality and cost-effective products which forces organizations to adopt several approaches related to production process and planned maintenance, like Total Productive Maintenance (TPM) and Lean Manufacturing, to increase productivity and reduce cost of manufacturing. About 15-60% manufacturing cost is associated with the maintenance activities (Poduval, et al.,2013). In order to achieve the above goals, Manufacturing organizations have compelled to adopt new manufacturing philosophies to improve Overall Equipment Effectiveness (OEE) which is directly linked with availability and performance of the equipment (Singh et al., 2014; Attri et al., 2013). It is evident from the published literature that poorly maintained equipment caused machine downtime, loss of performance of equipment and produce poor quality products. As a result, manufacturing organizations are losing its competitive edge in the market and force to rethink about the conventional maintenance practices. TPM has been recognized as a new manufacturing paradigm ever since and widely accepted philosophy as most effective maintenance strategy by all organizations in general and manufacturing organizations in particular. Therefore, a handsome amount of literature is available which enlightens the effectiveness of TPM in manufacturing organizations. Ahuja et al. (2008b) gave a detailed review about TPM and summarized the eight pillars of TPM i.e., focused maintenance, planned maintenance, autonomous maintenance, education and training, quality maintenance, safety health and environment, development management and office TPM. Putro (2013) presented a study about implementation of 5S (as it considered the base of TPM) in Bengkel ABC organization that shows the successful implementation of 5S in spare and waste sections where about 30200cm2 space available. The study further added the 5S implementation provided an immediate return within 48 days. Cesar et al. (2014) reported a work related to autonomous maintenance and mentioned it as an important pillar of TPM as it reduces losses significantly by involving workers who are responsible for equipment working. The study concluded that repetitive maintenance problems are responsible for 80% of machine downtime which can be easily rectified by the worker after getting some training only 20% of the problems required external assistance. Salunkhe et al. carried out a study related to Kaizen which is another important topic of TPM. During the study, authors successfully implemented Kaizen and 5S to improve the inventory management in spare parts industry. Mentioned study focuses on implementing TPM in an industry making food grade packaging located in Lahore, Pakistan (Shehzad et al., 2018). The organization is pioneer and the biggest supplier of packaging product all across Pakistan such as beverages, food and fast-moving consumers' goods etc. The study has been carried out in the Business Flexible Unit of that mainly deals in flexible packaging for food stuff. Current work focused on identification of weak areas and then planning for TPM implementation considering the importance of TPM pillars. After successful implementation the improvement was gauged by overall equipment efficiency that provides very encouraging results.

1.2 Background and Present State of the Problem:

TPM is an innovative approach to maintenance that optimized equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance involving the total workforce (Poduval et al., 2013). The TPM strategy is widely used globally including our neighboring country. Industrial sector has a huge contribution in our rapid economic growth. But a very few numbers of industries are using TPM. Although there are a lot of research has been done on TPM implementation, research on the reasons behind the failure of TPM implementation are quite very few. The purpose of this project is to identify the barriers to the successful implementation of TPM in Bangladesh and create a structural framework by building relationship among them using TISM (Total Interpretive Structural Modeling) approach. TISM approach is a qualitative modeling technique used to analyze interaction among multiple factors. The application of TISM appears in several fields, including Supply chain (Sabuj et al., 2021; Attri et al., 2013), manufacturing Industry (Pradhani & Senapati, 2014), telecom service providers (Yadav & Sushil, 2014; Yadav & Sagar, 2021) and analyzing supply chain resilience (Rajesh, 2017; Zhao et al., 2019).

Analyzing barriers of implementing TPM in Bangladesh is very important because so that we can take proper measure to make a successful implementation and increase our sustainability in global market.

1.3 Research Gap and Motivation

The survival of companies depends on their ability to rapidly innovate and improve to compete in the local and global market accordingly, industries must start reviewing their methods, systems and others ways that they are using and try to modify through continuous improvement to sustain in the business. Implementation of TPM in industries, in service sectors have been examined by many scholars. However, throughout the implementation process of TPM, so many barriers have been arising that have impeded the actual growth of implementation of TPM, does not receive much attention as it should get. To address this issue, we worked to build a structural framework of barriers of TPM implementation for industrial managers to sustain global competition. Interactions among barriers need to be evaluated for formulating a structural framework. So, Total Interpretive Structural Modeling (TISM) approach can be applied to analyze the interactions among multiple factors. TISM, a qualitative modeling technique, is an extension of the Interpretive Structural Modeling (ISM). The application of TISM appears in several fields, including telecom service providers, manufacturing industry(Jain & Raj, 2015), and analyzing supply chain resilience (Rajesh, 2017).

Examining barriers for TPM implementation in industries is an essential topic to industrial managers in the manufacturing industry of Bangladesh. This study considers a case of a tube manufacturing industry and will examine barriers by means of TISM approach.

1.4 Objectives of the Present Work

The specific objectives of this project work are as follows:

1. To identify barriers to implement TPM in industries of Bangladesh.
2. To find the contextual relationships among identified barriers.
3. To suggest a structural model of barriers to implement TPM with the help of TISM approach.

The possible outcome of this work is a structural framework of barriers of implementing TPM in industries. This framework will help the company management to focus on the most significant barriers during implementation of TPM which influence the most.

1.5 Scope of the Thesis

This thesis consists of five chapters, along with a list of references and appendices. They are as follows:

Chapter 1 is entitled as "INTRODUCTION", which describes the motivation and background of this research for analyzing the barriers of implementing TPM in the manufacturing industry of Bangladesh. The research objectives and the outline of the methodology followed in this thesis are also described there.

Chapter 2 is titled as "LITERATURE REVIEW" that discussed the Theoretical background of TPM and its field of implementation. Previous work of TPM in different sectors also has been briefly discussed in this chapter. An overview of the manufacturing industry of Bangladesh and status of its TPM practices has been presented in Chapter 2.

The methodology followed for conducting the research has been presented in Chapter 3. The procedure is summarized in a flowchart. Then, the TISM methodology used for developing the frameworks of barriers is described in this chapter. The

Driving power and dependency of the factors has also been identified by using MICMAC analysis

The next portion of this thesis deals with developing a structural framework using TISM indicating the relationships among barriers of TPM implementation, which is illustrated in Chapter 4, named as “MODEL DEVELOPMENT OF BARRIERS USING TISM APPROACH”. Hierarchical relationships among the barriers are illustrated by the MICMAC analysis.

Chapter 5, termed as “CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH” briefly summarizes the work of this thesis, the findings and the managerial implications of this research along with recommendations for the future research. References and appendix are presented at the end of the thesis.

Chapter 2
Literature Review

Machine performance or equipment performance also directly related to the productivity, efficiency, and quality of products. A major percentage of defects of the product are due to the malfunction or improper setting of the machine. From the one-year machine related defects data of a case factory, it is very much visual that more than 53% of the defects are happening due to the machine or its setting related issue (Inspectorio | Supply Chain Management Software).

Defects	Percentage
Threads uncut	16.97%
Broken stitch	16.80%
Skipped stitch	13.87%
Puckering	6.04%
Total	**53.68%**

Defects cannot be omitted totally, but proper maintenance can significantly reduce the percentage of the defects related to machine where TPM works wonderfully. TPM not only suggests maintenance department to work but to involve everyone from helper to operator to manager of the organization to do some common routine maintenance work by themselves and maintenance department to monitor and do critical maintenance work. Industries are doing business for money and success and survive. And this could be archived only by providing faultless service and defect-free high quality products which are useful to customers for a reasonable price.

2.1 Total Productive Maintenance (TPM): Elaborate view

Total: it implies a comprehensive look at all activities that are related to maintenance of the equipment (Rotaru, 2008). It also involve the entire workforce of an organization – top, middle and lower level management and non-management personnel. Hence, here involve the most important word “OUR” – Our Plant, Our Machines, Our Processes, Our People. To be successful in TPM support from top management is crucial. Surprisingly, this act of involvement from the upper management works as a cohesive force to untie all the employees of the Organization.

Sincere support from all the employees of the organization is the most rung needed for successful implementation of TPM. They must involve right from the beginning till the very end of the implementation program.

Productive: *"Producing or able to produce large amount of goods, crops or other commodities"* is the dictionary form of definition of the word productive. The more you want to produce, the more you have to focus on eliminating waste and loses thus reducing costs. So, employees have to work sincerely and profoundly to get the maximum quality output. Therefore, it is obvious that employees of the organization have to involve completely to achieve these goals. For running a particular process or activity productively, persons with the required competencies are engaged. To ensure the right persons for the right job, a skill matrix is formed, then according to the matrix, the person placed into where they could do their best for the job. And if required, extensive training is carried out to the employees to not only enhance the skill, but also learn to eliminate waste and loss.

Maintenance: Main focus of the Maintenance part of TPM is to foster a sense of ownership among the operating personnel working in production and operation section. Traditional sense of maintenance, even in the present time, is maintenance department carried out all the maintenance work in the organization, while production section take care of the production and operation. Therefore Maintenance personnel are always so much busy finding the routine works solution that they barely find any quality time to spent analyzing failures and developing programs to prevent failures in future. A rigid barrier between operations and maintenance impede the progress of maintenance work which needs to be brought down. TPM concept express that operating personnel should take care of regular basis routine maintenance of the equipment like greasing, replacement of oil, cleaning, point to point checking etc. and freed up the maintenance personnel from regular checking to take care of modification programs which will result in increasing reliability and quality of goods produced. Hence, the concept is to develop ownership sense in the plant operator towards their equipment of daily use to competently carry out routine maintenance of the equipment (Poduval et al., 2013).

As a whole, Total productive maintenance (TPM) can be described as the systematic process of using machines, equipment, employees and supporting processes to maintain and improve the integrity of production and the quality of systems. Simply, it is the process of involving employees into the maintaining activities of their own equipment and encouraging proactive and preventive maintenance techniques. TPM strives for perfect production. That is:

- No breakdowns
- No stops or running slowly
- No defects
- No accidents

TPM emphasizes proactive and preventative maintenance to maximize the operational efficiency of equipment. It blurs the distinction between the roles of production and maintenance in the organization by placing a strong emphasis on empowering operators to help maintain their equipment (Agustiady & Cudney, 2018).

Traditional TPM

The traditional approach of TPM was first developed in the 1960s. The approach is a house like structure that consists of 5S (Sort, Set in Order, Shine, Standardize, and Sustain) as a foundation of the house and eight pillars as supporting activities to achieve a result. This structure in the figure is called "the house of TPM" which depicts the TPM at a glance.

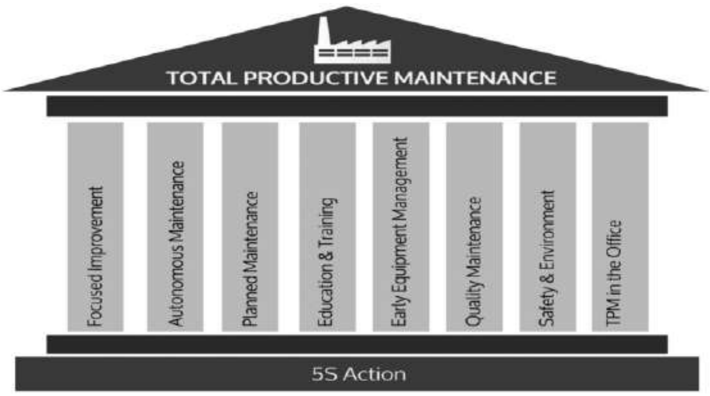

Fig. 2.1. Eight pillars of TPM

5S is a systematic approach for organizing and standardizing workplaces, so that work can be perform efficiently, effectively, and safely. This system allows to sort everything in the workplace based on their necessity, have places for everything from frequently used tools to less necessary work and keep them in an orderly manner, which makes it easier for people to do their jobs without wasting time or risking injury (Kumar et al., 2017).

