The Impact of Total Productive Maintenance on Performance in the South African Food Manufacturing Industry

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Abstract

Consumer demands and global competition continuously increase, compelling South African food manufacturers to constantly improve resource efficiency and quality. Total Productive Maintenance (TPM) is a program aimed at equipment effectiveness. While TPM can improve maintenance aspects of equipment, food manufacturers are also mandated to implement a Total Quality Management system (TQM), often requiring the same resources and skill set as TPM. This paper aimed to investigate the impact of TPM on the organizational performance of a food manufacturing company while identifying TQM synergies and common barriers to success. The researchers aimed to work towards a practical model for successful TPM implementation for companies facing similar challenges. A large multi-national company was used as the population and 12 of its factories were used as a sample. The 12 factories represented a diverse yet representative mix of food-producing plants. Quantitative data collection and analysis were used to understand the impact of TPM and its core construct, i.e., Overall Equipment Effectiveness (OEE), on performance. Subsequently, a qualitative case study analysis was done to deliver an understanding beyond the data, identifying barriers to success and opportunities. The results indicated that TPM implementation in a food manufacturing environment does not necessarily lead to an increase in OEE. There is insufficient evidence to suggest that OEE can be used as a predictor of performance in productivity.

Keywords
Total Productive Maintenance, Total Quality Management, Overall Equipment Effectiveness, and Food manufacturing.

1. Introduction
Manufacturers are continuously challenged by unpredictable global economic conditions, more demanding customers and growing competition. This scenario is no different for South African food producers. (Nakajima, 1998) stated that manufacturing organizations need to focus on low-cost structures, improved resource utilization, superior quality, and the flexible and dependable delivery of products. These focus points are required to meet the customers' expectations and ensure a long-term sustainable business (Huang et al., 2003).

Slack and Brandon-Jones (Slack et al., 2018) proposed that manufacturing can contribute to organizational success by reducing costs, decreasing waste, improving productivity, and increasing service dependability. Globally, manufacturers have managed to accomplish this through the application of world-class manufacturing practices (Diaz-Reza et al.). A myriad of continuous improvement interventions has been implemented in the manufacturing sector with varying degrees of success (Beardsell et al., 1999). Total Productive Maintenance (TPM) and Total Quality Management (TQM) are management systems that can be used as a supportive framework for implementing world-class manufacturing principles.

TPM has demonstrated that it can positively impact on productivity, quality and costs (Afefy,2003, Ahuja et al., 2008 and Yusuf et al., 2007). Konecny and Thun (Philipp et al., 2011) further argue that manufacturers needed to pay attention to the reliability of their production processes. When striving for manufacturing excellence, TPM alone can thus contribute to productivity, but it is seldom applied in isolation.

Retailers often mandate food producers to implement a Quality Management System (QMS). The QMS must manage food safety and improve quality, which builds consumer trust and loyalty (Moore et al., 1995). QMS leads to greater consumer satisfaction, which can positively impact on a firm's performance (Hitchner et al., 1994). This has led to numerous producers implementing TPM and TQM systems to demonstrate continuous improvement, which is found more in the food manufacturing industry than in other industries (Andersson et al., 2015).

The implementation, objectives, and resources required for TPM and TQM are very similar, and in some instances, these overlap (Azyan et al., 2017, Khan et al., 2020). Due to the scarcity of these resources, food manufacturers often fail to achieve the full benefit of either system. Food manufacturers thus often miss the opportunity to use TPM principles to enhance manufacturing performance, and therefore, organizational success. Overall Equipment Effectiveness (OEE) is generally accepted as an indicator of TPM success and has shown that it can influence the efficiency of a production system (Andersson et al., 2015).

In addition, there is a lack of research on the application of TPM in the food manufacturing industry, as Diaz-Reza, García-Alcaraz and Martínez-Loya (2019) reported. If food manufacturers could develop a greater understanding of how to use TQM and TPM in harmony, it could be contended that resources would be used more efficiently and effectively, leading to greater competitiveness and sustainable operations (Cooke et al., 2000, Djolov et al., 2015, Muchiri et al., 2008).

