Achieving Sustainability through Holistic Maintenance- Key for Competitiveness

Ashutosh Samadhiya and Rajat Agrawal
Department of Management Studies
Indian Institute of Technology Roorkee
Roorkee, Uttarakhand-247667, INDIA
asamadhiya@bm.iitr.ac.in, rajatfdm@iitr.ac.in

Abstract

The Manufacturing sector is considered to be an engine of economic growth for most of the developing nations. At the same time, issues related to environmental sustainability cannot be ignored. Therefore, every aspect of manufacturing activities needs to play its part in ensuring the sustainability of overall manufacturing. To ensure, optimal use of manufacturing facilities, the use of maintenance function is very important. Most of the time, maintenance is considered to be a reactive function. It does not find many places in sustainability-related discussions of manufacturing. It is found that world-class organisations have started considering maintenance as a strategic activity. It is expected that maintenance management will find a place like quality management. When maintenance is to be strategic/ proactive function, it requires to be performed in sync with sustainability aspects. Total Productive Maintenance (TPM) is a futuristic maintenance strategy that will give a holistic concept of strategic maintenance. The performance of organisations on TPM can be evaluated using Overall Equipment Effectiveness (OEE). Research has suggested that OEE is not sufficient to capture the sustainability aspects of maintenance. This study has proposed a concept of Green TPM, which can take care of sustainability and maintenance simultaneously. Maintenance activities may release hazardous chemicals, defected/ unrepairable spare parts, and other components that can negatively impact the environment. This paper explains the concept of Green TPM as a future-oriented vision that follows the philosophy of customer-orientation, environmental concern, mass production with customization and sustainability. It is an integrated approach that covers elements like green training, green maintenance, and green lean six sigma. This approach is not only helpful in achieving higher manufacturing performance but also environmental performance.

Keywords- Green TPM, Maintenance, OEE, Sustainability, TPM.

1. Introduction

The manufacturing sector is facing a lot of turbulence in its field because of the global market changes, which creates significant attention towards the process capability and better machine functionality to achieve the less process variation and high quality. These features have created special attention to regain the original performance of the machine to get better production demands to honour the commitments. Performances of machines are not insurmountable, and it affected as the machine comes in use but depends on the type of use. So maintenance comes in the picture to restore and repair the original performance of the machines to get the desired output in a certain period. But maintenance timing is a big problem, means it is always a debatable question that the maintenance should be before or after the damage.

Breakdown maintenance versus preventive maintenance, the debate has gone much beyond, and now people have also started looking maintenance from the strategic point of view, and the concept of TPM is developed for strategic management perspective, but it is again limited only to the manufacturing aspect like shop floor activities, which explore the better output at the shop floor.

TPM has given a suitable playground to maintenance to play an essential role in making a better organisation in terms of profit and competition. It also used as a valuable weapon for other quality philosophies like lean manufacturing and total quality management (TQM) to achieve the different functional priorities (Ahuja and Khamba 2008).

Linking this with the broader issues related to sustainability will give more impetus to maintenance activities in the organisations. Now only professionally managed organisations are looking for TPM type of concepts. In India, over some time, there is a good amount of increase in organisations adopting TPM philosophy, they are getting more and

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more TPM awards, but broader Indian sector is SME's oriented, which is unorganised with lack of advance knowledge. So maintenance has to make in such a way that the SME's could adapt that with some ease. Those organisations only focused on output, but for that output, maintenance can play a perfect role. In recent four to five decades, quality has gained wider acceptance than maintenance. Strategies related to managing maintenance and improving quality don't combine to act and especially maintenance is ignored as a thought of competitive weapon (Wireman 1991).