This system focuses on putting everything where it belongs and keeping the workplace clean. The goal of 5S is to create a work environment that is clean, risk-free and well-organized. Elements of 5S are:

- Seiri - Sort (All relevant and irrelevant items should be sorted out and eliminate anything that is not necessary in the work area)
- Seiton - Set in Order (each and every sorted items should have a specific place to keep them in an organized way so that they can be identified and reached easily when needed)
- Seiso - Shine (Cleaning the workplace till it spic and span and inspect the work area, so that any kind of hazardous items or probability of defect could easily be spotted)
- Seiketsu - Standardize (Create standardization for performing the above three activities, display it and maintain the standard work practice)
- Shitsuke - Sustain (Sustain the progress made. Ensure the standards are following regularly. Keep a check-list and follow-up regularly.)

That is how 5S become the foundation of TPM as a vital part. It creates the environment and provide the basic minimum requirement for implementing TPM. For example, in a clean and well-organized work environment, tools and parts are much easier to find, and it is much easier to spot emerging issues such as fluid leaks, material spills, metal shavings from unexpected wear, hairline cracks in mechanisms, etc. (Devaraj et al., 2015)

TPM acts as a tool in the different areas of an organization samultaneously including office area to production area, aiming to increase productivity of office personnel as well as machines and increase overall equipment efficiency, reduce costs and defects, develop an autonomous maintenance based production chain involving all, from top management to bottom line people of an organization. TPM implementation considers everything from management to production to safety of an organization. It means including maintenance based production in every steps of the production processes to deliver final product. Industries can get more profits and competitive advantages in the market by implementing TPM in their organization.

However, in reality, implementation process of Total Productive Maintenance is lot more challenging and difficult than theory. It is very much time consuming, requires patience to have the result and have to face and overcome many predictable and non-predictable difficulties. Therefore, it is important to identify the barriers that affecting the implementation phase and develop a hierarchical relationship among them to learn where and how to start and manage.

2.2 About Total Interpretive Structural Modeling (TISM)

To find out the answer of the fundamental research questions like what, how and why, Total Interpretive Structural Modelling (TISM) approach, which acts as a theory building approach, helps researchers regarding this. This method helps to identify and define the variables (or barriers), find out the relationship between them and the reason for causality between variables. TISM is an upgrade version of interpretive structural modeling (ISM) technique. This extended methodology transforms unclear and poorly articulated models of systems (that are being studied) into clear, well-defined models. It uses experts' opinion to judge the variables, and interpret the relationship among the variables (Yadav & Sushil, 2014).

2.3 Barriers of implementing TPM

If an industry decides and comes to an agreement to implement TPM, they have to go through a lot of planning, processing, checking and many more steps. Throughout the process of implementation, a lot of predefined and ghostly obstacles will arise. These obstacles may be defined as "barriers". Barriers are the factors that negatively influence the implementation of TPM throughout the processes. At the initial stage, fourteen barriers are identified through literature review and experts' opinion and with a simple description they are presented in this chapter.

2.3.1 Lack of top management commitment, Involvement and understanding

Due to have the decision-making power and influential characteristics, role of top management's commitment, leadership and involvement of the management has been emphasized in many literatures. Hence, TPM programs in an organization can be effectively carried out if the top management is totally committed and involved throughout the implementation process.

TPM requires a radical change in the traditional mindset of present work culture and maintenance approach. However, during the implementation phase, middle managements are often encountered with the resistance from the operators and maintenance personnel. To this extent, active support from the top management during transition period played a crucial role. It is the responsibility of the top management to distill the benefits of TPM down the organizational levels. Management commitment for TPM implementation comes in the form of operator's time and a short-term investment of dollars that brings equipment into condition (Jostes & Helms, 1994; Ahuja & Khamba, 2007).

2.3.2 Resistance to change by employee

A common problem faced by management of this continent's organizations is *"This is not my job"*, a very simple sentence to avoid responsibility. When the work culture promotes such mindset, it is difficult to bring changes in the existing state of organization. When new approaches are introduced, employees become insecure about their job and develop a fear of losing it, hence, resist to accept the new concept. A narrow sense of vision hinders growth of an organization. It is the task of the management to align employees to the organization's vision and goals and remve insecurity from their mind.

2.3.3 Lack of proper training and education

Training and education enlighten the acting personnel, clear the concept and show a way to how with a new idea an organization could progress. Every position has their own side of training. But without training and education, concept of TPM cannot be delivered to the employees properly, therefore a gap created and proper implementation is hindered due to this. For implementing any new ideas, training to employees, are mandatory to make sure everything is understandable. Training open-up the mind and create acceptance of new approaches (Attri et al., 2014)

2.3.4 Failure to allow sufficient time and resources for the evolution

TPM implementation requires adequate resources, including money, people, a certain period of time to implement, appropriate choice of technology. But this could only be possible if top management could ensure that. Most of the time organizations are not willing to provide time and required resources, makes it difficult to work properly in long run (Mishra et al., 2008; Venkatesh, 2007; Ahuja & Khamba, 2007; Bamber et al., 1999).

2.3.5 Non-Implementation of pilot study

For a new concept, organization-wide implementation should be done only after implementing a pilot study on a specific area of requirement. Pilot-program requires a small area to initiate implementation. This a must step to follow to identify difficulties, and finding solutions to the problems uncovered in the pilot study. A pilot study is very important from the view point of uncovering productivity related issues.

2.3.6 Repair driven maintenance

This is an offshoot of attitude towards manufacturing process. In a large number of organizations, instead of carrying out maintenance jobs to avoid failure and repair, they focus is on carrying out immediate support to bring the machine back on line as fast as possible. Which resist maintenance personnel to develop and upgrade machine technology, make new tools to support production. So this acts as a barriers to implement TPM as it works with autonomous maintenance, planned maintenance etc. (Moore, 1997).

2.3.7 Poor relation between production and maintenance

Relationship between maintenance and production department is very much positive for the industry. Reliability of work and support increases in the work environment. Not having a reliable and good relation impacts the support system and hamper it, thus impede the growth of TPM as it required to work together.

2.3.8 Considering TPM activities as additional work/threat

Managements must be made a clear concept about TPM to the employees from top to bottom that it is not an extra burden on production, manufacturing or engineering, but are instead, ways to ease the accomplishment of their own goals. TPM introduced some monitoring system, reporting system to the production floor to properly monitor and acquire appropriate data for work and impose basic maintenance work like oiling to the machine, cleaning machine parts on a daily basis, learn some basic maintenance and does those without the help of maintenance department if minor problems are occurred. Not knowing the benefit, these works often overlooked and considered as additional, thus it refrains from proper implementation and taken as a burden by employees.

2.3.9 Lack of time for autonomous maintenance

Existing practice of organizations are doing maintenance activities only after a problem occurs, whereas regular maintenance work should be done by shop-floor worker and critical maintenance works by maintenance personnel. There should have a schedule when, how and by whom it should be done and check-list and audit system to ensure that these are done properly. But employees are not interested to do maintenance work by themselves because of the typical mindset of “this is not my work”. This resulting in an increase of machine related defects such as broken stitch, skip stitch, oil spot, puckering etc (Baluch et al., 2012).

2.3.10 Production pressure

TPM related works are often take as burden especially during the time of higher order quantity, pressure of complete production in time and to catch schedule of shipment. As a result priority of work changes and shifts from maintain TPM activities to on-time shipment. Thus create obstacle to maintain TPM practice (Rodrigues & Hatakeyama, 2006).

2.3.11 Non-availability of Standard Operating Procedures:

SOP (Standard Operating Procedure) is a set of clearly written down instructions of any activities that are carried out in the organization. They document the activities in such a way that facilitate conformance to technical and quality system and assist an organization to maintain quality control and quality assurance processes (United States Environmental Protection Agency, 2007). Clearly written down procedures ensure that the equipment are run properly and the probability of failure is minimal. But not following SOP or not having one causes loss of production and quality which works as a barrier.

2.3.12 Lack of KPI based analysis/performance-based analysis

While working with the organization that are implementing TPM, I found out that a set of KPIs that indicate overall performance of the processes as well as organization. Not setting KPIs for measuring performance can lead fail implementation of TPM as it cannot be defined whether the system is working or not. Increase/decrease of KPI indicated performance.

2.3.13 Lack of middle managements proper monitoring and corrective measure

During working in an organization where TPM is implementing, it is observed that middle management have to continuously monitor and keep track of the progress. But after a certain time of starting TPM, middle management started to overlook regular periodical monitoring and almost stop taking corrective measure which obstructs outgrowth of TPM As a result implementation impede and slow down. Role of middle management is very important in the implementation process and to keep consistency for long run.

2.3.14 Absence of reward system for sustainability

TPM implementation is unlike the normal routine activities carried out by the employees of an organization. It is a specialized job demanding specific skill sets. Employees whole heartedly invest their time and knowledge for a successful implementation and for this reason they should be publicly appreciated by the management for their efforts. Absence of that discourage employees to do the work and implementation will not properly work for long run.

2.4 Application of Total interpretive Structural Modeling (TISM) technique

ISM is an interactive learning process. In this technique, a set of different directly and indirectly related elements are structured into a comprehensive systematic model. The model so formed portrays the structure of a complex issue or problem in a carefully designed pattern implying graphics as well as words. It is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. For any complex problem under consideration, a number of factors/barriers may be related to the problem. However, the direct and indirect relationships between the factors/barriers describe the situation far more accurately than the individual factor taken into isolation. Therefore, ISM develops insights into collective understandings of these relationships.

Total interpretive structural modeling (TISM) enables depiction of intricate and complex relations of interrelated factors in the system in a graphical form and it is the nest stage of Interpretive Structural Modeling (ISM) technique (Sushil and

Gerhard, 2015). TISM is a modified and upgraded version of Interpretive Structural Modeling (ISM). The model incorporates interpretation of relation between each variable, may, it be a direct relation or transitive relation. It is used to understand the relationships amongst factors as also to identify hierarchy amongst them. [other 4]

In the paper by (Sabuj et al., 2021), presented contextual relationships among key factors related to environmental sustainability by using TISM

In the paper by Agarwal (2007), they analyze the agility variables of supply chain by using ISM and use MICMAC analysis to identify and to analyze the variables according to their driving power and dependence power towards supply chain agility.

In the paper of Jena et al. (2017), their motive is to elucidate the methodology of Total Interpretive Structural Modeling (TISM) in order to provide interpretation for direct as well as significant transitive linkages in a directed-graph.

In another paper of Agrawal & Vinod (2019), they used TISM method for analysis of factors that influencing a sustainable additive manufacturing and develop a structural model and use MICMAC analysis to carried out to categorize the factors. (Agrawal & Vinod, 2019)

This study considers the overall ready-made garments manufacturing industry of Bangladesh and will analyze the barriers that have to face during the implementation of TPM.

Chapter 3
Methodology

Identification of the interrelationship among barriers in implementing TPM in the manufacturing industry of Bangladesh is the core purpose of this study. The approach of data collection involves virtual discussions with senior personnel/executive heads using semi-structured interviews, mainly in the broader issue of 'implementing TPM in Bangladesh's manufacturing industry'. The research methodology used for this study is presented with a diagram illustrated in Figure 3.1.

3.1 Identification of barriers

By conducting a literature review, barriers of implementing TPM was identified. Initially, 14 number of potential barriers were taken out from the review. Then a questionnaire survey was made with those barriers and after contacting with the industry experts, the survey was sent to them for selection of most relevant barriers.

