

# World-class manufacturing through ‘Total Productive Maintenance’ via ISO 9001:2015 standard

M. Santhosé<sup>1</sup>, T. Suresh Kumar<sup>2</sup>, V. Senthil<sup>3</sup>, S.R. Devadasan<sup>4</sup>, and V.M.M. Thilak<sup>5</sup>

<sup>1</sup>Department of Mechanical Engineering, Al-Ameen Engineering College

<sup>2</sup>Department of Mechanical Engineering, K.S.R. College of Engineering

<sup>3</sup>Department of Mechanical Engineering, Coimbatore Institute of Technology

<sup>4</sup>Department of Production Engineering, PSG College of Technology

<sup>5</sup>Department of Mechanical Engineering, Nehru Institute of Engineering and Technology

<sup>1</sup>santhosesurya@gmail.com, <sup>2</sup>tsureshkumar17@gmail.com

<sup>3</sup>vsenthil.me.cit@gmail.com, <sup>4</sup>devadasan\_srd@yahoo.com, <sup>5</sup>vmmthilak@gmail.com

## Abstract

*In this work, a study is reported in which the proposition of implementing ‘Total Productive Maintenance’ (TPM) via ISO 9001:2015 standard was investigated. Two main contributions have been made to enhance knowledge in the existing domains of knowledge by carrying out the research described in this article. The first contribution is the design of the TPM 9001:2015 Model. In this model, the elements of TPM have been integrated with ISO 9001:2015 standard in such a way that a company implementing this standard will be able to smoothly implement the elements of TPM. Both ISO 9001 standard and TPM contain specific elements that would guide the organizations to plan implement measures and improve the performance. Hence, an organization implementing the TPM 9001:2015 model will be able to continuously monitor the implementation and ensure that the resources input for implementation is utilized for enabling the organization to implement ‘World Class Manufacturing’ (WCM) essentials. The second contribution is the quantitative and qualitative assessment of practically implementing the TPM 9001:2015 model. This assessment was made considering ‘Diesel Machinery Works’ (DMW) which is a typical organization included in implementing ISO 9001:2015 standard and TPM. This assessment indicates the additional actions required for implementing the TPM 9001:2015 model in today’s organizations. Apart from the two main contributions, the knowledge gathered by reviewing the research paper was studied this knowledge is useful to the researchers and practices for adapting appropriate methodologies for implementing the elements of ISO 9001:2015 standard and TPM.*

**Keywords:** *We would like to encourage you to list your keywords in this section*

## 1. Introduction

During the past 30 years, the world has been observing the increase in competition in the manufacturing field (Akçura and Ozdemir 2019). This intensification of competition has been occurring because trade barriers that were existing earlier along the borders of the countries and continent have now been removed to enable the companies for competing globally (Kaur et al. 2015). This kind of globalization has been driving the modern companies to carry out WCM journey. While carrying out this journey, modern companies are required to adopt WCM strategies. One of the WCM

strategies identified by the researchers is TPM (Aspinwall and Elgharib et al. 2013; Attri et al. 2014; Kaur et al. 2015; Agustyadi and Cudney 2018). TPM is one of the maintenance quality approaches that emerged in the history of maintenance engineering (Bataineh et al. 2019). The beginning of TPM can be outlined in the maintenance engineering principles adopted in Nippon Denso Company Limited in Japan during 1971 (Jain et al. 2015).

A historical study would reveal that the first model that emerged in the maintenance engineering field was 'breakdown maintenance'. The subsequent model emerged was 'periodic maintenance'. After that, several models like 'preventive maintenance' and 'reliability centered maintenance' emerged in the world (Singh and Ahuja 2013; Bartz et al. 2014; Braglia et al. 2019). This progression was taking place from the 19<sup>th</sup> century to the mid of the 20<sup>th</sup> century. From the middle of the 20<sup>th</sup> century, the world witnessed the progress of the 'continuous quality improvement' method. On witnessing the progress of several 'continuous quality improvement' and 'maintenance engineering', models, Naakajima, a Japanese expert, developed the TPM concept by integrating the 'preventive maintenance' approach with the 'continuous quality improvement' concept. After the emergence of TPM, it spread across the world (Bataineh et al. 2019). Several companies implemented TPM and reported the achievement of improvement in maintenance quality (Jain et al. 2014). Meanwhile, the researchers who began to work on TPM improved its elements, to increase the scope of its application (Kaur et al. 2015). This enlargement of the scope of TPM has been enabling the companies to carry out WCM practices.

