Cost Performance of Overall Equipment Effectiveness in Manufacturing: The Activity-Based Effectiveness Approach

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DECLARATION

I, Elmarie David, declare that this research article is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the Graduate School of Business Administration, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

27 May 2024

Student Signature | Date

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ABSTRACT

This research paper aimed to develop, validate, and implement a structured and replicable method for assessing overall equipment effectiveness (OEE) using a cost-oriented approach known as the Activity-Based Effectiveness (ABE) methodology. Integrating principles from both the Overall Equipment Effectiveness (OEE) and Activity-Based Costing (ABC) methodologies, the proposed ABE methodology offered a systematic framework for evaluating and enhancing organizational performance. By shifting the focus from time-based or percentage-based metrics to cost-based metrics, the ABE approach sought to enhance understanding, benchmarking, and decision-making within organizations. The study adopted a mixed-methods approach, involving two phases of data collection. Firstly, an electronic survey and interview questionnaire were administered to participants employed across various organizational levels within the manufacturing industry. A minimum of 125 participants were surveyed, and the data were analysed using SPSS software. Secondly, the ABE methodology was implemented at a case company operating in the automotive component manufacturing sector, where OEE data were collected over a three-month period from ten different machines. The collected data were analysed using the ABE methodology, with informed consent obtained from the case company and strict confidentiality measures in place. The findings revealed that the implementation of the ABE approach facilitated a clear identification of areas requiring improvement, thereby enhancing understanding, benchmarking, and decision-making processes. However, it should be noted that this study was limited to the implementation of the ABE system within a single case company. While the standardized cost approach implied generalizability, it could not be conclusively verified through this research alone. Additionally, since the case company already had OEE and ABC methodologies in place prior to the study, the full implementation of the ABE system remained untested. Nevertheless, this research offered a practical framework for calculating OEE as a cost metric in a structured manner, thereby supporting organizational effectiveness.

KEYWORDS

Overall Equipment Effectiveness (OEE), Overall Organizational Effectiveness (OOE) Activity-Based Costing (ABC), Capacity Improvement, Performance Improvement, Activity-Based Effectiveness (ABE), Complex Systems Theory

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ABBREVIATIONS

Abbreviation	Description
OEE	Overall Equipment Effectiveness
A	Availability
P	Performance
Q	Quality
TPM	Total Productive Maintenance
KPI	Key Performance Indicator
ABC	Activity Based Costing
ABM	Activity Based Management
OECL	Overall Equipment Cost Loss
AL	Availability Loss
PL	Performance Loss
QL	Quality Loss
ABE	Activity-Based Effectiveness

CHAPTER ONE
INTRODUCTION

1.0. Introduction

Manufacturing is a crucial sector in any economy as it constitutes a substantial contribution to a nation's Gross Domestic Product (GDP) and serves as a significant contributor of employment (Singh, Singh Khamba, & Singh, 2020). Amid escalating competition, manufacturing companies faces the challenge of optimizing operations and cutting costs to stay competitive. Overall Equipment Effectiveness (OEE) stood out as a significant performance metric in manufacturing, assessing the productivity and efficiency of production equipment. While OEE was a broadly used metric for identifying and addressing inefficiencies, conventional approaches had limitations in accurately gauging equipment's true cost impact on performance. This research aimed to delve into the cost performance of OEE in manufacturing and proposed an alternative method, Activity-Based Effectiveness (ABE), which offered a more comprehensive and precise assessment of equipment performance.

This chapter delved into the development and evolution of Overall Equipment Effectiveness (OEE) in the manufacturing sector, emphasizing the limitations associated with this approach. It clarified the research problem that the proposed study would undertake, outlining the research methodology and underscoring the significance of the research to both the body of knowledge and the manufacturing industry.

1.1. Background of the Study

Kenessey classified the economy into four primary sectors: primary, secondary, tertiary, and quaternary (Kenessey, 1987). The manufacturing industry, a subset of the secondary sector responsible for transforming raw materials into finished products (Levinson, 2017), received attention and emphasis due to its significant economic contributions to a country (Singh, Singh Khamba, & Singh, 2020). Consequently, enhancing operational productivity emerged as a critical Key Performance Indicator (KPI) for ensuring business continuity and fostering economic growth (Baily et al., 1992). Productivity, traditionally defined as the proportion of total tangible inputs to total tangible outputs (Tsarouhas, 2019), was largely associated with a "time" denominator (e.g., output per man hour) in measurement systems (Koss & Lewis, 1993). The emphasis on enhancing productivity shifted towards improving effectiveness when it was recognized that varying levels of output could be achieved within the same time frame

(Kennedy, 2017). This realization prompted the development of a methodology that could comprehensively measure all production losses (Kennedy, 2017).

Seiichi Nakajima introduced the notion of Overall Equipment Effectiveness (OEE) in 1982 as part of the Total Productive Maintenance (TPM) system, detailed in his book "TPM Tenkai" (Koch, 2022), where he addressed the methodological “time” gap of productivity by detailing losses into categories. According to Nakajima, achieving OEE involved reducing inputs into the process while simultaneously increasing outputs. This goal was accomplished through the analysis and improvement of six big losses: unplanned stops, planned stops, minor stops, reduced speed, defects or rework, and reduced yield (Nakajima, 1988), and was visualized through Figure 1 below. These six losses were later consolidated into three categories, namely, Availability (A), Quality (Q), and Productivity (P), forming the basis of the OEE concept (Sowmya & Chetan, 2016). The OEE formula was expressed as follows:

$$OEE = A \times Q \times P$$

Equation 1: OEE Formula (Nakajima, 1988).

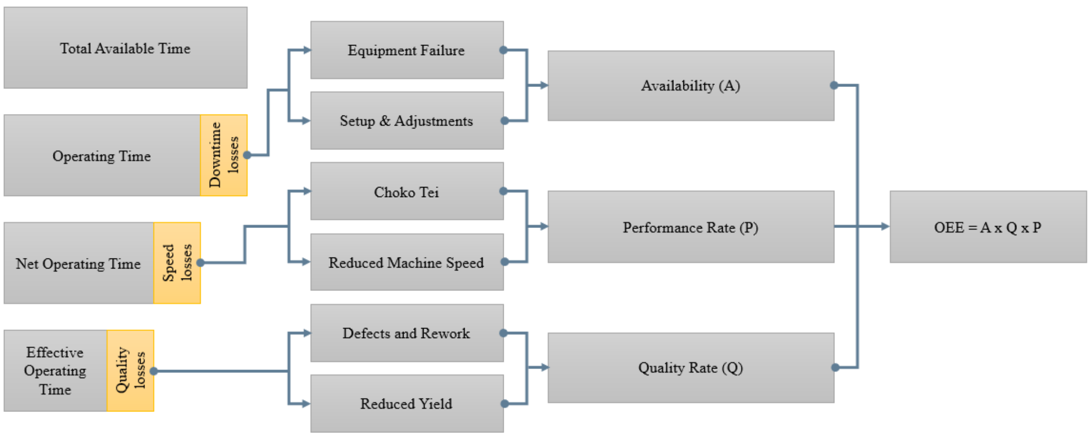


Figure 1: The six big losses (Ahmad, Hossen, & Ali, 2018)

While OEE was widely recognised as the gold standard for evaluating equipment effectiveness (Tsarouhas, 2019), with the global best practice target set at an achievement of 90% Availability, 95% Performance, and 99% Quality resulting in an OEE of 85% (Kennedy, 2017), it was important to recognize that OEE was not without its criticisms. The metric posed challenges in terms of comprehension at various organizational levels (Lelis, 2022). OEE was measured as a percentage, with the Availability (A), Quality (Q), and Performance (P) elements carrying an equal weight. This uniform weighting had the potential to create confusion regarding the cost benefit of improving the various process-related issues (Sapot, 2020), whereas the lowest OEE proportion for a machine might not necessarily align with the most significant business losses, and a full understanding of the impact of losses was required before improvements could be made (Wudhikarn, 2016).

Conversely, Nakajima offered insight into the latent financial benefits of OEE, suggesting its potential to unveil the hidden costs of a factory (Nakajima, 1988). The enhancement of OEE had the prospective to unlock additional production capacity, that translated into additional incremental revenue. However, Nakajima's focus was on the perceived cost advantages of the OEE methodology and lacked an exploration of a concrete cost approach (Jonsson & Lesshammar, 1999). True organizational improvement hinges on addressing the disparity between actual and desired performance levels. This necessitated a clear understanding of total losses, targeted achievements, and the potential cost benefit of each identified improvement initiative (Ramachandra, Prashanth Pai, Srinivas, & Raghavendra, 2016).

As we delved into the potential financial benefits of enhancing OEE, particularly in uncovering hidden factory costs to unlock additional production capacity, it became apparent that a more nuanced cost analysis was necessary. While Nakajima's insight highlighted the perceived advantages of OEE in terms of potential revenue gains, a comprehensive exploration of concrete cost implications was notably absent (Jonsson & Lesshammar, 1999).

As the discussion of OEE transitioned to the cost application of OEE, it had been made evident that a detailed understanding of cost structures was crucial for meaningful organizational improvement (Ramachandra, Prashanth Pai, Srinivas, & Raghavendra, 2016). This brought us to the Activity-Based Costing (ABC) methodology, a robust management costing approach designed to meticulously evaluate and allocate all costs across various business activities (Gosselin, 2007). Unlike traditional costing methods, ABC provided detailed evidence of cost information, offering a more accurate reflection of a company's current operational conditions (LaScola Needy et al., 2003). A well-executed implementation of ABC yielded precise cost allocations for each significant activity, thereby furnishing accurate cost drivers for each product line (Gosselin, 2007). One prominent advantage associated with the adoption of ABC was its provision of an enhanced method of portraying a full itemisation for calculating and explaining costs, potentially leading to improved cost management. The supplementary benefit of ABC lay in its seamless integration with other improvement initiatives (Gosselin, 2007).

OEE and ABC were both widely employed methodologies within the manufacturing industry that played pivotal roles in enhancing organizational profitability (Kenton, 2023). OEE, dedicated to identifying areas of low productivity, aligned with ABC's role in clarifying the specific activities and cost drivers contributing to potential cost improvements. This correlation facilitated the development of targeted strategies, aiming at enhancing overall production effectiveness and concurrently reducing costs (Kenton, 2023).

1.1.1. Definition of Terms

1.1.1.1. Manufacturing Industry

The manufacturing industry is defined as the transformation of materials into products, or the assembly of various components into new products, thus creating economic value (Levinson, 2017).

1.1.1.2. Overall Equipment Effectiveness

Expressed by Kennedy (2017), the Overall Equipment Effectiveness (OEE) methodology defined the genuine effectiveness of equipment, assessing factors such as equipment availability, quality, and performance in relation to the six major losses as outlined by Ahmad, Hossen, and Ali (2018).

OEE viewed as the current optimal method to determine equipment effectiveness in the manufacturing industry (Stamatis, 2017), could be used to understand all components of the six big losses (Singh, Singh Khamba, & Singh, 2020) offering the organization a comprehensive perspective, on how effectively the manufacturing operations were utilized (Stamatis, 2017). This was stated through the three elements of OEE Availability (A), Quality (Q) and Performance (P) (Del Carmen Ng Corrales et al., 2020).

- Availability: The portion of time in which the equipment was operational, measured as a ratio to possible production time (Singh, Singh Khamba, & Singh, 2020). The availability is expressed through the following formula:

  $$Availability = \frac{Machine\ Up\ Time}{Total\ Time} \times 100$$

  Equation 2: Availability (Singh, Singh Khamba, & Singh, 2020)

  Machine Up Time: Conveyed in hours, stipulated as the proportion of operational time to non-operational time (Stamatis, 2017).

  Total Time: The total time that the machine was planned to be in production, this time is limited to the total time available in a day (24 hours or 1440 minutes) (Van De Ginste, Aghezzafa, & Cottyna, 2022).

- Quality: The ratio of good quality products (non-defective output) produced against the total products produced (total output) (Van De Ginste, Aghezzafa, & Cottyna, 2022). The quality can be expressed through the following formula:

$$Quality: \frac{Good\ quality\ products}{Total\ products\ produced} \times 100$$

Equation 3: Quality (Singh, Singh Khamba, & Singh, 2020)

- Performance: The ratio of products that was made at the correct speed versus the total expected output for the same time unit (Van De Ginste, Aghezzafa, & Cottyna, 2022). Performance can be expressed with the following formulas:

$$Performance: \frac{Actual\ Output\ per\ time\ unit}{Expected\ output\ per\ time\ unit} \times 100$$

Equation 4: Performance (Van De Ginste, Aghezzafa, & Cottyna, 2022).

The three ratios of the OEE formula are then multiplied to together (as expressed in Equation 1) to provide an indication of the total effectiveness of the machine (Stamatis, 2017).

1.1.1.3. Management Accounting

Management accounting involved utilizing accounting information to fulfil internal information requirements (Ambe et al., 2008). It served to facilitate organizational management in formulating policies and making internal decisions (Jha, Ubale, & Jani, 2015), and accurately assesses the efficiency of resource utilization (Williams et al., 2018).

1.1.1.4. Activity Based Costing (ABC)

Almeida & Cunha (2017) described Activity-Based Costing (ABC) as a method that involves allocating resource costs to activities and then assigning activity costs to products or services. This approach enabled companies to measure the overall cost and performance of activities, as emphasized by Lu, Wang, Wu, and Cheng (2017), facilitating the determination of competitive costs for products or services (Almeida & Cunha, 2017).

Activity Based Costing (ABC) is a cost allocation technique devised to address the limitations of conventional costing in manufacturing. It achieves this by distributing overhead expenses across various cost drivers (Cromwell, 2021). This method allocates the proportion of cost to the product based on the reliance of that product on the overhead costs. Cost pools are developed using the individual resource consumption of each of the overhead costs and is then separated by proportionally allocating it to the individual products, thus the product costs will differ depending on the absorption of cost through multiple cost drivers (Kaplan & Anderson, 2004).

The ABC method involves identifying resources and resource drivers for activities and assigning costs on allocation basis to different cost objects (Almeida & Cunha, 2017).

Figure 2: ABC Method (Almeida & Cunha, 2017)

The typical ABC procedure involves two main phases: initially, overhead costs are segmented into activity cost pools, and subsequently, these costs within the activity cost pools are assigned to production individually to determine product costs (Williams, Haka, Bettner, & Carcello, 2018)

The cost drivers are determined through employee surveys and machine information as per the requirement of the overhead cost under analysis (Kaplan & Anderson, 2004).

- Activity Cost Pools: Activity cost pools are the resource and overhead aggregate costs that are all related to an activity, which is then separated on a basis of allocation relating to that activity (Williams, Haka, Bettner, & Carcello, 2018). The basis for allocation is centred on the consumption ratio of a particular resource or overhead for each activity (Williams, Haka, Bettner, & Carcello, 2018). The separation or basis of allocation can be seen in Figure 3 below:

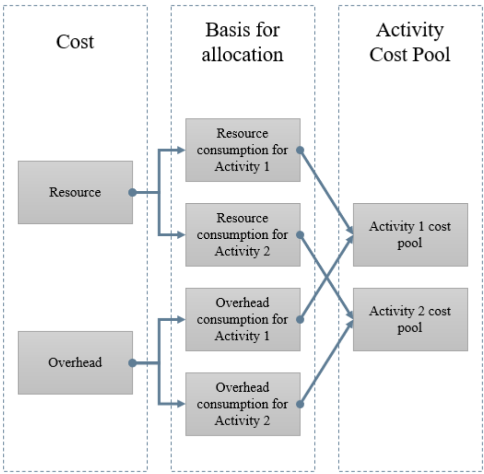


Figure 3: Activity Cost Pools (Williams, Haka, Bettner, & Carcello, 2018)

This segregation of costs can generally be expressed through the following formula:

$$Activity\ Cost\ Pool = \sum_{a=1}^{n} \frac{Total\ Cost\ Pool}{Allocation\ of\ cost\ driver}$$

Equation 5: Activity Cost Pool (Srivastav, 2019)

- <u>Product Costs</u>: Product costs are determined through proportioning the activity costs into each cost driver for the product, the summation of the total allocations from each activity related to the product is the product cost (Williams, Haka, Bettner, & Carcello, 2018). The allocation of cost drivers from activity cost pools is illustrated in Figure 4 below, which continues the process depicted in Figure 3.

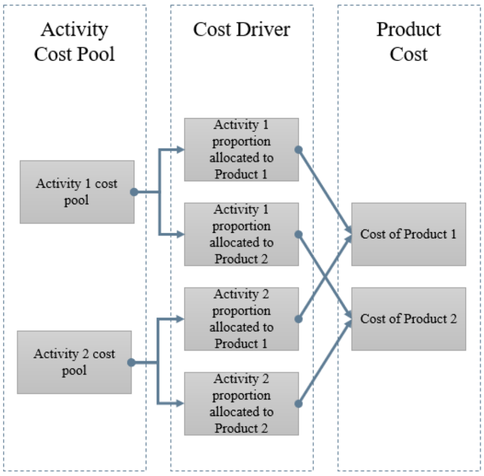


Figure 4: Product Cost (Williams, Haka, Bettner, & Carcello, 2018)

Product costs can thus be expressed through the following equation:

$$Product\ cost = \sum_{p=1}^{n} \frac{Activity\ Cost\ Pool}{Cost\ Driver}$$

Equation 6: Product Cost (Srivastav, 2019)

The formula provides for the summation of all costs that are directly related to a product, stemming from the basis of each activity cost pool (Williams, Haka, Bettner, & Carcello, 2018).

ABC provides the organization a detailed activity-based cost information allowing them to assign more accurate costs to each product (Almeida & Cunha, 2017), this will provide the organization the opportunity to set accurate sales prices based on actual consumption of materials and overheads (Kenton, 2023) and supports the evaluation of profitability of each production line (Williams, Haka, Bettner, & Carcello, 2018).

1.1.1.5. Complex systems theory

Complex systems theory in manufacturing describes how a system adapts and responds to both external and internal challenges (Chang, 2007). Through studying the behavior of these systems and the complexity associated with them, alternative perspectives for modeling their internal dynamics can be developed (McCarthy, 2000).

1.2. Research Problem

In the modern business landscape, manufacturing companies face heightened competition (Singh, Singh Khamba, & Singh, 2020) compounded by a decline in consumer demand amid increasing living costs (Cawdery, 2023). In response to these challenges, manufacturing companies are compelled to optimize the effectiveness and flexibility of their production processes while concurrently reducing unnecessary expenses (Singh, Singh Khamba, & Singh, 2020). This highlighted the need for a structured approach to facilitate the improvement of process losses. Within the complex systems theory context that promote the quick adoption of manufacturing ability in a shifting environment (Chang, 2007), the identification and resolution of capacity losses emerged as a pivotal objective, quantified by the metric Overall Equipment Effectiveness (OEE) (Slack & Brandon-Jones, 2019), designed to measure the true effectiveness of equipment (Tsarouhas, 2020).

However, a primary misconception surrounding Overall Equipment Effectiveness (OEE) focus on the difficulty in articulating a clear rationale for the costs linked to losses in manufacturing companies (Jonsson & Lesshammar, 1999). The lack of detailed costing information created ambiguity in understanding how a lower OEE influences the overall process. Additionally, the misconception that the lowest OEE output for a piece of equipment may not necessarily align with the most significant business losses, introduced misunderstanding between various operational organizational levels (Wudhikarn, 2016). These misconceptions highlighted the need for a methodology to quantify OEE as a cost, to promote understanding and develop clear rationale for improvement.

Contemporary scholarly works primarily concentrate on cost allocation to the elements of OEE, rather than integration with an established and proven financial methodology. This was achieved through the introduction of methodologies such as the Overall Equipment Cost Loss (OECL), the methodology involved assessing the overall cost losses associated with equipment inefficiencies, through a set of developed formulations to OECL (Wudhikarn, 2016). Additionally, the Equipment Cost Efficiency (ECE) approach which quantified the cost wasted through non-productive activities, through a set of developed formulations of ECE (Liew, Prakash, & Ong, 2023). However, in the existing body of literature, a notable gap is discernible concerning the establishment of a clear linkage between an established financial cost approach and Overall Equipment Effectiveness (OEE). Specifically, there was a deficiency in research that systematically address the structured integration of a financial cost approach with OEE, ensuring uniformity in the utilization of base costs across various equipment types. Moreover, there was a scarcity of studies outlining a generalizable framework that can be easily implemented to various types of manufacturing facilities. This gap poses a challenge that will lead to potential misunderstandings and misalignment during benchmarking exercises, both between internal machines and across organizational boundaries and underscore the necessity for further scholarly investigation to bridge the theoretical and methodological gap.

1.3. Research Questions

Overall Equipment Effectiveness (OEE) has emerged as a significant concern in novel manufacturing, driven by the perceived knowledge gap regarding its impact on business performance (Esmaeel, Zakuan, Jamal, & Taherdoost, 2018). This research proposal focussed on the ambiguity surrounding OEE methodology across organizational levels (Binti Aminuddin, et al., 2015) and its limitations as a descriptive business or financial Key Performance Indicator (KPI) (Wudhikarn, 2016). This study aimed to offer insights into the financial implications of Overall Equipment Effectiveness (OEE), encompassing both its benefits and potential losses. Furthermore, it sought to establish a systematic method for the analysis for manufacturing organizations to optimize areas exhibiting low productivity and ineffectiveness, through the link to an established financial methodology. The following questions guide the research to comprehensively understand OEE practices, refine cost approaches, assess awareness levels, and validate a deduced approach within a case organization.

- What is the current proportion of employees in the manufacturing sector who understand OEE and its impact on overall organizational effectiveness? Furthermore, how is this understanding influenced by adopting a cost-centric approach to OEE?
- Can a structured, replicable cost-centric approach to OEE be developed based on the key strengths and findings in current methodologies, to improve benchmarking of equipment?
- How does the performance optimization differ when utilizing the OEE and ABE approaches within an organization, and does it support effective decision making?

1.4. Research Objectives

The research conducted an empirical investigation into the current practices of OEE and its cost applications in a manufacturing setting. This study seeks to comprehensively understand how OEE is currently understood and used for productivity improvement in manufacturing processes. Additionally, the research explored the function of Activity-Based Costing (ABC) in the manufacturing context, exploring its potential impact on refining and enhancing cost-related assessments within the effectiveness of operations. The combination of these two methodologies will be concatenated with insights into the current literature knowledge to form a deduced Activity-Based Effectiveness (ABE) methodology.

Upon examination of the existing literature, the first objective involved developing an alternative methodology for determining the cost performance of Overall Equipment Effectiveness (OEE). The proposed Activity-Based Effectiveness (ABE) approach was constructed based on the results of the critical analysis of current approaches, focussing on the core elements of success of each approach.

Secondly, the research aimed to conduct a study to gauge to current level of understanding the impact of Overall Equipment Effectiveness (OEE). The investigation encompassed a survey sent to multiple professionals spanning operational, managerial, and strategic or specialist levels of a manufacturing firm, shedding light on the current understanding of OEE and its implication on decision-making, performance optimization, and overall organizational effectiveness.

The final objective of this study was to validate the efficacy of the deduced Activity-Based Effectiveness (ABE) approach by implementing it within a specific case organization. The research endeavours to explore and analyse the variances in the impact of the OEE and ABE approaches on decision-making, performance optimization, and overall organizational effectiveness to provide concrete evidence regarding the practical effectiveness of the deduced approach in real-world organizational contexts.

These objectives can be summarised as follows:

1. Gauge the current proportion of professional that understand OEE and its implications on organizational effectiveness.
2. Develop a methodology for expressing OEE as a cost-centric approach to facilitate equipment benchmarking.
3. Implement the deduced structured cost application to OEE and contrast the results to the traditional OEE to confirm the impact on decision-making.

1.5. Preliminary Research Gaps and Hypothesis

The literature review exhibits limitations in addressing the current interlinked weaknesses of OEE through a cost measurement approach. The literature of Bengtsson, Andersson, & Ekström (2022), Binti Aminuddin et al., (2015), Cheah, Prakash, & Ong (2020), Sapot (2020) and Lelis (2022) found that the context of OEE which stipulated as a percentage, was difficult to understand, and that hindered effective decision making, stipulating that a cost approach would support solving this gap. They do not provide solutions in how to address this understanding. Garza-Reyes (2015) and Wudhikarn (2016) found that benchmarking OEE was difficult. Wudhikarn (2016) developed the OECL approach to support understanding and replicability, however their approach was difficult to implement without a structured costing system. This supports the view of Mahmoud et al., (2019), and Sapot (2020) who finds that replicating the OEE and OECL approaches throughout industries are difficult.