3.2 Development of the TISM model

Due to several advantages offered by TISM over ISM, this methodology is adopted it to analyze the barriers and develop a hierarchical structural among them (Jena et al, 2017). All the steps of developing the TISM model have been explained below (Ruben & Varthanan, 2019; Sabuj et al., 2021):

Step I: identification of the most relevant barriers

Basically, this step is the primary step of TISM. The most relevant barriers are finalized from the list of initially sorted barriers that are identified in the literature review. They are selected on the base of the opinion of industry experts. Statistical tools have been used to evaluate expert opinion.

Step II: Develop contextual relationship among barriers

This step describes why any barrier will be linked to or affected by the other barriers. It is of paramount important to describe the relevant relationship among the barriers. For this feature, Complex systems can be easily translated into TISM.

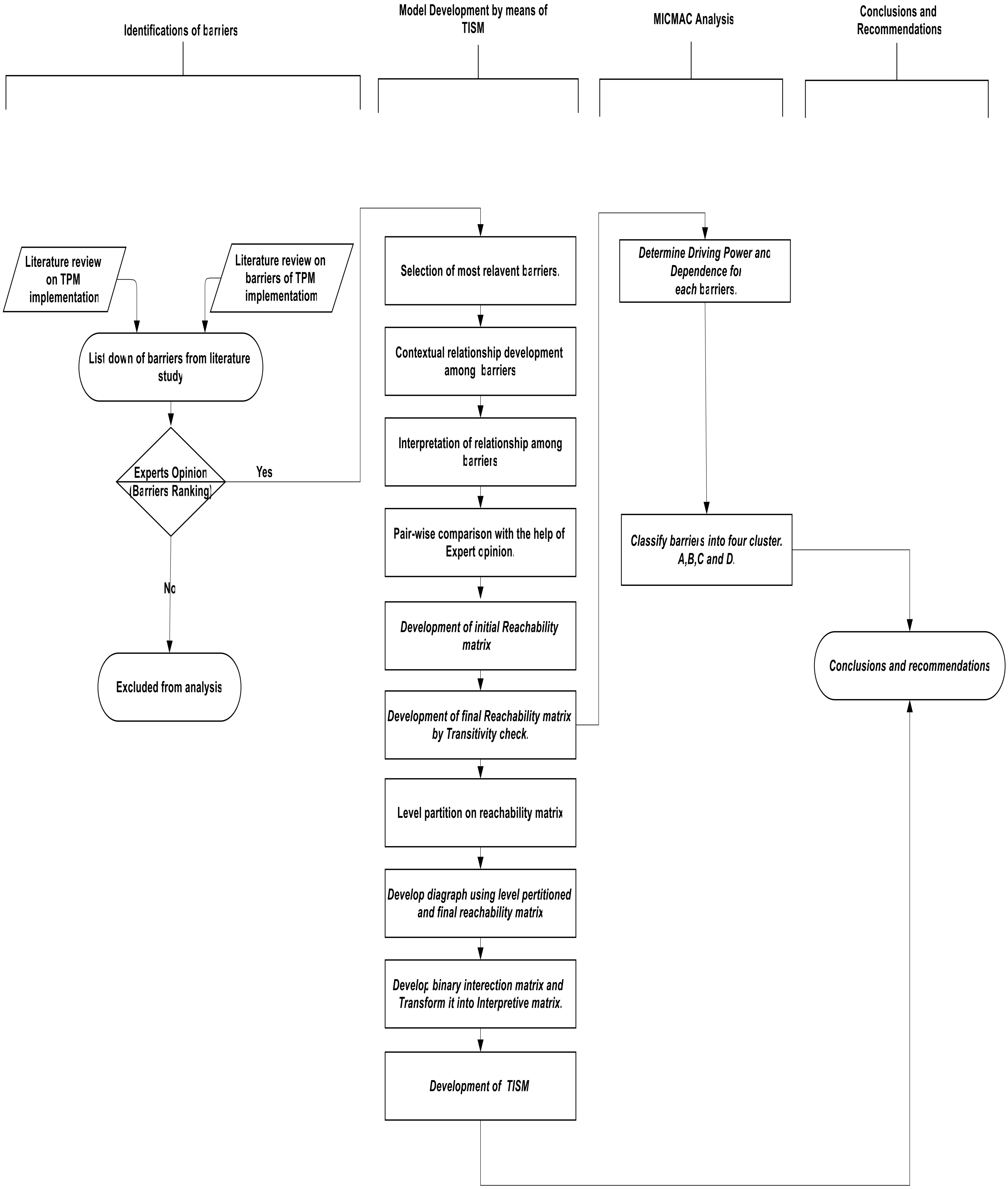

Fig. 3.1 Overall approach of the research methodology

Step III: Interpretation of relationship

This is considered as the first step towards the TISM that is required to further interpret the traditional ISM. Although traditional ISM seeks to capture contextual relationship, it does not reveal how this relationship really works. Therefore, clarification of the relationship in TISM is achieved by describing how one barrier will influence others. This explanation of relationship will help to get deep knowledge about interrelationship among barriers.

Step IV: Interpretive logic of pair-wise comparison

For pair-wise comparison, each element is individually compared with all the other elements. As there are two possible directional links i-j or j-i, total number of pair-wise comparison for n identified elements will be $n \times (n-1)$. Eventually there will be $n \times (n-1)$ numbers of rows in the knowledge base for performing study. An “Interpretive Logic- Knowledge Base” is developed for pair wise comparison, is represented by entry code “Y” for yes and “N” for no and if it is “Y”, it is further interpreted.

Step V: Development of Initial Reachability matrix

The initial reachability matrix was developed by converting yes to 1 and no to 0 according to the data that has been collected from the pair-wise comparison.

Step VI: Development of final Reachability matrix by transitivity test

In this step, the transitivity rule is applied to check the initial reachability matrix. According to this, "I" can be transitively connected with "K" while "I" is directly linked with "J" and "J" is linked with "K". Knowledgebase has been updated as "Y" for the new transitive link and inserted "transitive" in the Explanation column. If the transitive link is significant in nature, the reason behind its significance is also noted along with the "transitive" entry. Hence, the final reachability matrix developed from initial reachability matrix by transitivity check.

Step VII: Level determination by partitioning reachability matrix

The level portioning is performed to understand the level-wise placement of elements (Jharkharia and Shankar, 2004; Pandey and Garg, 2009). With the help of the final; reachability matrix, the reachability set and antecedent set for each element are determined. The reachability set for one particular element consists of the element itself and other element to which it will influence/enhance, whereas antecedent set for one particular element consists of the element itself and other elements, which will influence/enhance it. Further, intersection of those two sets is determined for all the elements.

The elements, for which the reachability set and intersection set are same, will achieve the top level in the TISM hierarchy. The elements in the top level of hierarchy would not reach any other elements above their own level. Therefore, the top level elements are differentiated from the other elements. The same procedure is carried out to find the next level of elements. This iteration is repeated till the level of each element is determined (Sushil, 2012; Dixit & Raj, 2017)

Step VIII: Develop digraph

Digraph which is also known as directed graph for factors is constructed by arranging all the factors at their respective levels determined in step VII and showing the links indicated by the relation displayed in the final reachability matrix. Among all the transitive relations, only those are considered whose interpretations are very important according to the opinion of the experts and if the combined significance of the transitivity link was at least 50%. (Sabuj et al., 2021)

Step IX: Interpretive Matrix

The final diagraph is converted into a binary interaction matrix form by depicting all interaction by “1” in the respective cells. Further, each cell with “1” is interpreted with respective relevant interpretation taken from the interpretive logic-knowledge base to form the interpretive matrix.

Step X: Total Interpretive Structural Model

By using the digraph and interpretation table, TISM has been developed for the identified barriers. From this TISM, the managers will be able to identify the relationship between those factors as well as prioritize the factors according to their importance.

3.3 MICMAC Analysis

MICMAC (Cross-impact Matrix Multiplication Applied to Classification analysis) is generally used as a classification analysis. The main purpose of this analysis is to identify the barriers which are responsible against implementation of TPM in the industry. Initially the driving power and the dependence powers of the barriers are identified and then the barriers are classified into 4 clusters like Cluster A, Cluster B, Cluster C and Cluster D (Jena et al., 2017).

Cluster A: Autonomous factor

These inhibitors have weak driving power as well a dependence. These are comparatively detached from the system, with which these have hardly any links, which may be considerably strong (Jena et al., 2017)

Cluster B: Dependent Factor

Basically this group contains those inhibitors that have weak driving power but strong dependence (Jena et al., 2017).

Cluster C: Linkage Factor

These inhibitors have strong dependence as well as strong driving power. These are unstable and so any action perform on these inhibitors will have an impact on others too. These are also take into account a feedback effect on themselves.

Cluster D: Independent Element

These inhibitors have strong driving power but weak dependence. It generally considered that aninhibitor that has a vry high driving power, also known as key inhibitor, comes in the group of indipendent.

The detailed calculation of the MICMAC analysis of the factors will be conducted in the following Chapter.

Chapter 4

Model Development of Barriers using TISM Approach

Interrelation among identified barriers of TPM implementation are developed by using TISM approach in this chapter. This is the focus of this chapter. Another focal point is to develop model. At first, relevant barriers are identified through literature review, and then academician's and industry expert's opinion are taken to select most relevant barriers. Once the most relevant barriers are finalized, we will follow step-by-step procedures to develop the model using TISM approach. Lastly, driving power of the factors that are negatively affect others and dependency of the factors are find out using the MICMAC analysis.

4.1 Identification and selection of relevant Barriers

Identification of the barriers is the primary step to develop the basic framework. In this study, a total number of fourteen possible barriers has been identified and finalized from the existing literature review. The summary has been given in the Table 4.1.

Table 4.1 Fourteen Possible Barriers of TPM Implementation.

Sl. No.	Factors	Description	References
1	Lack of top management's commitment, involvement and understanding	TPM implementation is initiated by top managements of any organization, hence their continuous involvement, support and understanding is required to implement TPM. If not, this creates the major barriers towards implementing TPM.	Ahuja & Khamba (2008a, 2007), Mishra et al. (2008), Brah and Chong (2004), Hansson et al. (2003) and Bamber et al. (1999)
2	Resistance to change by	Employees being reluctant to change, hence fear of failure, works as a barrier	Venkatesh (2007), Ireland and Dale

	employee	as TPM brough some positive changes in day-to-day work	(2001), Cooke (2000), Maggard and Rhyne (1992) and Bamber et al. (1999)
3	Lack of proper understanding, training and education	from starting until achieve result, lack of proper training and education may create misunderstanding and leads to wrong result instead of success.	Mishra et al. (2008), Venkatesh (2007), Rodrigues & Hatakeyama (2006) and Bamber et al. (1999)
4	Failure to allow sufficient time and resources for the evolution	TPM implementation requires some time and resource support to properly flourish in better way, and most of the time organizations are not willing to provide time and resources, makes it difficult to work properly	Ahuja & Khamba (2008a, 2007), Venkatesh (2007) and Bamber et al. (1999)
5	Non-implementation of pilot study	Pilot-program requires a small area to initiate implementation to identify upcoming problems and find solutions, which, most of the organization are not willing to do and face unexpected problems during the implementation	Ahuja & Khamba (2008a, 2007),
6	Repair driven maintenance	Repair increases loss of time, money and resources which impede TPM implementation	Moore (1997)
7	Poor relation between production and maintenance	Production and maintenance department's poor relation hindered the growth of TPM as autonomous maintenance is a must require. And also, this kind of relation causes loss of production and money.	Ahuja & Khamba (2008a, b)
8	Considering	TPM requires some systematic works to	Ahuja & Khamba