It can thus be argued that to ensure their long-term sustainability, South African food manufacturing companies need to successfully implement methodologies that can guide them in the journey to excellence (van Heerden, 2016). According to the United Nations Industrial Development Organisation (UNIDO), South African manufacturing competitiveness has declined, as the country was ranked 53rd in 2018 (Wakjira et al., 2012). Djolov found that although manufacturing success in South Africa can be attributed to various factors, it is ultimately the ability of the organizations to use their resources innovatively that sets them apart from the competition.

Majumdar and Manohar (2012) suggested using TPM as a TQM tool, due to its focus on machine performance and quality. Kauer et al. (2012) further highlighted the competitive advantage that can be gained by organizations that implement both TPM and TQM successfully.

When considering the above conclusions made through investigation, the research problem becomes clear. Organizations implementing both TPM and TQM can gain a significant competitive advantage but often lack an understanding of how TPM can impact on performance and how best to utilize limited resources to manage both programs successfully. TPM and TQM share many similar resources and often require the same approach to change management, resource allocation and cultural changes (Linderman et al., 2005). The actual impact is reflected in the tracking of the OEE performance metric and the influence of its constructs on performance.

The objectives of TQM and TPM have commonalities because both systems are designed to promote a continuous improvement culture and advocate the involvement of all employees. The organization thus risks missing an opportunity to enhance its competitive bearing should the implementation and management of both TPM and TQM not be used to their full capacity (Modgil et al., 2016). With a better understanding of the influence of TPM on performance, organizations may be in a better position to harness the full potential of the program.

The conceptual framework proposed for this study is shown in Figure 1. The accepted model was that OEE is an accurate representation of TPM success. It was hypothesized that OEE impacted organizational performance over time since continuous improvement lies at the core of a TPM program. The key performance metrics used to gauge organizational performance in the manufacturing units were organizational success (volume growth or profit margins), quality performance, cost performance, delivery (or flexibility), people aspects and employee safety. TPM elements have varying degrees of influence on these metrics, while TQM elements can simultaneously impact on these areas.

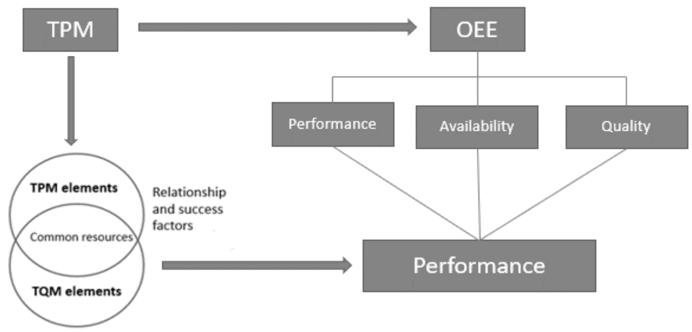

Figure 1. Conceptual framework (author's model)

1.1 Objectives

The primary research objective was to establish a TPM implementation framework that could contribute to organizational competitiveness in the South African food manufacturing industry where TQM principles are also implemented. This could be accomplished through understanding the impact of TPM on business unit performance. Researchers and practitioners alike agree that TPM and TQM can positively impact on performance, as is evident from the literature review. Food manufacturers must implement a TQM program or a derivative of it by law or through customer demands. This leads to a situation where resources and processes must be shared or prioritized to achieve the same goal as a TPM program.

The secondary research objectives were:

i. Investigate the impact of OEE and its components on business unit performance and productivity.
ii. Identify barriers to the successful implementation of TPM in food manufacturing.
iii. Evaluate if and how TQM systems impact on TPM implementation to establish critical success factors for implementation.

The research furthermore sought to answer the following research questions:

i. How does TPM impact on factory performance (where OEE is the definitive performance measure for TPM success)?
ii. Can OEE be used as a predictor of factory performance?
iii. What are the barriers to success and critical success factors in TPM and TQM implementation; are these common to various business units?
iv. Since resources are scarce, how can the organization best use these shared elements?