The research gaps will thus be preliminarily expressed as:

1. Limited understanding of OEE due to OEE being expressed as a percentage value.
2. Absence of accurate benchmarking mechanisms between equipment and organizations, that will lead to challenges in assessing performance effectively.
3. Lack of structured and replicable costing approaches to OEE, that would result in inaccurate decision-making.

The research hypothesis is thus preliminarily expressed as:

1. Expressing OEE as a monetary value would lead to an improved understanding of OEE.
2. Expressing OEE as a monetary value would enable equipment losses to be benchmarked accurately.
3. Implementing a structured cost application in OEE would enhance decision-making.

These preliminary research gaps and hypotheses were analysed and refined through the literature review chapter and restated to ensure clarity.

1.6. Research Purpose

This mixed-method study sought to establish Overall Equipment Effectiveness (OEE) as a pivotal financial key performance indicator through its integration with the structured Activity-Based Costing (ABC) approach. The aim was to enhance comprehension of OEE's impact across various organizational levels and explain the financial implications associated with increased effectiveness in the manufacturing process (Sapot, 2020). This clarification was instrumental in facilitating informed decision-making regarding investments in OEE improvement, thereby fostering growth for manufacturing companies.

The overarching purpose of this research study was to develop a structured, replicable, and generalizable Activity-Based Effectiveness (ABE) methodology. This methodology sought to enhance understanding of OEE and its influence on benchmarking and decision-making within the realm of manufacturing operations. The research commenced with a qualitative investigation into the current perception of OEE in the manufacturing environment to confirm and refine the ABE theory. Subsequently, a quantitative case study was conducted to implement the Activity-Based Effectiveness (ABE) approach. This case study assessed the impact of ABE on prioritizing improvement actions between various types of equipment within a manufacturing company.

1.7. Significance of the Research

The literature suggested that the challenge with the current Overall Equipment Effectiveness (OEE) methodology, expressed as a percentage, was not easily comprehended across the business landscape (Lelis, 2022). This complexity results in uncertainty when attempting to effectively assign Key Performance Indicators (KPIs) or business improvement metrics to areas with potential losses (Jonsson & Lesshammar, 1999).

This research held significant practical implications as it contributed to the manufacturing industry by introducing a cost metric to the prevailing Overall Equipment Effectiveness (OEE) methodology. This addition was designed to enhance comprehension among individuals who did not possess qualifications or training as OEE practitioners. Consequently, it fostered an increased willingness to actively engage in problem-solving, supporting manufacturing operations and naturally mitigating losses. This dimension of cost introduced a clear understanding and heightened visibility concerning cost drivers and initiatives, empowering businesses to implement strategies ensuring long-term sustainability.

Additionally, this study extended its significance to the theoretical and methodological body of knowledge by adding a nuanced layer to the existing literature on the cost implications of OEE. It introduced the Activity-Based Effectiveness (ABE) methodology, offering a structured and replicable approach to analysing and incorporating all relevant costs associated with an activity into OEE losses, through association with an existing and proven financial methodology. This expansion elevated the depth and precision of understanding within this domain.

Traditionally, OEE had been predominantly viewed as a productivity metric, focused on measuring equipment efficiency in manufacturing processes. However, this research took a significant step forward by incorporating a detailed examination of the costs associated with operational activities. It applied Activity-Based Costing (ABC) and analysed various cost components, including direct and indirect costs, maintenance expenses, and potential downtime-related expenditures, to introduce a holistic systems approach to evaluating OEE losses.

This detailed methodology not only broadened the scope of understanding but also enabled a more accurate representation of the true financial impact of equipment effectiveness. The structured and replicable nature of its incorporation into an established financial methodology ensured consistency and reliability in assessing OEE losses across diverse manufacturing scenarios. This modernization of the OEE methodology advanced the depth and precision of knowledge, providing industry practitioners and researchers with a more comprehensive toolset to analyse, interpret, and optimize manufacturing processes from a financial standpoint.

1.8. Delimitations and Assumptions of the Study

1.8.1. Delimitations

1.8.1.1. Generalizability

Although the study aimed to develop a structured and replicable approach to the cost integration of Overall Equipment Effectiveness (OEE) across the manufacturing industry, the study was conducted within the South African Manufacturing industry and generalizability has not been established.

1.8.1.2. Methodology

The intended qualitative stage of this mixed-method research involved data collection using an electronic survey and interview questionnaire, by means of a convenience sampling method. This study was potentially limited by the number of employees in manufacturing companies who chose to participate in the data collection phase, which could affect the confidence level of the study. This was due to the potentially sensitive nature of the information required; however, the impact could be reduced by providing full anonymity of responses.

The intended quantitative stage of this mixed-methods research proposal only analysed one case company, and benchmarking between different manufacturing companies was not established.

1.8.1.3. Scope

This study focused on the manufacturing industry, although the application of OEE could be implemented in other sectors, such as the tertiary sector. Determining the effectiveness of services was a different process, and the scope of this research focused on building an equipment improvement framework.

This study only focused on the inclusion of manufacturing-related costs and did not consider any non-manufacturing cost allocation within the development of the Activity-Based Effectiveness (ABE) approach, which could be considered during future studies.

1.8.1.4. Timeframe

This study follows a cross sectional approach, analysing operational data for a three-month period. A longitudinal approach could be considered during future studies.

1.8.2. Assumptions

1.8.2.1. Questionnaire

It was assumed that the coverage and content of the set questionnaire would be sufficient to derive the impact of financializing OEE. The questionnaires were set up in a manner that is non-biased and neutral to ensure relevance to the study.

1.8.2.2. Survey Results

This study assumed that the answers received from survey participants had been answered truthfully and that meaningful conclusions could be derived from the data. It was clearly explained to all survey participants that no data on the individual participating companies would be released, and that anonymity and confidentiality would be guaranteed.

1.8.2.3. Case Company

It was assumed that the effective implementation of the ABE framework at the case company would derive accurate financial information, and meaningful input into the generalisability of the proposed ABE methodology.

1.9. Structural outline of the Paper

Chapter 1: Defining the Research Problem: In this chapter the background and definitions pertaining to Overall Equipment Effectiveness (OEE) has been introduced, the research problem, objectives and questions identified, and the benefits of the study argued. The chapter also shared the delimitations and assumptions that pertains to the research.

Chapter 2: Literature Review: In this section, the existing literature was reviewed and contrasted in support of the foundational understanding of OEE as a cost approach and the identification of gaps in the current knowledge. This was followed by a theoretical framework where the current theories were analysed, and the new Activity-Based Effectiveness (ABE) theory was developed. Lastly, a conceptual framework was completed where the interdependencies of the variables were established.

Chapter 3: Research Methodology: The research approach, design methods, and phenomenon were identified, explained, and justified in detail in this section. It included all information regarding the sampling, data collection, and data analysis techniques of how the collected data would be compiled to yield comprehensive results.

Chapter 4: Data Analysis and Research Findings: This chapter presented the collected data of both the qualitative and quantitative stages, with in-depth analysis of the findings. The findings were discussed in the context of the research questions.

Chapter 5: Discussion and Conclusion: This chapter interpreted the results of the data analysis for both the qualitative and quantitative stages of the research, compared the findings with the existing literature on the cost application of OEE, and discussed the implications of the findings. Additionally, this chapter discussed the findings on the comparison of the OEE and ABE approaches.

CHAPTER TWO
LITERATURE REVIEW

2.0. Introduction

The purpose of this literature review chapter was to comprehensively examine and synthesize the existing literature on the understanding and benchmarking of Overall Equipment Effectiveness (OEE) and the cost applications to OEE in relation to the research objective of developing the proposed Activity-Based Effectiveness (ABE) approach.

Overall Equipment Effectiveness (OEE), expressed as a percentage, served as a comprehensive metric widely used in manufacturing to assess the effectiveness of both production processes and individual equipment (Kennedy, 2017). From a systems theory perspective, OEE functions as a key performance indicator reflecting the interconnectedness of various components within a manufacturing system (Hussain, ul Haque, & Baloch, 2019). The primary objective of OEE was to identify and target areas responsible for significant productivity losses, thereby directing improvement efforts to enhance overall operational performance (Lelis, 2022). One of the significant challenges lay in the difficulty of accurately comparing OEE percentage values among different machine types and capacities, which impeded effective communication and understanding of the metric's impact on business losses (Mahmoud et al., 2019). This knowledge gap highlighted the necessity of overcoming these challenges to achieve improved operational efficiency and competitiveness in the manufacturing sector (Wudhikarn, 2016).

Complex systems theory provided a novel perspective for manufacturing organizations, enabling them to comprehend and model the behaviour of their systems as they evolved and adapted to meet increasingly stringent productivity standards (McCarthy, 2000). This theoretical approach connects to the concept of Overall Equipment Effectiveness (OEE) by elucidating how individual components of a system interact to produce collective behaviours.

New methodologies emerged to address this fundamental gap in Overall Equipment Effectiveness (OEE) through identifying the cost loss associated with the three elements of the OEE methodology. The initial part of the discussion delved into key themes surrounding the challenges inherent in the OEE methodology. These included the varying levels of understanding of OEE across an organization and its ability to be effectively benchmarked among equipment or between organizations. This literature investigation intended to identify existing OEE cost methodologies structured to bridge the understanding and benchmarking gaps in the OEE framework and identify the key components necessary for their efficacy. The discussion then shifted to the development of the deduced Activity-Based Effectiveness (ABE) approach, focusing specifically on identifying and integrating an established financial approach to the established effective components of the current OEE cost methodologies.

The proposed ABE approach was developed to introduce a structured and accurate method to identify the cost of OEE, enabling both internal benchmarking between equipment and external benchmarks with other manufacturing companies. This scope is illustrated through Figure 5 below:

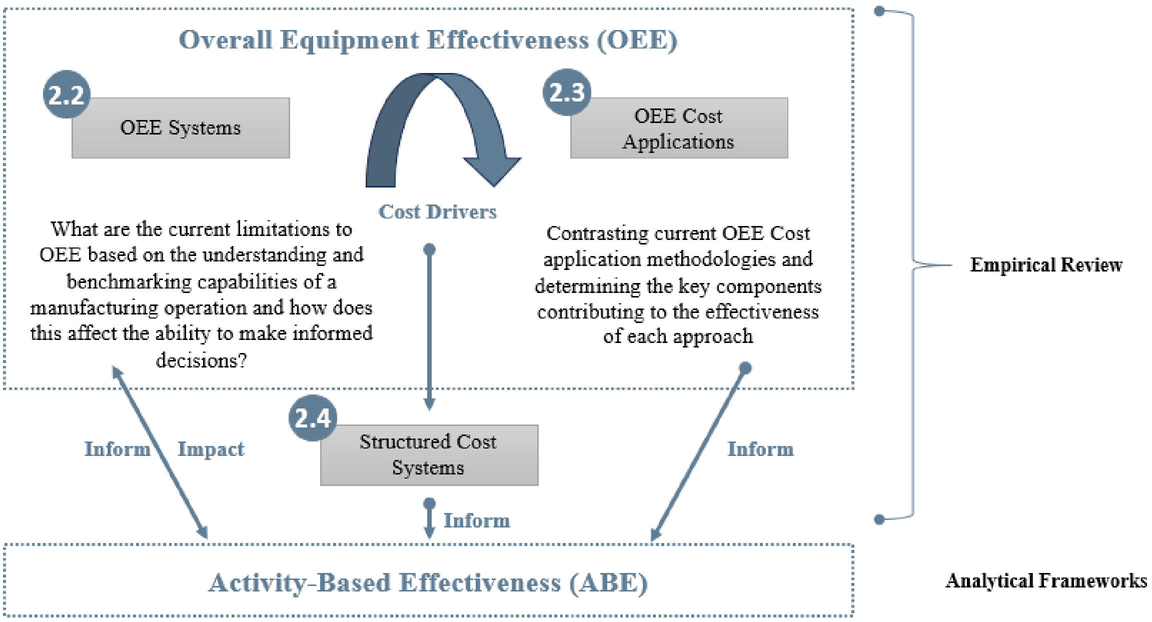


Figure 5: Scope and structure of the literature review (Author's own)

The literature review was structured firstly to explain the foundation of the Overall Equipment Effectiveness (OEE) theory, elucidating the fundamental concepts of OEE in relation to the themes of understanding of OEE within the different layers of an organization, followed by the level of benchmarking potential that OEE provides and the impact that this understanding and benchmarking has on the organization's capability to make effective decisions supporting the concept of Overall Organizational Effectiveness (OOE). Secondly, the literature review analysed the current methodologies that have been developed as cost approaches to OEE and unpacked the elements of these studies that contribute to their effectiveness. Through this discussion, the literature attempted to define the relationship between these key variables. This was followed by a critical analysis of the results of the implementation of different cost approaches to OEE, contrasting the various concepts to determine the level of variation or inconsistencies in the results, to identify the gaps that needed to be addressed. The literature review concluded with the integration of the theoretical and critical analysis through the proposal of the Activity-Based Effectiveness (ABE) approach.

2.1. Empirical review of Overall Equipment Effectiveness (OEE) Systems

The work of Nakajima (1988) first proposed an improved method for calculating the productivity of a manufacturing facility through the development of OEE within the Total Productive Maintenance (TPM) framework and suggested that OEE enhanced operational performance. Supporting this notion, Tsarouhas (2019) demonstrated the efficacy of OEE in identifying equipment losses through its application in a croissant production factory and demonstrated how the three Overall Equipment Effectiveness (OEE) elements facilitated the identification of operational issues to enable immediate resolution.

In contrast, Bengtsson, Andersson, & Ekström (2022) asserted that while existing studies predominantly focused on the technical aspects of OEE, the managerial impact remained overlooked. Through a case study in the automotive industry, they underlined the limitations posed by managerial misunderstanding and lack of awareness, hindering the optimal utilization of OEE. Further supporting this perspective, Cheah, Prakash, & Ong (2020) identified a lack of structured implementation guidance for OEE. Their case study in a semiconductor manufacturing facility over 38 weeks revealed that this deficiency led to misunderstanding and impeded effective OEE utilization.

Similarly, Binti Aminuddin et al., (2015), who emphasized the importance of managerial understanding for effective OEE implementation through a survey of 139 manufacturing companies worldwide highlighted the necessity of management comprehension to leverage OEE effectively. This was further supported by the work of Garza-Reyes (2015), who contended the sufficiency of the OEE approach in controlling interconnected processes. Through an industrial and simulation-based study, Garza-Reyes (2015) developed a mathematical model for Overall Resource Effectiveness (ORE), that argued that OEE failed to measure relevant factors beyond individual machines, leading into the perception of benchmarking as a measure of organizational effectiveness.

The benchmarking concerns stemmed from the use and application of percentages in the OEE formulation. A percentage reduction for one activity could have substantially different productivity implications than that of the same percentage reduction in another activity (Sapot, 2020). The way OEE was measured could vary slightly as there was room for interpretation in the definitions of Availability, Performance, and Quality. This could lead to the inability to benchmark OEE across machines or organizations (Kennedy, 2017), as the lowest OEE value might not necessarily be the biggest loss (Wudhikarn, 2016).

Al-Najjar (1997) emphasized the significance of benchmarking among machines by introducing Overall Process Effectiveness (OPE). This metric was utilized to assess losses within the entire process of manufacturing rolling element bearings, aimed to improve their lifespan through an optimized maintenance strategy. Al-Najjar (1997) underscored the variability of OPE values among similar equipment types, that highlighted the importance of efficient equipment benchmarking. This perspective aligned with Oechsner et al. (2002), who through the development and implementation of Overall Fab Effectiveness (OFE) in a semiconductor factory argued that while Overall Equipment Effectiveness (OEE) assessed individual equipment effectiveness, it falls short in evaluating organizational effectiveness since equipment operates as an interconnected system rather than in isolation.

The view was supported by the work of Braglia, Frosolini, & Zammori, (2009) who argued that when machines work together in a manufacturing line, OEE by itself was insufficient to raise system performance. Further reinforcement of this perspective was supplied by Braglia, Frosolini, & Zammori (2009), who asserted that machines within a manufacturing line function collaboratively. They argued that relying solely on OEE was inadequate for enhancing the overall performance of the system. Through their implementation of the Overall Equipment Effectiveness of a Manufacturing Line (OEEML) (Braglia, Frosolini, & Zammori, 2009) within engine basements production, they concluded that incremental deterioration of the design speed was observed within a production line. They proposed that a comprehensive approach to evaluating the performance of a production line was essential for enhanced organizational effectiveness.

The literature therefore showed that there was a strong correlation between the impact and potential benefit that can be derived from the implementation of OEE and managerial understanding of OEE (Binti Aminuddin et al., 2015). It suggested that while OEE had the potential to enhance organizational effectiveness, it could only be realized when there was a comprehensive understanding of its implications across all levels of the organization. Additionally, there was a recognized difficulty in benchmarking OEE between equipment (Braglia, Frosolini, & Zammori, 2009), as the lowest OEE value may not necessarily correspond to the biggest impact on organizational effectiveness (Wudhikarn, 2016). This highlighted the research gap in the OEE methodology that resulted from the lack of understanding and the inability to effectively benchmark equipment.

2.2. Empirical review of Overall Equipment Effectiveness (OEE) Cost Applications

Georgopoulos & Tannenbaum (1957) defined the concept of organizational effectiveness as the combination of organizational productivity, net profit and the ability of the orgnization to meet it’s mission for successful expansion.

Georgopoulos & Tannenbaum (1957) defined the concept of organizational effectiveness as the combination of organizational productivity, net profit, and the ability of the organization to meet its mission for successful expansion. Through the lens of systems theory, organizational effectiveness can be viewed as the outcome of the dynamic interactions among various components within the organization (McCarthy, 2000). In this context, organizational effectiveness arose from the organization's capacity to effectively integrate and coordinate these complex elements to achieve its goals and objectives (Hussain, ul Haque, & Baloch, 2019).

Cost based synthesis of OEE, which forms the ability to improve net profit, through the clear analysis of productivity measures, has been debated since the inception of Overall Equipment Effectiveness Cost Loss (OECL) by Wudhikarn, Smithikul, & Manopiniwes (2009), after discussion at the 6th International Conference of Digital Enterprise Technology held in Hong Kong. Cost-based synthesis could be seen as an alternative way to calculate equipment effectiveness, as OEE did not provide business context, merely the effectiveness measure of a piece of equipment (Sapot, 2020). This led to the requirement that OEE be modified to link the improvement of OEE to business Key Performance Indicators (KPIs) and incentives (Lelis, 2022). The overall idea of cost synthesis was to enable the effectiveness to be recorded as a monetary value, to support effective decision-making (Lelis, 2022).

In a case study conducted over 12 months involving 10 machines in a fibre cement ceiling manufacturing plant, Wudhikarn (2016) argued that Overall Equipment Effectiveness (OEE) assigned similar weights to the elements of Availability, Quality, and Performance. Consequently, improvements in one element of OEE may not necessarily translate to equivalent savings in another element. This resulted in the ranking of equipment based on their percentage effectiveness, which limited the focus of improvement to the least effective machine. To address this issue, Wudhikarn developed the Overall Equipment Effectiveness

Cost Loss (OECL), which regarded the production and financial elements of OEE as costs. By employing this methodology, they found that the ranking of ineffective machines differs from that obtained through the traditional OEE methodology. This enabled organizations to effectively benchmark and prioritize problematic equipment for improvement, thereby driving organizational enhancement through informed decision-making.

The OECL approach is to a certain degree supported by Mahmoud et al., (2019) who through a case study approach in a printing and packaging company by employing a linear programming and production based mathematical approach maintained that the weakness of OECL wss the lack of structure for the model. Thus, the argument of the paper was to integrate OECL with a Data Envelopment Analysis (DEA) model to provide a structure for comparing equipment performance to best practise. They found that the results should not be generalised to all industries, however the effectiveness of the implementation is shown through substantial imporvements realised.

The view of Wudhikarn (2016) further supported by Terry (2022) who through a packaging equipment case analysis focussed on the Total Cost of Ownership (TCO) and the Return on Investment (ROI). The equipment, labour costs, downtime costs and other indirect costs were analysed to determine the impact of OEE, supporting the formulations developed by Wudhikarn (2016). The study argued that when considering the case company, the customer's final buy decision was always related to price, and that the direct impact of OEE loss could be seen in the revenue of the case company, thus as the organizational effectiveness improved, the product price will reduce, leading to a reduced price for the customer.

Lelis (2022), supported the concept of cost synthesis in OEE, maintained that with the implementation of a cost-centric approach to OEE various improvement activities became more predictable. Through theoretically examining the fiscal impact of OEE and applying fixed-and-variable cost analysis to income statements, the researcher suggested that including shared general industrial expenses and measuring OEE as a proportion of product cost will yield noticeable differences in OEE outcomes. Emphasizing the application of variable cost within income statements, this study highlighted the necessity of incorporating all associated product cost drivers when assessing the cost implications of OEE.

Similarly, the view that OEE alone could not effectively measure the financial impact of productivity was supported by Liew, Prakash, & Ong (2023). In their three month study that introduced Equipment Cost Efficiency (ECE) to twelve automated test equipment units at a semiconductor manufacturer, found that through the implementation of this cost-centric approach to OEE the organization could realize significant financial benefits. Their view suggested that these benefits could be realized due to practical benchmark comparisons between units that facilitated informed decision making on improvement efforts.

The literature firstly underscored the significant benefits organizations could derive from adopting a cost-centric approach to OEE, particularly in terms of understanding and benchmarking OEE. Across these various studies, this approach had consistently been linked to improved decision-making, thereby enhancing organizational effectiveness. Secondly, it could be seen that integrating a systems methodology into the cost-centric approach enhanced equipment benchmarking, however, it is important to note that while this approach demonstrated favorable outcomes within specific industries, its generalizability to other sectors remains untested, revealing a research gap. Furthermore, there was a remaining research gap in recognizing that for the cost approach to be truly effective, all linked cost drivers to the product must be taken into consideration.

2.3. Emperical review of Structured Accounting Methodologies

The ultimate purpose of cost accounting was to support organizational management to make effective decisions (Budd, 2010). Management accounting facilitated the differentiation between direct and indirect costs within a system or process, thereby distinguishing costs that were directly attributable to the product from those that were not (Chapman et al., 2016). It was this principle of cost accounting that supported the purpose of the research proposal in developing a cost-centric approach to Overall Equipment Effectiveness (OEE).

Kaplan and Cooper (1998) introduced the concept of leveraging financial methodologies to support continuous improvement efforts with their four-stage model of cost system evolution. They advocated for the utilization of Activity-Based Costing (ABC) to convert seemingly fixed costs into variable cost drivers, which aligned with organizational improvement initiatives. Moreover, they argued that integrating ABC into management processes, such as budgeting, pricing, and scenario-based simulations, enabled the provision of timely and pertinent financial information, thereby facilitating more effective decision-making.

This perspective was supported by Cagwin and Bouwman (2002), who conducted a cross-sectional mail survey involving 1,058 internal auditors, with 204 responses gathered. Their findings revealed a positive correlation between the implementation of Activity-Based Costing (ABC) and favorable shifts in financial performance, particularly when ABC was utilized alongside efficiency enhancement strategies like Total Quality Management (TQM), and Just-In-Time (JIT). They argued that organizations employing ABC in conjunction with such methodologies experienced a more pronounced enhancement in financial performance compared to those implementing these initiatives in isolation.

These views are further supported by Chapman et al., (2016) who conducted a study on health system efficiency and observed that traditional volume-based absorption costing assumes all indirect costs are fixed and evenly allocated them to each process or product. They argued that the approach tended to overestimate the costs of high-volume simple processes while underestimating those of low-volume complex ones. This highlighted a gap in the utilization of traditional costing methods for evaluating effectiveness, as it poses a risk of yielding unreliable cost assignments, ultimately leading to biased or distorted decision-making within the organization. They further proposed the implementation of Activity-Based Costing (ABC) to enhance the granularity of allocating cost drivers to individual products or processes.