By the time TPM was introduced and subsequently implemented in companies, the world witnessed the emergence of the ISO 9001 standard. The first version of ISO 9001 appeared in 1987 (Cândido et al. 2016). Subsequently, ISO 9000 series standards were subjected to revision in the years 1994, 2000, and 2008. Initially, other standards namely ISO 9002 and ISO 9003 were brought out as ISO 9000 series standards (Allur et al. 2014). It was restricted to ISO 9001 when the revision to ISO 9000 series standard was made in 2000. The latest revision has been made in the year 2015 and this standard is given the code number ISO 9001: 2015 (Hadidi et al. 2017).

Whenever researchers carried out researches on implementing ISO 9001 standards, many of its capabilities were tested. One such capability tested was the effectiveness of making the WCM journey through the implementation of a TPM integrated ISO 9001 standard-based quality system. Such kind of study was reported by Sivaram et al. (2014). In this research, the effectiveness of carrying out the WCM journey through the industrial application of TPM and ISO 9001:2008 standard-based quality system was tested. The model presented in Sivaram et al. (2014) cannot be now used to carry out WCM as the modern companies are required to implement ISO 9001:2015. In this standard, the clauses presented vary to a large extent from that of ISO 9001:2008 (Hadidi et al. 2017). Hence, it is high time that a model facilitating the combination of TPM with ISO 9001:2015 standard is developed which will be useful to the researchers, consultants, and practitioners for contributing towards the speeding up of the WCM journey. To fulfill this imperative, the research described in this paper was performed. By carrying out this research, a model has been designed to enable modern companies to implement TPM via ISO 9001:2015 standard-based quality system and carry out the WCM journey.

The research being reported here was carried out in file distinct phases. During the first phase, the elements of ISO 9001:2015 standard were studied. This study was necessary because major changes and few additions have been made in ISO 9001:2015 standard from the earlier version namely ISO 9001:2008. During the second phase, the

development in the TPM field was taking. This study was necessary because researchers have been working hard to expand the scope of TPM for making an effective WCM strategy. During the third phase, the nodes and links that are available in ISO 9001:2015 standard and TPM principles. Which would facilitate the integration of both this world-class strategy by making the use of knowledge gathered by carrying out the above three phases, during the fourth phase a model combining TPM with ISO 9001:2015 standard was proposed. This model has been named a TPM 9001:2015 model. During the fifth phase, a company in which both ISO 9001:2015 and TPM have been implemented was approached by a competent person in this company. The practicality of implementing the TPM 9001:2015 model in practice was studied by quantitative and qualitative assessing the possibility of implementing the stipulation of this model. This research was concluded in this phase by suggesting the featured case of an action that is needed for successfully Implementing the TPM 9001:2015 model and thereby enable organized to perform at the WCM level.

## **2. Literature Survey**

Through the past 40 years, the world has been witnessing the emergence of several strategies that would enable the companies to perform at the WCM level (Satolo et al. 2018, Modgil and Sharma 2016). On implementation, these strategies have been enabling the companies to acquire WCM capabilities. In coincidence to this development, many researchers have been endeavoring to integrate many of these strategies for enabling modern companies to acquire WCM capabilities. One such endeavor is the combination of TPM with an ISO 9001 based quality system (Sahoo 2019). One of such kind of endeavor was reported in Sivaram et al. (2014). In the research reported in this paper, the three TPM elements were integrated with ISO 9001:2008 standard. Currently, ISO 9001:2015 is in vogue and modern companies are required to implement it. This development indicated the need to design the model that would facilitate the integration of the three TPM elements with the main clauses of ISO 9001:2015 standard.