2. Literature Review

A comprehensive search for recent research articles on applying TPM and TQM principles in the food industry delivered very few results. When adding key concepts (organizational improvement and food manufacturing) to Boolean logic, the conclusion was made that this field has not been thoroughly researched in recent years, particularly in the South African food industry.

2.1 TPM and TQM Commonalities

According to Wakjira and Singh (2012), TPM implementation over time can significantly enhance manufacturing performance and has proven to meaningfully impact on organizational performance (Huang et al., 2003, Khan et al., 2020, Linderman et al., 2005 and Moore et al., 1995). Very few of these studies have investigated the impact of TPM on food manufacturing. TPM can assist managers in unleashing opportunities for improvement by unlocking concealed capacity in equipment, reducing production costs, and permitting the deference of substantial capital investments that may be required (Creswell et al., 2013, Datta et al., 2011, Nakajima et al., 1988 and UNIDO). TPM has thus been the proven manufacturing strategy generally implemented for realizing core competence and achieving organizational objectives for manufacturing companies (Ahuja et al., 2004).

TPM is essentially built on eight pillars that cultivate effective organizational performance management (Williamson et al., 2006). The first four pillars target production efficiency and effective improvements focusing on improvement, autonomous maintenance, planned maintenance and early management, while quality management, training, administration, and safety play a supportive role in achieving success through TPM initiatives (Ahuja et al., 2008). The preferred metric used in the industry to indicate TPM success is Overall Equipment Effectiveness (OEE), which consists of three key factors (Islam et al., 2012). These factors (availability, performance, and quality) provide the user with a clear indication of whether or not the equipment does what it is supposed to do and delivers a return on the original investment as promised. OEE is seen as the authoritative tool for recognizing and reducing losses and developing a world-class production system (Garza-Reyes, 2015).

OEE improvements, therefore, also contribute to the enhancement of various TQM performance objectives. One of the primary requirements of a TQM program is to define organizational goals, which speak to continuous improvement (Jacobs et al., 2004). TQM can be succinctly defined as the best practices in which manufacturers carry out quality control, quality assurance, and continuous improvements in all their core business practices and procedures (Sivaram et al., 2014). The purpose of TQM is to supply quality products to the market at a reduced cost and increased productivity and competitiveness, thereby enhancing the organization's competitive position (Nagaraj et al., 2016). The objective of TQM thus shows familiar decrees when compared to a traditional TPM program. Some organizations prefer to use both TPM and TQM; others prefer to use one of the two systems exclusively, although their customers often mandate that food manufacturers implement a TQM system or an ISO standard quality management system (Slack et al., 2018, Khan et al., 2020). In the food manufacturing industry it is found that preference is given to TQM adherence and hence, more resources are allocated to its successful implementation.

The two programs (TPM and TQM) share many commonalities (Majumdar et al., 2012), especially in the human capital facet (Linderman et al., 2005). While the characteristics unique to TPM seem to address machine performance aspects, the TQM-specific details address quality and process elements. The common elements are aimed at people, as well as at strategic characteristics.

2.2 The TPM Methodology

TPM implementation addresses eight aspects of the organization, emphasizing its multi-disciplinary approach. These eight areas have become known as the eight pillars of TPM. These pillars are: autonomous maintenance, focused maintenance, planned maintenance, quality maintenance, education and training, safety, health and environment (SHE), office TPM and development management. The 5S principles are the foundation of these eight pillars, influencing how a successful TPM program is implemented and managed. Rodrigues and Hatakeyama (2016) argue that the organization's own unique culture will influence the way TPM is addressed and that it may differ in the application, according to the organizational design and existing culture. A 5S program may be beneficial in the food industry, due to its strong link to good manufacturing practices (GMP), therefore, building on a cultural aspect of continuous improvement (Wang et al., 2001).