Parallel with prevailing views, yet offering an expanded perspective, Perčević & Hladika (2016) through a theoretical analysis of costing systmes, advocated for adopting a dynamic cost management approach to precisely ascertain product costs. The approach integrated Activity-Based Costing (ABC) within manufacturing processes while extending its application to non-manufacturing expenses. By employing this method, they were able to evaluate the entire product life cycle cost and make accurate assessments of product profitability.

These perspectives argued that traditional costing systems are outdated for contemporary businesses (Perčević & Hladika, 2016), as they assumed indirect costs are fixed and distribute them uniformly across all processes (Chapman et al., 2016). However, often this assumption did not align with the reality of most organizations, resulting in inaccurate cost allocations and the overvaluation or undervaluation of certain processes. The literature advocated for the adoption of Activity-Based Costing (ABC), which broke down all associated costs into activities and cost drivers, allowing for more precise allocation of costs to various processes within an organization. Although Perčević & Hladika (2016) suggested incorporating possible non-manufacturing costs related to products, such as warehousing and transportation, this aspect is beyond the current scope of the research proposal and could be explored in future studies.

2.3.1. Research Gaps

The result of the critical analysis of OEE systems, OEE Cost applications, and Structured cost systems revealed several key research gaps. Firstly, there existed a limited understanding of OEE, primarily because it was commonly expressed as a percentage value, which may not fully capture the complexities of equipment performance. Secondly, there was a notable absence of accurate benchmarking mechanisms between equipment and organizations, hindering the ability to accurately assess performance. Lastly, the current lack of structured and replicable costing approaches to OEE resulted in the incomplete consideration of all linked costs, undermining the accuracy of the decision-making process. These gaps underscored the need for a more comprehensive and standardized approach to evaluating OEE and its associated costs, ultimately enhancing organizational effectiveness and efficiency. The research gaps was summarised as follows:

- Although substantial research had been conducted on Overall Equipment Effectiveness, there remained a gap in understanding its impact on manufacturing operations (Contextual Gap).
- The lack of precise benchmarking mechanisms between equipment and organizations impeded the accurate assessment of performance (Methodological Gap).
- The absence of a structured and replicable costing approach to OEE resulted in incomplete consideration of all associated costs, thus undermining the accuracy of decision-making processes (Methodological Gap).

2.4. Theoretical Framework

The research aimed to devise a precise method for analysing the cost breakdown of Overall Equipment Effectiveness (OEE), with the goal of enhancing comprehension of OEE and enabling organizations to make well-informed decisions regarding areas for improvement. This objective will be realized through the formulation of the Activity-Based Effectiveness (ABE) methodology, which integrates principles from OEE and Activity-Based Costing (ABC) to address the research problem.

The target of the theoretical framework is to delve into the theoretical foundations of the deduced Activity-Based Efficiency (ABE) approach proposed in this study. This involves assessing, selecting, and comparing the most pertinent theories related to the cost synthesis of

OEE, to determine the most pertinent factors to their success and critically evaluate the approach to OEE ensure adaptability to cost synthesis.

2.4.1. Contrasting Current Cost-based Approaches to OEE

The comparison focused on two approaches; the OECL approach developed by Wudhikarn (2016), and the Equipment Cost Efficiency (ECE) method proposed by Liew, Prakash, and Ong (2023). These approaches were chosen for their significant relevance to the research proposal and their overlapping areas of interest.

The OECL approach developed by Wudhikarn (2016) and the Equipment Cost Efficiency (ECE) method proposed by Liew, Prakash, & Ong (2023) both aimed to address the limitation of the understandability of the traditional Overall Equipment Effectiveness (OEE) through integrated cost analysis within the framework of OEE. However, there were notable differences between the two approaches in the key elements that contributed to their success.

The OECL Approach and the ECE Method differ in their focus and approach to evaluating equipment effectiveness. The OECL Approach integrated the six big losses model with a general financial framework to assess equipment performance, providing a cost-centric perspective (Wudhikarn, 2016). This approach evaluated equipment based on both production metrics and financial factors, ultimately ranking equipment according to its cost efficiency. On the other hand, the ECE Method incorporated costs correlated with non-productive activities, aiming to establish a benchmark for comparison and facilitation of targeted improvement initiatives (Liew, Prakash, & Ong, 2023). By delving into the various cost components linked to equipment operation, the ECE Method sought to provide a comprehensive insight into equipment cost efficiency.

The OECL Approach involved constructing a cost-centric framework within the OEE model. This approach included assigning expense time per unit and opportunity loss time per unit, with quantification of losses for each element of the OEE formulation varying based on resource consumption. It considered both the direct and indirect costs associated with factors like production volume, downtime, and maintenance expenses, integrating these factors into the six big loss model (Wudhikarn, 2016). On the other hand, the ECE Method established a relationship between OEE and various cost components such as profit, revenue, operating expenses, equipment acquisition costs, and maintenance expenses. It distributed life cycle costs to enable allocation of costs to specific equipment or processes (Liew, Prakash, & Ong, 2023).

Additionally, the ECE Method considered external factors like product demand, recognizing that opportunity cost loss may not always translate directly into increased profit. Moreover, this method evaluated the potential costs associated with improving OEE to accurately determine the Return on Investment (ROI) of each improvement (Liew, Prakash, & Ong, 2023).

Both the OECL Approach and the ECE Method had specific application limitations. The OECL Approach was versatile and could be applied across various industries to evaluate equipment cost effectiveness in diverse manufacturing settings. However, it was noted during the study that there were scenarios where the OECL Approach may not be applicable (Wudhikarn, 2016). In contrast, the ECE Method was more suited for industries where equipment utilization and maintenance costs significantly impact overall operational efficiency, such as manufacturing and production facilities. Its focus on these industries allowed for a more tailored and effective assessment of equipment cost efficiency (Liew, Prakash, & Ong, 2023).

The outcome of both the OECL Approach and the ECE Method underscored their effectiveness in enhancing equipment efficiency through cost analysis. Applying the OECL Approach, organizations could prioritize equipment for improvement based on their cost efficiency, as it ranked problematic machines differently compared to traditional OEE methodologies. This approach facilitated more informed decision-making by directing resources towards areas with the highest potential for cost reduction and process optimization (Wudhikarn, 2016). Similarly, the ECE Method provided valuable insights into the specific costs impacting equipment efficiency. By identifying and analysing these cost components, organizations could pinpoint areas for cost reduction and process optimization with greater precision. This allowed for targeted improvement initiatives that addressed the root causes of inefficiencies, ultimately leading to enhanced operational performance and financial outcomes (Liew, Prakash, & Ong, 2023).

Both approaches contributed to the theoretical understanding of cost management within the context of OEE, shedding light on the importance of integrating cost considerations for enhancing equipment efficiency.

The comparison of the elements contributing to the success of each of these two approaches revealed several key considerations. Firstly, incorporate a comprehensive evaluation of Overall Equipment Effectiveness (OEE) by integrating both production and financial metrics, while also considering non-productive metrics to facilitate thorough benchmarking. Secondly, they emphasized the importance of customizing the formulation of each OEE element based on resource consumption, thereby ensuring accurate assessment tailored to specific operational contexts, while also considering external factors such as demand to provide a more holistic perspective. Lastly, prioritize applicability across diverse industries, by leveraging a structured financial framework that allowed for flexible adaptation and implementation across various organizational settings. It was worth noting that assigning opportunity loss time per unit does not necessarily translate into increased profit, depending on the market conditions and external factors within the systems theory.

2.4.2. Contrasting Approaches to OEE

Two primary approaches to the Overall Equipment Effectiveness (OEE) methodology was investigated: the traditional OEE methodology and the OEE time loss methodology.

The traditional method of assessing OEE was defined as the ratio of actual manufacturing output to ideal manufacturing output, which was determined by the product of Availability, Performance, and Quality (Del Carmen Ng Corrales et al., 2020).

In contrast, the OEE time loss methodology assigned a time value to each element of the OEE formulation. In this approach, Availability (A) represented the time lost due to planned and unplanned stops, Performance (P) denoted the time lost due to minor stops or operating at reduced speed, and Quality (Q) indicated the time lost during production of defective material (Kennedy, 2017). The time loss methodology can be expressed mathematically as:

$$OEE = \frac{Effective\ Operating\ Time}{Planned\ Operating\ Time}$$

Equation 7: OEE Time Loss Methodology (Kennedy, 2017)

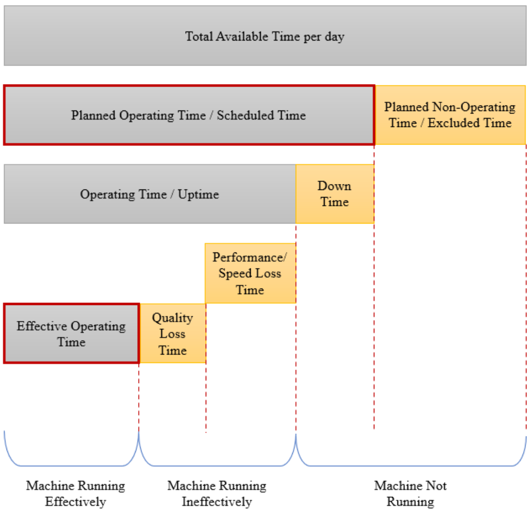


Figure 6: OEE time-based methodology (Kennedy, 2017)

The two OEE methodologies result to the same percentage outcome of OEE and can thus be expressed as:

$$OEE = A \times Q \times P = \frac{Effective\ Operating\ Time}{Planned\ Operating\ Time}$$

Equation 8: OEE expanded (Kennedy, 2017)

A full comparison of the two calculation methods of the OEE methodology can be viewed in Annexure C.

Contrasting the two approaches to the Overall Equipment Effectiveness (OEE) methodology, it became evident that the time-based methodology offered a more comprehensive understanding of OEE by accounting for the time implications (Kennedy, 2017). Unlike the traditional method, which merely presented OEE as percentage values, the time-based approach provided insight into the temporal aspects of equipment performance (Del Carmen Ng Corrales et al., 2020). This differentiation in the equation was particularly significant for our research, as it allowed for a more detailed analysis of OEE, enabling the assignment of cost elements and facilitating a deeper understanding of the financial implications of equipment efficiency.

2.4.3. Activity-Based Effectiveness (ABE)

Drawing on insights gleaned from contrasting existing pertinent approaches to cost-centric approaches to OEE and OEE methodologies, the Activity-Based Effectiveness (ABE) framework addressed the following to cover the research gaps. Firstly, the ABE methodology would build upon the foundation of the OEE time loss methodology, providing a basis for cost allocation to each loss within the process (Kennedy, 2017). Secondly, ABE would integrate both production-related (direct) and non-production-related (indirect) costs, utilizing Activity-Based Costing (ABC) to distribute costs based on resource consumption (Chapman, Kern, Laguecir, & Quentin, 2016). This structured approach would additionally enhance generalizability across industries. Lastly, the framework would separate opportunity costs (representing time not allocated to production) from the OEE calculation. This consideration of external factors, such as demand, would enable the use of opportunity costs for return-on-investment calculations, while still allowing for informed internal decision-making (Wudhikarn, 2016).

The ABE methodology, a deduced cost-centric approach to OEE that was designed to improve understanding and decision making at all levels of the organisation through the allocation of ABC to the parameters of the OEE formulation (Braglia, Frosolini, & Zammori, 2009).

The ABE approach incorporated various parameters derived from the analysis of the OEE and ABC methodologies. These parameters included machine downtime, performance loss time, and quality loss time, each of which contributes to the overall assessment of equipment efficiency (Wudhikarn, 2016).

The machine downtime component considered the increase in direct labour costs resulting from employee idle time during machine downtime. Additionally, it accounted for the rise in overhead costs attributable to machine output reduction. The variable costs of the machine escalated as the output increased, while the fixed costs decreased due to cost saturation (Kaplan & Anderson, 2004).

Performance Loss Time considered the rise in direct labour costs stemming from the variance between the design speed and actual speed of the machine. As the cycle time approached the design speed, fewer man-hours were required to complete the product. Moreover, it acknowledged the increase in overhead costs due to machine output reduction, where the variable costs escalated with higher machine output, while fixed costs decreased owing to cost saturation (Wudhikarn, 2016).

The Quality Loss Time aspect encompassed several factors, including the increase in direct material costs due to non-conforming products. These products, which does not contribute to the company's revenue, incur material, and labour cost despite not meeting quality standards. Non-conforming products comprised both scrap and rework items. Scrap products entail the complete loss of direct material, while rework products require additional time and material resources to meet quality parameters. This differentiation impacted the quality cost of the process. Additionally, there was an increase in direct labour costs due to the time spent on producing non-conforming products. Moreover, there was a rise in overhead costs due to the reduction in valuable machine output (Liew, Prakash, & Ong, 2023).

The Overall Equipment Effectiveness (OEE) elements of Availability (A), Quality (Q), and Performance (P) as analysed through the time-based OEE methodology (Del Carmen Ng Corrales, Lambán, Korner, & Royo, 2020) would be distinguished and compared to the ABC methodology as follows and a detailed breakdown of the costs (Williams, Haka, Bettner, & Carcello, 2018) OEE links to the ABC methodology can be viewed in Annexure D.

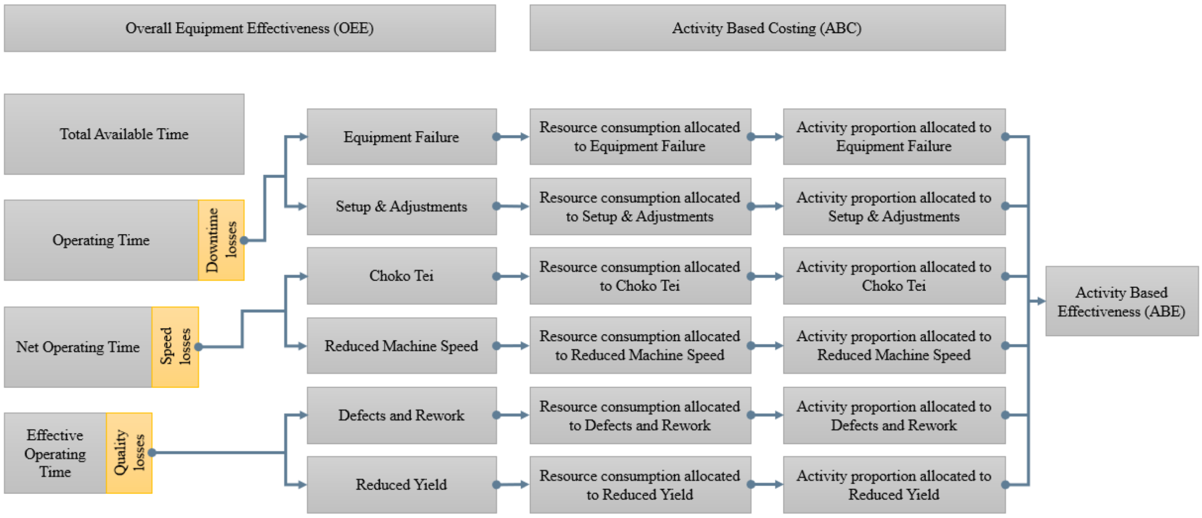


Figure 7: ABE (Author's own – Deduced)

The ABE methodology used the Marginal Cost per product derived from the Activity Based Cost (ABC) and converted it into a time measure using maximum production output. This was achieved through the ratio of loss time and design speed, to attain the cost loss. The result was multiplied by the marginal cost.

$$Loss\ Cost = \frac{Loss\ Time}{Design\ Speed} \times Marginal\ Cost$$

Equation 9: Maximum Equipment Output

The total cost of effective operations as calculated through the ABC methodology, applied to the OEE methodology was calculated as the total maximum production that can be achieved in the given timeframe multiplied by the marginal cost of the product and is expressed as follows:

$$TCO_E = Max.Prod \times MC$$

Equation 10: Total Cost of Effective Operation

$$ABE = \frac{TCO_E - \sum Loss\ Cost}{TCO_E}$$

Equation 11: ABE Formula

A theoretical application of the ABE approach can be seen in Annexure E.

The deduced Activity-Based Effectiveness (ABE) approach aimed to rectify the existing understanding deficiencies of the Overall Equipment Effectiveness (OEE) methodology (Lelis, 2022) while filling the gaps in current research. This approach sought to enhance comprehension of losses within production processes across all organizational levels and facilitated precise equipment benchmarking to address these losses and support effective decision-making. Moreover, it enabled generalizability through the structured implementation of Activity-Based Costing (ABC). However, it was worth noting that the ABE methodology was contingent upon the prior adoption of an ABC system, which may pose implementation challenges for organizations (Kenton, 2023). Future research endeavours could explore alternative methods to streamline cost assignment processes for increased feasibility and ease of adoption.

2.4.4. Conceptual Framework

The purpose of the conceptual framework was to define and arrange the cause-and-effect of the variables of this research.

The ABE methodology that provided the monetary value of OEE would result in an improved understanding of the impact of OEE on the process. This hypothesis was supported by the work of Lelis (2022) that explained that the percentage usage of the OEE methodology form misunderstanding in organizations. The hypothesis was structured around the understanding that would be achieved when the ABE methodology changed the percentage value to currency value.

The relationship between ABE and equipment effectiveness understanding could be measured through the number of people that are able to use the system to understand equipment performance.

The monetary value that was achieved through adapting the ABE approach, would address the enigma of the lowest OEE not causing the highest business losses (Wudhikarn, 2016). As the cost value of losses was a standardized way of analysing business performance, the value can be easily benchmarked to other equipment in the same facility or equipment outside of the facility.

The relationship between ABE and accurate benchmarking could be measured through the number of machines that has adopted the system and regulating the effect of improvement, thus if the effectiveness of the equipment improved the relative position related to the benchmark would change. As the same OEE percentage could be achieved with vastly different output results, the OEE measure is not a reliable source of information to develop the top loss of an organization (Sapot, 2019). The relationship between ABE and effective decision-making can be measured through the number of successful improvements achieved on equipment.

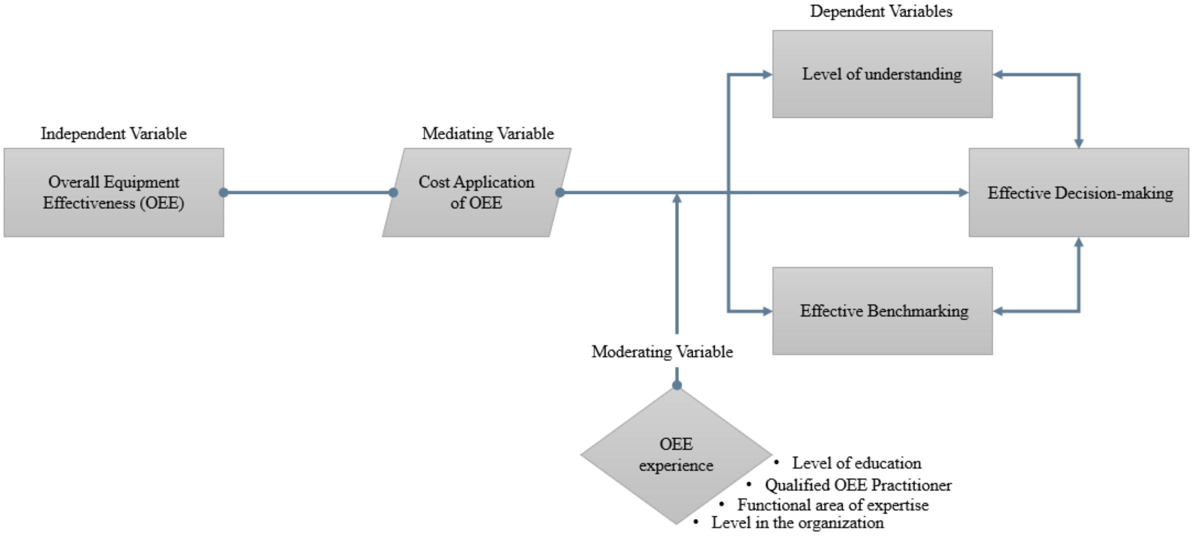


Figure 8: Cause-Effect Relationship

The analysis of the cause-and-effect relationship that exists between the variables results in the following hypothesis:

Hypothesis 0_1: The proportion of employees in a manufacturing organization that understand OEE was directly affected by the organization following a structured way of calculating OEE as a cost-centric metric.

Hypothesis 0_2: Implementing Activity-Based Effectiveness (ABE) would yield clear cost allocations for each loss, thus improving benchmarking of equipment.

Hypothesis 0_3: Implementing Activity-Based Effectiveness (ABE) would yield different results than traditional OEE, thus improving effective decision making.

2.5. Conclusion of Literature Review

Since its inception in 1982, Overall Equipment Effectiveness (OEE) had been the benchmark for assessing equipment effectiveness and initiating enhancements to minimize losses. However, this metric was inherently flawed, as it failed to account for the varying implications of achieving the same OEE value on organizational output and profitability. To address this issue, the literature advocated for the implementation of a cost-centric approach to OEE, which assigned a monetary value to equipment effectiveness, facilitating easier understanding, benchmarking, and informed decision-making. Addressing this gap, the Activity-Based

Costing (ABC) methodology, which allocated costs to individual activities using multiple cost drivers had been integrated with the OEE methodology to form the basis for the Activity-Based Effectiveness (ABE) methodology. The ABE methodology analysed the cost allocation to the three main components of the OEE formulation by establishing the Total Cost of Effective Operations (TCO_E) for each activity. This structured approach provided a straightforward means of assessing the cost of losses and addressed the shortcomings of the traditional OEE methodology by enabling organizations to prioritize areas for improvement based on potential cost savings. Consequently, ABE provides a transparent perspective on improvements, facilitating informed decision-making and ultimately contributing to business sustainability.

The result of this theoretical literature analysis would be tested to confirm the hypothesis through data analysis.

CHAPTER THREE
RESEARCH METHODOLOGY

3.0. Introduction

The purpose of this research was to develop a structured and replicable framework to express Overall Equipment Effectiveness (OEE) as a financial value. The Activity-Based Effectiveness (ABE) methodology aimed to improve understanding, benchmarking and decision making of efficiency improvements in the manufacturing industry.

The methodology chapter delineated the systematic strategy and framework for conducting the research, enabling the reader to assess its reliability and validity (Creswell, 2009). This section was organized to discuss the research approach adopted, the study's design for gathering information on OEE's understandability, benchmarking, and decision-making aspects, and the procedures implemented during the research (Terrell, 2022).

3.1. Research Approach

Research could be approached through either employing qualitative, quantitative, or mixed methods approaches (Terrell, 2022). Qualitative approaches applied tools such as interviews, and participant observation to gain a greater understanding of the research problem (Dawadi, Shrestha, & Giri, 2021). This method gathered multiple participants' meaning in their natural setting with the researcher as the primary instrument (Creswell & Creswell, 2018). Quantitative approaches applied tools such as close-ended highly structured surveys and numerical data collection (Schoonenboom, 2023) to gain breadth of understanding (Terrell, 2022) within numerical calculation sets.

This research study would employ a convergent, exploratory sequential mixed methods approach (Creswell & Creswell, 2018). The study would be conducted in an exploratory sequential method, starting with convergent data collection (both qualitative and quantitative), the result of the data collection would form the basis of the qualitative refinement of ABE. This was followed by the quantitative analysis of the ABE framework implementation (Creswell & Creswell, 2018). The initial convergent phase would provide comprehensive analysis of the research problem, allowing interpretation of current OEE and the cost of OEE practises. This would support the calibration of the ABE framework implementation and numerical justification through the understanding of the current experiences and difficulties in the manufacturing industry. The sequence is explained by Figure 9 below.