Many researchers focused on quality and quality became the hot topic during these years, but the author suggested that even quality is achievable by implementing the proper maintenance. It can be understood in such a way as if one has to achieve Six-Sigma to improve process capabilities, proper maintenance can help to provide six-sigma in a much easier way, and the process capabilities will be excellent, and the variations will be less. If the machine is well and good with the help of maintenance, it can achieve excellent quality in every manner. Profit sustainability is not achievable with slowly improved manufacturing operations as per the current rapidly changing market scenario (Oke 2005). So it is an essential issue that, how to achieve sustainability, and what are the enablers of sustainability?

Maintenance can help in dealing with various resources in organisational manufacturing aspects like availability of materials, machine performance by proper maintenance, and reduce the loss of time and money with the help of engineering tools if implemented effectively (Moubray 2003).

We need to have an extreme focus on maintenance, and it requires a complete shift in our priorities to achieve sustainability. Profit is our top priority as per current scenario but if the perception changes in such a way that proper maintenance will help employees contributing to the organisations, doing things without the risk that promotes social sustainability, productivity, and less cost of maintenance over a period promoting profit sustainability, so in this way, the purpose of maintenance is to minimise the risk systems of organisations like employees related risks, production uncertainty risks. If a machine breakdown happens, the delivery commitments will be disturbed and will not be honoured.

Maintenance on time can help to maintain the honour of production commitments, which will help to profit and customer-related satisfaction. Maintenance will help to reduce the chance of machine failure related risk, which will help to achieve employee safety concern. Proper maintenance will also help to reduce environmental pollution. So in this way, maintenance can be an enabler and a pillar for sustainability, and it is working as a prerequisite for every sustainability as profit, social and environmental. Maintenance is mostly ignored in such a way that it can affect sustainability. It is discussed previously as a point of productivity.

The market is changing globally and affecting the organisational performance with different focus factors like reducing the cost, improving the level of productivity, raising the bar of quality, and create customer satisfaction by honouring the delivery commitments (Raouf 1994). Different researchers have given the concept of the effective performance measurement system (PMS) and suggested some questions, which must be answered to implement the effective PMS. In the past, this PMS was related to the organisation's progress, which was a way of narrating that the organisation is going in the right or wrong direction towards achieving their goals (Rose 1999).

Maintenance is not a secondary or supportive activity as the organisations presumed it, and it is quite essential to understand that it is not a financial burden. TPM implemented by the organised and professional organisations but failed to perform in SME's because of the complexity. So it is needed to be in such a way so that the SME's can have the benefits of TPM. TPM lacks to achieve environmental sustainability more efficiently, but the proposed concept of Green TPM can help to meet all the three sustainabilities in such a way that good productivity and quality is easily visible. In the past, maintenance has seen as an additional and supportive activity, but this paper discusses that it could be an integrated approach which involves the top management of the organisation, shop floor people, and the customers. The author has proposed a framework in this paper which also covers environmental sustainability.

The purpose of this paper is to provide an essential bridge between sustainability and Maintenance with the help of a new concept like green TPM, which will help to understand that individual sustainabilities should not be considered with maintenance as isolation. All the three sustainabilities as per the triple bottom line (TBL) approach, can be seen at a single platform and all can perform to achieve their functionalities with the help of maintenance, act as a precursor.

Further, this paper is classified into four more parts. Part 2 represents the literature review of maintenance, TPM, quality, and sustainability. This part also finds out the research gap form the literature and helps to understand the motivation of the objective. Part 3 covers the proposed framework of Green TPM. It also explains the various factors introduced in the framework and gives a brief about connecting all the elements in the framework. Part 4 takes you to the conclusion of the whole paper, which shows the projection of sustainability with the help of green TPM from holistic maintenance. Part 5 is the last part, which tells the limitation of this paper until now. This part also gives a glimpse of the future direction of this study.

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2. Literature Review

The literature review has covered those topics which were essential to this paper-like sustainability, TPM, maintenance, quality, and employee involvement. This literature has also mentioned some green terms like green maintenance, green training, and green lean six sigma, which will help to understand the invasion of the green terms. There were different keywords used to find the literature like maintenance, maintenance management, quality, six-sigma, sustainability, triple bottom line etc.