	TPM activities as additional work	be done in each and every process throughout the organization. Not knowing the benefit, these works often overlooked and considered as additional, thus it refrains from proper implementation	(2008a, 2007), Rodrigues & Hatakeyama (2006) and Bamber et al. (1999)
9	Lack of time for autonomous maintenance	We are used to do maintenance activities only after a problem occurs which resist proper implementation, whereas it should be done regularly and frequently by everybody involved.	Rodrigues & Hatakeyama (2006), Thun (2006), Ahmed et al. (2005) and Bamber et al. (1999)
10	Production pressure	Load of production and pressure to complete in time creates obstacle to maintain TPM practice.	Rodrigues & Hatakeyama (2006), Thun (2006) and Bamber et al. (1999)
11	Non-availability/following of Standard Operation Procedure (SOP)	SOP requires to make process standard including all necessary steps to maintain proper production. But not following SOP or not having one causes loss of production and quality which works as a barrier.	Ahuja & Khamba (2008a, 2007)
12	Lack of KPI based analysis/performance based analysis	KPI indicates vital focal points. Keeping kpi up is organization's motto and all the work done have ultimate goal to improve it, hence improve organization. TPM focuses on KPI's and performance and lack of these can lead to fail implementation of TPM.	Expert opinion
13	Lack of middle	After certain time of starting TPM implementation, middle management	Expert opinion

	management's proper monitoring and corrective measures	overlook periodical monitoring and reporting problem for revise or only change that obstructs outgrowth of TPM.	
14	Absence of Reward system for sustainability	Although TPM implemented in some extent, it would be difficult to sustain for long run if there is no proper recognition system.	Ahuja & Khamba (2008a, 2007), Rodrigues & Hatakeyama (2006) and Bamber et al. (1999)

After done listing, these fourteen barriers are analyzed and with the help of industry expert's opinion, the most relevant barriers are selected for further analysis and draw conclusion. To do so, a questionnaire survey form developed with listed barriers, and send to the experts for their opinion. The Experts taking part in this selection process have extensive knowledge on TPM and process of implementation. They have 5 to 10 years of experience in the relevant field and directly or indirectly being involved with the manufacturing process. For effective result, it is better that the number of cases studied is in the range from 4 to 10. In this study we considered four ready-made garments factories, one association and one buying house organizations. A total of eight (08) experts were interviewed in two phases. Primarily, experts were communicated and provided with the questionnaire shown in the Appendix 1 for their initial observation. And then, a Zoom meeting was arranged with the experts as because of the pandemic, it was difficult and unsafe to meet person-to-person. Expert's opinion and given number were taken from the interview and put it on the chart to get the result. The questionnaire includes all the barriers (14 no.) that has numbering options ranging from 1 to 5. Number 5 being the most relevant and number 1 being the least relevant. This numbering system called Likert scale (Balon, et al., 2016). The profile of the experts are included in the Appendix 2. After their interview, based on the numbering, 10 barriers were selected. These are considered to be the most significant barriers according to the scoring system. The barriers with average score of 3.5 or above (75 percent) were selected for further research (Rajesh, 2017).

The score and selection of the factors can be viewed in Appendix 3. Finally, selected list of barriers is shown in Table 4.2.

Table 4.2 Selected list of relevant barriers

Barrier Code	Name of the selected most relevant barriers
F1	Lack of top management's commitment, involvement and understanding
F2	Resistance to change by employee
F3	Lack of proper training and education
F4	Non-implementation of pilot study
F5	Repair driven maintenance
F6	Poor relation between production and maintenance
F7	Considering TPM activities as additional work
F8	Non-availability/following of Standard Operation Procedure (SOP)
F9	Lack of KPI based analysis/performance-based analysis
F10	Absence of Reward system for sustainability

4.2 Contextual relationship development among Barriers

To identify the contextual relationship among the barriers, expert's consultation were taken through questionnaire where the contextual relationship between barriers is represented as "Barrier A will negatively influence Barrier B". All the questions are basically a "yes or no" type questions and answer will either be "Yes" or "No" based on the relationship between the barriers.

4.3 Interpretation of relationship

In this step, to interpret relationship among barriers, if any of the barriers negatively influences any other barrier, the experts not only indicate "barrier A will negatively influence barrier B", but also explain how a barrier affecting another. This is the first step that gives TISM advantage over ISM.

4.4 Interpretive logic of pair-wise comparison

The interpretation of barriers was used to construct a databased matrix of pair-wise comparison. There are 10 selected barriers in total. Each of the barrier has been compared with another barriers saying how it would negatively affect the others. So, there were 10*9 or 90 rows of pairwise comparison with description of how each is being affected. A questionnaire set has been sent to the experts. Based on their response reachability matrix and pair-wise comparison has been developed.

Reachability matrix has two responses including 1 and 0. If 60% of the response is given "Yes", then it is taken as 1, otherwise 0 (Jain & Raj, 2015). Appendix 4 shows the result of the contextual relationship database.

4.5 Initial Reachability Matrix Development

From the interpretive logic of pair-wise comparison the initial reachability matrix has been developed. Matrix contains "1" where the pair-wise relation is yes, otherwise "0". The matrix is illustrated in Table 4.3.

Table 4.3 Initial Reachability Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	1	1	1	0	0	1	1	1	1
F2	1	1	0	0	0	1	1	0	0	0
F3	0	1	1	0	1	0	1	1	0	1
F4	0	0	0	1	0	0	1	1	0	0
F5	0	0	0	0	1	1	1	1	1	0
F6	0	1	0	0	1	1	0	0	0	0
F7	0	1	0	0	0	0	1	1	0	0
F8	0	0	1	0	1	0	0	1	1	0
F9	0	0	0	0	1	0	1	0	1	0
F10	0	1	0	0	0	0	0	0	1	1

4.6 Development of final Reachability matrix by transitivity test

The barriers themselves have direct and indirect both type of relationship. Initial reachability matrix shows direct relationship whereas in final reachability matrix, indirect relationship is included. To identify the indirect relationship between barriers, initial reachability matrix is checked for the transitivity rule. The barriers which passed the transitivity test, their values were changed from 0 to 1 and also given a (*) in the upper right side for identification. After that, final reachability matrix has been developed which is shown in Table 4.4.

Table 4.4 Final Reachability Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Driving
F1	1	1	1	1	1*	1*	1	1	1	1	10
F2	1	1	1*	1*	1*	1	1	1*	1*	1*	10
F3	1*	1	1	0	1	1*	1	1	1*	1	9
F4	0	1*	1*	1	1*	0	1	1	1*	0	7
F5	0	1*	1*	0	1	1	1	1	1	0	7
F6	1*	1	0	0	1	1	1*	1*	1*	0	7
F7	1*	1	1*	0	1*	1*	1	1	1*	0	8
F8	0	1*	1	0	1	1*	1*	1	1	1*	8
F9	0	1*	0	0	1	1*	1	1*	1	0	6
F10	1*	1	0	0	1*	1*	1*	0	1	1	7
Driven	6	10	7	3	10	9	10	9	10	5	

4.7 Level of barriers determination by partitioning reachability matrix

To determine the level of barriers, a total of 5 iterations were required from the final reachability matrix. Step by step iteration have been shown in Table 4.5(a) the summary matrix has been shown in Table 4.5(b)

Table 4.5(a) Level Partition Matrix

Iteration # 1

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
F1	1,2,3,4,5,6,7,8,9,10	1,2,3,6,7,10	1,2,3,6,7,10	
F2	1,2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9,10	1
F3	1,2,3,5,6,7,8,9,10	1,2,3,4,5,7,8	1,2,3,5,7,8	
F4	2,3,4,5,7,8,9	1,2,4	2,4	
F5	2,3,5,6,7,8,9	1,2,3,4,5,6,7,8,9,10	2,3,5,6,7,8,9	1
F6	1,2,5,6,7,8,9	1,2,3,5,6,7,8,9,10	1,2,5,6,7,8,9	1
F7	1,2,3,5,6,7,8,9	1,2,3,4,5,6,7,8,9,10	1,2,3,5,6,7,8,9	1
F8	2,3,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9	2,3,5,6,7,8,9	
F9	2,5,6,7,8,9	1,2,3,4,5,6,7,8,9,10	2,5,6,7,8,9	1
F10	1,2,5,6,7,9,10	1,2,3,8,10	1,2,10	

Iteration # 2

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
F1	1,3,4,8,10	1,3,10	1, ,3, 10	
F3	1,3,8,10	1,3,4,8	1,3 ,8	
F4	3,4,8	1,4	4	
F8	3,8,10	1,3,4,8	3,8	
F10	1,10	1,3,8,10	1,10	2

Iteration # 3

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
F1	1,3,4,8	1,3	1,3	
F3	1,3,8	1,3,4,8	1,3,8	3
F4	3,4,8	1,4	4	
F8	3,8	1,3,4,8	3,8	3

Iteration # 4

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
F1	1,4	1	1	
F4	4	1,4	4	4

Iteration # 5

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
F1	1	1	1	5

Table 4.5(b) Summary of Level Partition Matrix

Barrier Code	Name Of the Barrier	Level
F2	Resistance to change by employee	1
F5	Repair driven maintenance	
F6	Poor relation between production and maintenance	
F7	Considering TPM activities as additional work	
F9	Lack of KPI based analysis/performance-based analysis	
F10	Absence of Reward system for sustainability	2
F3	Lack of proper understanding, training and education	3
F8	Non-availability/following of Standard Operation Procedure (SOP)	
F4	Non-implementation of pilot study	4
F1	Lack of top management's commitment, involvement and understanding	5

4.8 Development of digraph

After the level iteration done, a graphical diagram of barriers has been drawn according to the level determined by iteration and linked the barriers according to the relationship based on final reachability matrix. Not all transitivity links are shown in the diagram. Only the crucial ones are shown. During the transitivity check, if experts' responses are more than 50%, then the transitivity taken as significant transitivity (Jain & Raj, 2015). Developed diagraph is shown in Figure 4.1.

4.9 Development of Binary interaction matrix and Interpretive Matrix

A binary interaction matrix has been developed from the final diagraph which is shown in Table 4.6. The interpretation of diagraph known as interpretive matrix also have been prepared and shown in Table 4.7.