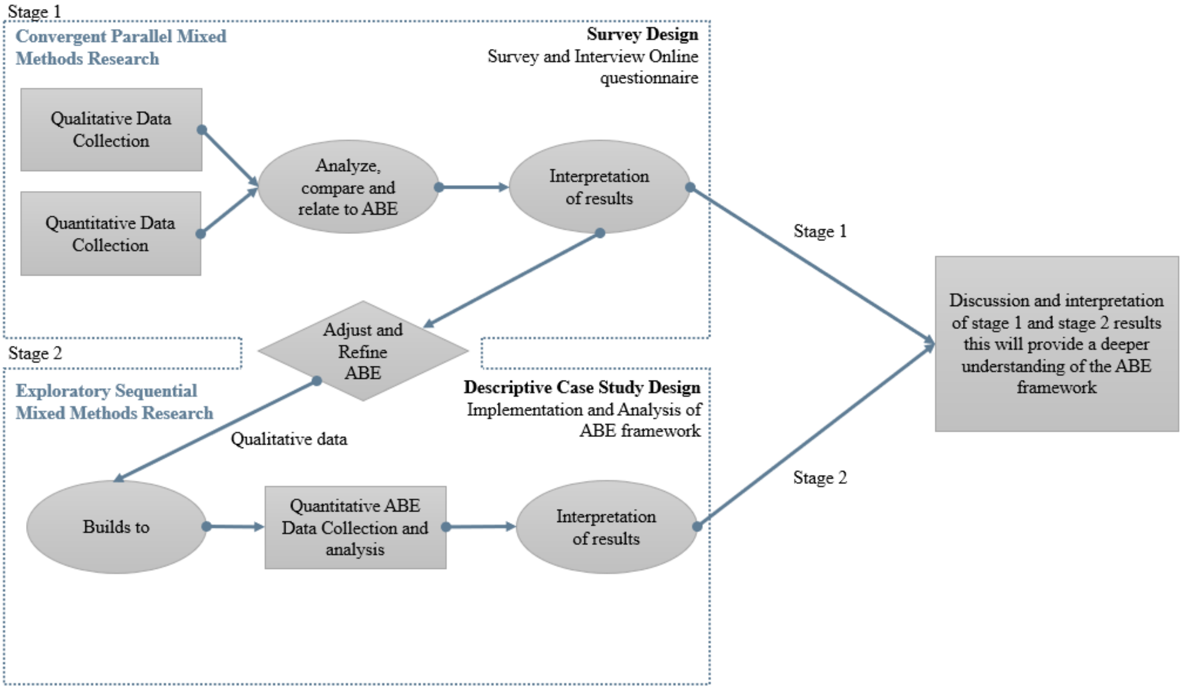


Figure 9: Mixed Methods Research Approach (Author's Own)

The mixed method approach was selected to firstly, understand the relationship between the variables of OEE understandability, accurate OEE benchmarking and effective decision making and the impact that the implementation of a structured, replicable cost approach would have on these variables. Secondly, explore the in-depth application results of the implementation of the ABE approach in contrast with the traditional OEE results.

The mixed methods approach advantages in contrast to the single approach of qualitative and quantitative research, would provide both deeper qualitative expertise into the phenomena of OEE, and scale through the accumulation of quantitative ABE data (Dawadi, Shrestha, & Giri, 2021). This approach would also allow the findings to be generalised to the manufacturing industry while providing breadth of understanding.

The challenge of this approach was that it was more complex to carry out as there are multiple stages of data collection and different analysis systems as opposed to the single approaches of qualitative and quantitative research (Dawadi, Shrestha, & Giri, 2021).

3.2. Research Paradigm

The research paradigm was the nature and alignment of the research (Creswell & Creswell, 2018). The paradigm was the worldview of the axiology, which is beliefs surrounding ethics, ontology which is the belief around reality, epistemology which is the belief of the researcher's role. The methodology which was based on the first three aspects which forms the methodological approach as viewed by the researcher (Terrell, 2022).

There were various research paradigms that could be adopted within the research context. The most popular normally discussed in research were positivism, interpretivism and pragmatism. Positivism which was common in quantitative studies assumed that the researcher existed independently from reality, positivists strive to understand the disposition of the research problem through the investigation of the cause-and-effect relationship (Rehman & Alharthi, 2016). Interpretivism which was common in qualitative studies focus on the depth of the variables related to context, and individual meanings (Alharahsheh & Pius, 2020). Pragmatism was concerned with developing solutions to problems, it focussed on the research problems and questions in order to develop the best understanding (Creswell & Creswell, 2018).

The research paradigm that would be used in compiling this research paper was pragmatism. Pragmatism was real-world practise orientated and problem centred (Creswell, 2009) which makes this paradigm the most suitable for this research project. The current understanding of the OEE methodology and the implications on decision making and benchmarking forming the problem. The pragmatist paradigm provided the advantage of investigation of the effect of the implementation of ABE and the individual meaning supporting the calibration of the framework. This approach would enable the research to use all available approaches to understand the problem (Creswell, 2009).

3.3. Research Design

The research design was the overall direction and procedures for the research project (Creswell & Creswell, 2018). This research would follow a multi-step reasoning approach. The study would start with the use of inductive reasoning starting with observations to generalize and refine the ABE methodology. The ABE methodology would then be deductively tested through collecting and analysing OEE and ABE data to either accept or reject the hypothesis for modification of the ABE methodology (Ochara, 2023).

The combination of the two research types was selected to clearly articulate the impact of understanding, decision-making and benchmarking as experienced in the manufacturing industry, to adjust and affect the ABE methodology.

The reasoning approaches would be complimented with a survey design in stage one of the research, where participants would be requested to answer a set of open-and-close-ended questions to support the refinement and precision of the ABE approach. This method was suitable for the first stage of the research design as it allowed the researcher to examine the relationship among variables to generalise the findings. This would be followed in stage two by a descriptive case study implementation of the ABE approach for the reliability and validation of the ABE framework. All information would be collected from primary sources.

This study was conducted using a cross-sectional time frame for both stages of the research design, with data collected at single points in time. This approach was suitable for the research project, as all data were captured at specific points in time for both instances. This method was advantageous given the high complexity of the mixed methods approach used in the project, as it alleviated the burden of extended data collection. However, this time frame did not allow for observing the evolution of the implemented ABE methodology over time.

3.4. Data Collection Method

The data collection method was the approach used to gather data for the research project, tightly linked to the research approach, paradigm, and design, and determining how the research analysis would be conducted (Paradis et al., 2016).

In the first stage of the data collection (convergent stage), data were gathered using an electronic survey and interview questionnaire, with the same variables employed for both data collection methods (Creswell & Creswell, 2018).

According to Wright (2017), the advantages of using an electronic questionnaire were as follows:

- As it was distributed electronically it supported the collection of significant amounts of data in a relatively short amount of time with low difficulty and low cost.
- Electronic surveys and interviews provided a standardised questionnaire set thus the information received from participants were consistent, leading to easier analysis.

However, Wright (2017) stated that electronic questionnaires also come with certain disadvantages:

- There was a lack of personal collaboration between the researcher and the participant, thus the questionnaire could be completed quickly without applying depth of knowledge.

- An electronic questionnaire could be ignored resulting in non-response bias affecting the generalizability of the survey and interview.
- Technological challenges could be experienced by participants, where they struggled to complete the survey on their mobile device or have limited access to internet.

In the second stage of the data collection (exploratory sequential stage), the ABE framework was implemented using a case study approach. This involved gathering all relevant information, including OEE and costing data, from the case company to compile the ABE framework information.

Based on research from Zainal (2007), the advantages of using a descriptive case study in context:

- The researcher gained in-depth understanding and context of the ABE phenomenon investigated.
- Implementing the ABE methodology provided practical relevance for the use of the framework.
- Implementing the ABE methodology at the case company allowed the researcher to see the shortcomings of the framework.

Based on research from Zainal (2007), the disadvantages of using a descriptive case study in context:

- Due to the implementation at one case company, it limited the generalisability of the ABE methodology.
- The participation of the researcher in the data collection process led to subjective biases from the researcher leading to difficulty in replication of the study.

3.4.1. Population and Sampling Strategy

3.4.1.1. Population

The population and sampling strategy only referred to stage 1 of this mixed methods research, involving the electronic survey and interview questionnaire, as stage 2 employed a case study approach at one case company.

The target population for the survey and interview questionnaire were as follows:

- All employees of companies within the manufacturing industry.

- Employees within different levels of companies to determine the understanding at different levels of the organisation.
- Employees from various disciplines within the organisation to determine the understanding of OEE and the cost of OEE throughout the organisation.

The parameters of interest for the population were the current levels of understanding of OEE of the participant, the current understanding of the cost metric of OEE and the impact that it had on the decision-making of the organization, and what the influence of a possible implementation of a structured and replicable approach would mean.

3.4.1.2. Sampling Strategy

The sampling strategy determined how the participants of the research project were selected (Terrell, 2022) for the qualitative and quantitative sections of the research project within mixed methods research (Creswell & Creswell, 2018).

The sampling used in the first stage (convergent stage) of this research project was non-probability convenience sampling, this sampling type involved selecting participants based on availability or convenience (Ochara, 2023). During the second stage (exploratory sequential stage) non-probability purposive sampling was employed, as the case company was chosen by the researcher.

The advantages of these types of sampling are that potential participants are not pre-selected but are instead reached through the survey within the population. The case company was selected by the researcher, eliminating the need for initial preparation to ensure sample participation.

The disadvantage of convenience sampling was that it was unclear if there would be enough respondents to the survey and interview questionnaire. The disadvantage of purposive sampling was that it created sampling bias, which could hamper the generalizability of the data.

The sample size for the convergent stage of this research project was calculated using a 5% margin of error and 95% confidence level. This research project followed the respondent rate guideline from Kass & Tinsley (1979), that recommend the use of 5 to 10 respondents per variable. This research project focused on 5 variables, requiring a minimum of 25 to 50 participants for the electronic questionnaire. To ensure adequate data, 5 respondents were needed per question, making a minimum of 125 respondents necessary for this stage of the research project.

3.4.2. Development of instrument

3.4.2.1. Electronic Questionnaire

The electronic questionnaire was developed and executed through the Qualtrics platform. The survey was developed into the following blocks:

- Demographic information (8 questions): Personal information from the participant, this information was collected anonymously to ensure the anonymity of the participant.
- Understanding of Overall Equipment Effectiveness (13 questions): This section was included to gather information regarding the participant's knowledge and understanding of the OEE methodology, and the perceived challenges experienced.
- Financial Calculation of OEE (9 questions): This section gathered information regarding the practise of calculating OEE as a cost metric for the organization, this information was collected confidentially.
- The perceived impact of implementing a cost approach OEE (5 questions): This section was geared towards the participant's perception of the potential impact of the implementation of OEE as a cost metric.

The electronic questionnaire was made up of 5-point Likert scale questions and open-ended questions and was piloted before the main questionnaire was launched. This gathered information regarding the ease of completion of the questionnaire and the validity of the information received from the questionnaire. This ensured that when the questionnaire was published that the researcher received valid responses to the questionnaire. The full questionnaire can be seen in Annexure G.

3.4.2.2. Case Study

The case study data collection was collected at the case company as follows:

- The case company remained anonymous, the sector and industry were reported within this research proposal.
- OEE data was collected through the developed platforms within the case company. This data was validated through the literature as explained in this research proposal.
- The costing information was collected through the support of the case company finance team, they were allowed to revoke participation at any point of the data collection

process. Confidentiality of data was upheld through replacing the financial information with representative information for the writing of this research project.
- The ABE framework was implemented using this information and the OEE and ABE information was contrasted.

3.5. Data Analysis

The convergent electronic survey and interview questionnaires will be analysed in three phases. Firstly, the qualitative data will be collapsed as themes (deductive thematic analysis), secondly, the quantitative data will be analysed through the SPSS software. This will be followed by the integration of the two databases by capturing the themes as quantitative data, the resulting data will be analysed as follows:

The data analysis comprised of several key components aimed at providing a comprehensive understanding of the data:

- Descriptive Statistics: This analysis focussed on the central tendency of the nominal data collected, specifically identifying the mode. This analysis supported revealing any relationships and associations among the variables (SPSS Tutorials, 2023).
- Analysis of Goodness: To assess the consistency and stability of the data, Cronbach's alpha was calculated to determine internal consistency and reliability. Additionally, both quantitative and qualitative validity of the data were evaluated to confirm accuracy and identify any duplicates (SPSS Tutorials, 2023).
- Chi-Square Independence Test: This test was employed to investigate the association between variables and assess their independence (SPSS Tutorials, 2023).

Furthermore, the case study information was analysed using equations and formulations outlined in the literature review. This involved computing the mean, median, and standard variation of the data to gain insight into the overall trends and patterns.

3.6. Ethical Considerations

The ethical considerations for the rights, needs and values of the participants of both the convergent stage and the exploratory sequential stage was highly important (Creswell & Creswell, 2018). To ensure the ethical compliance of this research the subsequent measures is put in place:

- Informed consent: Participants in both phases of the research endeavour received clear information about the research's aims and objectives. Each participant provided informed consent, signifying their voluntary participation, with the option to withdraw at any stage of the study.
- Written permission: Written permission was obtained by the case company for the completion of the exploratory sequential stage.
- Confidentiality: All the participants was informed that all data was treated as confidential to keep the identity of the participant anonymous.

3.7. Conclusion

The mixed methods research approach was selected to enable perspectives from both the qualitative and quantitative methods. The strategic approach was to follow a convergent, exploratory sequential approach over two stages of data collection, with the convergent information refining the ABE framework to be implemented during the exploratory sequential stage.

The research was conducted with a pragmatic worldview that enabled this research problem to be viewed with a real-world practise and problem orientation. Supporting the pragmatic view, the research was designed as inductive during the convergent stage and deductive during the exploratory sequential stage. This grows the understanding of the relationship between the variables in stage 1 for refinement, reliability, and validation of the ABE framework in stage 2.

This population of research project were within the manufacturing industry using a convenience sampling method though the use of an electronic survey and interview questionnaire followed by a purposive sampling method for the case company implementation. The electronic questionnaire was analysed using the SPSS software and the case company data analysis will be analysed using the ABE framework with comparison to the OEE information.

CHAPTER FOUR
DATA ANALYSIS AND RESEARCH FINDINGS

4.0. Introduction

The data analysis and research findings chapter were the chapter where the data was objectively and neutrally analysed and presented. Subsequently, assessment of the research findings was conducted, considering their alignment with the research objectives, questions, and hypotheses.

The purpose of this research was to develop a structured and replicable framework to express Overall Equipment Effectiveness (OEE) as a financial value. In order to achieve this data was gathered through the utilization of a survey questionnaire to evaluate the current state of understanding, benchmarking and decision-making in the scope of OEE and a cost-centric model. Additionally, data was collected through the implementation of the Activity-Based Effectiveness (ABE) methodology within a case organization to compare and contrast the potential impact of the deduced structured approach on to the current understanding, benchmarking and decision-making of the case company.

The study followed a convergent, exploratory sequential mixed methods approach; thus, this chapter was structured in two parts. The first part explaining the convergent data collection (both qualitative and quantitative) and the second part explaining the exploratory sequential case study (quantitative) approaches and analysis.

4.1. Phase 1: Convergent Data Analysis

The purpose of this phase of the analysis was to support investigation into the first hypothesis: The proportion of employees in a manufacturing organization that understand OEE is directly affected by the organization following a structured way of calculating OEE as a cost-centric metric.

The data for phase 1 was collected using a convenience sampling method though the use of an electronic survey and interview questionnaire. The questionnaire comprised of 30 quantitative multiple-choice questions and 5 qualitative, open ended interview questions. The survey was distributed to professionals within the manufacturing industry using the Qualtrics survey engine, promoted indirectly on the LinkedIn platform and directly via approved email distribution using the University of Witwatersrand, the South African Institute of Industrial Engineering, and the Textile Federation email distribution lists. A total of 241 responses was received, of which 83 responses was excluded from the investigation due to incomplete data, where incomplete data was considered as less than 60% of the questions was answered. A total of 158 (n=158) usable responses was obtained, resulting in a completion rate of 65.5%. The minimum total required for this research was 125 respondents, thus a success rate of 126.4% was achieved. The survey comprised of four sections in support of the research questions, and the collected data will be presented as follows (See Annexure G: Survey questions):

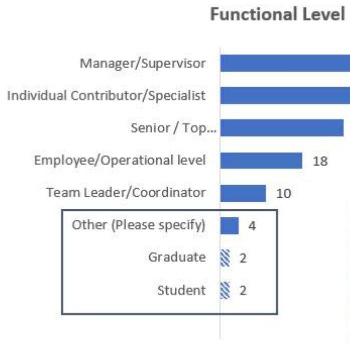
- Demographic Information: The first section gathered professional and personal demographics through eight quantitative questions, aimed to gather information the ensure accurate distribution and representation of the sample.
- OEE Systems Analysis (Understanding of OEE): The second section assessed respondents' comprehension of OEE with eleven quantitative and two qualitative questions. These questions supported answering research question 1: What is the current proportion of employees in the manufacturing sector who understand OEE and its impact on overall organizational effectiveness? Furthermore, how is this understanding influenced by adopting a cost-centric approach to OEE?
- OEE Cost Application Analysis (Cost-Centric Approach to OEE): The third section explored respondents' views on portraying OEE as a monetary value through five quantitative questions. These questions supported answering research question 3: How does the performance optimization differ when utilizing the OEE and ABE approaches within an organization, and does it support effective decision making?
- Structured Cost System Analysis (Financial Calculation of OEE): The final section examined the financial aspects of OEE calculation with six quantitative and three qualitative questions to gauge cost tracking in respondents' organizations. These questions supported answering research question 2: Can a structured, replicable cost-centric approach to OEE be developed based on the key strengths and findings in current methodologies, to improve benchmarking of equipment?
- The qualitative data was organized into themes using deductive thematic analysis, while the quantitative data was analysed using SPSS software. Since all the data collected was nominal, the only measure of central tendency available was the mode (McCluskey & Lalkhen, 2007).

4.1.1. Demographic Analysis

The survey responses collected in this section was analysed to ensure adequate representation of the broader population through dispersion statistics. This section informed the analysis of the understanding of OEE (moderating variables), determining the impact on the correlation between the mediating and dependant different variables.

4.1.1.1. Analysis of Professional Demographics

The functional level demographic ensures accurate measurement of the understanding of OEE throughout the organization. A total completion rate of 99.4% was achieved, with one participant preferring not to answer.



Statistics

Q1

N	Valid	157
	Missing	1
Mode		2
Skewness		.515
Std. Error of Skewness		.194
Kurtosis		-.893
Std. Error of Kurtosis		.385

Functional Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Senior / Top Management/Executive/Leadership (e.g., CEO, CTO, Vice President)	27	17.1	17.2	17.2
	Manager/Supervisor	63	39.9	40.1	57.3
	Team Leader/Coordinator	10	6.3	6.4	63.7
	Individual Contributor/Specialist	34	21.5	21.7	85.4
	Employee/Operational level	18	11.4	11.5	96.8
	Other (Please specify)	5	3.2	3.2	100.0
	Total	157	99.4	100.0	
Missing	7	1	.6		
Total		158	100.0		

Figure 10: Organizational Functional Level Distribution

The functional area demographic was aimed to measure if the respondents are distributed throughout various functions, to ensure understanding for an organization rather than an individual function. A 100% completion rate was achieved. The data showed that the respondents was skewed to the higher organizational levels, with Managers and Supervisors contributing to 40.1% of valid responses received.

Statistics

Q2

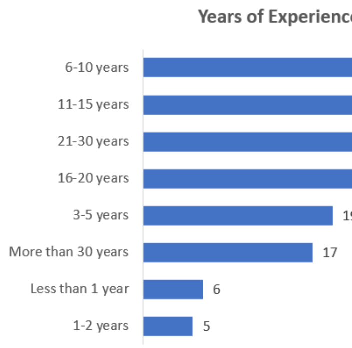
N	Valid	158
	Missing	0
Mode		2
Skewness		1.237
Std. Error of Skewness		.193
Kurtosis		.214
Std. Error of Kurtosis		.384

Functional Area

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Industrial Engineering	49	31.0	31.0	46.8
	Operations/Production	37	23.4	23.4	77.8
	Engineering/Technician	19	12.0	12.0	12.0
	Other (Please specify)	14	8.9	8.9	86.7
	Quality Assurance/Control	9	5.7	5.7	92.4
	Sales/Marketing	8	5.1	5.1	97.5
	Maintenance	7	4.4	4.4	54.4
	Finance/Accounting	5	3.2	3.2	15.2
	Information Technology	5	3.2	3.2	50.0
	Supply Chain/Logistics	4	2.5	2.5	100.0
	Human Resources	1	.6	.6	15.8
	Total	158	100.0	100.0	

Figure 11: Organizational Functional Area Distribution

The years of experience demographic was aimed at ascertaining a representative distribution of experience for the study to determine if a clearer understanding could be achieved through more years of service. A completion rate of 100% was achieved. The findings show that employees from the Industrial Engineering, operations and engineering functional areas contributed to the majority of the responses received, with a combined contribution of 66%.



Statistics

Q3

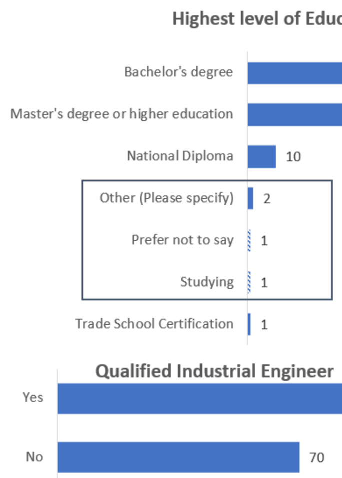
N	Valid	158
	Missing	0
Mode		4
Skewness		-.078
Std. Error of Skewness		.193
Kurtosis		-.586
Std. Error of Kurtosis		.384

Years of Experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6-10 years	37	23.4	23.4	85.4
	11-15 years	31	19.6	19.6	22.8
	21-30 years	22	13.9	13.9	50.0
	16-20 years	21	13.3	13.3	36.1
	3-5 years	19	12.0	12.0	62.0
	More than 30 years	17	10.8	10.8	100.0
	Less than 1 year	6	3.8	3.8	89.2
	1-2 years	5	3.2	3.2	3.2
	Total	158	100.0	100.0	

Figure 12: Years of Experience Distribution

The highest level of education demographic aimed to ensure representation of educational levels, guiding the study to establish the impact of education on OEE understanding. A completion rate of 99.4% was achieved, with one participant choosing not to answer. This demographic is further supported by determining if participants hold a degree in Industrial Engineering, as this discipline closely relates to Overall Equipment Effectiveness (OEE), aiming to discern its impact on understanding. It was notable that the sample data is skewed towards higher levels of education, which imposes a research limitation of including more unskilled employees in the survey and can be addressed through future research.



Statistics

		Education	IE
N	Valid	158	158
	Missing	0	0
Mode		4	1
Skewness		-1.193	.232
Std. Error of Skewness		.193	.193
Kurtosis		2.174	-1.972
Std. Error of Kurtosis		.384	.384

Highest level of Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bachelor's degree	82	51.9	51.9	51.9
	Master's degree or higher education	63	39.9	39.9	91.8
	National Diploma	10	6.3	6.3	98.1
	Other (Please specify)	2	1.3	1.3	99.4
	Trade School Certification	1	.6	.6	100.0
	Total	158	100.0	100.0	

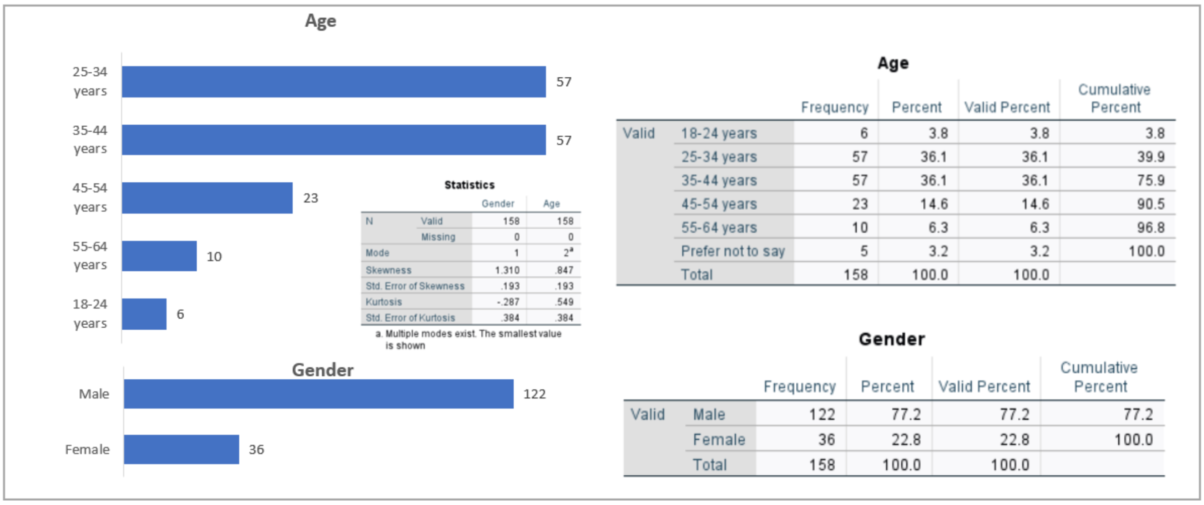
Qualified Industrial Engineer

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	88	55.7	55.7	100.0
	No	70	44.3	44.3	44.3
	Total	158	100.0	100.0	

Figure 13: Highest Level of Education Demographic

4.1.1.2. Analysis of Personal Demographics

Personal demographics, including age and gender, were collected to ensure accurate distribution within the population. A completion rate of 100% was achieved.