## **3. Design of TPM 9001:2015 Model**

As stated in the preceding section, the enlarged scope of TPM coincides with the scope of the ISO 9001 based quality system. This coincidence is motivating the researchers to superimpose the implementation of TPM elements with the model incorporated in ISO 9001 standard. As mentioned earlier, in this direction, research on combining the TPM with ISO 9001:2008 was reported by Sivaram et al. (2014). This observation has now indicated the need to propose a model that would facilitate the superimposing of TPM elements with the model incorporated in ISO 9001:2015 standard. To fulfill this need, the TPM 9001:2015 model was proposed while pursuing the research reported in this paper. The design aspects of this model are presented in this section.

While designing the TPM 9001:2015 model, the three TPM elements and main clauses of ISO 9001:2015 standard were studied thoroughly. The information and knowledge gathered by carrying out these studies were integrated to design the TPM 9001:2015 model. This feature is shown in Figure 1. As presented, the TPM pillars and six big losses were considered together with the focus on enhancing the Overall Equipment Effectiveness (OEE). This concept was infused in the main

clauses of ISO 9001:2015 standard. Keeping these conceptual features as the reference, the detailed design of the TPM ISO 9001:2015 model was carried out.

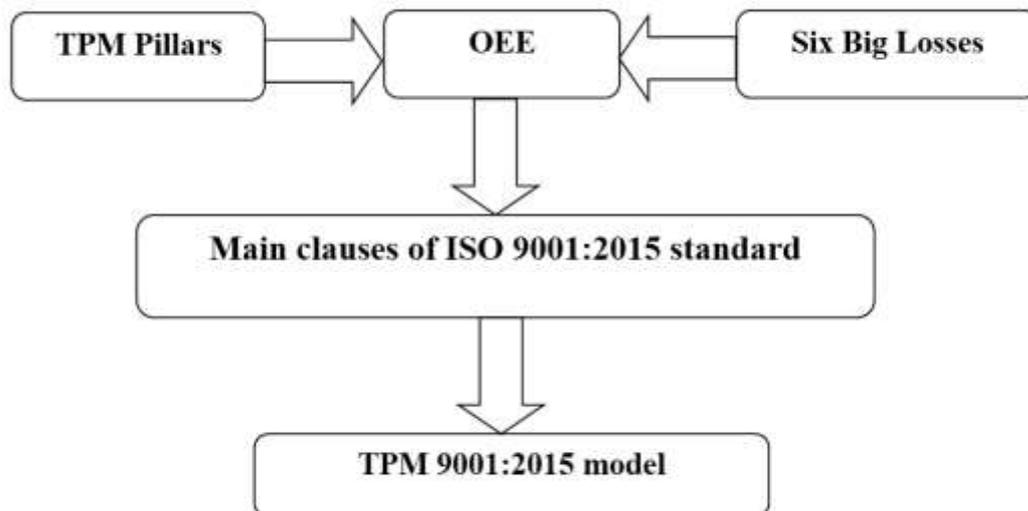


Figure 1. The methodology followed to design TPM 9001:2015 model

A sample of such detailed design which is indicated as clause 5.1.1 of TPM 9001:2015 model is shown in Table 1. Initially, the contents of ISO 9001:2015 were adopted. To infuse the principles of TPM element, the word ‘quality’ presented in ISO 9001:2015 standard was appended by the word ‘maintenance’ to create the title ‘maintenance quality’. Further, OEE was impregnated in suitable clauses of ISO 9001:2015 standard. As shown in Table 1, the TPM pillars were added, where it founds necessary. Accordingly, the TPM pillars namely ‘focused improvement’ and ‘autonomous maintenance’ have been appended with the contents of clause 5.1.1 of ISO 9001:2015. Further, the enhancing of OEE through maintenance quality improvement is specified in this clause of the TPM 9001:2015 model. This exercise was performed in all the major clauses of ISO 9001:2015 standard for designing the TPM 9001:2015 model. This exercise was carried without changing the contents of the ISO 9001:2015 standard. This aspect will ensure that the operation of the ISO 9001:2015 based quality system is unaffected due to the employment of the TPM 9001:2015 model in the organization.