2.3 The TQM Approaches

Beardsell and Dale (1999) argue that the TQM principles applicable in the food industry are similar to other manufacturing concerns. When reviewing available literature on TQM it becomes clear that there are numerous varying opinions on how many core concepts or "pillars" there are to a TQM program. It is also perceived that the "pillar" concept has not been branded as the 8 TPM pillars.

A literature study revealed the most common TQM constructs are leadership, commitment, support, culture, information management and reporting, process management and improvement, employee involvement and customer focus (Ahire et al., 1996, Black et al., 1996, Sila et al., 2005, Flick, 2019, Bulent et al., 2000, Hooi et al., 2017, Jonsson et al., 1999, Thun et al., 2011 and Psomas, 2014).

2.4 OEE as a Performance Metric

The TPM concept, introduced by Nakajima (1988), allowed for developing a quantitative metric to clarify performance, namely OEE. The primary goal of TPM, which is to achieve zero breakdowns and zero defects through zero equipment errors, provides a secondary benefit, due to an inventory reduction, improved production rate, increased labor productivity, and ultimately, better service levels. OEE is the unique measurement that encapsulates these factors; it can be defined as a measurement for total equipment performance, in other words, the degree to which the equipment does what it is supposed to do (Gotzamani et al., 2010, Zammori et al., 2011).

2.5 Conclusion on the Literature review
From the literature, it becomes clear that there are commonalities in the implementation of TPM and TQM as well as similar goals. OEE is the preferred method used to track the performance of TPM but also touches on certain TQM aspects. If the organization can gain maximum benefit from the TPM and TQM, improved OEE as well as improved productivity or business performance should be expected.

3. Methods
The methodology used in this section describes how to achieve the research objectives, through consideration of the research questions as outlined previously. The research method, data collection and sampling rationale are described in this section. There are three techniques used for the collection of data, namely qualitative, quantitative and mixed methods. Collins (2010) contends that multiple methods are advantageous when the researcher aims to better evaluate the research findings' trustworthiness and extrapolations from them. It can thus be used at different stages of the research to test the validity of the findings. Another major advantage of multiple method research is the ability of the researcher to triangulate the research findings. This increases the credibility and validity of the research. The researchers chose to use the mixed-method approach to answer the research questions. Qualitative data collection aimed to provide deeper insight into the quantitative results that emerged from the descriptive statistics and regression analysis.

3.1 Research Strategy
The impact of OEE on performance metrics was explored, with OEE being the main TPM construct. It is clear from the literature that OEE is the definitive performance metric for a TPM program. Firstly, a quantitative analysis was performed to gain a better understanding of the relationship between OEE and productivity performance. Descriptive statistics and regression analysis were used for the quantitative investigation. A case study was subsequently undertaken to develop a deeper understanding of the impact of OEE on performance, the barriers to success, and the critical success factors. This was accomplished through semi-structured interviews. The results were compared to the literature, conclusions drawn and recommendations suggested. From the literature review, a common theme emerged: TPM can positively impact on organizational performance. Certain commonalities are shared with TQM (tools, techniques, resources and barriers to success), which creates a strong link between the two disciplines. The OEE metric is accepted as the preferred TPM performance measurement and an element of TQM is also captured in this metric.

Considering the above, the null hypothesis was developed and noted as follows:
H0 – TPM (OEE) has no significant impact on business unit performance.
H1 – TPM (OEE) has a significant impact on business unit performance.
The independent variable is:

- OEE and its constructs (quality, availability and performance).

The dependent variable is:

- Productivity (rand/kg or output/input)

Therefore, the composite hypotheses below were developed.
H2 – OEE (performance) has a significant impact on business unit performance.
H3 – OEE (availability) has a significant impact on business unit performance.
H4 – OEE (quality) has a significant impact on business unit performance.
One of the secondary research objectives was to investigate the impact of OEE and its components on business unit performance and productivity. The stated hypothesis enabled the researchers to evaluate the impact of the components of OEE on performance and draw conclusions and recommendations. It thus addressed the other research objectives, which were to understand the impact of TPM on business performance and to develop a TPM framework for its successful implementation in the food manufacturing industry.