Statistics

		Gender	Age
N	Valid	158	158
	Missing	0	0
Mode		1	2[a]
Skewness		1.310	.847
Std. Error of Skewness		.193	.193
Kurtosis		-.287	.549
Std. Error of Kurtosis		.384	.384

a. Multiple modes exist. The smallest value is shown

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-24 years	6	3.8	3.8	3.8
	25-34 years	57	36.1	36.1	39.9
	35-44 years	57	36.1	36.1	75.9
	45-54 years	23	14.6	14.6	90.5
	55-64 years	10	6.3	6.3	96.8
	Prefer not to say	5	3.2	3.2	100.0
	Total	158	100.0	100.0	

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	122	77.2	77.2	77.2
	Female	36	22.8	22.8	100.0
	Total	158	100.0	100.0	

Figure 14: Personal Demographics

4.1.2. OEE Systems Analysis

The qualitative responses collected in this section was analysed and according to the primary themes that emerged from the data collected. This data was then added to SPSS and analysed alongside the quantitative data. The predominant themes identified were elucidated in the tables provided below.

Table 1; Theme Analysis for understanding of OEE.

Question 10	Theme
In your experience are there any other barriers apart from the ones above that affect how you or others understand OEE?	Lack of knowledge, commitment, or attention by leadership
	Lack of understanding of the impact
	Differences in definition
	Lack of training and awareness
	Organizational Culture or mindset
	Lack of exposure, examples, and differences in interpretation
	Specific Organisational requirements and transparency
	Implementation, calculations, and data availability
	Capability to follow process
	Lack of systems or resources

Question 13	Theme
In your experience, is it easy to understand and communicate the impact of low OEE to all levels of the organization?	Difficult
	Easy
	Easy with conditions

After the thematic synthesis of the qualitative questions, all survey responses collected in this section were analysed for the central tendency by calculating the mode and skewness of the data. The consistency, and the stability of the data by determining the Cronbach's alpha. Following the first tests, the understanding questions were all concatenated using the data's mode, which was then utilized to contrast the data to ascertain the impact of the moderating variables on the dependant variables.

Statistics

		Q8_1	Q8_2	Q8_3	Q8_4	Q8_5	Q9_1	Q9_2	Q9_3	Q9_4	Q10	Q11	Q12	Q13
N	Valid	157	156	156	156	155	156	156	155	154	58	152	157	106
	Missing	1	2	2	2	3	2	2	3	4	100	6	1	52
Mode		1	1	1	1	1	1	1	2	4	8	1	1	1
Skewness		1.786	1.939	1.275	1.968	1.101	.200	.487	.178	.082	.061	1.453	.720	.385
Std. Error of Skewness		.194	.194	.194	.194	.195	.194	.194	.195	.195	.314	.197	.194	.235
Kurtosis		2.131	2.687	.390	2.993	-.177	-1.093	-.745	-1.070	-1.236	-1.468	1.195	-.345	-1.152
Std. Error of Kurtosis		.385	.386	.386	.386	.387	.386	.386	.387	.389	.618	.391	.385	.465

Figure 15: Descriptive Statistics: Understanding of OEE

Case Processing Summary

		N	%
Cases	Valid	144	91.1
	Excluded[a]	14	8.9
	Total	158	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.864	.858	13

Figure 16: Understanding of OEE Reliability Statistics

The first set research question was geared toward gauging the respondent's view of how they, themselves understand OEE.

Please rate your level of understanding for each of the following statements:

- I am familiar with the concept of Overall Equipment Effectiveness (OEE)
- I understand the key components of OEE (Availability, Performance, Quality)
- I can accurately calculate and interpret OEE values.
- I am aware of the benefits of improving OEE for an organization.
- I feel confident in explaining OEE to others.

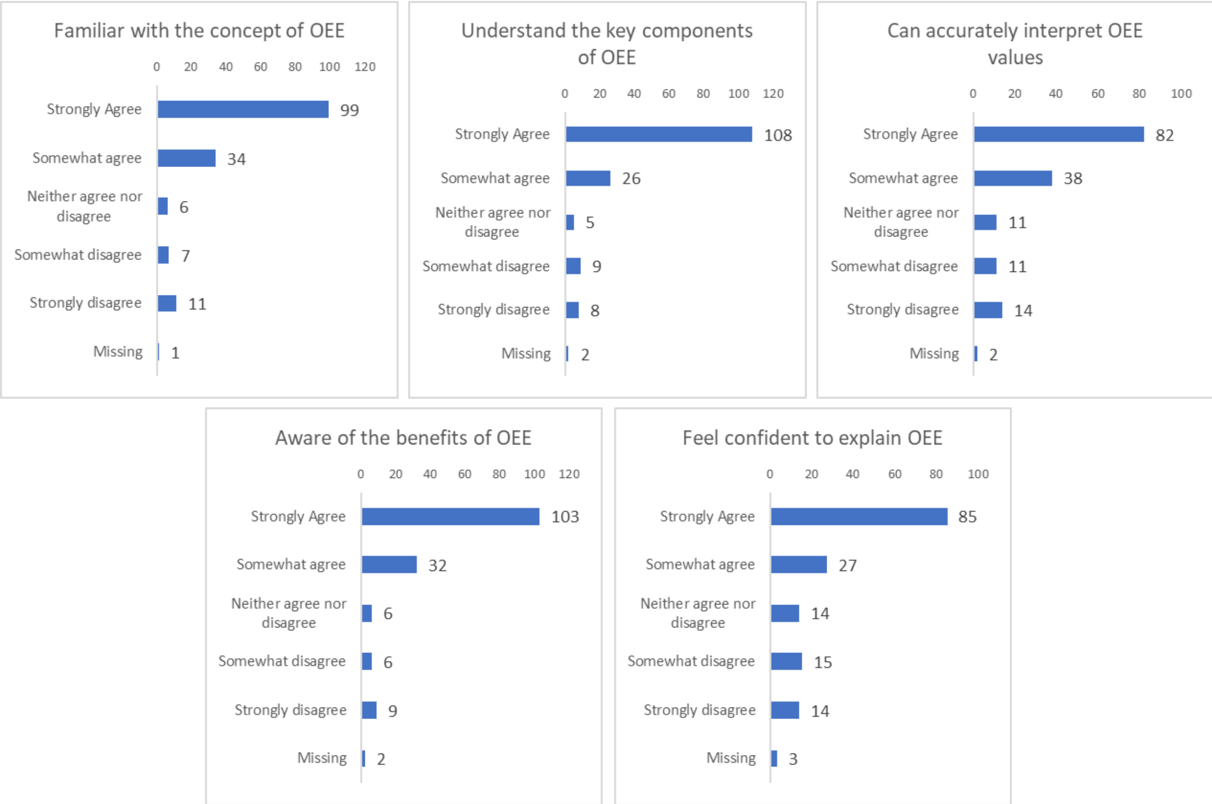
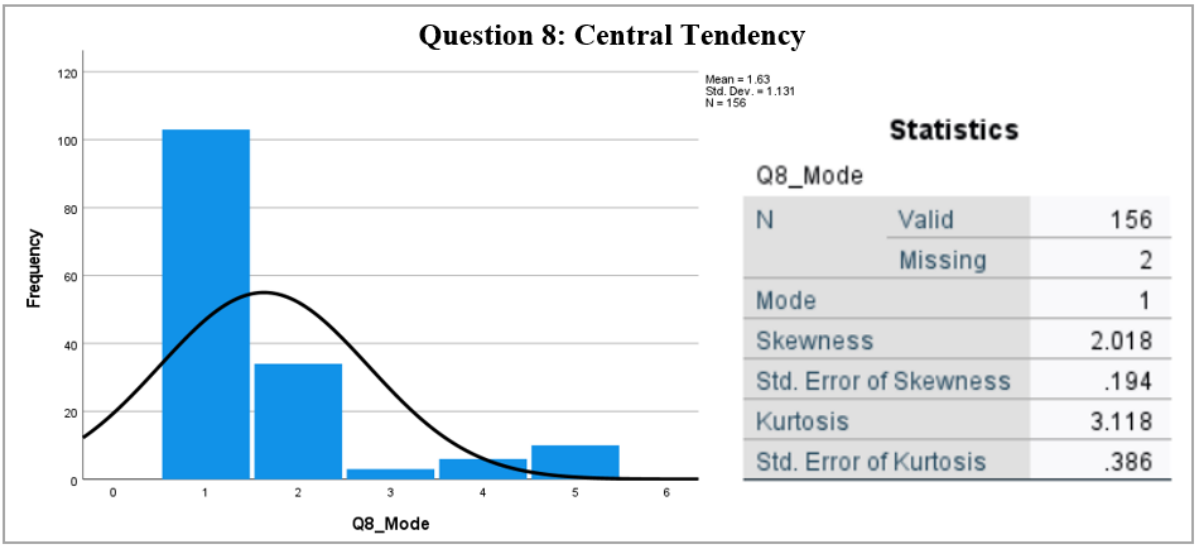


Figure 17: Analysis: Q8



Statistics

Q8_Mode

N	Valid	156
	Missing	2
Mode		1
Skewness		2.018
Std. Error of Skewness		.194
Kurtosis		3.118
Std. Error of Kurtosis		.386

Figure 18: Central Tendency: Q8

The main theme identified:

- Strongly Agree

The five distinct questions were analysed by respondent to find the modal response for the series, used to identify the participants overall contribution of the impact of certain factors on OEE.

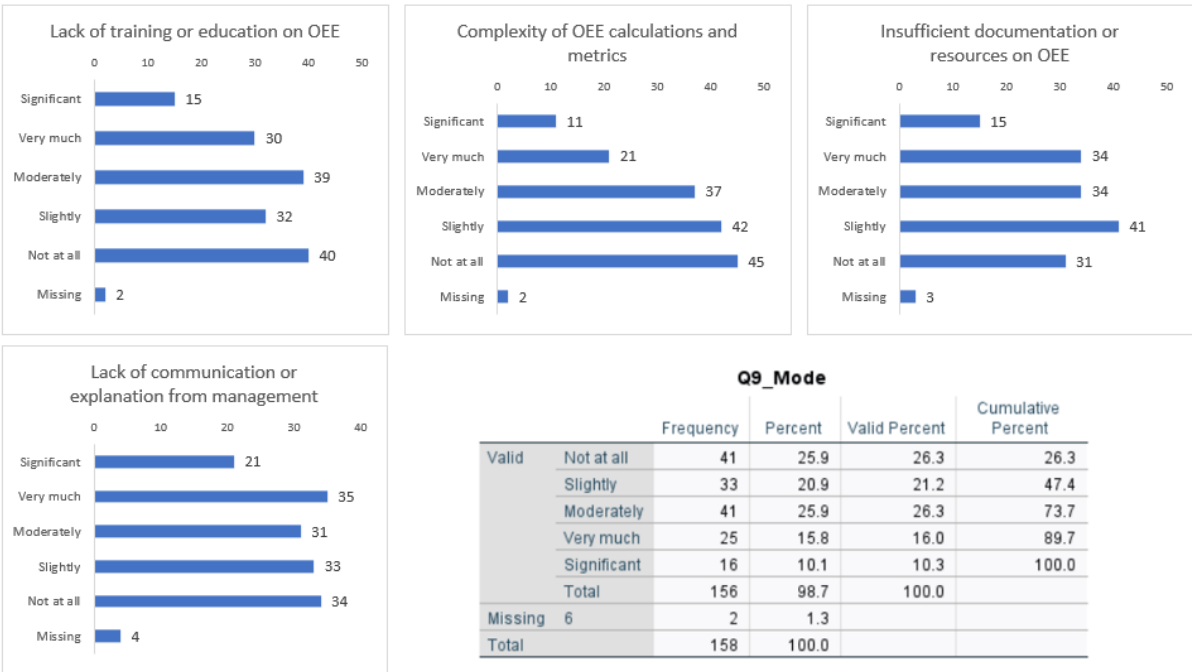
The participants believe that they, themselves have a strong understanding of OEE, the breakdown of OEE and the impact that it has on organizational effectiveness.

The second set of research questions was aimed at understanding what the respondent's view was on what obstacles had the biggest impact on their ability to understand OEE.

Please indicate the extent to which the following factors have affected your understanding of OEE:

- Lack of training or education on OEE
- Complexity of OEE calculations and metrics
- Insufficient documentation or resources on OEE
- Lack of communication or explanation from management

The four distinct questions were analysed by respondent to find the modal response for the series, used to identify the participants overall contribution of the impact of certain factors on OEE.



Q9_Mode

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	41	25.9	26.3	26.3
	Slightly	33	20.9	21.2	47.4
	Moderately	41	25.9	26.3	73.7
	Very much	25	15.8	16.0	89.7
	Significant	16	10.1	10.3	100.0
	Total	156	98.7	100.0	
Missing	6	2	1.3		
Total		158	100.0		

Figure 19: Analysis: Q9

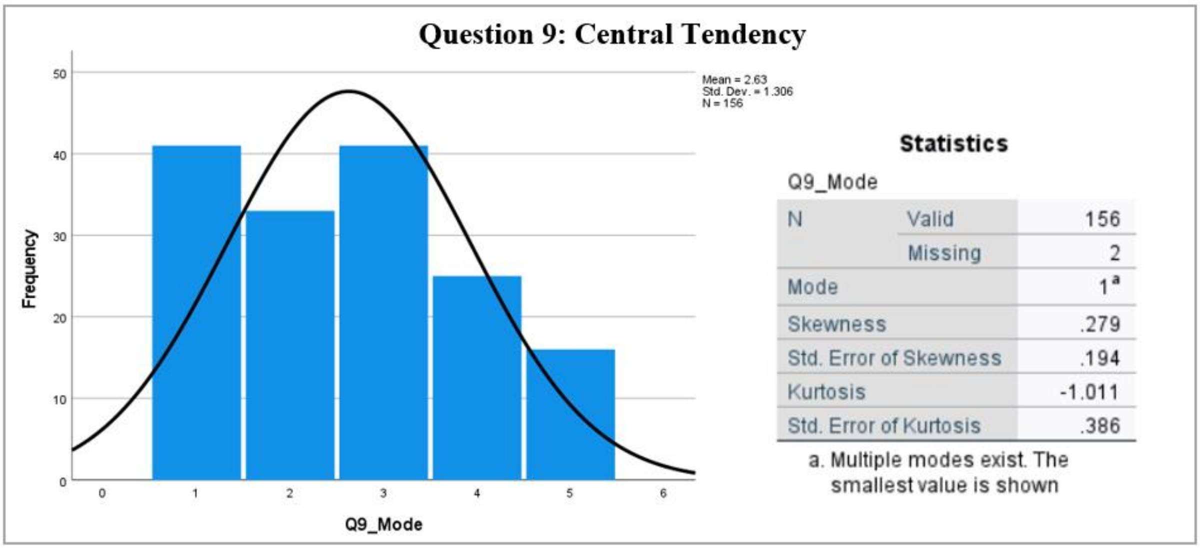


Figure 20: Central Tendency: Q9

Main themes identified:

- Not at all
- Moderately

The respondents identified that overall, the impact of training or education, complexity, insufficient resources, and lack of communication as a small effect on the way that they understand OEE, both with a frequency of 41 responses. A total of 33 participants responded that the categories had a slight impact on the way that they perceive OEE, and the remainder acquiesced that it either had a very high (25 participants) or significant (16 participants) on them.

Research question 10 was an open-ended question, geared toward gaining understanding of the true impact on OEE, that could not be covered by question 9. This question received a very low response rate of 36.7% (n=58).

In your experience are there any other barriers apart from the ones above that affect how you or others understand OEE?

Table 2: Challenges to OEE understanding.

Challenge	Frequency
Implementation, calculations, and data availability	15
Lack of knowledge, commitment, or attention by leadership	8
Differences in definition	8

Lack of understanding of the impact	7
Organizational Culture or mindset	6
Lack of training and awareness	6
Lack of exposure, examples, and differences in interpretation	3
Specific Organisational requirements and transparency	3
Capability to follow process	2

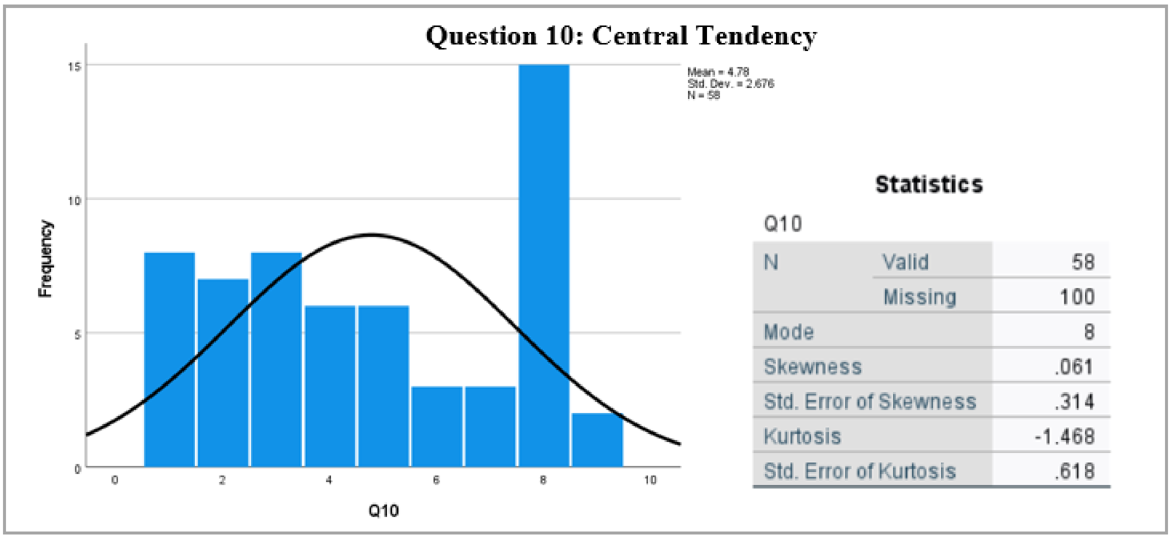


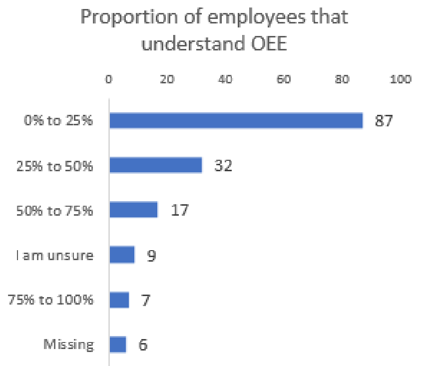
Figure 21: Central Tendency: Q10

Main themes identified:

- Implementation, calculations, and data availability

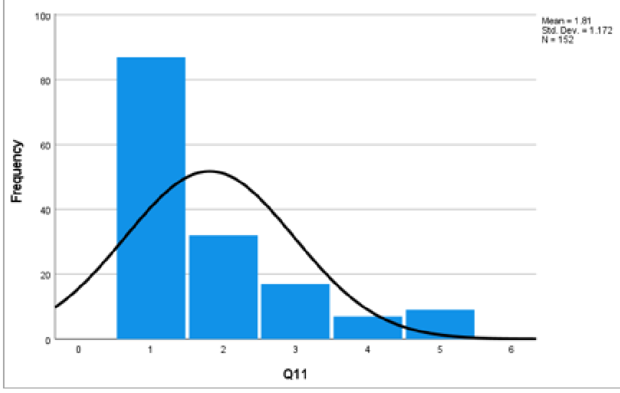
This qualitative question clarified additional barriers to understanding within OEE, with the highest barrier portraying the difficulty in collecting data, followed by a lack of knowledge, commitment, or attention by leadership, and differences in the definition of OEE across the various levels of the organization.

Question 11 is a very important question for the analysis of this research. It examines the view that the participants have on others' understanding of OEE.



Q11

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0% to 25%	87	55.1	57.2	57.2
	25% to 50%	32	20.3	21.1	78.3
	50% to 75%	17	10.8	11.2	89.5
	75% to 100%	7	4.4	4.6	94.1
	I am unsure	9	5.7	5.9	100.0
	Total	152	96.2	100.0	
Missing	6	6	3.8		
Total		158	100.0		



Statistics

Q11

N	Valid	152
	Missing	6
Mode		1
Skewness		1.453
Std. Error of Skewness		.197
Kurtosis		1.195
Std. Error of Kurtosis		.391

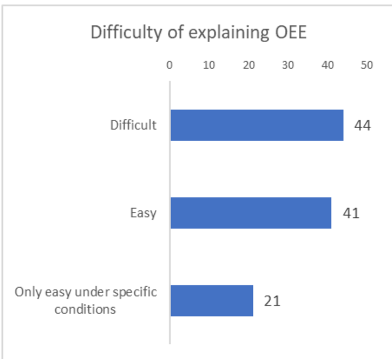
Figure 22: Analysis: Q11

Main theme identified:

- Respondents believed that employees within their organization did not understand the concept of OEE.

The overwhelming majority of respondents believed that less than 25% of the employees understand the concept of OEE, closely followed by respondent's who believe between 25% and 50% of employees understand OEE.

The next set of questions was aimed at building insight into how effectively an organization communicated OEE, and what impact the OEE methodology had on the effectiveness of the training.



Statistics

		Q12	Q13
N	Valid	157	106
	Missing	1	52
Mode		1	1
Skewness		.720	.385
Std. Error of Skewness		.194	.235
Kurtosis		-.345	-1.152
Std. Error of Kurtosis		.385	.465

Figure 23: Analysis of the impact of effective communication on OEE.

Main themes identified:

- Organizations do not communicate OEE effectively.
- OEE was difficult to explain.

The respondents identified that communication about the impact of OEE was not effective at all with 44 agreeing that it was difficult to communicate OEE to other levels of the organization.

4.1.3. OEE Cost application analysis

This section explored the perceived advantages of implementing the Activity-Based Effectiveness methodology within the respondent's organization.