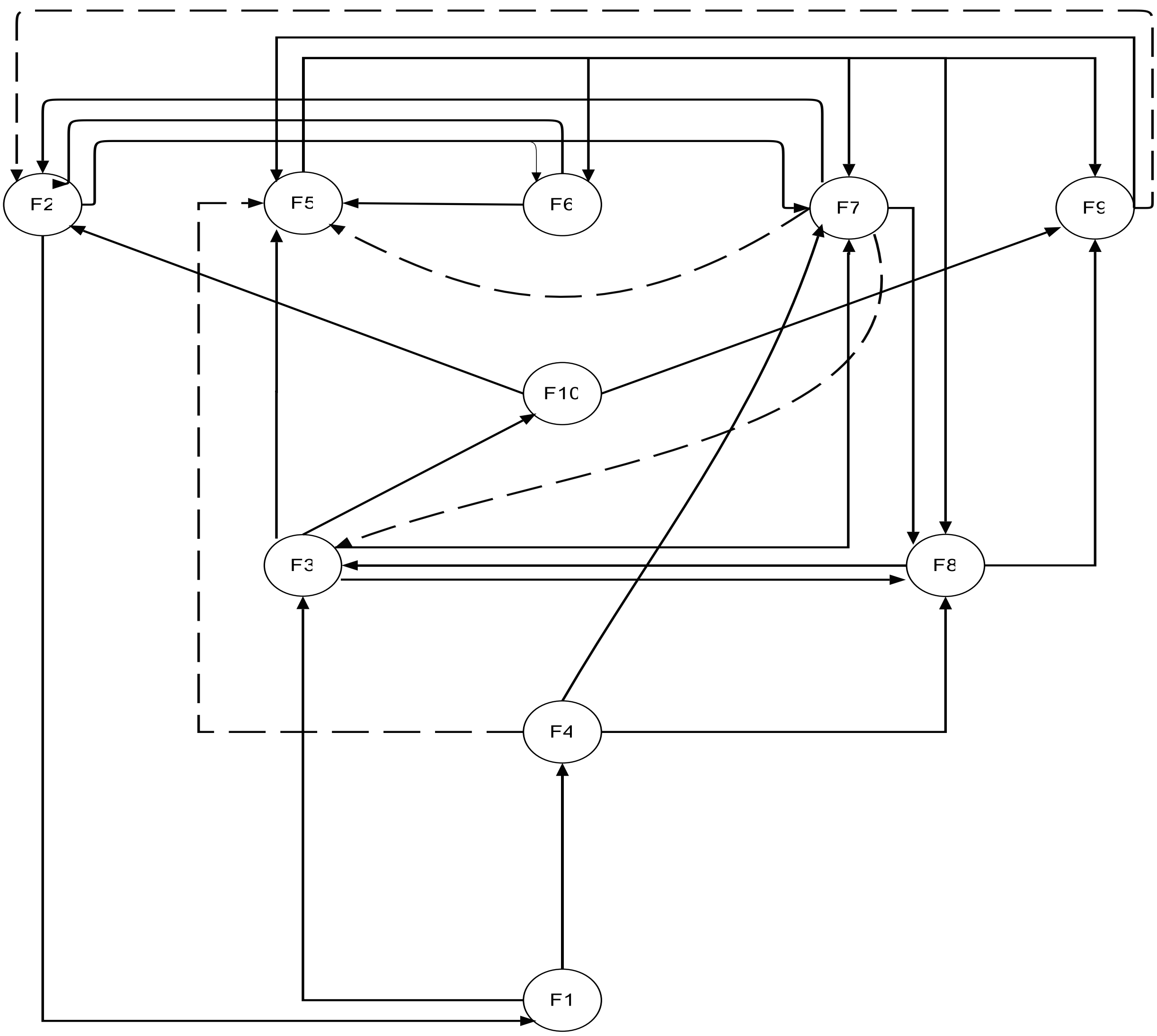

Figure 4.1: Diagraph of Initial Framework of Barriers.

Table 4.6 Binary Interaction matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	-	0	1	1	0	0	0	0	0	0
F2	1	-	0	0	0	1	1	0	0	0
F3	0	0	-	0	1	0	1	1	0	1
F4	0	0	0	-	1*	0	1	1	0	0
F5	0	0	0	0	-	1	1	1	1	0
F6	0	1	0	0	1	-	0	0	0	0
F7	0	1	1*	0	1*	0	-	1	0	0
F8	0	0	1	0	0	0	0	-	1	0
F9	0	1*	0	0	1	0	0	0	-	0
F10	0	1	0	0	0	0	0	0	1	-

(* Refers to Significant Transitive Linkage)

Table 4.7 Interpretive matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1			By not creating proper influence for the need of training	By not giving importance to pilot program rather to implement directly.						
F2	motivation and influence come from the top personnel					Old mindset does not allow to accept changes	Cannot accept change, hence new activities act as a burden to them			
F3					The less the knowledge of autonomous maintenance, the more the maintenance after broken develop		Do not know the importance of TPM activities	Less knowledge, less understanding of SOP		Designing of proper reward system is based on knowledge
F4					Not introducing pilot program leads to high repair-based maintenance as potential risk is unknown		To better understand of hoe TPM works	Development or correction of existing SOP will perfectly possible if pilot-run can be implemented		

F5						Production wants continuous support from maintenance whereas practically it is not possible	Repair consume valuable time, so it becomes difficult to maintain TPM activities	SOP doesn't contain repair driven maintenance rather focuses on autonomous maintenance	It is a crucial part of KPI	
F6		It influences employees to play blame-game			From repair-driven to convert autonomous, proper support and collaboration is needed					
F7		Do not want to do works related to TPM, hence resistance develop against change	Considering TPM as additional work indirectly leads to not having any interest to know something new, hence lack of training and education		TPM includes autonomous maintenance which leads to low repair-driven maintenance. So considering it as additional job, increase repairing chances.			Considering TPM as additional activities leads to not include these essential works in the SOP, if available.		
F8			SOP (if available) provides a clear understanding of existing procedure						SOP prevents from falling performance	
F9		KPIs clarify the focuses of any organization. Not knowing how KPI impacts overall performance, employees cannot accept new works and changes.			KPI based performance is invertedly depends on frequency of repair					
F10		Reward system creates positive mindset							To improve and sustain certain improvements, it is required to have reward system	

4.10 Development of Total Interpretive Structural Model

The initial total interpretive structural model of barriers, has been developed based on the diagraph and the interpretive matrix. A TISM based model of barriers is presented in Figure 4.2.

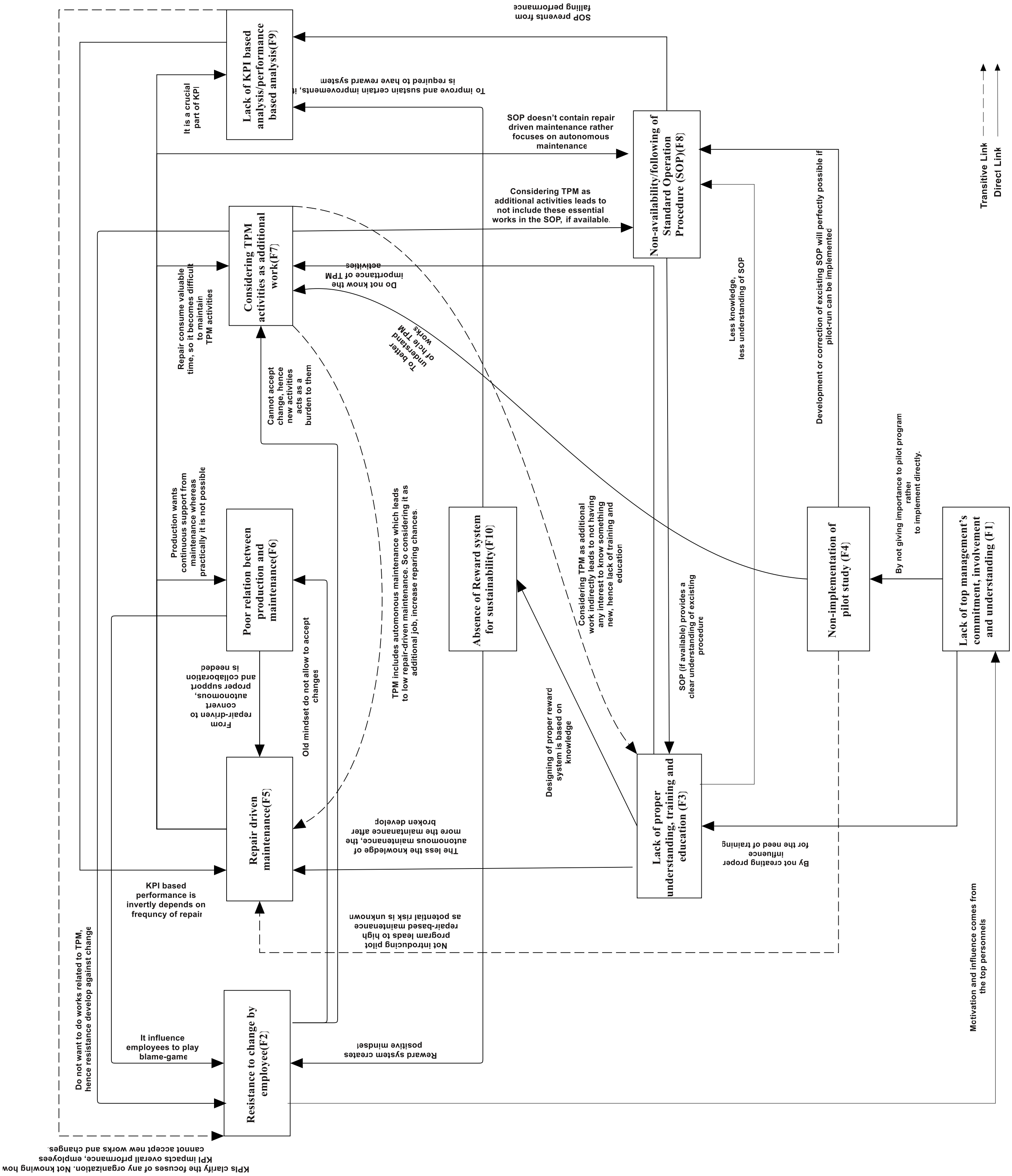

Figure 4.2: TISM based model of barriers.

4.11 MICMAC Analysis:

MICMAC analysis has been used to segregate the barriers into 4 clusters based on their Driving power and dependency. Initially the driving power and the dependence of the barriers are identified from the final reachability matrix. Table 4.8 has presented the total driving power and the dependence of the TPM implementation barriers in the industry of Bangladesh. The driving power and dependence of each barrier has been determined by sum-up all "1" exist in the rows and columns of final reachability matrix. Sum-up of all rows represent the driving power and all columns represents the dependence of each barrier.

Table 4.8: Final reachability matrix with driving power and dependence

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Driving Power
F1	1	1	1	1	1*	1*	1	1	1	1	10
F2	1	1	1*	1*	1*	1	1	1*	1*	1*	10
F3	1*	1	1	0	1	1*	1	1	1*	1	9
F4	0	1*	1*	1	1*	0	1	1	1*	0	7
F5	0	1*	1*	0	1	1	1	1	1	0	7
F6	1*	1	0	0	1	1	1*	1*	1*	0	7
F7	1*	1	1*	0	1*	1*	1	1	1*	0	8
F8	0	1*	1	0	1	1*	1*	1	1	1*	8
F9	0	1*	0	0	1	1*	1	1*	1	0	6
F10	1*	1	0	0	1*	1*	1*	0	1	1	7
Driven	6	10	7	3	10	9	10	9	10	5	

After that, barriers are plotted on a diagram based on their driving power and dependence and segregated the barriers into 4 clusters named as Cluster A (Autonomous Factor), Cluster B (Dependent Factor), Cluster C (Linkage Factor) and Cluster D (Independent Factor).

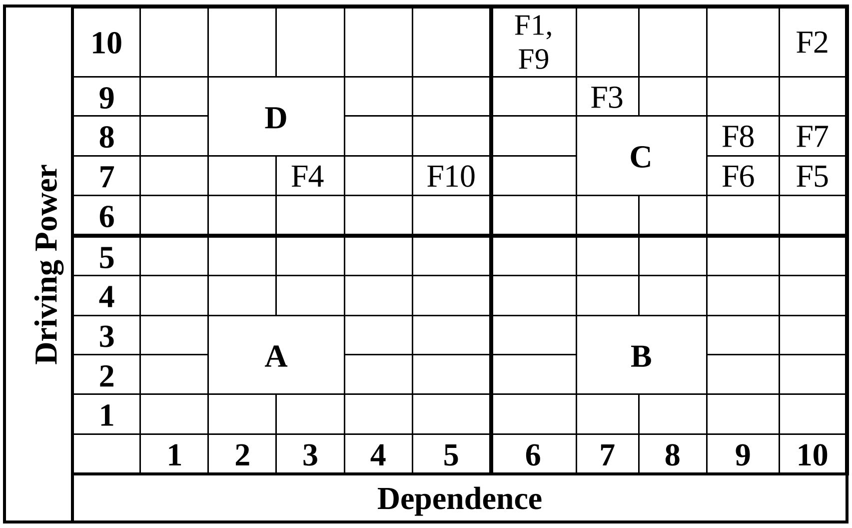

Figure 4.3: MICMAC Analysis of the barriers of TPM Implementation

4.11.1 Cluster A: Autonomous Factor

Segment A is known as Autonomous Factors which represents data fall in this segment has very weak driving power as well as dependence. As per plotted data in the Figure 4.3 there is no barriers fall into this segment A. That means there is no factors in the system having comparatively very weak driving power as well as dependence.