TPM came in the picture in 1971 by Japan, but it gained recognition when Nakajima introduced it. Initially, TPM philosophy was understood to solve the problem of maintenance with the help of operators and the employees (Nakajima 1984). The Japan Management Association (JMA) has established a plant maintenance committee in 1961. Later Japan Institute of Plant Maintenance (JIPM) helped TPM to gain reputation by involving it to the industries and relate it with different machine maintenance (Marin-Garcia et al. 2013).

Some authors pressurised on specific tools during TPM philosophy implementation. 5s is a vital tool of TPM to get profit sustainability because it provides the punctuality and cleanness at the working place and also set the orders of machines and processes. TPM focuses on the documentation of the activities, which helps to keep the record and obtain the profitability of the organisation (Méndez and Rodriguez 2017).

A limited comparative analysis is done for maintenance and quality to understand the importance of focusing on maintenance rather than quality. Keywords, quality and maintenance used in the web of science separately and three fields which are operations research management science, engineering manufacturing, and engineering industrial used as a filter within the duration from 1999-2019. Total 4537 papers found out in the field of quality, and 2390 papers were found out for maintenance. Papers published in the area of maintenance is only 52% of the quality area, which shows that the quality was a hot topic for researchers in the past and maintenance is largely ignored.

Now companies are more concern about the functionality of their equipment. Companies are focusing more on the effective working of the equipment and paying more attention to its maintenance. They are adapting the philosophy of TPM in such a way that the employees should be responsible for the maintenance of the equipment to get the prior or original performance of that equipment (Wireman 2004).

Nakajima promoted TPM and it leads towards a metric named as Overall Equipment Effectiveness (OEE), which used to measure TPM by calculating the three factors such as performance rate, availability rate, and quality rate. These three factors help to measure machine productivity and support to conclude the effective implementation of TPM (Sayuti 2019). This way, TPM allows organisations to improve their business process. Hindustan Unilever Limited (HUL) is one of the most renounced FMCG company of India. They applied TPM in their company and gained an excellent competitive advantage for the long term. Some previous reports had given the statistics of HUL when TPM was implemented, as follows-

Table 1. Effect of TPM Implementation on Hindustan Unilever Limited **(**Sangameshwran and Jagannathan 2002)

S.No.	HUL Plant Location	Investment (Rs. Crores)	Profits (Rs. Crores)
1.	Silvassa PP Plant	1.50	21
2.	Chhindwara Plant	0.80	2.40
3.	Yavatmal Plant	0.60	6.0
4.	Orai Plant	0.45	6.0
5.	Rajpura Plant	0.42	6.20

The reports have also cleared that the effect of TPM on organisations give returns almost 8 to 12 times of the investments, which shows the useful potential of TPM (Sangameshwran and Jagannathan 2002).

It is crucial to understand the use of maintenance or necessary maintenance is required because of the public concern on the degradation of the environment by massive maintenance activities to achieve the process capabilities through machine performance. Maintenance is an essential activity to run the plant operations efficiently by regaining the machine capabilities, but the wastages repaired parts, and other environmental pollutants have become the environmental burden. Maintenance requirements are increasing because of the global competitive pressure on the organisation to honour their production commitments, which are also increasing these wastes to the environment and participating in the phase of environmental degradation. These type of circumstances demands maintenance activities with ecological concern. Green maintenance is a concept which required three major factors as Environmental compatibility, energy efficiency, and human health and safety risks (Ajukumar and Gandhi 2013). Green Maintenance concludes in the following points-

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- Environmental compatibility covers the process, policy, and types of materials used during the maintenance to avoid environmental degradation.
- Energy efficiency includes the kinds of energy and the process by which power is using. It consists of renewable energy resources, tools and technologies related to the energy consumption to reduce the use of energy.
- Human health and safety risks mainly focus on the use of regulations and the process during the maintenance to avoid the risk factor involves human health.