3.2 Data Collection Technique
Data for the quantitative analysis was obtained from a large multinational food manufacturer operating in South Africa. The company has 44 manufacturing units in the country of which 12 were selected as a sample. The data used is recorded monthly as part of the firm's financial reporting as well as the factory's production reporting. The data was readily available and consent was given by senior executive management members to use it anonymously. For the qualitative analysis, the researchers used thematic analysis guidelines. Each segment of data in the transcripts was coded to be relevant to one of the research questions. The themes that emerged for each research question were analyzed, as shown in the data analysis. The themes were evaluated continuously to determine whether or not sub-

themes were emerging and to establish if the data associated with each theme supported the theme relevant to the research question. It was also noted that themes overlapped. These overlapping themes were segregated and defined to ensure clarity in the data collection. After refining the themes, the main theme associated with each question was defined and the essence was captured. A total of 12 employees were approached to be interviewed for this research. None of the selected respondents indicated that they were uncomfortable with participating in the interviews.

3.3 Sampling

For the quantitative and qualitative study, the target population was manufacturing units that have implemented TPM principles and a TQM system. The units under review were all part of the same company and subjected to the same manufacturing model. While the company's manufacturing profile consists of 44 factories, 12 were available for the sampling of data. The reason for this was that the 12 mentioned units were all part of the same category of products, classed as food and beverages. These units provided the researchers with accurate data interviewing key personnel. The company operates within the Fast-Moving Consumer Goods (FMCG) environment in South Africa and provided the researchers with monthly productivity data of the 12 manufacturing units for four years, from January 2017 to December 2020. Written permission was requested before the study commenced. The company mentioned in the study remained anonymous. The names of the various operating units and the names of the participants in the semi-structured interviews were kept anonymous.

3.4 Authenticity, Credibility, Reliability and Validity

The business units used in the data collection process were all manufacturing facilities operating in the food manufacturing industry. The units all measured the same manufacturing key performance indicators since they were subsidiaries of the same holding company. The units had implemented a TQM system (ISO 9001, BRC and FSSC 22 000). At the same time, all the units had also implemented TPM principles to varying degrees of maturity.

The validity and reliability of the quantitative research were demonstrated by selecting the sample population and applying measuring instruments. The consistency of results and adherence to the general theory were used to test the validity. Furthermore, a qualitative study linked the quantitative results to the same sample population.

Creswell (2013) noted that qualitative researchers prefer to focus on descriptions, such as quality, credibility or trustworthiness of the research when validity must be demonstrated. For the qualitative research, a combination of triangulation of the results and respondent validation was used.

After completion of the interviews, the results were compared with topics in the literature and the quantitative results. This was done to ensure further corroboration of the interview outcomes. The thematic analysis themes were established based on the literature review conducted in the field of TPM and TQM to ensure the validity of the results. To ensure the reliability of the interview results, the participants were interviewed in a private, comfortable space, so that their full attention was given to the researcher for the duration of the interview. To minimize the risk of errors, the researcher conducted a maximum of two interviews per day. This method ensured that the researcher remained focused on the interview to obtain accurate results. The researcher was aware of the risk of a biased opinion; therefore, care was taken to ensure the results were recorded and analyzed factually. The construct validity, which refers to the degree to which the research measures what it claims to be measuring, is addressed through the application of the deductive method of testing constructs. Internal validity was addressed by testing the strength of the relationship of the variables (dependent and independent).

3.5 Limitations

Due to limitations in terms of access to data, time constraints and the standardization of reporting, only business units in one company were sampled. Therefore, certain assumptions were made. These included:

- Data collected on OEE reporting was accurate and correct and the same calculation method was used by all the factories sampled.
- OEE was always measured at the same monitoring point (i.e., the "bottleneck" process).
- Information given during the interview process was not biased.
- Participants understood the fundamentals of both TPM and TQM.