Table 3: Question 20 Thematic breakdown

Rate the extent to which the following statements is applicable to your organization:	**Theme**
Expressing OEE as a cost will improve understanding	Understanding
Expressing OEE as a cost will lead to improved decision making	Decision Making
Expressing OEE as a cost will lead to increased focus on low productivity equipment or areas	Benchmarking
Expressing OEE as a cost will improve cost management and resource allocation within your organization	Benchmarking
Expressing OEE as a cost will lead to better budgeting and financial planning for your organization	Decision Making

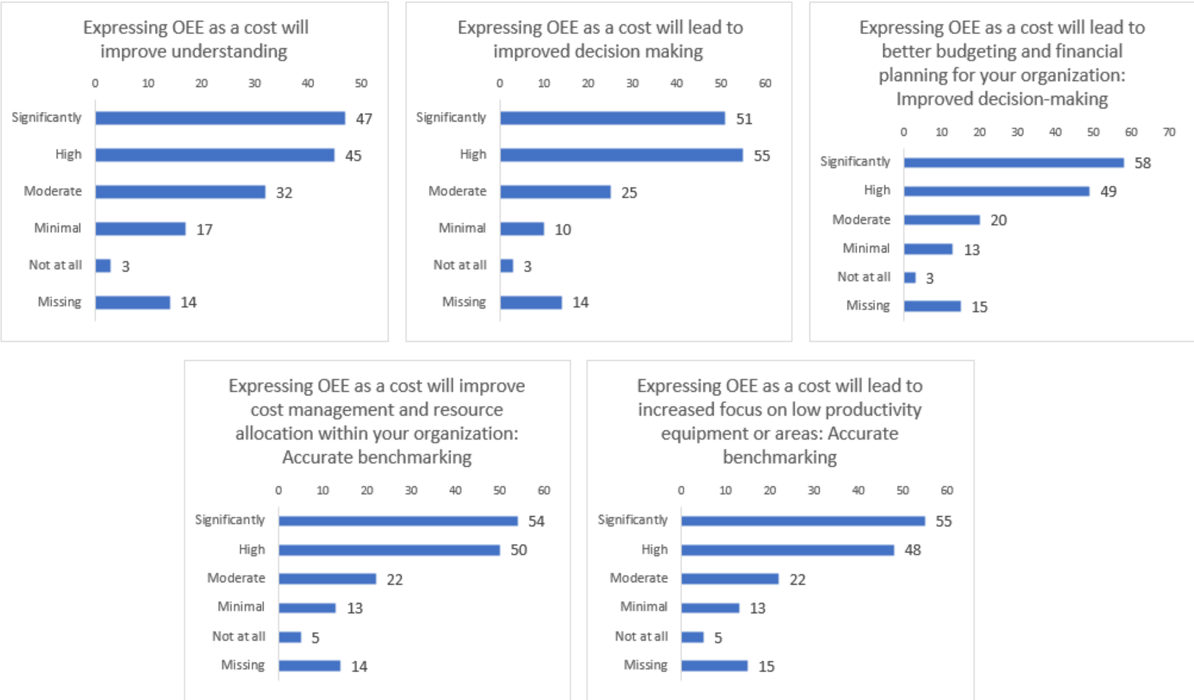


Figure 24: Analysis: Q20

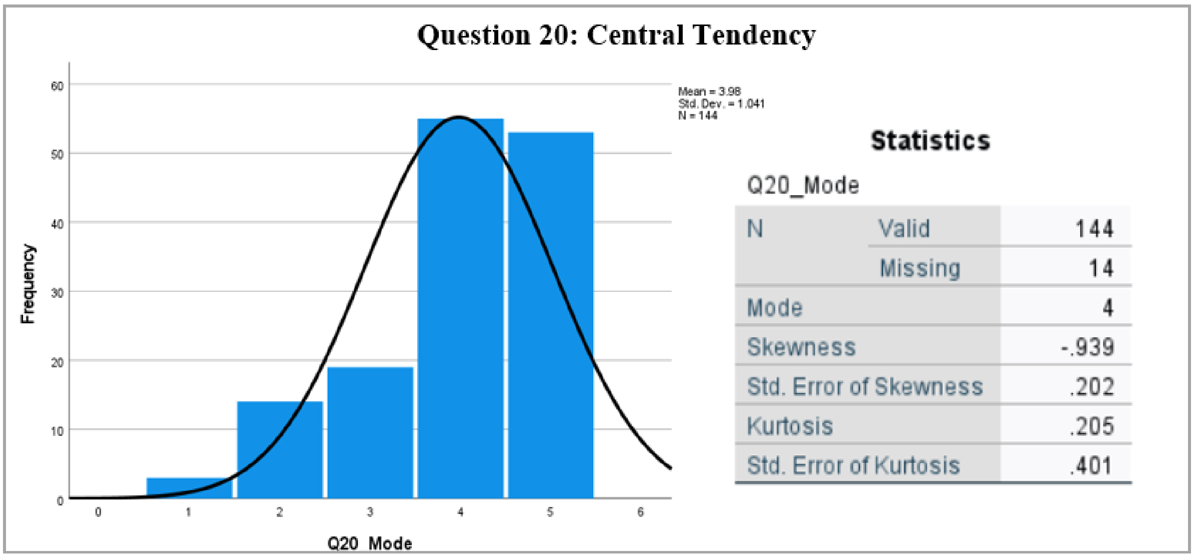


Figure 25: Survey question 20 Central Tendency

Main themes identified:

- High probability for improving.
- Significant probability for improving.

Most participants believed that implementing a cost-centric approach would enhance organizational effectiveness across key areas such as understanding, benchmarking, and decision-making.

4.1.4. Structured Cost Systems Analysis

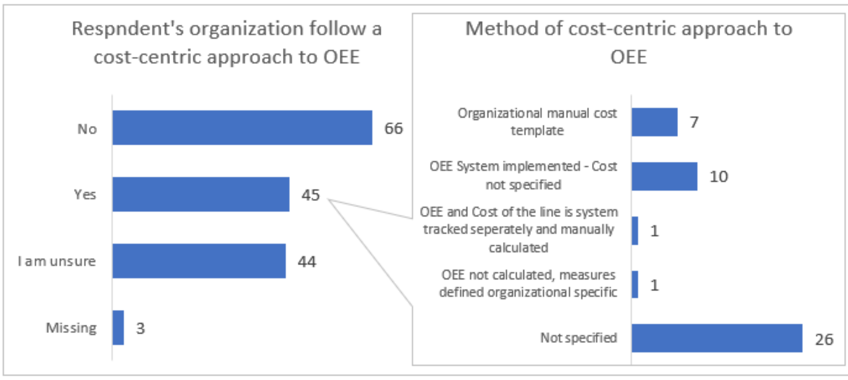
In this segment, we will examine the responses regarding the current approaches utilized in participants' organizations for cost centric OEE, the challenges encountered, the level of cost visibility within their organizations, and the potential for methodology generalization.

This section was analysed with three qualitative questions, which were thematically synthesised as follows:

Table 4: Structured Cost Systems Qualitative Thematic Synthesis

Question 14	Theme
Does your organization follow a structured way of calculating the cost impact of OEE? If yes, please elaborate. - Yes - Text	Organizational manual cost template
	OEE System implemented - Cost not specified
	OEE and Cost of the line is system tracked separately and manually calculated
	OEE not calculated, measures defined organizational specific
Question 18	**Theme**
Has there been challenges or obstacles that your organization has faced in implementing the cost approach in relation to OEE? If yes, please elaborate on those challenges and their impact. - Yes - Text	Lack of commitment / understanding
	Ineffective systems / data
	Lack of proper communication or training
	Lack of resources, not attempted or low priority
	Lack of transparency or buy-in
	Difficulties in calculation steps of OEE
	Inadequate implementation / change management
	Budget constraints
	Numerous factors contributing to complexity
	Lack of integration between systems
Question 19	**Theme**
Would you say that your cost approach to OEE can be replicated in other industries? If yes, please elaborate. - Yes - Text	OEE Calculation can be replicated - Cost not specified
	When implemented through a system
	Can be replicated in similar industries
	Replicable when the correct data is available
	Unsure
	Calculations are not detailed and can be replicated
	When training is available
	Concepts will remain the same, variables will change

Following the thematic synthesis, the collected quantitative and qualitative responses collected were analysed for the central tendency which involved determining the mode and skewness of the data. The consistency, and the stability of the data by determining the Cronbach's alpha.



Statistics

Q14

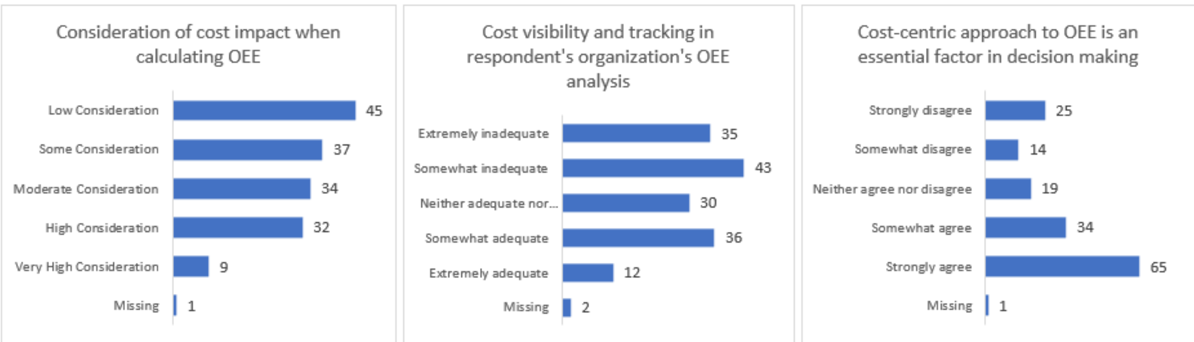
N	Valid	155
	Missing	3
Mode		2
Skewness		.011
Std. Error of Skewness		.195
Kurtosis		-1.260
Std. Error of Kurtosis		.387

Figure 26: Cost-centric organizational approaches to OEE.

Main themes identified:

- Most respondents did not have a cost-centric approach implemented in their organizations.
- Among respondents with a cost-centric approach, the majority use manual calculations or did not specify a specific costing system, instead referring to an OEE system.

The survey results reveal that 42.6% of organizations lack a structured cost-centric approach, and 28.4% of respondents were unsure if such a system was in place. Only 29% of respondents reported that they had a system implemented, but within this group, only one respondent indicated that they had implemented a structured system.



Statistics

		Q15	Q16	Q17
N	Valid	157	157	156
	Missing	1	1	2
Mode		1	5	2
Skewness		.291	-.710	.221
Std. Error of Skewness		.194	.194	.194
Kurtosis		-1.090	-.956	-1.110
Std. Error of Kurtosis		.385	.385	.386

Figure 27: Cost impact and visibility impact on decision making.

Main themes identified:

- Low consideration to the cost impact to OEE.
- Somewhat inadequate cost visibility to the broader organization.
- The respondents strongly agree that a cost-centric approach is an essential factor in decision making.

The analysis revealed several key findings regarding the consideration of cost impact on Overall Equipment Effectiveness (OEE) and its visibility within the organization. 28.6% of the respondents agree that there was a noted low consideration given to the cost impact on OEE within their organization. Additionally, the survey outcome suggested that 27.6% of the respondents agreed that there was only somewhat inadequate visibility of costs within the broader organization. Despite these challenges, 41.4% respondents strongly agree that adopting a cost-centric approach was crucial for informed decision-making processes.

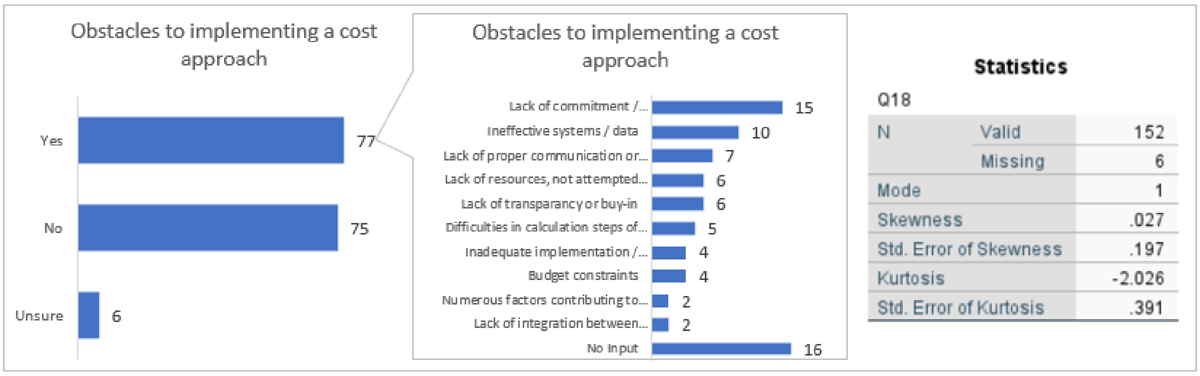
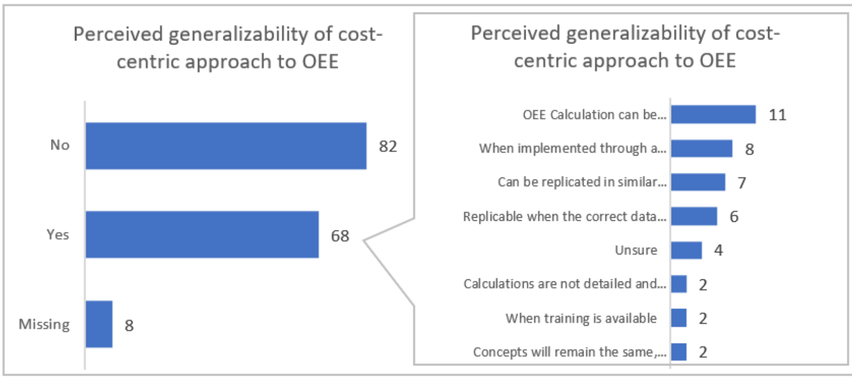


Figure 28: Obstacles to implementing a cost approach to OEE.

Main themes identified:

- The respondents were approximately evenly split on whether there were obstacles while implementing a cost approach to OEE.
- Lack of commitment / understanding was identified as the leading cause for the obstacles experienced.

The respondents' perspectives on obstacles encountered during the implementation of a cost approach to OEE were roughly divided, with 47.5% of respondents that did not have obstacles and 48.7% of respondents that did experience obstacles. Among those who reported facing challenges, the primary cause identified was a lack of commitment or understanding within their organizations, contributing 19.5% of the responses, closely followed by ineffective systems or data available with 13% of the total responses.



Statistics

Q19

N	Valid	150
	Missing	8
Mode		2
Skewness		-.189
Std. Error of Skewness		.198
Kurtosis		-1.991
Std. Error of Kurtosis		.394

Figure 29: Perceived generalizability of the respondent's cost centric OEE approach.

Main themes identified:

- The current cost-centric approaches are not viewed as generalizable.
- Respondents who perceive the approaches as generalizable primarily cite OEE's generalizability, while expressing reservations about the applicability of the cost approach.

The prevailing perception among respondents was that existing cost-centric approaches lack generalizability. While 16.2% respondents acknowledged the generalizability of OEE, they expressed reservations regarding the generalizability of the cost approach. Specifically, they highlighted concerns about its adaptability and effectiveness across different contexts and industries. Additionally, 11.8% of respondents indicated that a cost-centric approach could be generalized, but only if implemented as a structured approach.

4.1.5. Inter-theme correlation

To accurately analyse the data to address the research objectives, research questions and hypothesis (a summary is provided in Annexure K), a chi square test was conducted to verify the relationship between the variables.

The null hypothesis (H_0) is the hypothesis that there is no statistically significant relationship between the two variables (Taylor, 2024). This research used a 5% deviation, anything higher would mean that the H_0 would be true.

Research Question 1: What is the current proportion of employees in the manufacturing sector who understand OEE and its impact on overall organizational effectiveness? Furthermore, how was this understanding influenced by adopting a cost-centric approach to OEE?

The first aspect of the research question was explored through demographic inquiries, while the second aspect was investigated by examining the correlation between respondents' understanding of OEE and their organizations' consideration of the cost approach.

Q11 * Q14 Crosstabulation

Count

		Q14 Yes	No	I am unsure	Total
Q11	0% to 25%	18	45	24	87
	25% to 50%	12	13	7	32
	50% to 75%	9	1	4	14
	75% to 100%	2	3	2	7
	I am unsure	1	1	7	9
Total		42	63	44	149

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	25.983[a]	8	.001
Likelihood Ratio	25.395	8	.001
Linear-by-Linear Association	.468	1	.494
N of Valid Cases	149		

a. 8 cells (53.3%) have expected count less than 5. The minimum expected count is 1.97.

Figure 30: Understanding of OEE and cost-centric approach crosstabulation and chi square.

The chi square showed that the asymptomatic significance is 0.001, thus there is a strong correlation between an implemented cost-centric approach to OEE and understanding OEE.

Q11 * Q12 Crosstabulation

Count

		Q12 Not effective at all	Slightly effective	Moderately effective	Very effective	Extremely effective	Total
Q11	0% to 25%	48	23	14	1	1	87
	25% to 50%	6	10	14	2	0	32
	50% to 75%	1	3	6	6	1	17
	75% to 100%	2	0	3	1	1	7
	I am unsure	7	0	0	0	1	8
Total		64	36	37	10	4	151

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	67.949[a]	16	<.001
Likelihood Ratio	64.982	16	<.001
Linear-by-Linear Association	10.778	1	.001
N of Valid Cases	151		

a. 17 cells (68.0%) have expected count less than 5. The minimum expected count is .19.

Figure 31: Understanding of OEE and management communication crosstabulation and chi square.

The chi square showed an asymptomatic significance of <0.001, accordingly there is a strong correlation between management communication and understanding OEE.

Q11 * Q15 Crosstabulation

Count

		Q15 Low Consideration	Some Consideration	Moderate Consideration	High Consideration	Very High Consideration	Total
Q11	0% to 25%	29	23	19	10	6	87
	25% to 50%	4	9	10	7	2	32
	50% to 75%	1	2	2	10	1	16
	75% to 100%	4	0	1	2	0	7
	I am unsure	5	2	1	1	0	9
Total		43	36	33	30	9	151

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	35.803[a]	16	.003
Likelihood Ratio	34.971	16	.004
Linear-by-Linear Association	.163	1	.686
N of Valid Cases	151		

a. 16 cells (64.0%) have expected count less than 5. The minimum expected count is .42.

Figure 32: Understanding of OEE and the extent of consideration of the cost aspect crosstabulation and chi square.

The chi square showed an asymptomatic significance of 0.003, thus there is a significant correlation between consideration of the cost aspect and understanding OEE.

The inter theme correlations showed that the respondents to the survey believed that implementing a structured approach to the cost-centric application of OEE would be beneficial to the organisations.

4.2. Phase 2: ABE Case Study Analysis

The case company, an international giant in the automotive component supply industry, had been in operation for more than fifty years in South Africa. The manufacturing facility typically follows a batch manufacturing principle, with the product of one process stored in a First-In-First-Out (FIFO) system before the next process.

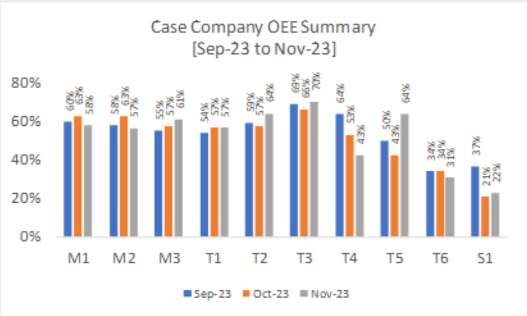
The case company already had an Overall Equipment Effectiveness (OEE) and Activity-Based Costing (ABC) system implemented before the commencement of this research. This research study ran for a three-month period, including 10 different machines in their process.

In order to implement the Activity-Based Effectiveness approach, data of the OEE of the various different types of equipment was collected and analysed as per the OEE time-based methodology. Simultaneously, the ABC data for each of the operations was collected, the ABE calculated and then contrasted to the OEE data.

Data on OEE for the case company was gathered from September 1, 2023, to November 30, 2023, providing the study with a comprehensive three-month dataset. The case company utilized an automated downtime capture system, facilitating efficient data collection. The initial step involved converting the conventional OEE formulation into a time-based formulation. This was accomplished by extracting downtime data from the automatic data capture system and organizing it according to the structure of the OEE time-based methodology. The full OEE detailed analysis can be seen in Annexure J and are summarised as follows.

Table 5: Case company OEE summary.

	23-Sep	23-Oct	23-Nov	Mean	Median	St Dev
M1	60%	63%	58%	60%	60%	2%
M2	58%	63%	57%	59%	58%	3%
M3	55%	57%	61%	58%	57%	2%
T1	54%	57%	57%	56%	57%	1%
T2	59%	57%	64%	60%	59%	3%
T3	69%	66%	70%	68%	69%	2%
T4	64%	53%	43%	53%	53%	9%
T5	50%	43%	64%	52%	50%	9%
T6	34%	34%	31%	33%	34%	1%
S1	37%	21%	22%	26%	22%	7%



Each of the Overall Equipment Effectiveness was broken into the following time based categories: Lunch & Break, Start-up, Planned Maintenance (PM), Size Change, Material Change, Other Planned Downtime (PDT), Exceeded Time of Lunch & Break, Exceeded Time of Start-Up, Exceeded Time of PM, Exceeded Time of Size Change, Exceeded Time of Material Change, Exceeded Time of Other PDT, Undefined, Machine Breakdown, Material

Shortage, Material Quality, Material Handling Equipment (MHE), Man, Technical, Power Failure, Other Unplanned Downtime (UPDT), Rate Loss and Quality Loss.

The Activity-Based Costing system, which comprised of 47 different cost classifications, was consolidated into the categories: Labour, Material, Depreciation, Utilities, Support services and Maintenance Services (The full list can be viewed in Annexure I).

The Overall Equipment Effectiveness (OEE) and Activity-Based Costing data was then combined to form the basis of the Activity-Based Effectiveness data.

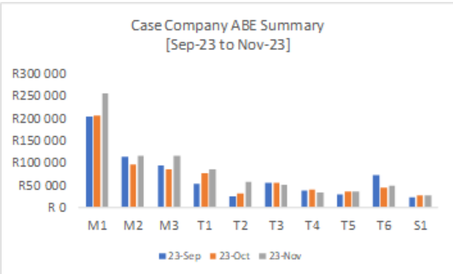
Table 6: Foundation of the ABE Methodology

Reference	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services
Lunch & Break	✓	by mc	✓	✓	✓	
Start-up & 2C	✓	by mc	✓	✓	✓	
Planned Maintenance (PM)	✓	✓	✓	✓	✓	✓
Size Change	✓	✓	✓	✓	✓	by mc
Material Change	✓	✓	✓	✓	✓	
Other PDT	✓		✓	✓	✓	
Exceeded Time of Lunch & Break	✓		✓	✓	✓	
Exceeded Time of Start-Up & 2C	✓		✓	✓	✓	
Exceeded Time of PM	✓		✓	✓	✓	✓
Exceeded Time of Size Change	✓		✓	✓	✓	by mc
Exceeded Time of Material Change	✓		✓	✓	✓	
Exceeded Time of Other PDT	✓		✓	✓	✓	
Undefined	✓		✓	✓	✓	
Machine Breakdown	✓		✓	✓	✓	✓
Process Failure	✓		✓	✓	✓	✓
Material Shortage	✓		✓	✓	✓	
Material Quality	✓	Previous	✓	✓	✓	
MHE	✓		✓	✓	✓	
Man	✓		✓	✓	✓	
Technical	✓	✓	✓	✓	✓	
Power Failure	✓	✓	✓		✓	
Other UPDT	✓		✓	✓	✓	
Rate Loss	✓		✓	✓	✓	✓
Quality Loss	✓	✓	✓	✓	✓	

The information was consolidated to form the ABE information for the 10 case machines analysed (A detailed breakdown of the ABE calculations can be found in Annexure J)

Table 7: Case company ABE.

	23-Sep	23-Oct	23-Nov	Mean	Median	St Dev
M1	R204 162	R206 057	R255 943	R220 818	R206 057	R23 976
M2	R114 432	R96 658	R115 565	R108 527	R114 432	R8 658
M3	R94 195	R85 271	R115 935	R97 652	R94 195	R12 878
T1	R53 429	R75 607	R84 337	R69 842	R75 607	R13 010
T2	R23 355	R31 688	R55 990	R34 604	R31 688	R13 845
T3	R54 501	R53 907	R49 705	R52 660	R53 907	R2 134
T4	R36 532	R39 932	R34 106	R36 780	R36 532	R2 390
T5	R29 745	R35 125	R35 727	R33 420	R35 125	R2 690
T6	R72 896	R43 369	R47 472	R53 142	R47 472	R13 060
S1	R22 049	R27 008	R26 673	R25 137	R26 673	R2 263



The data indicated a significant disparity between the OEE and ABE values for the case machines. Existing literature suggested that understanding OEE was challenging since it was typically expressed as a percentage (Lelis, 2022). By comparing the mean values of the two methods over the three-month period, we delved into the comprehension of percentage-based values.

Table 8: Mean comparison between OEE and ABE

	OEE Mean	ABE Mean
M1	60.3%	R220 818
M2	59.3%	R108 527
M3	57.6%	R97 652
T1	56.0%	R69 842
T2	59.9%	R34 604
T3	68.3%	R52 660
T4	52.6%	R36 780
T5	51.6%	R33 420
T6	33.0%	R53 142
S1	25.8%	R25 137

Table 9: Ranking based on decision making between OEE and ABE

	OEE	ABE
Ranking*	**Smallest to Largest**	**Largest to Smallest**
M1	9	1
M2	7	2
M3	6	3
T1	5	4
T2	8	8
T3	10	6
T4	4	7
T5	3	9
T6	2	5
S1	1	10

**Ranking chosen in order of decision priority*

The comparison between the two approaches was made based on their impact on decision-making within the organization. It was observed that when relying solely on OEE data, the equipment prioritized for improvement would be categorized as S1, despite contributing the least in terms of monetary value. Conversely, if decisions were based on the ABE approach, the focus would shift to machine M1. These findings show that if an organization used the structured ABE framework, the impact of the effectiveness improvements will be greater than if the organization were to only improve effectiveness based on the OEE approach.