4.11.2 Cluster B: Dependent Factor

Cluster B represents strong dependence over weak driving power. Again, from the Figure 4.3 it can be seen that no factors has fallen in this segment. That means there is no barriers having strong dependence over other factors but weak driving power.

4.11.3 Cluster C: Linkage Factor

Cluster C known as Linkage Factor, represents those have strong driving power and dependence. Barriers having strong driving power and strong dependence are plotted in this cluster. Lack of top management’s commitment, involvement and understanding (F1), Resistance to change by employee (F2), Lack of proper understanding, training and education (F3), Repair driven maintenance (F5), Poor relation between production and maintenance (F6), Considering TPM activities as additional work (F7), Non-availability/following of Standard Operation Procedure

(SOP) (F8) and Lack of KPI based analysis/performance based analysis (F9) are in this cluster.

4.11.4 Cluster D: Independent Factor

Segment D represents strong driving power but low dependence. Non-implementation of pilot study (F4) and Absence of Reward system for sustainability (F10) have strong driving power but low dependence over other barriers which are in Cluster D.

4.12 Discussion of Findings

The final model of barriers obtained from our TISM-based analysis provides important insights by quantifying the levels of barriers, and then prioritizing them accordingly. More specifically, we established that "Lack of top management's commitment, involvement and understanding" (F1), "Non-implementation of pilot study" (F4), provide the basic grounding of the model. Total Productive Maintenance is an emerging topic for country like Bangladesh. Many organizations and industries are trying to adopt this as their core techniques to improve the overall performance of the organization. Bangladesh government is also taking this seriously and National Productivity Organizations (NPO) under Ministry of Industry initiate Kaizen (used in TPM) program to let people know about it. In Bangladesh, very few industries are there whom introducing TPM fully or partially in their organizations. Furthermore, many other organizations trying to introduce it. Bur many obstacles are arises even during the introducing stage known as barriers. If TPM are introduced, for its long run nature, many organization's top management lost their interest on it, be less involved day by day. For this reason, TPM stumbling to bloom in its initial stage and ultimately vanished. Another barrier is directly go to the implementation stage instead of pilot-program. Which leads tons of problem arise during the implementation stage. As a result, progress fall immediately and in some case full implementation turns into a failure project. So instead of study "how to get success", one should study "what are the barriers to success and how to prevent them".

Meanwhile, we found that Resistance to change by employee (F2), Repair driven maintenance (F5), Poor relation between production and maintenance (F6), Considering TPM activities as additional work (F7), Lack of KPI based analysis/ performance based analysis (F9) have the strong driving power as well as driven power and have most of the linkage with others. It means that these barriers have most influence and also can also be influenced by others. Inter dependency is high.

However. there are no barriers have weak driving power and dependence. Also no barriers have strong dependence but weak driving power. Each and every barriers have powerful impact on hindering implementation of TPM.

Our research also shows that intermediate barriers like Lack of proper understanding, training and education (F3), Non-availability/following of Standard Operation Procedure (SOP) (F8), Absence of Reward system for sustainability (F10) directly interrelated with other barriers. These barriers also affected by the previous partition as well as it can drive nest level partitions too. To overcome other barriers, educate people, arrange proper training with appropriate materials, involve third party trainer to make sure a good overall understanding is a must. Even follow-up regularly after training is must to see whether it is working or not. To a successful implementation, SOP of each step of manufacturing should be present and displayed in a visible area. Also there should be a check-list to confirm SOP is followed properly. Last but not least, sustainability is the key to success. Not being sustainable in each phase leads to the failure of any project. To keep sustainability, reward system can be great way to give people encouragement. Absence of reward system is a barriers that can effect long term plan.

As noted previously, this thesis used MICMAC analysis to visually categorize and cluster the barriers as per their driving power and dependence. According to this, F4 and F10 have high driving power and other have both high driving power as well as being driven by other factors.

CHAPTER 5

Conclusion and Recommendations for Future Research

The chapter briefly presented the summary of the research conducted, findings and the managerial implications. Recommendations for the future research are also presented here.

5.1 Conclusion

Bangladesh is now on the process of entering in to developing country from the LDC (least developed country). Moreover, the Covid-19 pandemic has a colossal impact on social life and economical condition of this small country. The social and economic gain we have achieved through rapid industrialization have faced a lot during the pandemic. GDP growth has been declined, inflation has been increased, a lot of people lost their job and business that leads them to leave behind their house and business and go back to village. Among all the sectors, internal production industries and garments industries have played the prime mover roll. Internal market flow increased; export increased. This rapid growth creates a fuss and due to the pandemic, labor cost increased, cost of material increased, availability of some resource is declined due to the war between Russia and Ukraine. So, industries are opting more sustainable way like TPM to get the best result from the existing resources. As it is a philosophy, it is difficult to understand the concept well and make it presentable and reasonable to the top-bottom related personnel of the organization. Because though it is a not a new concept, but most of the people of the organization is not familiar to this concept. So, it is relatively a tough job to implement TPM and take a long time to sustain for long run. Basically, there are so many barriers, but we took some major ones, analyze them and develop a structural framework using TISM approach to show which barriers to be work with first. Hence this thesis aimed to develop structural frameworks of barriers of TPM implementation in the manufacturing industries of Bangladesh. The contribution of this research is to actually find out the barriers of that are affecting more to the TPM implementation by showing their driving force and being driven. The identification of barriers was done from a review of relevant literature and consultation with the industry experts.

Lack of top management's commitment, involvement and understanding, Resistance to change by employee, Lack of proper understanding, training and education, Non-implementation of pilot study, Repair driven maintenance, Poor relation between production and maintenance, Considering TPM activities as additional work, Non-availability/following of Standard Operation Procedure (SOP), Lack of KPI based analysis/performance based analysis, Absence of Reward system for sustainability are the significant barriers of TPM implementation in the manufacturing industries of Bangladesh.

Using the TISM quantitative tool, structural framework of the barriers has been developed. The framework also displays that, barriers have influenced each other. That is, one barrier can influence another one or more barriers and simultaneously impede the growth of TPM introduced. The driving power and the dependence of all barriers were identified and subsequently categorized into four clusters with the help of MICMAC analysis.

After doing MICMAC analysis and analyzing the structural framwork of barriers, Lack of top management's commitment, involvement and understanding (F1), Resistance to change by employee (F2), Lack of proper understanding, training and education (F3), Repair driven maintenance (F5), Poor relation between production and maintenance (F6), Considering TPM activities as additional work (F7), Non-availability/following of Standard Operation Procedure (SOP) (F8), Lack of KPI based analysis/performance based analysis (F9) have both, strong driving power and dependence. They influence others, and also be influenced by others. These barriers should be focused on first when any organization wanted to start TPM, so that they can take proper measure even before starting and organize work plan accordingly. Two barriers have high driving power and those should closely monitor as they are influence others.

5.2 Recommendations for Future Research

TISM technique has been used to construct the represented framework for the barriers identified. To check the validity of the TISM Model some other tools such as fuzzy TISM can be used to conduct the same research. For the validation of the proposed theoretical model here, Structural Equation Modelling (SEM) technique can be used. In this research, initially fourteen barriers were taken and then it was reduced to most crucial ten according to the industry expert's opinion. More factors may have been included in future studies for conducting this experiment. In this research MICMAC analysis tool has been used to identify the driving power and the dependency of the barriers. Similar research work can be conducted in the future by using another analysis tool such as Fuzzy MICMAC. This research has been focused on the garment manufacturing industry of Bangladesh. Similar research methodologies are also applicable to any other industry, even service sectors. For this research, data has been collected from experts of four case study factories and from some other organizations related to this sector. In the future research more factories and organizations experts can be included.

REFERENCES

Agarwal, A., & Ravi, S., Tiwari, M.K. (2007). Modeling Agility of Supply Chain', *Industrial Marketing Management, 36(4),* 443–457. DOI:10.1016/j.indmarman.2005.12.004

Agrawal, R., & Vinodh, S., (2019). Application Of Total Interpretive Structural Modeling (TISM) for Analysis of Factors Influencing Sustainable Additive Manufacturing: A Case Study. *Rapid Prototype Journal*. DOI:10.1108/RPJ-06-2018-0152

Agustiady, T. K., & Cudney, E. A. (2018). Total productive maintenance. *Total Quality Management & Business Excellence,* 1-8. https://doi.org/10.1080/14783363.2018.1438843

Ahmad, R., Min, C.S., Kamaruddin, S., & Azid, I.A. (2011). Development of Autonomous Maintenance Implementation Framework for Semiconductor Industries. *Int. J. Industrial and Systems Engineering, 9(3),* 268–297. DOI:10.1504/IJISE.2011.043139

Ahuja, I.P.S., & Khamba, J.S. (2008b). Total Productive Maintenance: Literature Review and Directions‖. *International Journal of Quality & Reliability Management, 25(7),* 709-756. DOI:10.1108/02656710810890890

Ahuja, I.P.S., & Khamba, J.S. (2008). Strategies and Success Factors for Overcoming Challenges in TPM Implementation in Indian Manufacturing Industry. *Journal of Quality in Maintenance Engineering. 14(2),* 123-147. DOI:10.1108/13552510810877647

Ahuja, I.P.S., & Khamba, J.S. (2007). An Evaluation of TPM Implementation Initiatives in an Indian Manufacturing Enterprise. *Journal of Quality in Maintenance Engineering, 13(4),* 338-352. DOI:10.1108/13552510710829443

Attri, R., Grover, S., Dev, N., & Kumar, D. (2013). Analysis of barriers of total productive maintenance (TPM). *International Journal of System Assurance Engineering and Management, 4(4),* 365-377. https//:10.1007/s13198-012-0122-9

Attri, R., Grover, S., & Dev, N. (2014). A Graph Theoretic Approach to Evaluate The Intensity of Barriers in The Implementation of Total Productive Maintenance (TPM). *International Journal of Production Research, 52(10),* 3032-3051. DOI:10.1080/00207543.2013.860250

Badli Shah, M.Y. (2012). Total productive maintenance: a study of Malaysian automotive SMEs. *Proceedings of the World Congress on Engineering London, UK, 3,* 1460-1464. www.iaeng.org/publication/WCE2012/WCE2012_pp1460-1464.pdf

Balon, V., Sharma, A. K., & Barua, M. K. (2016). Assessment of Barriers in Green Supply Chain Management Using ISM: A Case Study of the Automobile Industry in India. *Global Business Review, 17(1),* 116–135. https://doi.org/10.1177/0972150915610701

Baluch, N., Abdullah, C.S. and Mohtar, S. (2012). TPM and lean maintenance – a critical review. *Interdisciplinary Journal of Contemporary Research in Business, 4(2),* 850–857. https://www.researchgate.net/publication/288608942

Bamber, C. J., Sharp, J. M., & Hides, M. T. (1999). Factors Affecting Successful Implementation of Total Productive Maintenance: a UK Manufacturing Case Study Perspective. *Journal of Quality in Maintenance engineering*, *5*(3), 162-181. DOI:10.1108/02656710010378789

Brah, S. A., & Chong, W. K. (2004). Relationship Between Total Productive Maintenance and Performance. *International journal of production research*, *42(12),* 2383-2401. DOI:10.1080/00207540410001661418

César, F.I., Lima, C.R., & Simon, A.T. (2014). TPM implementation in its Autonomous Maintenance Phase: Case Study in a Food Industry. 35(12), 23-44. https://www.researchgate.net/publication/288313291

Devaraj, B.N., Patidar., L., & Soni, P.K. (2015). Relationship of 5S and Manufacturing Performance with Mediator of TPM and TQM. *International Research Journal of Engineering and Technology (IRJET), 2(7),* 1217-1222. https://www.researchgate.net/publication/284096672

Dixit, S., & Raj, T. (2017). A TISM Model for Structuring the Productivity Elements of Flexible Manufacturing System. *International Journal of Industrial and Manufacturing Engineering, 11(4),* 905-912.