#### 4. TPM through Leadership

The leadership towards implementing TPM is required to be driven by the top management personal. This drive has to be made necessary by the person occupying the topmost position in the organization. The designation of this position varies in different organizations. In small organizations, the leadership is denoted by the owner who is generally designated as proprietor. In a medium-size organization, the topmost position is designated as managing director. In large size organization, the topmost position is designated as a resident. The TPM 9001:2015 model is required to be implemented through the involvement of such personal occupying the topmost position of the organization. To increase the smoothness of the execution of the TPM 9001:2015 model, such topmost personal may form a leadership team to support the implementation of the TPM 9001:2015 model such a TPM 9001:2015 team shall be headed by the topmost personal. The responsibility of this team to promote an enunciation of the TPM 9001:2015 model occurrence. The organization

in such a way that the implementation of the elements of the TPM 9001:2015 model is focused on achieving customer requirements and thereby steer the organization towards performing at a world-class level. The TPM 9001:2015 model facilitates carrying out these activities to commitment, customer focus, and establishing maintenance quality policy.

### **5. Synchronization and commitment**

As mentioned earlier the leadership is represented by TPM 9001:2015 team. This team is responsible for synchronization of the activities of the TPM 9001:2015 model with the business objectives of the organization and customer focus. In other words, TPM 9001:2015 team is required to ensure that the activities being carried in the organization to implement ISO 9001:2015 model fulfill the business objectives like achieving high profit, becoming a market leader, and high service provider. Those activities are to be implemented in such a way that the customer requirements like high availability, low price, and high serviceability are much. The implementation of the TPM 9001:2015 model as to be steered by the leadership with high commitment towards the successful, fruitful, and outcome-oriented execution of the TPM 9001:2015 model. In this regard, the leadership must ensure that the maintenance Quality Management System (QMS) incorporated in TPM 9001:2015 model is followed by all the employees of the organization which will have the reflections in the form of directing the activities with customer focus for implementing world-class level actions.

The above synchronization and commitment aspects are enunciated in keep a 9001:2015 model 12 sub-clauses. Some of the enunciations of the sub-clauses are highly unique and powerful in effecting the maintenance QMS. For example clauses, 5.1.1(d) clarify the usage of method processing and risk base thinking will facilitate to implement world-class level maintenance QMS likewise, clauses 5.1.2(b) enunciation that achievement of customer fulfillment over the operation of maintenance QMS. In short, the sub-clauses enunciation the leadership to steer the operation of maintenance QMS to achieve the goals of implementing the TPM 9001:2015 model.

### **6. Implementation study**

While carrying out the quantitative and qualitative assessment, it was quite interesting to note that this stipulation encapsulated in the case clause of the TPM 9001:2015 model varied widely in number. Those numbers are presented in Figure 2. If the number of stipulations is taken as reference, it indicates that implementation clause 8 (titled TPM through operation) is going to consume more time for implementation. On the other hand, the number of stipulations is a minimum of 17 in the case of the 10<sup>th</sup> clause of the TPM 9001:2015 model.