Both TPM and TQM programs were implemented, albeit to varying degrees of maturity. It would thus be misleading to claim that all units were maintaining a fully operational TPM and TQM system. This is however the case in most factories and is thus seen as representative of the industry and its unique challenges.

3.6 Population

The data used for the descriptive statistics and regression analysis were production performance data, which were captured over 48 months at 12 factories. The data were captured automatically in some cases and manually in others. Some factories did not have the means to capture data digitally, while others with highly automated systems could perform the necessary data collection and deliver the required reports. The philosophy of OEE calculation was the same in all instances.

The aim was to include at least one representative from each of the 12 factories used in the quantitative analysis to ensure a representative sample. The interview feedback swiftly gained a degree of data saturation due to the consistent feedback from participants, indicating a degree of similarity in the responses.

4. Data Collection

The average OEE is 67.65%, which is well below the world-class benchmark of 85%. When examining the reason for the low OEE further it becomes clear that availability is the main contributor to lower performance. The availability average is 76.37%, with a standard deviation of 9.58, which is higher than the other OEE factors. Bulent et al. (2000) proposed that OEE should be used to measure the effectiveness of equipment over time by tracking advances or declines. Availability is defined as the time the production line is not operating due to either unplanned stoppages (e.g., waiting on material), set-ups (or changeovers), or breakdown of equipment (Kaur et al., 2012). Six of the factories show an improvement in OEE over time, while six show a decline. The availability factor is the biggest contributor to the decline and it can, therefore, be argued that these six factories either experienced an increase in the number of changeovers, unplanned equipment failures increased (which could point toward a poor maintenance program), or numerous short stoppages negatively impacted production efficiency.

Second to availability, the quality factor is noted as being the lowest of the three OEE factors. The quality factor comprises reduced yields and the manufacture of defective units (Powel, 1995). This could mean the varying quality of raw materials used in the food industry. Performance (or the original equipment manufacturer's (OEM) speed of the machine versus the actual speed) is the better performer of the three OEE factors. The R/kg metric is varied and ranges from a minimum of R0.89 to a maximum of R22.81. This indicates the diversity of the converting cost associated with each of these factories. The conversion cost is totaled by calculating manpower, maintenance costs, energy and factory overheads. The high variance indicates various levels of automation (manpower variance) and process characteristics (energy and maintenance characteristics). The R/kg metric will be the dependent variable in the regression analysis since it is a useful indicator of productivity where inputs are represented by the cost of resources, while output is delineated by the tonnages produced.

The performance factor of the OEE calculation shows the least variance and can thus also be the most constant performing of the three OEE factors. The performance factor shows the highest average value, with the data leaning towards normality in its distribution. Performance is calculated by dividing the OEM-rated production speed into the actual speed of observing production. The high average percentage noted in the performance factor shows that most factories have little trouble ensuring the equipment produces at full speed. The performance also encapsulates the OEE calculation of short-stops or idling equipment, as demonstrated in the six big losses. These losses seem to have a slight impact on the OEE performance of the 12 factories sampled.

The summarised statistics for the 12 factories provide a useful insight into the performance of the plants from an OEE and productivity perspective as shown in Table 1. This is important to provide context for further regression analyses and shows the basic features of the data used to answer the research questions. OEE seems to be improving in certain factories, but an equal number of factories show a decline in OEE performance, which should be of concern to the businesses. Considering the inflationary environment in which these factories operate (increases in wages, rising steel prices and energy costs), the R/kg performance seems to have been controlled successfully, although the metric is acutely dependent on volumes produced. Volumes produced may relate to sales and market share growth, which is an uncontrollable variable for manufacturing units and in the hands of the commercial sales and marketing teams.