Now customers thought process regarding the quality of the product is changed. Previously quality was measured with the cost and durability of the product, but it has replaced with the less environmental impact and the long product life cycle (Marousek et al. 2015). This way, industries are facing more pressure towards ecology and concerning more about sustainability. Manufacturing industries are trying to integrate different types of operational strategies, philosophies, techniques, tools, and principles to achieve these types of goals focused on customer satisfaction and fulfil production commitments. These strategies are now on more related to the ecology such as less pollution based, fewer materials and energy consumption, more biodegradable materials, less discharge based, and more eco-efficient. Even manufacturing approaches are focusing on green philosophies such as green manufacturing. Change in quality perception has increased the global competition and challenges, and Green Lean Six Sigma (GLS) can be a powerful weapon to compete with these new challenges.

GLS is a green approach focused on reducing environmental pollution during the process and deliver high-quality products simultaneously (Kaswan and Rathi 2019). This approach leads towards the environmental sustainability of the organisations. Sustainability is well defined by the World Commission on Environment and Development (WCED) 1987 report, which focuses on the compatibility of present and future needs. The clarity of sustainability comes with the help of Triple Bottom line (TBL) approach, which further classifies the sustainabilities in three different parts as economic or profit sustainability, social sustainability, and environmental sustainability. It is essential to understand that all three sustainabilities should not be competitive with each other, but be performed together. That's why sustainability enablers can participate as a catalyst to achieve the sustainabilities as a competitive weapon, but some authors suggested to simplify the complex processes in spite of using the sustainability indicators (Lodhia and Martin 2014).

Therefore corporate sustainability indicators (CSI) can be an excellent participator to achieve sustainability because it linked the sustainability to corporate level sustainability. Corporate sustainability comes with the practical approach and direct implementation of government policies related to sustainable development (Schaltegger and Burritt 2006). Sustainability indicators have got tremendous growth in terms of research, means different researchers tried to identify the indicators of sustainability. Initially, the study comes with the objectives of the sustainability indicators (SI), which summarises that the potential of indicators should show the practical efficiency and consistency of the organisations with their real values, culture, and capabilities (Keeble et al. 2003). It will help the organisations to understand the real picture of itself and identify the resources and potential of the organisations to achieve the desired goals of sustainability. Organisations will not blindly trust in any statistics to achieve sustainability if they know their original potential and values. It will help them to move in the right direction and use the right actions to achieve the goal. Different approaches towards finding the SI comes in the picture after deciding the objectives of SI. Top-down and bottom-up are two approaches, which used in literature to find out the different types of SI. The top-down approach is called as main ones because it consists of all the macro-level indicators considered from a global perspective and bottom-up approach also known as a complementary or specific approach, consists of micro-level indicators as local perspective (Tahir and Darton 2010).

Sustainability indicators emphasised on different environmental concerns such as minimisation of the landfill by waste management, less pollutant release, recycling and the reuse of the substances, some strict regulations related to the environment like environmental penalties and product life cycle comprehension (Mayyas et al. 2012). Different subjects are given for the set of SI for industry, which is classified as environmental subjects, social subjects, and economic subjects (Feil et al. 2019). These indicators are supporting the TBL's approach of sustainability which suggests all three sustainabilities for individuals. Employee involvement is also important to achieve the goals of sustainability. It will easy to follow all these philosophies if every employee is engaged in these activities because then only the true meaning of sustainability will be fulfilled. There are different training programs within the organisations to educate and train the employee for adapting the culture of employee involvement. But nowadays the training programs are designed with obvious environment concern so that employees will be more responsible for the environment such as green training. It improves the employee's engagement towards environmental routines within the organisation if the competition is also involved (Pinzone et al. 2019).