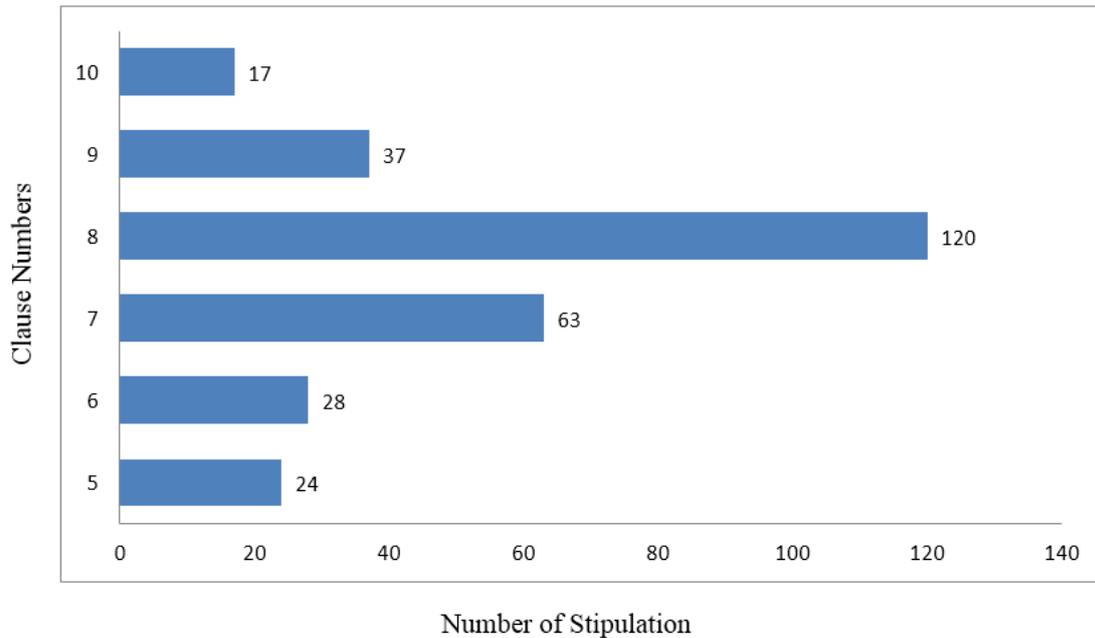


Figure 2. Number of stipulations presented under the main clauses of the TPM 9001:2015 model

It gives the impression that the implementation of the last clause of the TPM 9001:2015 model will take the least time.

The implementation study being reported here indicated the extent of the practicality of implementing each clause of the TPM 9001:2015 model. These values are presented in Table 1

Clause number of TPM 9001:2015 model	Title of the clause of the TPM 9001:2015 model	The extent of the practicality of implementation in percentage
5	TPM through leadership	57.5%
6	TPM through planning	55%
7	TPM through support	55.07%
8	TPM through operation	56.83%
9	TPM through performance Evaluation	58.64%
10	TPM through improvement	55.88%
Grand average in percentage = $\frac{57.5+55+55.07+56.83+58.64+55.88}{6} = 56.48\%$		

Table 1. The extent of the practicality of implementing the clause of TPM 9001:2015 model

As shown the extent of the practicality of implementing the clause of TPM 9001:2015 ranged from 55% to 58.64%. The range of these values is 3.64%, this narrow range indicates that the extent of the practicality of implementing all clauses of TPM 9001:2015 thus not vary much among themselves. This inference is confirmed by viewing the grand average in which case the values 56.48%. These values indicate that the practicality of implementing the TPM 9001:2015 model is

around 55% which is just about half of the implementation requirements. This is due to the reason, companies like DMW having implemented ISO 9001:2015 standard. DMW is situated in the Perundurai town of India. Hence up to about 50% extent TPM 9001:2015 model can be implemented today in companies like DMW. Further, the elements of TPM have been implemented by companies like DMW. Hence another 5% of the extent of implementation on the TPM 9001:2015 model can be achieved in companies like DMW. The remaining 45% of practical implementation of achieved by conducting on-the-job and off-the-job training and educational program on the TPM 9001:2015 model.

It is also interesting to note that, some stipulations of the clause of the TPM 9001:2015 model can be fully implemented in DMW. As shown the percentage of fully implementable stipulations is highest with a value of 32.43% in the case of the 9<sup>th</sup> clause of TPM 9001:2015 model. It's lowest with a value of 23.52% in the case of the last clause of the TPM 9001:2015 model. These absorbents indicate the TPM can be achieved practically in companies like DMW through performance improvement then the last clause title is an improvement. The total inference is that the percentage of fully implementable stipulations in all clauses are TPM 9001:2015 is less than that the mark (which is 50%). This is a concerning observation which indicates that constructive efforts like on-the-job and off-the-job training and education of the TPM 9001:2015 model are to be conducted. The statistics of this qualitative assessment are summarized in Table 2.

Clause number of TPM 9001:2015 model	Title of the clause of the TPM 9001:2015 model	Number of fully implementable stipulation	Total number of stipulations	Percentage of fully implementable stipulation
5	TPM through leadership	6	24	25%
6	TPM through planning	7	28	25%
7	TPM through support	17	63	26.98%
8	TPM through operation	34	120	28.33%
9	TPM through performance evaluation	12	37	32.43%
10	TPM through improvement	4	17	23.52%
Grand average in percentage = $\frac{25+25+26.98+28.33+32.43+23.52}{6} = 26.87\%$				

Table 2. Number of fully implementable stipulations of TPM 9001:2015 model

It should be followed by on the job evaluation by the top management monitoring efforts.