A multiple regression analysis using R/kg as the dependent variable and OEE and its constructs as the independent variable showed that of the 12 factories, the null hypothesis of seven can be rejected and that OEE significantly impacts R/kg performance. However, the strength of the relationships are very poor and seldom show that OEE can explain a large percentage of the variance in performance. One would have to be careful to use these models for meaningful conclusions. The multiple regression models show a much better R-squared value in general; six of these multiple regression models are strong enough to be used for inferential statistics. The multiple regression models show that performance significantly explains variance in R/kg performance, followed by the availability factor. Therefore, one could state that in most cases, hypothesis H2 can be accepted. Quality only had a significant impact on performance in one of the 12 models. Performance can, therefore, also be used to predict R/kg performance in most cases. This is one of the research objectives, as stated earlier.

Table 1. Descriptive Statistics for 12 Factories

	R/KG	P	A	Q	OEE
Mean	7.66	96.93	76.37	92.22	67.65
Standard Error	1.95	0.03	2.76	0.24	2.53
Median	6.66	96.88	73.78	92.07	65.14
Mode	1.41	96.83	69.06	91.98	61.04
Standard Deviation	6.77	0.12	9.58	0.83	8.77
Sample Variance	45.83	0.01	91.74	0.68	76.99
Kurtosis	0.72	-1.71	-1.25	8.72	-1.39
Skewness	1.03	0.45	0.28	2.74	0.29
Range	21.92	0.31	29.75	3.23	26.21
Minimum	0.89	96.81	63.21	91.46	55.88
Maximum	22.81	97.13	92.96	94.69	82.08
Sum	91.88	1163.17	916.46	1106.63	811.81
Count	12	12	12	12	12
Confidence Level(95.0%)	4.3	0.07	6.09	0.53	5.58

The qualitative analysis used semi-structured interviews to obtain useful data. After data analysis, themes were identified. The final, refined themes are the result of a rigorous, iterative process of theme definition and grouping. The themes were then linked to the literature review and the summary below emerged as the overarching themes in the interviews:

- Office TPM – how data are collected and used, as well as the administrative burden on administrating the two systems (TPM and TQM).
- Availability – is the main overarching reason for lower OEE values.
- Quality management – the regulatory aspect of quality management systems and the customer are central to the concept of a TQM system.
- Leadership and management commitment – the understanding and support from leadership and management, also their commitment to the systems.
- Learning and development – specifically technical skills for operators and artisans to ensure higher availability.

The quantitative analysis is linked with some of the constructs highlighted in the qualitative analysis, namely availability as an OEE factor. Furthermore, it provided deeper insight into how the system can be improved as well as more granular details on why availability is an area that should be the focus of improvement if OEE is to be enhanced, and therefore better business results are expected.

5. Analysis

There is a strong link between the quantitative and qualitative results obtained from the data analysis. The reason for lower OEE values, i.e., the impact of availability, was corroborated through the interviews. The interviews provided a better understanding of why the availability factor is the most significant contributor to a lower OEE. The lack of a correlation between OEE and performance was verified in the interviews. This finding connects with the quantitative analysis results. Not once was it mentioned that OEE has an impact on the R/kg metric. The interviews brought forth some details regarding the understanding of the teams' perception of TPM and TQM. The essence of the systems is absent in many instances, and therefore, the organization needs to better understand how the two systems could be utilized more effectively.

6. Results, Conclusion and Recommendation

The research aimed to ultimately provide a food manufacturer with an implementation model to assist with TPM in an environment where TQM is required. The conceptual model (Figure 1) can be used as a guide to implementation. After considering the research results, the model can be slightly modified to express detail in the concepts, focusing on availability and the specific shared resources highlighted in the research. In the food industry, machine availability due to frequent changeovers, cleaning regimes and breakdowns, significantly impact on OEE and must be prioritized for better OEE results and improved competitive positions.