The literature is involved with different topics such as maintenance, quality, green maintenance, green lean six sigma, sustainability, corporate sustainability, sustainability indicators, employee involvement, and green training. Some

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research gaps were found within the literature, which will clear the objective and the essence of this paper. There was a lack of literature regarding the maintenance connecting with all three sustainabilities. Different techniques like green maintenance, green training, and green lean six sigma are present in research, but a combined effort of all these techniques is missing. So the author has combined all these techniques and integrate at a single platform and proposed a framework for green TPM, which connects maintenance and sustainability.

2. Proposed Framework

The framework is proposed with the help of literature and experts of this domain. It explains the integration of different philosophies in TPM with the multiple involvements and delivers sustainability as its outcomes. This is a two-stage framework, which represents TPM in its first stage and deliver all the three dimensions of sustainability by providing a new concept of green TPM. The structure of the framework is looking like a two-floor hut, which placed all three dimensions of sustainability at its top floor. It is already assumed that organisations have implemented TPM and now the integration of other pillars will provide Green TPM. JIPM suggested TPM model is placed at the first stage with eight pillars of TPM and new eight pillars are integrated with the second stage to propose the green TPM concept. Conventional TPM is not effective in preventing environmental degradation so the author suggested a new concept such as green TPM, which concerns with environmental development and other dimensions of sustainability. This environmental awareness has created a rigorous need for adapting green philosophies in this framework.