CHAPTER FIVE
DISCUSSION AND CONCLUSION

5.0. Introduction

The aim of the discussion and conclusion chapter is to carefully analyse the discussed findings outlined in Chapter 4, with the aim of interpreting the results to effectively address the research questions and validate or refute the research hypotheses, thereby fulfilling the research objectives. The study was designed to thematically examine the correlation between the comprehension of Overall Equipment Effectiveness (OEE) and the adoption of a cost-centric approach to OEE, specifically the Activity-Based Effectiveness (ABE) approach. The findings will encompass an in-depth analysis of the current proportion of professionals who understand OEE and its implications for organizational effectiveness, as well as the extent to which the ABE approach facilitates more precise benchmarking and decision-making within organizations.

5.1. Discussion: Understanding of OEE

Research Question 1: What is the current proportion of employees in the manufacturing sector who understand OEE and its impact on overall organizational effectiveness? Furthermore, how is this understanding influenced by adopting a cost-centric approach to OEE?

The systems analysis of Overall Equipment Effectiveness (OEE) indicates a common oversight in its managerial aspect, resulting in a lack of awareness and thereby impeding the optimal utilization of OEE (Bengtsson, Andersson, & Ekström, 2022). This observation is corroborated by the variability in OEE measurement approaches, which can differ based on the specific process or company (Kennedy, 2017).

The first research question was explored during the thematic investigation conducted in Phase one of the data analysis, which encompassed the collection and examination of survey responses. The findings denoted that most respondents expressed confidence in their understanding of the OEE concept. However, they also noted a disparity, recognizing that only a minority of employees within their organizations possess a clear grasp of OEE. This discrepancy in understanding poses challenges for organizations in pinpointing the root causes of effectiveness issues, thereby impeding the effectiveness of improvement efforts, and limiting opportunities for cost savings and capacity enhancements. The findings also indicated that OEE is inadequately communicated within organizations, exacerbating the issue. The inter-item analysis revealed that the organizations that had a structured costing approach implemented, had a much higher belief that the employees in the organization understand the concept of OEE, thus confirming the hypothesis that a cost-centric approach to OEE will improve the understanding within organizations.

5.2. Discussion: Cost application of OEE

Research question 2; Can a structured, replicable cost-centric approach to OEE be developed based on the key strengths and findings in current methodologies, to improve benchmarking of equipment?

The literature review highlighted the point that significant financial benefits can be achieved if a cost centric approach to OEE is implemented, due to the realization of practical benchmarking between equipment (Liew, Prakash, & Ong, 2023). The cost application analysis during Phase 1 of the research design, confirmed the sentiment from Liew, Prakash, & Ong (2023), through revealing that they believe that implementing such an approach will improve benchmarking between equipment.

This finding is corroborated by the implementation of the Activity-Based Effectiveness (ABE) approach at the case company, which has led to a significantly enhanced comprehension of each machine's impact on the overall process. The integration of the OEE approach with a structured costing system, such as Activity-Based Costing (ABC), has facilitated the straightforward allocation of costs to each process within the OEE methodology. Consequently, equipment benchmarking has become considerably more manageable compared to the traditional OEE methodology, which relies on percentage-based formats.

5.3. Discussion: Structured Cost Systems

Research question 3: How does the performance optimization differ when utilizing the OEE and ABE approaches within an organization, and does it support effective decision making?

During the implementation of the ABE approach at the case company it was found that there are significant ranking variations between the results of the OEE implementation and the ABE implementation.

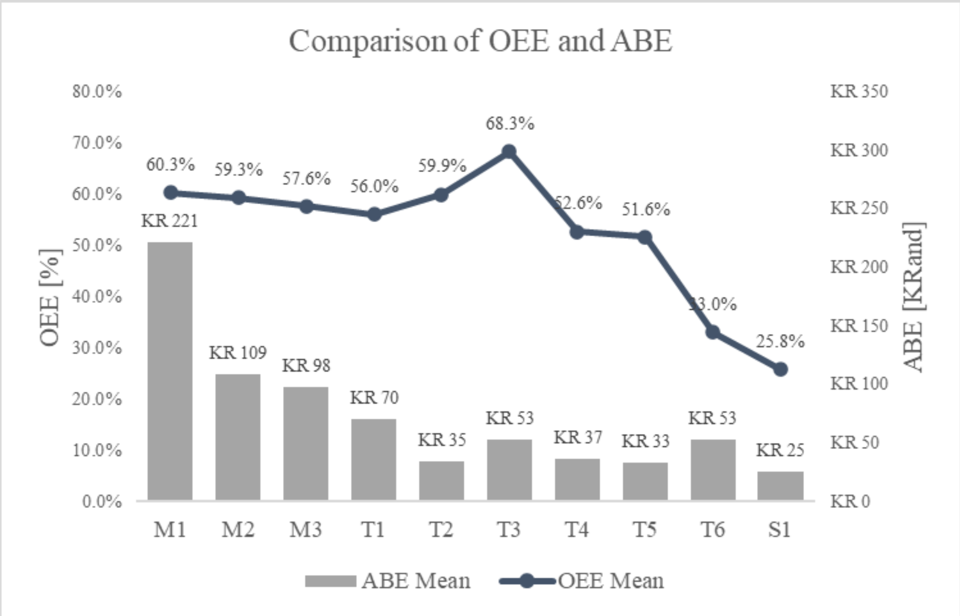


Figure 33; Comparison between OEE and ABE

During the ranking analysis, it became evident that the Activity-Based Effectiveness (ABE) approach yielded markedly different decisions regarding organizational effectiveness compared to the traditional OEE approach. By employing the ABE approach, improvement efforts were projected to generate significantly greater cost benefits than those achieved through the OEE approach. This outcome validated the hypothesis positing that the implementation of Activity-Based Effectiveness (ABE) would produce distinct outcomes from traditional OEE, thereby enhancing effective decision-making.

The significant disparities between the two approaches primarily arose from differences in costing methodologies applied to products and processes. Certain processes may incur material losses during equipment startup, while others may not experience such losses. However, if these losses are merely categorized as time losses, both scenarios would be considered equivalent, potentially leading to ineffective decision-making regarding improvement focus.

5.4. Conclusion

In conclusion, this research had aimed to develop, validate, and implement the Activity-Based Effectiveness (ABE) methodology as a structured and replicable approach for assessing Overall Equipment Effectiveness (OEE) in the manufacturing industry, through integrating principles from the Overall Equipment Effectiveness (OEE) and Activity-Based Costing (ABC) methodologies. The outcome of the convergent data analysis of the qualitative and quantitative questions showed a strong correlation between the successful improvement of manufacturing production operations and the ability of the employees to understand the cost impact of the effectiveness of the equipment. The results further showed through the implementation of the Activity-Based Effectiveness (ABE) approach, there was a significant difference to how the processes are assessed for efficiency improvement, thus showing accurate benchmarking and decision-making possibility. The results indicated that the ABE approach offered a systematic framework for evaluating organizational performance in terms of cost impact. Further findings showed that ABE addressed the lack of cost structure, while simultaneously increasing the understanding, ability to benchmark and enhancing decision making within organizations.

This research adds to the existing body of knowledge by combining the OEE approach with a widely recognized and frequently used costing methodology. This integration enhanced the practical utility of the approach, making it easier for organizations to adopt and integrate into their existing systems.

5.5. Policy Recommendations

The study demonstrated that an enhanced understanding of Overall Equipment Effectiveness (OEE) correlates with improved overall organizational effectiveness. This finding was further supported by the implementation of the Activity-Based Effectiveness (ABE) methodology, which indicated that cost analysis of OEE led to enhanced decision-making and equipment benchmarking. This was translated into policy recommendations for both the government and practitioners.

5.5.1. Policy recommendation for the government:

Based on the insights garnered from this study, it was advised that government entities overseeing manufacturing policy and regulation prioritize the adoption of a comprehensive strategy for assessing equipment effectiveness. This initiative aimed to foster reductions in product costs and enhance capacity throughput, ultimately expanding employment opportunities and consumer support. Government initiatives should support training programs and knowledge dissemination efforts aimed at enhancing understanding of Overall Equipment Effectiveness (OEE) among industry stakeholders.

5.5.2. Recommendation for practitioners:

This study suggested that manufacturing operations should be mindful that the machine with the lowest OEE may not necessarily be the cause for the biggest organizational loss. While it might have been tempting to focus solely on improving the OEE of underperforming machines, this study highlighted the importance of considering broader factors that contribute to the broader understanding organizational success within the parts of a system. Practitioners should have prioritized efforts to enhance their understanding of OEE and explore the potential benefits of implementing cost analysis methodologies like the Activity-Based Effectiveness (ABE) approach. By leveraging these tools, organizations could make more informed decisions about resource allocation, process improvement, and capacity optimization, ultimately leading to greater competitiveness and sustainability in today's challenging business landscape.

5.6. Suggestion for future studies

Firstly, the study faced a limitation concerning the distribution of survey respondents as a greater number of respondents held formal qualifications and occupied higher positions within the organization. This research proposes that future research should include the initial adoption of the Activity-Based Costing (ABC) and Overall Equipment Effectiveness (OEE) approaches before the application of the Activity-Based Effectiveness (ABE) approach. This will improve the body of knowledge around the full implementation scope of the ABE approach.

Secondly, a limitation of this research that has not been included in the scope of this research proposal is the implementations of the OEE and ABC systems to an organization prior to the implementation of the ABE approach. The case company had implemented both systems successfully, thus the full implementation scope remains unknown. The research proposed that that future research should attempt to increase the distribution of the survey to incorporate a vaster number of employees across different organizational levels to increase the knowledge of how OEE impacts to lower levels of any organization.

Lastly, the scope of this research was structured to only address all manufacturing related cost structures, including production and non-production related expenses. The research proposed that that future research should attempt to increase the scope of the research to potentially include non-manufacturing related costs such as logistics and transportation of finished goods, sales etc.

REFERENCES

Ahmad, N., Hossen, J., & Ali, S. M. (2018). Improvement of overall equipment efficiency of ring frame Improvement of overall equipment efficiency of ring frame. *The International Journal of Advanced Manufacturing Technology, 94*(3), 239–256. doi:10.1007/s00170-017-0783-2

Akyol, D. E., Tuncel, G., & Bayhan, G. M. (2005). A comparative analysis of activity-based costing and traditional costing. *World Academy of Science, Engineering and Technology, 3*, 44-47. Retrieved from https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=e08da485068f4ec1fd1bb9b489c93309cfdcbb5c

Alharahsheh, H. H., & Pius, A. (2020). A Review of key paradigms: positivism VS interpretivism. *Global Academic Journal of Humanities and Social Sciences, 2*(3), 39-43. doi:10.36348/gajhss.2020.v02i03.001

Almeida, A., & Cunha, J. (2017). The implementation of an Activity-Based Costing (ABC) system in a manufacturing company. *Manufacturing Engineering Society International Conference. 13*, pp. 932–939. Vigo (Pontevedra), Spain: Procedia Manufacturing. doi:doi.org/10.1016/j.promfg.2017.09.162

Al-Najjar, B. (1997). Condition-Based Maintenance: Selection and Improvement of a Cost-Effective Vibration-Based Maintenance Policy for Rolling element Bearings. *[Doctoral Thesis (compilation), Production Management]. Department of Industrial Engineering, Lund University.*

Ambe, C. M., Evangelou, O., Govender, B., Koortzen, P. J., & Ziemerink, J. E. (2008). *Cost and Management Accounting* (Second ed.). (M. van Rensburg, Ed.) Hatfield, Pretoria: Van Schaik Publishers.

Ardiansyah, G. B., Tjahjadi, B., & Soewarno, N. (2017). Measuring customer profitability through time-driven activitybased costing: a case study at hotel x Jogjakarta. *SHS Web of Conferences. 34*, pp. 1-6. Kuching, Sarawak, Malaysia: EDP Sciences. doi:10.1051/shsconf/20173408004

Baily, M. N., Hulten, C., Campbell, D., Bresnahan, T., & Caves, R. E. (1992). Productivity Dynamics in Manufacturing Plants. *Brookings Papers on Economic Activity. Microeconomics*, 187-267. Retrieved from https://www.jstor.org/stable/2534764

Balakrishnan, P. (2004). Measuring Productivity in Manufacturing Sector. *Economic and Political Weekly, 39*(14), 1465-1471. Retrieved from https://www.jstor.org/stable/4414861

Bengtsson, M., Andersson, L.-G., & Ekström, P. (2022). Measuring preconceived beliefs on the results of overall equipment effectiveness – A case study in the automotive manufacturing industry. *Journal of Quality in Maintenance Engineering, 28*(2), 391-410. doi:10.1108/JQME-03-2020-0016

Binti Aminuddin, N. A., Garza-Reyes, J. A., Kumar, V., Antony, J., & Rocha-Lona, L. (2015). An analysis of managerial factors affecting the implementation and use of overall equipment effectiveness. *International Journal of Production Research, 60*(5), 512-528. doi:10.1080/00207543.2015.1055849

Braglia, M., Frosolini, M., & Zammori, F. (2009). Overall equipment effectiveness of a manufacturing line (OEEML): An integrated approach to assess systems performance. *Journal of Manufacturing Technology Management, 29*(1), 8-29. doi:10.1108/17410380910925389

Budd, C. S. (2010). Traditional Measures in Finance and Accounting, Problems, Literature Review, and TOC Measures. In J. F. Cox III, & J. G. Schleier Jr (Eds.), *Theory of Constraints Handbook* (First ed.). McGraw-Hill.

Cagwin, D., & Bouwman, M. J. (2002). The association between activity-based costing and improvement in financial performance. *Management Accounting Research, 13*, 1–39. doi:10.1006/mare.2001.0175

Cawdery, J. (2023, January 31). *Consumer behaviour in a cost of living crisis*. Retrieved from Curated: https://curated-digital.com/insights/consumer-behaviour-in-a-cost-of-living-crisis

Chang, A.-Y. (2007). On the relationship between complexity theory and manufacturing system competitive advantages. *International Journal of Industrial Engineering, 14*(3), 229-238. Retrieved from https://www.researchgate.net/publication/296795002

Chapman, C. S., Kern, A., Laguecir, A., & Quentin, W. (2016). Management accounting and effciency in health services: the foundational role of cost analysis. In J. Cylus, I. Papanicolas, & P. C. Smith (Eds.), *Health system efficiency: How to make measurement matter for policy and management* (pp. 75-98). World Health . Retrieved from http://www.euro.who.int/en/aboutus/partners/observatory/publications/studies/health-system-efficiencyhow-to-make-measurement-matter-for-policy-and-management-2016

Cheah, C. K., Prakash, J., & Ong, K. S. (2020). An integrated OEE framework for structured productivity improvement in a semiconductor manufacturing facility. *International Journal of Productivity and Performance Management*, *69*(5), 1081-1105. doi:10.1108/IJPPM-04-2019-0176

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (3rd ed.). Los Angeles: Sage Publications. Retrieved from https://www.ucg.ac.me/skladiste/blog_609332/objava_105202/fajlovi/Creswell.pdf

Creswell, J. W., & Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (5th ed.). Los Angeles: Sage Publications. Retrieved from https://spada.uns.ac.id/pluginfile.php/510378/mod_resource/content/1/creswell.pdf

Cromwell, J. (2021, December 17). *What Are the Two Stages of Allocation in Activity-Based Costing?* Retrieved April 6, 2023, from https://smallbusiness.chron.com/example-traditional-costing-80441.html

Dawadi, S., Shrestha, S., & Giri, R. A. (2021). Mixed-Methods Research: A Discussion on its. *Journal of Practical Studies in Education, 2*(2), pp. 25–36. doi:https://doi.org/10.46809/jpse.v2i2.20

Del Carmen Ng Corrales, L., Lambán, M. P., Korner, M. E., & Royo, J. (2020). Overall Equipment Effectiveness: Systematic Literature Review and Overview of Different Approaches. *Journal of Applied Sciences, 10*. doi:10.3390/app10186469

Dewi, S., Alhilman, J., & Atmaji, F. T. (2020). Evaluation of Effectiveness and Cost of Machine Losses using Overall Equipment Effectiveness (OEE) and Overall Equipment Cost Loss (OECL) Methods, a case study on Toshiba CNC Machine. *IOP Conf. Series: Materials Science and Engineering. 847*, pp. 1-9. Malang - East Java, Indonesia: IOP Publishing Ltd. doi:10.1088/1757-899X/847/1/012020

Esmaeel, R. I., Zakuan, N., Jamal, N. M., & Taherdoost, H. (2018). Understanding of business performance from the perspective of manufacturing strategies: fit manufacturing and overall equipment effectiveness. *11th International Conference Interdisciplinarity in Engineering. 22*, pp. 998–1006. Tirgu-Mures, Romania: Procedia Manufacturing. doi:doi.org/10.1016/j.promfg.2018.03.142

Garza-Reyes, J. A. (2015). From measuring overall equipment effectiveness (OEE) to overall resource effectiveness (ORE). *Journal of Quality in Maintenance Engineering, 21*(4), 506-527. doi:10.1108/JQME-03-2014-0014

Geiszler, M., Baker, K., & Lippitt, J. (2017). Variable Activity-Based Costing and Decision Making. *Journal of Corporate Accounting & Finance, 28*(5), 1-75. doi:https://doi.org/10.1002/jcaf.22277

Georgopoulos, B. S., & Tannenbaum, A. S. (1957, October). A Study of Organizational Effectiveness. *American Sociological Review, 22*(5), 534-540. doi:https://doi.org/10.2307/2089477

Gibbons, P. M., & Burgess, S. (2010). Introducing OEE as a measure of lean Six Sigma capability. *International Journal of Lean Six Sigma, 1*(2), 134-156. doi:10.1108/20401461011049511

Gosselin, M. (2007). A Review of Activity-Based Costing: Technique, Implementation, and Consequences. In *Handbook of Management Accounting Research* (2 ed., pp. 641 - 671). doi:10.1016/S1751-3243(06)02008-6

Hansen, D. R., Mowen, M. M., & Heitger, D. L. (2021). Activity Based Costing. In *Cost Management* (pp. 144-215). United States: Cengage Learning.

Hussain, N., ul Haque, A., & Baloch, A. (2019). Management Theories: The Contribution of Contemporary Management Theorists in Tackling Contemporary Management Challenges. *Journal of Yaşar University, 14*, 156-169. doi:10.19168/jyasar.635061

Jha, N., Ubale, A. W., & Jani, N. N. (2015). *Introduction to Management Accounting.* Mumbai: Himalaya Publidhing House.

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007, April). Toward a Definition of Mixed Methods Research. *Journal of Mixed Methods Research, 1*(2), 112-133. doi:10.1177/1558689806298224

Jonsson, P., & Lesshammar, M. (1999). Evaluation and improvement of manufacturing performance measurement systems – the role of OEE. *International Journal of Operations & Production Management,*, *19*(1), 55-78. doi:10.1108/01443579910244223

Kannan, A. (2020, December 1). *Complete Guide to Calculating & Improving Overall Equipment Effectiveness (OEE)*. Retrieved April 2023, 29, from https://www.hakunamatatatech.com/our-resources/blog/complete-guide-to-calculating-improving-overall-equipment-effectiveness-oee/

Kaplan, R. S., & Anderson, S. R. (2004). Time-Driven Activity-Based Costing. *Harvard Business Review*. Retrieved from https://hbr.org/2004/11/time-driven-activity-based-costing

Kaplan, R. S., & Cooper, R. (1998). *Using integrated cost systems to drive profitability and performance.* Boston, Massachusetts: Harvard Business School Press. Retrieved from https://www.hbs.edu/faculty/Pages/item.aspx?num=238

Kass, R. A., & Tinsley, H. E. (1979). Factor Analysis. *Journal of Leisure Research, 11*(2), 120-138. doi:10.1080/00222216.1979.11969385

Kenessey, Z. (1987, December). The Primary, Secondary, Tertiary And Quaternary Sectors Of The Economy. *Review of Income and Wealth, 33*(4), 347-442. doi:https://doi.org/10.1111/j.1475-4991.1987.tb00680.x

Kennedy, R. K. (2017). *Understanding, Measuring, and Improving Overall Equipment Effectiveness.* Boca Raton, FL: CRC Press.

Kenton, W. (2023, March 7). *Activity-Based Costing (ABC): Method and Advantages Defined with Examples*. Retrieved April 7, 2023, from https://www.investopedia.com/terms/a/abc.asp

Koch, A. (2022, May 31). *What is the history of OEE and TPM?* Retrieved March 2023, 3, from https://oee.academy/oee-academy/history-of-oee-and-tpm/

Koss, E., & Lewis, D. A. (1993). Productivity or efficiency— Measuring what we really want. *National Productivity Review, 12*(2), 133-295. doi:https://doi.org/10.1002/npr.4040120212

LaScola Needy, K., Nachtmann, H., Roztocki, N., Colosimo Warner, R., & Bidanda, B. (2003). Implementing Activity-Based Costing Systems in Small Manufacturing Firms: A Field Study. *Engineering Management Journal, 15*(1), 3-10. Retrieved from https://www.tandfonline.com/doi/epdf/10.1080/10429247.2003.11415190?needAccess=true&role=button

Lelis, J. (2022, November 29). *OEE as a Financial KPI and Its Use in Product Costing*. Retrieved February 17, 2023, from https://evocon.com/articles/oee-as-a-financial-kpi-and-its-use-in-product-costing/

Levinson, M. (2017). *What Is Manufacturing? Why Does the Definition Matter?* Congressional Research Service. Retrieved March 2023, from https://ecommons.cornell.edu/bitstream/handle/1813/77707/CRS_What_is_manufacturing.pdf?sequence=1&isAllowed=y

Liew, C. F., Prakash, J., & Ong, K. S. (2023). Equipment cost efficiency: A comprehensive metric for evaluating operational and financial performance in manufacturing. *Manufacturing Letters, 39*, 16-19.

Lu, T.-Y., Wang, S.-L., Wu, M.-F., & Cheng, F.-T. (2017). Competitive Price Strategy with Activity-Based Costing – Case Study of Bicycle Part Company. *The 50th CIRP Conference on Manufacturing Systems. 63*, pp. 14-20. Taiwan: Procedia CIRP. doi:10.1016/j.procir.2017.03.102

Luolila, E. (2021). *Exploring the dynamics and financial impacts of overall equipment effectiveness in manufacturing department in automotive.* Tampere University. Retrieved from https://trepo.tuni.fi/bitstream/handle/10024/124987/LuolilaEemeli.pdf?sequence=2&isAllowed=y

Mahmoud, I. A., FahmyAly, M., Mohib, A., & Afefy, I. H. (2019). Integration of Benchmarking with Overall Equipment Cost Loss for Industrial Process Improvement. *Jordan Journal of Mechanical and Industrial Engineering, 13*(1), 49 - 59. Retrieved from http://jjmie.hu.edu.jo/vol13-1/jjmie_30_19-01.pdf

McCarthy, I. P. (2000). Complex systems theory: implications and promises for manufacturing organizations. *n International Journal of Manufacturing Technology and Management, 2*, 1–7. doi:10.1504/IJMTM.2000.001365

McCluskey, A., & Lalkhen, A. G. (2007). Statistics II: Central tendency and spread of data. *Continuing Education in Anaesthesia Critical Care & Pain, 7*(4), 127–130. doi:doi.org/10.1093/bjaceaccp/mkm020

Mertens, D. M. (2012). What Comes First? The Paradigm or the Approach? *Journal of Mixed Methods Research, 6*(4), 255–257. doi:10.1177/1558689812461574

Mjimer, I., Aoula, E.-S., & Achouyab , E. (2022). Monitoring of overall equipment effectiveness by multivariate statistical process control. *International Journal of Lean Six Sigma, 13*(4), 847-862. doi:10.1108/IJLSS-12-2020-0218

Nachiappan, R. M., & Anantharaman, N. (2006). Evaluation of overall line effectiveness (OLE) in a continuous product line manufacturing system. *Journal of Manufacturing Technology Management, 17*(7), 987-1008.

Nakajima, S. (1988). *Introduction to TPM.* Portland, Oregon: Productivity Press.