Hansson, J., Backlund, F., & Lycke, L. (2003). Managing Commitment: Increasing the Odds for Successful Implementation of TQM, TPM or RCM. *International Journal of Quality & Reliability Management*, 20(9), 993-1008. DOI:10.1108/02656710310500815

Ireland, F., & Dale, B. G. (2001). A study of total productive maintenance implementation. *Journal of quality in maintenance engineering*, *7(3)*, 183-192. DOI:10.1108/13552510110404495

Jain, V., & Raj, T. (2015). Modeling and analysis of FMS flexibility factors by TISM and fuzzy MICMAC. *International Journal of Systems Assurance Engineering and Management*, *6*(3), 350–371. https://doi.org/10.1007/s13198-015-0368-0

Jena, J., Sidharth, S., Thakur, L. S., Pathak, D. K., & Pandey, V. C. (2017). Total Interpretive Structural Modeling (TISM): approach and application. *Journal of Advances in Management Research, Emerald Group Publishing Limited*, *14(2)*, 162-181. DOI:10.1108/JAMR-10-2016-0087

Jostes, R.S., & Helms, M.M. (1994). Total Productive Maintenance and Its Link to Total Quality Management. *Work Study*, *43*, 18-20. DOI:10.1108/EUM0000000004012

Kumar, P., Chauhan, P., Chaudhary, R., Juneja, D. (2017). Implementation of 5S and Kobetsu Kaizen (TPM pillar) in a manufacturing organization. *International Research Journal of Engineering and Technology (IRJET)*, *4(7)*, 2987-2991. https://irjet.net/archives/V4/i7/IRJET-V4I7603.pdf

Lee Cooke, F. (2000). Implementing TPM in Plant Maintenance: Some Organisational Barriers. *International journal of Quality & Reliability management*, *17(9)*, 1003-1016. DOI:10.1108/02656710010378789

Maggard, B.N., & Rhyne, D.M. (1992). Total Productive Maintenance: A Timely Integration of Production and Maintenance. *Production and Inventory Management Journal*, 33(4), 6–10.

Mishra, R.P., Anand, G., & Kodali, R. (2008). A SWOT Analysis of Total Productive Maintenance Frameworks. *International Journal of Management Practice*, 3(1), 51–81. https://doi.org/10.1504/IJMP.2008.016047

Moore, R. (1997). Combining TPM and reliability-focused maintenance. *Plant Engineering, 51(6)*, 88-90.

Nakajima, S. (1988). Introduction to TPM: Total Productive Maintenance. (Translation). *Productivity Press, Inc.*, 129.

Patterson, J.W., Kennedy, W.J. and Fredendall, L.D. (1995). An Overview of Recent Literature on Spare Parts Inventories. *Production and Inventory Management Journal, 36(2),* 61–64. https://doi.org/10.1016/S0925-5273(01)00174-8

Poduval, P. S., Pramod, Dr. V. R., Raj V. P., Dr. J. (2013). Barriers In TPM Implementation In Industries. *International Journal of Scientific & Technology Research, 2(5)*, 28-33. http://www.ijstr.org/final-print/may2013/Barriers-In-Tpm-Implementation-In-Industries.pdf

Putro, C.R. (2013). 5S Implementation in Bengkel ABC [Undergraduate dissertation, Universitas Atma Jaya Yogyakarta]. *Universitas Atma Jaya Yogyakarta*. http://e-journal.uajy.ac.id/id/eprint/4233

Rajesh, R. (2017). Technological capabilities and supply chain resilience of firms: A relational analysis using Total Interpretive Structural Modeling (TISM). *Technological Forecasting and Social Change*, *118,* 161–169. https://doi.org/10.1016/j.techfore.2017.02.017

Rodrigues, M., & Hatakeyama, K. (2006). Analysis of the Fall of TPM in Companies. *Journal of Materials Processing Technology*, *179(1-3),* 276-279. DOI:10.1016/j.jmatprotec.2006.03.102

Rotaru, A. (2008). Total Productive Maintenance Overview. *Annals of" Dunarea de Jos" University of Galati*, *Fascicle V, Technologies in machine building*, *26,* 114-119. https://www.gup.ugal.ro/ugaljournals/index.php/tmb/article/view/1686

Ruben, R. B., & Varthanan, P. A. (2019). Application of total interpretive structural modeling (TISM) approach for analysis of barriers in deploying circular supply chains. *Indian Journal of Science and Technology*, *12(24),* 24. DOI:10.17485/ijst/2019/v12i24/144818

Sabuj, S. U., Ali, S. M., Hasan, K. W., & Paul, S. K. (2021). Contextual relationships among key factors related to environmental sustainability: Evidence from an emerging economy. *Sustainable Production and Consumption*, 27, 86-99. https://doi.org/10.1016/j.spc.2020.10.026

Salunkhe, R.T., Kamble, G.S., & Malage , P.(2009). Inventory control and spare part management through 5S, KANBAN and Kaizen at ABC industry. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), *16(18),* 43-47. https://www.iosrjournals.org/iosr-jmce/papers/sicete(mech)-volume4/39.pdf

Sharma, A.K., Shudhanshu and Bhardwaj, A. (2012), 'Manufacturing performance and evolution of TPM', *International Journal of Engineering Science and Technology,* Vol. 4, No. 3, pp.854–866.

Shehzad, A., Zahoor, S., Sarfraz, S., & Shehab, E. (2018). Implementation of TPM in a Process Industry: A Case Study from Pakistan. *6th International Conference on Manufacturing Research (ICMR 2018),* 511-516. DOI:10.3233/978-1-61499-902-7-511

Singh, M., Sachdeva, A., & Bhardwaj, A. (2014). An Interpretive Structural Modelling Approach for Analysing Barriers in Total Productive Maintenance Implementation. *International Journal of Industrial and Systems Engineering, 16(4),* 433-450. https://doi.org/10.1504/ijise.2014.060653

Ijmer, J., Suchisnata, P., & Prof., A.S. (2014). A Review on Implementation of TPM in Manufacturing Industry. *International Journal of Modern Engineering Research (IJMER), 4(11),* 11-16.

Sushil, & Gerhard (2015). Flexible Systems Management, Springer India.

Sushil, S. (2012). Interpreting the interpretive structural model. *Global Journal of Flexible Systems Management*, *13*(2), 87-106. DOI:10.1007/s40171-012-0008-3

Venkatesh, J. (2007). An introduction to total productive maintenance (TPM). *The plant maintenance resource center*, 3-20. http://faculty.nps.edu/dl/sysengineering/se3302/pdf/anintroductiontototalproductivemaintenance.pdf

Yadav, A., & Sagar, M. (2021). Modified Total Interpretive Structural Modeling of Marketing Flexibility Factors for Indian Telecommunications Service Providers. *Global Journal of Flexible Systems Management, 22(3),* 1-24. DOI:10.1007/s40171-021-00278-6

Yadav, N., & Sushil, (2014). Total Interpretive Structural Modelling (TISM) of Strategic Performance Management for Indian Telecom Service Providers. *International Journal of Productivity and Performance Management*, 63(4). DOI:10.1108/IJPPM-04-2013-0081

Zhao, G., Liu, S., Lu, H., Lopez, C., & Elgueta S. (2019). Building theory of agri-food supply chain resilience using total interpretive structural modelling and MICMAC analysis. *International Journal of Sustainable Agricultural Management and Informatics, 4(3-4),* 235-257. https://doi.org/10.1504/IJSAMI.2018.099236

APPENDIX

Appendix 1: Questionnaire.

Designation:
Company:
Years of Experience:
Keywords: TPM (Total Productive Maintenance).

We are trying to identify the barriers of TPM Implementation in Bangladeshi RMG factories.

[Just click on the scores and save it. Then please send it back]

S.NO	Name of potential Barriers	Do you think, this barriers negatively influence TPM implementation		IF yes, How much would you score this as a Barriers of TPM Implementation? (5 being the highest)				
		Yes	No	1	2	3	4	5
1	Lack of top management's commitment, involvement and understanding							
2	Resistance to change by employee							
3	Lack of proper training and education							
4	Failure to allow sufficient time and resources for the evolution							
5	Non-implementation of pilot study							
6	Repair driven maintenance							
7	Poor relation between production and maintenance							
8	Considering TPM activities as additional work							
9	Lack of time for autonomous maintenance							
10	Production pressure							
11	Non-availability/following of Standard Operation Procedure (SOP)							
12	Lack of KPI based analysis/performance based analysis							
13	Lack of middle management's proper monitoring and corrective measures							
14	Absence of Reward system for sustainability							
**** Please suggest any other barriers that Negatively Influence TPM Implementation.								
15								
16								
17								

Appendix 2: Industry Experts

Experts	Organization Name	Location of the Organization	Affiliation
Expert 1	Décor Global Inc.	Dhaka	Lead Production Engineer (Team -A)
Expert 2	Décor Global Inc.	Dhaka	Lead Production Engineer (Team -B)
Expert 3	Sepal Garments Ltd.	Gazipur	General Manager, Technical and QA
Expert 4	Glory Fashions Wear Ltd.	Gazipur	General Manager, Industrial Engineering
Expert 5	Orchid Garments Ltd.	Gazipur	General Manager, Operations
Expert 6	Glory Fashions Wear Ltd.	Gazipur	General Manager, Technical and QA
Expert 7	BKMEA	Dhaka	Deputy Secretary, PIC
Expert 8	AKH Eco Apparels	Manikganj	Asst.Genaral Manager, Maitenance

Appendix 3: The score and selection of the factors:

Sl.No.	Expert marking Barriers	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Mean	Std. dev	Response %	Selected / Not selected as relevant Barrier
1	Lack of top management's commitment, involvement and understanding	5	5	5	5	5	5	5	5	5	0.000	100%	Selected
2	Resistance to change by employee	5	4	3	3	4	4	5	3	3.875	0.835	78%	Selected
3	Lack of proper training and education	4	4	3	4	4	3	3	5	3.75	0.707	75%	Selected
4	Failure to allow sufficient time and resources for the evolution	2	3	2	3	3	3	3	2	2.625	0.518	53%	Not Selected
5	Non-implementation of pilot study	3	5	3	4	5	3	3	4	3.75	0.886	75%	Selected
6	Repair driven maintenance	5	5	3	4	5	3	5	4	4.25	0.886	85%	Selected
7	Poor relation between production and maintenance	4	4	3	4	3	5	3	4	3.75	0.707	75%	Selected
8	Considering TPM activities as additional work	5	4	3	4	4	5	5	3	4.125	0.835	83%	Selected
9	Lack of time for autonomous maintenance	2	4	0	1	4	0	2	1	1.75	1.581	35%	Not Selected
10	Production pressure	2	3	3	3	3	3	3	2	2.75	0.463	55%	Not Selected
11	Non-availability/following of Standard Operation Procedure (SOP)	4	5	5	3	5	5	4	3	4.25	0.886	85%	Selected
12	Lack of KPI based analysis/performance based analysis	4	5	4	3	5	4	5	5	4.375	0.744	88%	Selected
13	Lack of middle management's proper monitoring and corrective measures	3	3	2	3	3	2	3	3	2.75	0.463	55%	Not Selected
14	Absence of Reward system for sustainability	5	4	3	4	4	5	4	3	4	0.756	80%	Selected