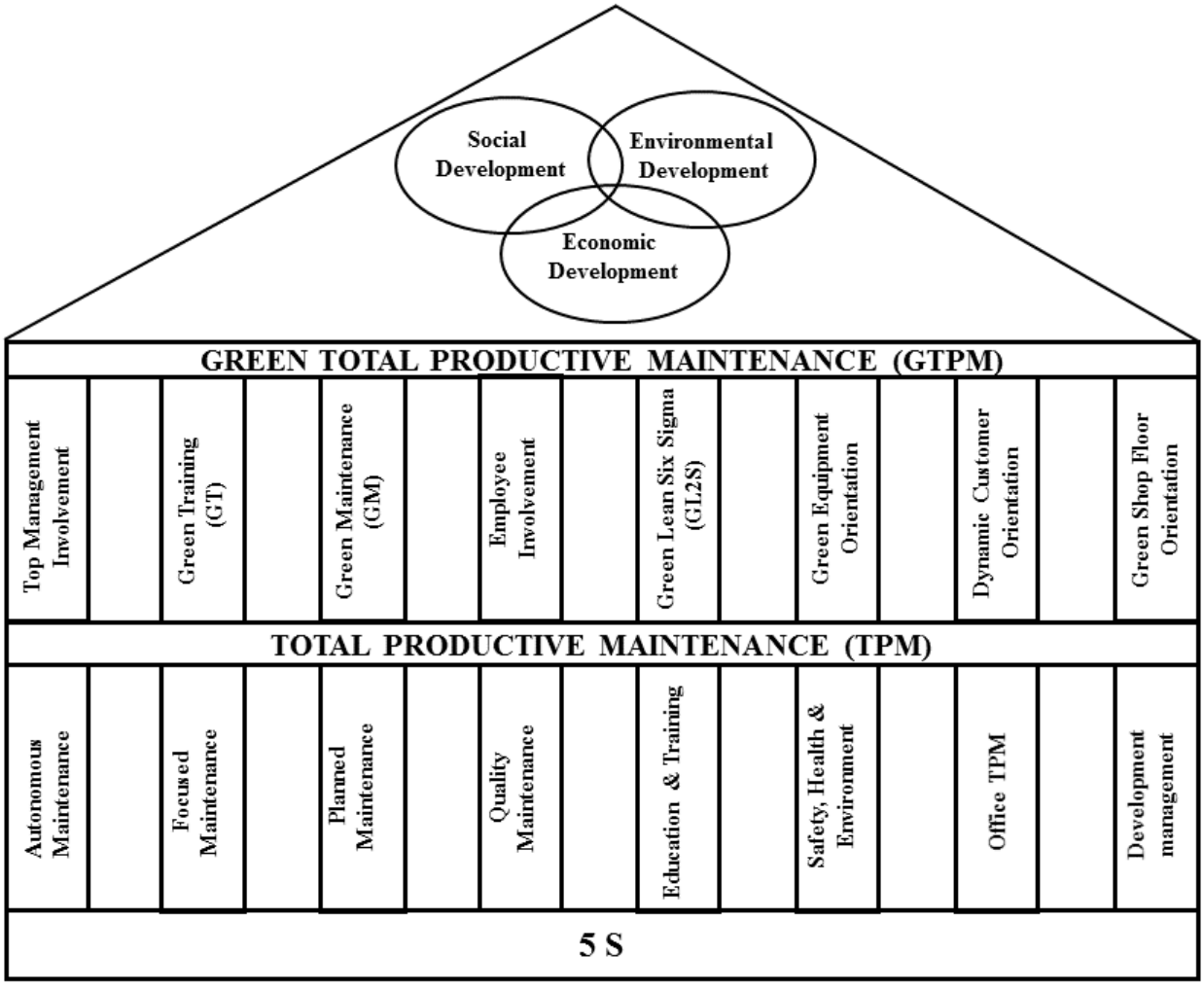

Figure 1. Proposed Green TPM Framework

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There are eight pillars, which placed above TPM, are explained further to give the proper understanding of this framework.

2.1 Top Management Involvement (Pillar I)

Top management is an essential part of any organisation which supervise and manage the organisational activities to fulfil the mission and vision of the company. Philosophies with maintenance activities can only be implemented genuinely if top management is taking those activities at the priority level. Top management would have to participate and encourage those educational training to create an atmosphere of environment-friendly. They can make reliable decisions in favour of the company and support the employees to participate in these kinds of exercise like green training, which will enhance the culture of the organisation. The effectiveness of implementing those philosophies depends on the top management seriousness about those philosophies, and for more prolonged effectiveness, it should be monitored continuously by the management people. They are the decision-maker of any organisations, so proper understanding and implementation of these philosophies involve the effective participation of top management. Top management can provide a better environment of adapting and implementing those practices.

2.2 Green Training (Pillar II)

Education and training have always been an important part of any organisation, which helps organisations to build and sustain. Training involves the participation of employees and monitoring of their performance in any organisation during and after the session. It is impossible to understand that these kind of improvements are not possible if employees are not committed, even these improvements mainly depend on employee's adaption of new philosophies and behaviours. There are certain effects of green training on organisations as follows-

- It helps to aware the employees about the environmental behaviour within the organisation, which also affects the daily decisions of the employees.
- This training helps employees to get a proper understanding of the issues related to the environments.

Green training helps to develop a green culture in society, which helps to achieve the environment-related organisational goals.

2.3 Green Maintenance (Pillar III)

It is important to understand the concept of necessary maintenance concerning with the minimum environmental impact because of the increased maintenance requirement creating an unproductive use of the parts and materials, which discarded into the environment and degrading it. Green maintenance comes in the picture with some requirements of it, which shows its potential in the concerned area. These requirements are divided into three categories, such as environmental capability, energy efficiency, and human health and safety risk (Ajukumar and Gandhi, 2013).

- Environmental capability covers the issue of the industry during maintenance, which contributes to environmental degradation. It applied to the industry with various concerns like preventing leakage, some policies related to the waste treatment, maintenance with up-gradation facility, and problems related to the landfill minimisation. These multiple concerns will be handled by green maintenance to reduce the negative impact on the environment.
- Energy efficiency is an important agenda as per today's requirement, which focuses on some areas related to primarily on reduction in energy consumption and the use of renewable energy. It can be sorted with the help of the right use of process, machines, techniques, and materials.
- Human health and safety risk is a significant issue because of the multi accidents during maintenance-related activities. It concerns with the ergonomics, regulations, and use of non-toxic materials.