## 7. Conclusion

During the past five decades, organizations situated in most parts of the world have been certified to ISO 9001 series standards. The beginning of ISO 9000 series standard can be traced to the release of BS 5750 standard in the United Kingdom during the year 1979 (Wilson and Campbell, 2018). By referring to this standard, ISO 9000 series standards were designed and released in the year 1987. After formal implementation began in organizations situated in most parts of the world, ISO 9000 series standards were revised and released during the years 1994, 2000, 2008, and 2015. When the revised version was released in the year 2000, the earlier

three models presented under the three standards namely, ISO 9001, ISO 9002, ISO 9003, were shrunk to one single model which was accommodated in the ISO 9001 standard. Thereafter, the ISO 9001 standard has been playing a crucial role in enabling organizations in the world to achieve continual quality improvement. Because of this development, time and again, researchers have been striving to integrate several WCM strategies with the ISO 9001 standard based QMS to enable the organizations to meet the WCM requirements. Quite interestingly, two of these requirements namely knowledge management and risk-based thinking have been explicitly incorporated in ISO 9001:2015 standard (ISO, 2015). As stated in the prior section, in this direction, efforts are to be made for combining TPM with ISO 9001:2015.

Although the previous work on combining TPM with ISO 9001:2008 presented in (Sivaram et al., 2014) can be extended, this task is going to be difficult and challenging. This is due to two reasons. The first reason is that many clauses of ISO 9001:2015 are required to be newly studied for integrating the elements of TPM as these clauses were not incorporated in ISO 9001:2008 standard. Another reason is that the implementation of ISO 9001:2015 standard is going to be challenging as many critical remarks are made in this regard by the researchers (Alič, 2018). In this direction, the appraisals presented in (Anttila and Jussila, 2017) are noted with high concern. These authors have pointed out the several pitfalls of the stipulations and concepts presented in ISO 9001:2015 standard. Due to the observation of these pitfalls, the integration of TPM with ISO 9001:2015 standard is required to be carried out very cautiously in such a way that these pitfalls do not act as the impediments in attaining the WCM strategies. Before concluding this article, it is projected that such research is to be carried out in three phases.

In the first phase, a model combining the ingredients of TPM with the stipulations of ISO 9001:2015 is required to be designed in such a way that the pitfalls of the latter do not affect the attainment of WCM strategies. In the second phase, this theoretically designed model is required to be subjected to implementation studies. During the third phase of this research, the experiences, information, and knowledge gained by conducting the implementation studies are required to be used for refining the theoretically designed model to implement TPM via ISO 9001: 2015 standard based QMS. Such implementation will enable the organization to make the WCM journey at a faster speed.

## References

1. Agustiadhy, T. K., & Cudney, E. A. (2018). *Total productive maintenance. Total Quality Management & Business Excellence*, 1–8. doi:10.1080/14783363.2018.1438843
2. Akçura, M.T., Ozdemir, Z.D.: *Data-driven manufacturer-retailer collaboration under competition. Enterprise Information Systems*.13(3), 303–328 (2019)
3. aki Heras-Saizarbitoria
4. Alič, M. (2018), “Integration of the ISO 9001 QMS with the company’s IT business system”, *Total Quality Management & Business Excellence*, Vol. 29 No. 9-10, pp. 1143-1160.
5. Anttila, J. and Jussila, K. (2017), “ISO 9001:2015 – a questionable reform. What should the implementing organisations understand and do?”, *Total Quality Management & Business Excellence*, Vol. 28 No. 9-10, pp. 1090-1105.