To answer the research questions, it can be concluded that TPM does impact on R/kg performance; that the OEE factors of availability and performance have a significant impact on R/kg, while quality does not. It is also important to note that a higher OEE will not necessarily always relate to a better performance in terms of productivity (R/kg), as can be inferred from the statistical analysis. This statement was further corroborated in the semi-structured interviews, where no participant mentioned a link between OEE and R/kg performance. Companies need to be cautious when using OEE as a performance predictor, mainly because of possible data integrity problems, a possible lack of understanding of the measurement and the lack of a strong correlation between OEE and performance. The office TPM theme included the automated collection of data, leading to a more reliable means of ensuring that OEE data are captured accurately. This may lead to using OEE as a performance predictor, although the numerous regression analyses suggest further research should be done on this contentious topic.

The impact of TPM on performance may take some time to establish itself as a meaningful contributor and, therefore, companies should not expect immediate results. Organizations could direct their efforts to improve availability and performance first to see quicker results. This is an observation that is further corroborated by the consistently lower performance index of the availability factor when deconstructing the OEE metric. This model of similarities between TPM and TQM can be re-evaluated with less emphasis on cultural aspects but more investment in learning and development, and leadership commitment. The research indicated a strong link between resources required for TPM and TQM as well as similar barriers to success. These are essential concepts because they will allow organizations to focus their limited time and resources in the right areas when implementing TPM and TQM. Therefore, industry leaders should prioritize their commitment before considering expensive investments in changing cultures and training interventions that focus on technical and problem-solving skills.

The investigation into a model that can successfully manage the various aspects of TPM and TQM is an opportunity for future research, due to the combined elements and similar challenges faced, as highlighted by this research. The impact of the Fourth Industrial Revolution on competitiveness in food manufacturing also presents a field for future research. With a large amount of gathered data, companies could use big data processing to assist in decision-making, thereby addressing many of the noted shortcomings of the current TPM system. The following recommendations are made to the organization operating in a food manufacturing environment, aiming to implement a practical TPM and TQM system. These factors are elaborated on and identified as critical to successful implementation but are also often the barriers to success that are not addressed effectively. These recommendations are not dissimilar to the best practices noted in the literature, but there are distinct areas where the focus can easily enhance performance. It is also important to note that the cultural aspect and resistance to change seemed to be less significant in the food manufacturing industry.

Availability (as an OEE construct) needs to be addressed in the form of more technical skills development for operators and artisans. This will ensure that concepts, like first-line maintenance, work effectively. The number of changeovers also seems to significantly impact on OEE, due to scheduled mandatory cleaning that used much available time and is inherent in the food processing industry. The equipment designers should consider these shortcomings and design essential maintenance functions for ease of use and cleaning. Early equipment management (one of the TPM pillars) is used for this function but seems absent as it was rarely mentioned in the interviews. This factor is pertinent to TPM implementation.

Training and development of skills must have a focus on problem-solving and root-cause analysis. These elements are critical in the TPM, as well as the TQM system and seem to be lacking. The root cause of problems is seldom identified and addressed in a preventive manner. Without a clear understanding and application of this concept, continuous improvement will not be possible, and the inability of the sampled factories to show constant OEE improvement over time may prove that it requires attention. This factor is common to both TPM and TQM success. Investment in the automation of data collection and analysis will undoubtedly contribute to alleviating the administrative workload. This will contribute to the efficiencies of both systems and enable the company to move toward the Fourth Industrial Revolution space. Big data is a concept that is emerging as a vital decision-making factor in the artificial intelligence space, and companies should gear themselves to operate in this space by starting to invest in these technologies. This factor can provide benefits to both TPM and TQM implementation.

Leadership and management need to spend more time understanding the concept of TPM and TQM and use it in their everyday working lives. This will show commitment and provide them with a better understanding of the barriers faced by the frontline teams. Management will also witness first-hand how their investments provide returns to the company and the unlocked potential in TPM and TQM. Viewing the organization as a system, with elements interacting with each other, may provide leadership with the insight to effectively use the scarce resources required for TPM and TQM. An understanding of the system archetype, and possible unintended consequences, are important to the success of the organization. From the research results, it is clear that the shared, albeit limited, resources in the training and development area may adversely impact on the implementation of both TPM and TQM.

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