Green maintenance concerns with all the three requirements affect the environment and support the green. This way, it leads towards the zero discharge of the materials and energy, which helps to prevent environmental degradation and that can lead towards the other two dimensions of sustainability which are social development and economic development.

2.4 Employee Involvement (Pillar IV)

Employee involvement or participation is an essential pillar of this framework to create and maintain this kind of culture within the organisation. Different education and training sessions can only be successful with the help of effective and sincere involvement of employees. Employees should not feel adaption of these practices as a burdon. They should follow these practices as a routine at every corner of the organisations, which will help the organisation to sustain and grow in this competitive environment. The sincerity of the work depends on the abidance of the employees. The organisations will provide education and training, but the exercise of those practices can only be successful by the employee's involvement. So this way, this pillar proves its importance in this framework.

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2.5 Green-Lean-Six-Sigma (Pillar V)

This pillar is the combination of three philosophies which are green, lean and six-sigma. Every philosophy has its characteristics and shortcomings. Lean used to eliminate the wastes of the system, but it is not involved much in environmental impacts. Some philosophies have integrated both lean and green, comes with the green-lean approach. Literature shows that green-lean integration did not help to achieve good sustainability.

Six-sigma helps to achieve this dimension and fill the gap between these two techniques. This way, green-lean-six-sigma helps to achieve a good quality of product and also helps to reduce the breakdowns or failure of machines. These influences lead to some organisational goals as per the current competitive scenario and the requirement of green initiatives such as good quality of product, zero rework, zero wastes, zero pollution, and fulfilling the production commitments, and customer satisfaction. These achievements will help organisations to travel the distance between maintenance and sustainability with gaining the concept of green TPM.

2.6 Green Equipment Orientation (Pillar VI)

Maintenance of equipment also depends on the type of machine using to fulfil the demand. Some machines are required heavy maintenance during the process. These machines required wastage of oil, repair parts, toxic materials, and other hazardous wastages, which causes environmental degradation.

The main goal of these pillars is to prevent environmental looses. There are certain ways of achieving this, which are-

- Upgrading the machine in such a way, that requirement of maintenance could be less.
- Machine maintenance with non-toxic materials.
- Equipment orientation should not be the responsibility of a person.
  The machine with autonomous maintenance will produce good quality and also reduction in different losses will honour the production and delivery commitments.

Equipment orientation should not be the responsibility of an individual person. It is needed that an operator of any machine should also know the maintenance of that machine to avoid the failure or breakdown of that machine. It will reduce the time of various losses during the running machine and also create a risk-free environment. Green maintenance will help to involve the maintenance with zero discharge, which will help individuals to become environmentally aware.

2.7 Dynamic Customer Orientation (Pillar VII)

Customer is an important segment for any industry, which helps organisations indirectly to sustain. The need of the customer always changes with time. Initially, the cost was the only concern for the customer about the product. Customer prefers the low-cost product and did not very much focus on the quality of the product. It was a thought that quality comes with a high price, but the Japanese system changes the thought about the quality of the product. As per the Japanese thought, quality is free.

Customers have adapted very fast about quality is free concept and switches towards low cost and high-quality product, But their demands are changing towards quality also. Customers are very dynamic about the products and services. These days their priorities are shifting towards some functional applications of products such as high-quality products which are environment-friendly with the prolonged life cycle.

Customer perception is an important criterion for the success of any organisation. It helps the organisation to achieve customer satisfaction, which is the primary goal of an organization to sustain in the competitive market. It will involve asking questions from customers about the company values, which helps the company to look into the area where they have to improve or change. Customer's perception will point out the main areas like the quality of the product, delivery time, and performance of the company. It will also help to understand the need of the customer and value cocreation that satisfies the customer. This way, a green concept also invades with the help of this pillar.