6. Aspinwall, E., & Elgharib, M. (2013). *TPM implementation in large and medium size organisations. Journal of Manufacturing Technology Management*, 24(5), 688–710. doi:10.1108/17410381311327972
7. Attri, R., Grover, S., Dev, N.: *A graph theoretic approach to evaluate the intensity of barriers in the implementation of total productive maintenance (TPM). Int. J. Production Research*. 52(10), 3032–3051(2014)
8. Bartz, T., Siluk, J.C.M., Bartz, A.P.B. *Improvement of industrial performance with TPM implementation. Journal of Quality in Maintenance Engineering*, 20(1), 2–19 (2014)
9. Bataineh, O., Al-Hawari, T., Alshraideh, H., Dalalah, D.: *A sequential TPM-based scheme for improving production effectiveness presented with a case study. Journal of Quality in Maintenance Engineering*. 25(1), 144– 161(2019)
10. Braglia, M., Castellano, D., Gallo, M.: *A novel operational approach to equipment maintenance: TPM and RCM jointly at work. Journal of Quality in Maintenance Engineering*. <https://doi.org/10.1108/JQME-05-2016-0018>(2019). Accessed 20 July 2019
11. Cândido, C.J.F., Coelho, L.M.S., Peixinho, R. M. T.: *The financial impact of awithdrawn ISO 9001 certificate. Int. J. Operations & Production Management*. 36(1), 23– 41(2016)
12. Erlantz Allur Iñaki Heras-Saizarbitoria Martí Casadesús , (2014), "Internalization of ISO 9001: a longitudinal survey", *Industrial Management & Data Systems*, Vol. 114 Iss 6 pp. 872 – 885
13. Hadidi, L., Assaf, S., Aluwfi, K., Akrawi, H.: *The effect of ISO 9001 implementation on the customer satisfaction of the engineering design services. Int. J. Building Pathology and Adaptation*. 35(2), 176–190 (2017)
14. *In Internalization of ISO 9001: a ISO, (2015), ISO 9001 Quality management systems - Requirements, Switzerland.*
15. Jain, A., Bhatti, R. S. and Singh, H. (2015), "OEE enhancement in SMEs through mobile maintenance: a TPM concept", *International Journal of Quality & Reliability Management*, Vol. 32 No. 5, pp. 503 – 516.
16. Jain, A., Bhatti, R., & Singh, H. (2014). *Total productive maintenance (TPM) implementation practice. International Journal of Lean Six Sigma*, 5(3), 293–323. doi:10.1108/ijlss-06-2013-0032
17. Kaur, M., Singh, K., Ahuja, I.S., Singh, P.: *Justification of synergistic implementation of TQM-TPM paradigms using analytical hierarchy process. International Journal Process Management and Benchmarking*, 5 (1), 1–18(2015)
18. Modgil, S., Sharma, S.: *Total productive maintenance, total quality management and operational performance: An empirical study of Indian pharmaceutical industry. Journal of Quality in Maintenance Engineering*. 22(4), 353–377 (2016)
19. Nakajima, S.: *Introduction to TPM: Total Productive Maintenance. Productivity Press New York.*(1988)
20. Sahoo, S.: *Assessment of TPM and TQM practices on business performance: a multi-sector analysis. Journal of Quality in Maintenance Engineering*. <https://doi.org/10.1108/JQME-06-2018-0048>. (2019) Accessed 20 July 2019
21. Satolo, E.G., Leite, C., Calado, R.D., Goes, G.A., Salgado, D.D.: *Ranking lean tools for world class reach through grey relational analysis. Grey Systems: Theory and Application*. 8(4), 399–423(2018)

22. Singh, K., Ahuja, I.S.: *Implementing TQM and TPM paradigms in Indian context: critical success factors and barriers*. *Int. J. Technology, Policy and Management*. 13(3), 226–244 (2013)
23. Singh, K., Ahuja, I.S.: *Synergistic suitability of transfusion of TQM-TPM for Indian manufacturing industries using fuzzy-based model simulation*. *Int. J. Business Continuity and Risk Management*. 4(1), 36–53 (2013)
24. Sivaram, N.M., Devadasan, S.R., Muruges, R., Karthi, S., Sreenivasa, C.G.: *Synergising total productive maintenance elements with ISO 9001:2008 standard based quality management system*. *The TQM Journal*. 26(6), 534–549 (2014)
25. Wilson, J. P. and Campbell, L. (2018), “ISO 9001:2015: the evolution and convergence of quality management and knowledge management for competitive advantage”, *Total Quality Management & Business Excellence*, <https://doi.org/10.1080/14783363.2018.1445965>