Appendix 4: Pairwise comparison database for factors

Sl. No.	Barrier No.	Paired Comparison of factors	Yes/No	If yes then in what way one Barrier negatively influence other.
1	F1 -F2	Lack of top management's commitment, involvement and understanding will negatively influence Resistance to change by employee	Yes	The more the top management is committed to the program, the less the chance to deny it by the employee
2	F1 -F3	Lack of top management's commitment, involvement and understanding will negatively influence Lack of proper understanding, training and education	Yes	By not creating proper influence for the need of training
3	F1 -F4	Lack of top management's commitment, involvement and understanding will negatively influence Non-implementation of pilot study	Yes	By not giving importance to pilot program rather to implement directly.
4	F1 -F5	Lack of top management's commitment, involvement and understanding will negatively influence Repair driven maintenance	No	
5	F1 -F6	Lack of top management's commitment, involvement and understanding will negatively influence Poor relation between production and maintenance	No	
6	F1 -F7	Lack of top management's commitment, involvement and understanding will negatively influence Considering TPM activities as additional work	Yes	The less the involvement of top management, the more the TPM activities will seems like a burden to the employees
7	F1 -F8	Lack of top management's commitment, involvement and understanding will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	Yes	SOP will developed by the top management involving middle management
8	F1 -F9	Lack of top management's commitment, involvement and understanding will negatively influence Lack of KPI based analysis/performance based analysis	Yes	KPI will be set by the top management
9	F1 -F10	Lack of top management's commitment, involvement and understanding will negatively influence Absence of Reward system for sustainability	Yes	Reward system is decided and developed by the top authorities

10	F2 -F1	Resistance to change by employee will negatively influence Lack of top management's commitment, involvement and understanding	Yes	motivation and influence comes from the top personnels
11	F2 -F3	Resistance to change by employee will negatively influence Lack of proper understanding, training and education	No	
12	F2 -F4	Resistance to change by employee will negatively influence Non-implementation of pilot study	No	
13	F2 -F5	Resistance to change by employee will negatively influence Repair driven maintenance	No	
14	F2 -F6	Resistance to change by employee will negatively influence Poor relation between production and maintenance	Yes	Old mindset do not allow to accept changes
15	F2 -F7	Resistance to change by employee will negatively influence Considering TPM activities as additional work	Yes	Cannot accept change, hence new activities acts as a burden to them
16	F2 -F8	Resistance to change by employee will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	No	
17	F2 -F9	Resistance to change by employee will negatively influence Lack of KPI based analysis/performance based analysis	No	
18	F2 -F10	Resistance to change by employee will negatively influence Absence of Reward system for sustainability	No	
19	F3 -F1	Lack of proper understanding, training and education will negatively influence Lack of top management's commitment, involvement and understanding	No	
20	F3 -F2	Lack of proper understanding, training and education will negatively influence Resistance to change by employee	Yes	Training and understanding changes point of view towards new things
21	F3 -F4	Lack of proper understanding, training and education will negatively influence Non-implementation of pilot study	No	
22	F3 -F5	Lack of proper understanding, training and education will negatively influence Repair driven maintenance	Yes	The less the knowledge of autonomous maintenance, the more the maintenance after broken develop

23	F3 -F6	Lack of proper understanding, training and education will negatively influence Poor relation between production and maintenance	No	
24	F3 -F7	Lack of proper understanding, training and education will negatively influence Considering TPM activities as additional work	Yes	Do not know the importance of TPM activities
25	F3 -F8	Lack of proper understanding, training and education will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	Yes	Less knowledge, less understanding of SOP
26	F3 -F9	Lack of proper understanding, training and education will negatively influence Lack of KPI based analysis/performance based analysis	No	
27	F3 -F10	Lack of proper understanding, training and education will negatively influence Absence of Reward system for sustainability	Yes	Designing of proper reward system is based on knowledge
28	F4 -F1	Non-implementation of pilot study will negatively influence Lack of top management's commitment, involvement and understanding	No	
29	F4 -F2	Non-implementation of pilot study will negatively influence Resistance to change by employee	No	
30	F4 -F3	Non-implementation of pilot study will negatively influence Lack of proper understanding, training and education	No	
31	F4 -F5	Non-implementation of pilot study will negatively influence Repair driven maintenance	No	
32	F4 -F6	Non-implementation of pilot study will negatively influence Poor relation between production and maintenance	No	
33	F4 -F7	Non-implementation of pilot study will negatively influence Considering TPM activities as additional work	Yes	To better understand of hole TPM works
34	F4 -F8	Non-implementation of pilot study will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	Yes	Development or correction of existing SOP will perfectly possible if pilot-run can be implemented
35	F4 -F9	Non-implementation of pilot study will negatively influence Lack of KPI based analysis/performance based analysis	No	

36	F4 -F10	Non-implementation of pilot study will negatively influence Absence of Reward system for sustainability	No	
37	F5 -F1	Repair driven maintenance will negatively influence Lack of top management's commitment, involvement and understanding	No	
38	F5 -F2	Repair driven maintenance will negatively influence Resistance to change by employee	No	
39	F5 -F3	Repair driven maintenance will negatively influence Lack of proper understanding, training and education	No	
40	F5 -F4	Repair driven maintenance will negatively influence non-implementation of pilot study	No	
41	F5 -F6	Repair driven maintenance will negatively influence Poor relation between production and maintenance	Yes	Production wants continuous support from maintenance whereas practically it is not possible
42	F5 -F7	Repair driven maintenance will negatively influence Considering TPM activities as additional work	Yes	Repair consume valuable time, so it becomes difficult to maintain TPM activities
43	F5 -F8	Repair driven maintenance will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	Yes	SOP doesn't contain repair driven maintenance rather focuses on autonomous maintenance
44	F5 -F9	Repair driven maintenance will negatively influence Lack of KPI based analysis/performance based analysis	Yes	It is a crucial part of KPI
45	F5 -F10	Repair driven maintenance will negatively influence Absence of Reward system for sustainability	No	
46	F6 -F1	Poor relation between production and maintenance will negatively influence Lack of top management's commitment, involvement and understanding	No	
47	F6 -F2	Poor relation between production and maintenance will negatively influence Resistance to change by employee	Yes	It influence employees to play blame-game
48	F6 -F3	Poor relation between production and maintenance will negatively influence Lack of proper understanding, training and education	No	

49	F6 -F4	Poor relation between production and maintenance will negatively influence Non-implementation of pilot study	No	
50	F6 -F5	Poor relation between production and maintenance will negatively influence Repair driven maintenance	Yes	From repair-driven to convert autonomous, proper support and collaboration is needed
51	F6 -F7	Poor relation between production and maintenance will negatively influence Considering TPM activities as additional work	No	
52	F6 -F8	Poor relation between production and maintenance will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	No	
53	F6 -F9	Poor relation between production and maintenance will negatively influence Lack of KPI based analysis/performance based analysis	No	
54	F6 -F10	Poor relation between production and maintenance will negatively influence Absence of Reward system for sustainability	No	
55	F7 -F1	Considering TPM activities as additional work will negatively influence Lack of top management's commitment, involvement and understanding	No	
56	F7 -F2	Considering TPM activities as additional work will negatively influence Resistance to change by employee	Yes	Do not want to do works related to TPM, hence resistance develop against change
57	F7 -F3	Considering TPM activities as additional work will negatively influence Lack of proper understanding, training and education	No	
58	F7 -F4	Considering TPM activities as additional work will negatively influence Non-implementation of pilot study	No	
59	F7 -F5	Considering TPM activities as additional work will negatively influence Repair driven maintenance	No	
60	F7 -F6	Considering TPM activities as additional work will negatively influence Poor relation between production and maintenance	No	

61	F7 -F8	Considering TPM activities as additional work will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	Yes	Considering TPM as additional activities leads to not include these essential works in the SOP, if available.
62	F7 -F9	Considering TPM activities as additional work will negatively influence Lack of KPI based analysis/performance based analysis	No	
63	F7 -F10	Considering TPM activities as additional work will negatively influence Absence of Reward system for sustainability	No	
64	F8 -F1	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Lack of top management’s commitment, involvement and understanding	No	
65	F8 -F2	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Resistance to change by employee	No	
66	F8 -F3	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Lack of proper understanding, training and education	Yes	SOP (if available) provides a clear understanding of existing procedure
67	F8 -F4	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Non-implementation of pilot study	No	
68	F8 -F5	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Repair driven maintenance	Yes	SOP mentions where checking and maintenance will required
69	F8 -F6	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Poor relation between production and maintenance	No	
70	F8 -F7	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Considering TPM activities as additional work	No	
71	F8 -F9	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Lack of KPI based analysis/performance based analysis	Yes	SOP prevents from falling performance
72	F8 -F10	Non-availability/following of Standard Operation Procedure (SOP) will negatively influence Absence of Reward system for sustainability	No	

73	F9 -F1	Lack of KPI based analysis/performance based analysis will negatively influence Lack of top management’s commitment, involvement and understanding	No	
74	F9 -F2	Lack of KPI based analysis/performance based analysis will negatively influence Resistance to change by employee	No	
75	F9 -F3	Lack of KPI based analysis/performance based analysis will negatively influence Lack of proper understanding, training and education	No	
76	F9 -F4	Lack of KPI based analysis/performance based analysis will negatively influence Non-implementation of pilot study	No	
77	F9 -F5	Lack of KPI based analysis/performance based analysis will negatively influence Repair driven maintenance	Yes	KPI based performance is invertedly depends on frequency of repair
78	F9 -F6	Lack of KPI based analysis/performance based analysis will negatively influence Poor relation between production and maintenance	No	
79	F9 -F7	Lack of KPI based analysis/performance based analysis will negatively influence Considering TPM activities as additional work	Yes	TPM activities will both, directly and indirectly influences performance
80	F9 -F8	Lack of KPI based analysis/performance based analysis will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	No	
81	F9 -F10	Lack of KPI based analysis/performance based analysis will negatively influence Absence of Reward system for sustainability	No	
82	F10 -F1	Absence of Reward system for sustainability will negatively influence Lack of top management’s commitment, involvement and understanding	No	
83	F10 -F2	Absence of Reward system for sustainability will negatively influence Resistance to change by employee	Yes	Reward system creates positive mindset

84	F10 -F3	Absence of Reward system for sustainability will negatively influence Lack of proper understanding, training and education	No	
85	F10 -F4	Absence of Reward system for sustainability will negatively influence Non-implementation of pilot study	No	
86	F10 -F5	Absence of Reward system for sustainability will negatively influence Repair driven maintenance	No	
87	F10 -F6	Absence of Reward system for sustainability will negatively influence Poor relation between production and maintenance	No	
88	F10 -F7	Absence of Reward system for sustainability will negatively influence Considering TPM activities as additional work	No	
89	F10 -F8	Absence of Reward system for sustainability will negatively influence Non-availability/following of Standard Operation Procedure (SOP)	No	
90	F10 -F9	Absence of Reward system for sustainability will negatively influence Lack of KPI based analysis/performance based analysis	Yes	To improve and sustain certain improvements, it is required to have reward system