2.8 Green Shop Floor Orientation (Pillar VIII)

This is the last pillar of this framework, which involves the controlled shop floor activities. Shop floor activities involve the various material handling tasks, and different other movements. Conventionally, unnecessary movements and energy consumption involves in shop floor activities, but the right orientation of shop floor people can reduce the energy consumption and movements during the shop floor activities.

Green shop floor orientation concerns with green activities involvement in shop floor activities, which involves the right use of materials, right techniques of movements with minimum time involvement, less energy consumption, and other factors which consume adequate time if not used properly. Orientation also explores the individual's participation with concerning the healthy environment by giving them green training and educate with the green philosophies. This way, it also helps to achieve the environment-related organisational goal, which leads to gain the other dimensions of sustainability.

These eight pillars are leading towards some primarily organisational goals of the current competitive environment-

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- It will lead towards the outcomes such as zero rework, zero accident, zero discharge, zero pollution, less energy consumption, and other green outcomes.
- These outcomes will help to achieve economic development because of the right use of resources and customer satisfaction.
- This economic prosperity of the organisation will help to achieve the social developments of the organisation by using green training and other pillars.

This way, it leads towards all the three main dimensions of sustainability as per the TBL's approach with the help of green TPM framework.

3. Conclusions

The conventional competitiveness is determined on your abilities to offer a superior quality product at low cost with faster deliveries. With more aware customers, the expectations are now moving into intangible aspects, particularly environment-related issues. The focus of maintenance has chased from a cost centre to strategic investment activity but adding 'green' aspect will help an organisation to achieve sustainability through green TPM. The efforts of different functional areas to help in achieving sustainability will create a more synergistic environment in the organisation. This synergy will be a very important enabler for competitiveness in coming times.

There will be a continuous requirement of spreading this synergy from internal-organisation level to inter-organisation level. The conventional TPM will be scaled up to green TPM using some of the green pillars coming from different functional aspects. This GTPM will open the door of economic, environmental, and social sustainabilities and this will become an important enabler for the competitiveness of the organisations in a period which is characterised by very frequent change of product designs, frequent change of jigs and fixtures, and frequent change of dies etc.

4. Limitations and Future Scope

This framework is being proposed on the basis of literature review and experts survey. So there is the future scope of the study to empirically validate the proposed framework. In this proposed framework, it is possible to have a few case studies as well as data collection from different organisations.

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Biographies

Ashutosh Samadhiya is a Research Scholar in the field of Operations Management in Department of Management Studies at Indian Institute of Technology Roorkee, Uttarakhand, India. He earned M.Tech in Mechanical Engineering from National Institute of Technology Agartala, India. He has published one paper in Journal of Manufacturing Process and one in IJPEM. His research interests include manufacturing, production, and operations.

Rajat Agrawal is a member of faculty (Associate Professor) at the Department of Management Studies, Indian Institute of Technology Roorkee, Uttarakhand, India. He administers various initiatives of IIT Roorkee in the field of IPR, incubation and entrepreneurship in different capacities. He initiated incubation centre at IIT Roorkee. He is a coordinator of the Design innovation centre. He is also IPR Chair Coordinator at IIT Roorkee. Dr. Rajat is a visiting fellow to Copenhagen Business School, Copenhagen, Denmark. His area of interest is Production and Operations Management including Supply Chain Management, Manufacturing Strategy and World Class Manufacturing. He has guided thirteen PhD thesis in these areas and published papers in journals of Emerald, Sage, Springer, Taylor and Francis, Elsevier, and Inderscience. He has developed more than 20 case studies on various aspects of supply chain management, organisational development, natural resource management, social entrepreneurship, and value co-creation. He has more than 200 hours of corporate training experience with organisations like BHEL, THDC India Ltd., Power Finance Corporation Ltd., Syndicate Bank, Everest Industries, and Rockman Industries etc.

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