Nurprihatin , F., Angely, M., & Tannady, H. (2019). Total Productive Maintenance Policy to Increase Effectivenessand Maintenance Performance Using Overall Equipment Effectiveness. *Journal of Applied Research on Industrial Engineering, 6*(3), 184–199. doi:10.22105/jarie.2019.199037.1104

Ochara, N. M. (2023). Module 1: Introduction: Applied Research Project and Critical Enquiry Skills. University of Witwatersrand, Johannesburg, South Africa.

Ochara, N. M. (2023). Module 3: Critical Review of Literature. University of Witwatersrand, Johannesburg, South Africa.

Ochara, N. M. (2023). Module 6: Elements of Research Methodology. University of Witwatersrand, Johannesburg, South Africa.

Oechsner, R., Pfeffer, M., Pfitzner, L., Binder, H., Müller, E., & Vonderstrass, T. (2002). From overall equipment efficiency (OEE) to overall Fab effectiveness (OFE). *Materials Science in Semiconductor Processing, 5*(4-5), 333-339.

Paradis, E., O’Brien, B., Nimmon, L., Bandiera, G., & Martimianakis, M. A. (2016). Design: Selection of Data Collection Methods. *Journal of Graduate Medical Education*, 263-264. Retrieved from http://meridian.allenpress.com/jgme/article-pdf/8/2/263/2220811/jgme-d-16-00098_1.pdf

Perčević, H., & Hladika, M. (2016). Movement From Traditional to Modern Cost Accounting Methods in Manufacturing Companies. *Muhasebe Ve Finans Tarihi Araştırmaları Dergisi, 10*, 155-180.

Ramachandra, C. G., Prashanth Pai, M., Srinivas, T. R., & Raghavendra, M. J. (2016). OEE - A Tool to Measure the Effectiveness of TPM Implementation in Industries - A Review. *GRD Journal for Engineering, 1*(12), 92-96. Retrieved from https://www.grdjournals.com/uploads/article/GRDJE/V01/I12/0043/GRDJEV01I120043.pdf

Rehman, A. A., & Alharthi, K. (2016). An Introduction to Research Paradigms. *International Journal of Educational Investigations, 3*(8), 51-59. Retrieved from http://www.ijeionline.com/attachments/article/57/IJEI.Vol.3.No.8.05.pdf

Sapot, B. (2019, September 16`). *OEE is a Flawed Manufacturing Metric. Why the Same OEE Number Can Mean Very Different Things*. Retrieved April 6, 2023, from https://gomingo.io/oee-flawed-manufacturing-metric/

Sapot, B. (2020, February 25). *The Cost Of OEE: The Missing Link Between Manufacturing And Finance*. Retrieved February 17, 2023, from https://gomingo.io/cost-oee-missing-link-between-manufacturing-finance/

Schoonenboom, J. (2023). The Fundamental Difference Between Qualitative and Quantitative Data in Mixed Methods Research. *Forum: Qualitative Social Research, 24*(1). doi:https://doi.org/10.17169/fqs-24.1.3986

Singh, S., Singh Khamba, J., & Singh, D. (2020). Analysis and directions of OEE and its integration with different strategic tools. *Journal of Process Mechanical Engineering, 235*(2), 594–605. doi:10.1177/0954408920952624

Slack, N., & Brandon-Jones, A. (2019). *Operations Management* (9 ed.). Harlow, United Kingdom: Pearson.

Sowmya, K., & Chetan, N. (2016). A Review on Effective Utilization of Resources Using Overall Equipment Effectiveness by Reducing Six Big Losses. *International Journal of Scientific Research in Science, Engineering and Technology, 2*(1), 556-562. Retrieved from https://www.academia.edu/25124754/A_Review_on_Effective_Utilization_of_Resources_Using_Overall_Equipment_Effectiveness_by_Reducing_Six_Big_Losses

SPSS Tutorials. (2023). *Which Statistical Test Should I Use?* Retrieved June 4, 2023, from https://www.spss-tutorials.com/which-statistical-test-should-i-use/

Srivastav, A. K. (2019, June 7). *https://www.wallstreetmojo.com/activity-based-costing/*. Retrieved April 7, 2023, from https://www.wallstreetmojo.com/activity-based-costing/

Stamatis, D. H. (2017). *The OEE primer - Understanding Overall Equipment Effectiveness, Reliability and Maintainability*. New York: Productivity Press. Retrieved from http://www.mescenter.ru/images/abook_file/The_OEE_Primer.pdf

Stefana, E., Cocca, P., Fantori, F., Marciano, F., & Marini, A. (2022). Resource Overall Equipment Cost. *Resource Overall Equipment Cost Loss indicator to assess equipment performance and product cost*. doi:10.1108/IJPPM-10-2021-0615

Szirmai, A. (2013). Pathways to industrialization in the twenty-first century: New challenges and emerging paradigms. Oxford: Oxford University Press. Retrieved from https://books.google.co.za/books?hl=en&lr=&id=XlxDKcxkWBMC&oi=fnd&pg=PA53&dq=why+is+the+manufacturing+sector+important&ots=XQ2xt7tmEX&sig=T3_10F4REdImdmvd8PjEAcXGlc8&redir_esc=y#v=onepage&q=why%20is%20the%20manufacturing%20sector%20important&f=false

Taylor, S. (2024). *Corporate Finance Institute*. Retrieved from Null Hypothesis: https://corporatefinanceinstitute.com/resources/data-science/null-hypothesis-2/

Terrell, S. R. (2022). *Writing a Proposal for Your Dissertation* (2nd ed.). New York: Guilford Publications, Inc.

Terry, M. (2022, June 20). *Paying The Cost of Poor Overall Equipment Effectiveness (OEE)*. Retrieved March 13, 2023, from https://www.harpak-ulma.com/resources/paying-the-cost-of-poor-overall-equipment-effectiveness-oee/

Tsarouhas, P. (2019). Improving operation of the croissant production line through overall equipment effectiveness (OEE): A case study. *Journal of Process Mechanical Engineering, 235*(2), 594–605. Retrieved from https://journals.sagepub.com/doi/10.1177/0954408920952624

Tsarouhas, P. (2020). Overall equipment effectiveness (OEE) evaluation for an automated ice cream production line. A Case Study. *International Journal of Productivity and Performance Management, 69*(5), 1009-1032. doi:10.1108/IJPPM-03-2019-0126

Tuncel, G., Akyol, D. E., Bayhan, G. M., & Koker, U. (2005). Application of Activity-Based Costing in a Manufacturing Company: A Comparison with Traditional Costing. In V. Sunderam, G. Albada, P. Sloot, & J. Dongarra (Eds.), *Computational Science – ICCS 2005. Lecture Notes in Computer Science* (pp. 562–569). Berlin, Heidelberg: Springer. Retrieved from https://doi.org/10.1007/11428862_77

Van De Ginste, L., Aghezzafa, E.-H., & Cottyna, J. (2022). The role of equipment flexibility in Overall Equipment Effectiveness (OEE)-driven process improvement. *55th CIRP Conference on Manufacturing Systems* (pp. 289-294). Elsevier B.V. doi:https://doi.org/10.1016/j.procir.2022.04.047

Williams, J. R., Haka, S. F., Bettner, M. S., & Carcello, J. V. (2018). *Financial & Managerial Accounting* (Vol. 18th). New York: McGraw Hill Education.

Wright, K. B. (2017). Researching Internet-Based Populations: Advantages and Disadvantages of Online Survey Research, Online Questionnaire Authoring Software Packages, and Web Survey Services. *Journal of Computer-Mediated Communication, 10*(3). doi:https://doi.org/10.1111/j.1083-6101.2005.tb00259.x

Wudhikarn, R. (2012). Improving overall equipment cost loss adding cost of quality. *International Journal of Production Research, 50*(12), 3434-3449. doi:10.1080/00207543.2011.587841

Wudhikarn, R. (2016). Implementation of the overall equipment cost loss (OECL) methodology for comparison with overall equipment effectiveness (OEE). *Journal of Quality in Maintenance, 22*(1), 81-93. doi:10.1108/JQME-12-2011-0001

Wudhikarn, R., Smithikul , C., & Manopiniwes, W. (2009). Developing Overall Equipment Cost Loss Indicator. *6th International Conference of Digital Enterprise Technology*, (pp. 1-7). Hing Kong. doi:10.1007/978-3-642-10430-5_43

Zainal, Z. (2007). Case study as a research method. *Jurnal Kemanusiaan, 9*. Retrieved from https://core.ac.uk/download/pdf/11784113.pdf

ANNEXURE A: LITERATURE MATRIX

Table 10: Literature Matrix

Author (Year)	Organisational Problem (why?)	Research Problem	Conceptual Frame Used	Population & Sample	Research Gap
Stefana et al. (2022)	The base understanding of OEE does not fully describe the nature of production losses in order to be an effective KPI and foster effective decision making.	The research was conducted to address one of the main weaknesses of OEE – Namely expressing the cost implications of OEE.	In order to link OEE to a financial KPI, the research team developed an approach of Overall Equipment Cost Loss (Overall Equipment Effectiveness Cost Loss)	This paper is structured as a literature review and does not include any data collection	The proposed Overall Equipment Effectiveness Cost Loss (OECL)approach concerns data collection effort of OEE presenting impediments to the implementation of this approach.
Luolila (2021)	The dynamics of the financial effect on OEE	Linking the case company's OEE to the financial performance of the company.	A deductive study to test a hypothesis on small scale to evaluate the behaviour of OEE on financials.	One case company analysed.	The study was unable to establish a financial link to all the components of OEE.

Sapot (2020)	OEE is not widely understood in the business when expressed as a percentage (%)	The cost of OEE can express the impact of improved OEE in the functions of the OEE formula	The three OEE functions are attributed to overhead and material costs.	This paper is structured as a literature review and does not include any data collection	The application of the cost implication of OEE was done on a sample basis rather than real-world application. Replicability in manufacturing industries remains untested.
Lelis (2022)	Many executives see OEE as a production KPI rather than a KPI that affects the business performance or profit.	How to express OEE in terms of fixed and variable cost to link the ratio to the total turnover.	Based on the Du Pont analysis that explains components of a company’s return on equity	This paper is structured as a literature review and does not include any data collection	This paper focusses on the business explanation of OEE, rather than providing the cost of losses.

ANNEXURE B1: LITERATURE REVIEW MATRIX

Table 11: Literature Review Matrix

Author (Year)	Methods	Arguments	Agrees with	Disagrees with	Research Gap
Weakness of OEE					
Garza-Reyes (2015)	**Approach:** Conducted 1 industrial based application study and 1 simulation based application study. N=2 **Methodology:** Develops the mathematical approach of overall resource effectiveness to determine the efficient use of resources for the case application.	OEE measures the components of availability, quality and performance, however is not sufficient to measure all resources, labour and production systems. The argument is formed in the development of the overall resource effectiveness approach gives a more comprehensive explanation to OEE.	(Nachiappan & Anantharaman, 2006)	(Nakajima, 1988) (Jonsson & Lesshammar, 1999)	Machines does not operate in silos - The OEE approach is not sufficient to control interlinked processes and measure other relevant factors for the company.
Bengtsson, Andersson, & Ekström (2022)	**Approach:** Case study within the automotive manufacturing industry. N=1.	Most studies on OEE deals with the technical implementation of OEE. This study argues that managerial impact of	(Binti Aminuddin et al.,, 2015)	N/A	Understanding, communication and visualization of OEE was found lacking in this study, however no

	Methodology: Through the use of a survey it study attempted to measure managers beliefs and preconceptions of OEE.	OEE limits the effective use of the OEE methodology due to misunderstanding of the measurements and lack of awareness.			solution to address the gap was supported in the results of the study.
Binti Aminuddin, Garza-Reyes, Kumar, Antony, & Rocha-Lona (2015)	**Approach:** Survey questionnaire responded by 139 manufacturing worldwide. N=139. **Methodology:** The survey was conducted using a combination of descriptive statistics in order to determine the managerial impact on OEE.	The study argues that in order to effectively implement OEE, a certain level of understanding from management needs to be established.	(Nachiappan & Anantharaman, 2006)	N/A	The study found that understanding of OEE (from both management and operators) was lacking that results in a barrier of implementation of OEE. No solution was posed in order to address the outcome.
Cheah, Prakash, & Ong (2020)	**Approach:** Literature review and case study approach over a period of 38 weeks in a semiconductor manufacturing facility. N=1.	There is a lack of a guiding approach to the implementation of OEE.	(Wudhikarn, 2016) (Tsarouhas, 2019)	N/A	The study provides a systematic approach to the implementation of OEE to help guide understanding of implementation principles.

	Methodology: Reviewing OEE literature to develop a new integrated framework for the implementation of OEE.				
Cost of OEE					
Wudhikarn (2016)	**Approach:** Study duration of 12 months for 10 machines. N=10 **Methodology:** Overall Equipment Cost Loss (Overall Equipment Effectiveness Cost Loss) method: Combines the three main aspects of OEE and portrays it as a monetary value.	The machine that operates at the lowest OEE, is not necessarily responsible for the biggest cost losses.	(Wudhikarn, Smithikul , & Manopiniwes, 2009)	N/A	No structured approach to cost data collection was provided in the research. The approach was unable to be duplicated in all scenarios.
Dewi, Alhilman, & Atmaji (2020)	**Approach:** Case study on a Toshiba CNC Machine. N=1 **Methodology:** Data collection and loss evaluation of the case study machine in terms of the OEE and Overall Equipment	Application of the methodology to determine the performance of the case study machine.	(Wudhikarn, 2016)	N/A	Only focus is on applying the principles of the article by Wudhikarn (2016), does not add any significance to the research gap.

	Effectiveness Cost Loss (OECL)approach.				
Stefana et al. (2022)	**Approach:** Literature review and case study on a smart multi-centre three-spindle machine. N=1 **Methodology:** Developed an approach based on Overall Equipment Effectiveness Cost Loss	The three main components of OEE are not sufficient to fully evaluate the effectiveness of a machine, other aspects such as cost are not accounted for.	(Wudhikarn, 2016)	N/A	The proposed Overall Equipment Effectiveness Cost Loss (OECL)approach concerns a big data collection effort of OEE presenting restrictions to the implementation of this approach.
Luolila (2021)	**Approach:** Case Study based on a manufacturing department paint shop. N=1 **Methodology:** A deductive study to determining the OEE related performance of the case machine in relation to financial performance.	The link between OEE and financial performance is not well established. As OEE decreased linked costs will increase due to the decreased throughput.	(Nakajima, 1988) (Jonsson & Lesshammar, 1999)	N/A	The study was unable to establish a financial link to all the components of OEE as the financial impact of each of the components of OEE is not always ambiguous.

Sapot (2020)	**Approach:** Descriptive review of applying the cost of OEE (calculation). N=0 **Methodology:** Defining each of the components of OEE (Availability, Quality & Performance) as monetary values through assigning cost to the elements of the component.	In order to give context to OEE, the KPI needs to be attributed as a financial KPI. In doing so the losses and improvements can be easily understood and benefits can be assigned to high performing machines, this will serve as motivation for running at high levels of OEE.	(Wudhikarn, 2016)	N/A	The application of the cost implication of OEE was done on a sample basis rather than real-world application. Replicability in manufacturing industries remains untested. OEE does not provide the right context for understanding.
Lelis (2022)	**Approach:** Theoretical application of the fiscal impact of OEE. N=0 **Methodology:** An income statement application of Fixed and Variable cost analysis in terms of OEE and expresses Total profit as a percentage of OEE. Cost-sharing of all general industrial expenses.	With the inclusion of the shared general industrial expenses, and measuring OEE as a proportion of product cost a measurable difference in the OEE will be seen.	N/A	As the approach is cantered around income statement application of variable cost, the study is disagreeing with (Wudhikarn, 2016) & (Mahmoud, FahmyAly, Mohib, & Afefy, 2019)	The paper is structured around theoretical production application. Replicability in manufacturing industries remains untested. Does not support understanding for management executives.

Mahmoud, FahmyAly, Mohib, & Afefy (2019)	**Approach:** A data envelopment analysis model is used to set benchmarks for the Overall Equipment Effectiveness Cost Loss (OECL)approach. Case study to a printing and packaging company. N=1 **Methodology:** Applying a linear programming and production theory-based mathematical approach to overcome the traditional challenges that arise when implementing Overall Equipment Effectiveness Cost Loss.	The analysis assumes that the weakness of Overall Equipment Effectiveness Cost Loss (OECL)is the lack of a benchmark for the model. Thus the argument of the paper is to integrate Overall Equipment Effectiveness Cost Loss (OECL)with data development analysis to set a benchmark for comparing machine's performance to best practise.	N/A	(Wudhikarn, 2016)	Results could not be generalised to all industries.
Terry (2022)	**Approach:** Packaging equipment case analysis. N=1	When considering the case company, the final buy decision is always	In general the study agrees that the cost of OEE has a big	N/A	The paper does not consider how to calculate the cost impact of OEE

	Methodology: Focus surrounding the Total Cost of Ownership (TCO) and the return on investment (ROI) of the equipment. Labour costs, downtime costs and other indirect costs are analysed to determine the impact of OEE.	related to price. The direct impact of OEE loss can be seen in the revenue of the case company, and the relationship with the customers as improved OEE will result in a reduction of product cost thus reducing the price.	impact on the revenue of the company - Linking to the discussion from Lelis (2022).		outside of the case company. All calculations were theoretical in nature.

Research Gap:
OEE does not provide a measurable metric that is relatable throughout the production line of a company.
OEE is not easily understood throughout the business.
Establishing a financial methodology to OEE
No structured approach to cost data collection.
Developing a replicable cost approach to OEE for all manufacturing industries.

ANNEXURE B2: THEMATIC SYNTHESIS SUMMARY

Table 12: Thematic Synthesis of research

Theme	**No. of Articles**	**References**	**Research Gap**
Understandability of OEE	5	• Bengtsson, Andersson, & Ekström (2022), • Binti Aminuddin, Garza-Reyes, Kumar, Antony, & Rocha-Lona (2015) • Cheah, Prakash, & Ong (2020) • Sapot (2020) • Lelis (2022)	The context for OEE is not understood throughout the business.
			Management and operators view OEE differently thus hindering effective decision making to the improvement of OEE.
Benchmarking of OEE throughout the company	2	• Garza-Reyes (2015) • Wudhikarn (2016)	Different machines utilize different resources and materials, thus the OEE result for one machine cannot easily be compared to other machines.
			The machine that operates at the lowest OEE, is not necessarily responsible for the biggest cost losses.
Establishing a financial methodology to OEE	6	• Wudhikarn (2016) • Dewi, Alhilman, &Atmaji (2020) • Stefana et al. (2022) • Luolila (2021) • Lelis (2022) • Terry (2022)	Direct and indirect costs need to be considered
			Linking to all costs that will appear on the balance sheet / income statement
			Costing all elements of OEE is unclear (Availability, Performance & Quality)
Replicable cost approach to OEE	2	• Mahmoud, FahmyAly, Mohib, & Afefy (2019) • Sapot (2020)	Costing approaches are not standardized to be replicated in all manufacturing companies

ANNEXURE C: CONTRAST OF OEE MODELS

Table 13: Contrast in OEE models

Item	**Abbreviation**	**Definition**	**Calculation**	**Sample**	**Unit**
Total Available Time per Day	TT	1 Day = 24 hours = 1440 min.	Time per day	1440	minutes
Planned Non-Operating Time / Excluded Time	ET	Time not scheduled to operate e.g., unworked shifts, start-ups or shutdowns or time spent on value adding activities e.g., modifications, upgrades, or training (Oechsner, et al., 2002).	Actual Planned Non-Operating Time	60	minutes
Planned Operating Time / Scheduled Time	ST	Total time available for valuable production (Oechsner, et al., 2002).	= TT – ET	1380	minutes
Planned Downtime	PDT	Planned shutdown and maintenance activities (Tsarouhas, 2019) E.g., Lunch, breaks, planned maintenance (Oechsner, et al., 2002).	Actual Occurrence	90	minutes
Unplanned Downtime	UPDT	Unexpected stoppage of the line due to breakdowns, adjustments, material losses etc. (Stefana, Cocca, Fantori, Marciano, & Marini, 2022).	Actual Occurrence	470	minutes
Downtime	DT	Total time the machine is not running. Divided into Planned Downtime and Unplanned Downtime (Stefana, Cocca, Fantori, Marciano, & Marini, 2022).	= PDT + UPDT	560	minutes

Operating Time / Uptime	UT	The time the machine is running without stops. It is divided into Rate Loss, Quality Loss, and Net production Time (Oechsner, et al., 2002).	= ST – DT	820	minutes
Availability	A	The portion of time in which the equipment is operational measured as a ratio to possible production time (Singh, Singh Khamba, & Singh, 2020).	= UT ÷ ST	59.4%	%
Design Speed	DS	The minimum time to produce one unit – Also referred to as Theoretical speed (Stefana, Cocca, Fantori, Marciano, & Marini, 2022).	Actual Speed from manufacturer	2.2	minutes/unit
Actual Speed	AS	Reduced speed due to minor stoppages or reduced speed (Del Carmen Ng Corrales, Lambán, Korner, & Royo, 2020).	= UT ÷ TPV	2.9	minutes/unit
Total Production Volume	TPV	Total Output of the Machine. Includes good quality and bad quality product (Tsarouhas, 2019).	Actual Output	280	units
Speed Loss Time	SL	The difference between equipment design speed and actual operating speed (Stefana, Cocca, Fantori, Marciano, & Marini, 2022).	= (AS – DS) x TVP	204	minutes
Performance	P	The proportion of design speed to actual speed per time unit (Van De Ginste, Aghezzafa, & Cottyna, 2022).	= AS ÷ DS	75.1%	%
Quality Loss Volume	QLV	The volume identified as bad quality products, can be due to process defects, reduced yield (Del Carmen Ng	Actual Occurrence	10	units

		Corrales, Lambán, Korner, & Royo, 2020) or rework (Tsarouhas, 2019).			
Net Production Volume	NPV	Total good quality volume produced	= TPV-QLV	270	units
Quality Loss Time	QL	The amount of time spent producing bad quality products (Stefana, Cocca, Fantori, Marciano, & Marini, 2022).	= DS x QLV	22	minutes
Quality	Q	The ratio of good quality products (non-defective output) produced against the total products produced (total output) (Van De Ginste, Aghezzafa, & Cottyna, 2022).	=(TPV-QLV) ÷ TPV = NPV ÷ TPV	96.4%	%
Effective Operating Time / Effective Production Time	EPT	Total productive time available for regular production (Stefana, Cocca, Fantori, Marciano, & Marini, 2022).	= DS x NPV	594	minutes
Overall Equipment Effectiveness	OEE	The gold standard indicator (Stamatis, 2017) to be used as the standard for measuring productivity (Del Carmen Ng Corrales, Lambán, Korner, & Royo, 2020). It shows how well time can be used for pure, valuable production (Kennedy, 2017).	<u>Traditional method:</u> = A x Q x P	43.04%	%
			<u>Time Based method:</u> = EPT ÷ ST	43.04%	%

ANNEXURE D: ACTIVITY BASED COSTING MODEL

Table 14: Activity Based Costing Example

				Cost Driver Value				
Item	**Abbreviation**	**Calculation**	**Cost Driver**	**Product A**	**Product B**	**Product A**	**Product B**	**Total**
Total Production Volume	TPV	Actual Output				220	60	280
Total Direct Material Cost	DM	Actual Material cost	Material Cost per product			R 60 000	R 20 000	R 80 000
Direct Material per product	DMpp	= DM ÷ TPV				R 272.73	R 333.33	R 285.71
Total Direct Labour Cost	DL	Actual Labour cost	Labour cost per product			R 18 000	R 9 000	R 27 000
Direct Labour per product	DLpp	= DL ÷ TPV				R 81.82	R 150.00	R 96.43
Utilities		Actual Utility cost	KWH	68.4	95.1	R 4 602	R 6 398	R 11 000
Maintenance		Actual Maintenance cost	MTTR min	180	200	R 4 026	R 4 474	R 8 500
Total Variable Cost	TVC	Sum of all variable cost				R 8 628	R 10 872	R 19 500
Variable Cost per product	VCpp	= VC ÷ TPV				R 39.22	R 181.20	R 69.64
Marginal Cost	MC	= sum of all variable costs				R 86 628	R 39 872	R126 500
Marginal Cost per product	MCpp	= sum of all variable costs per product = MC ÷ TPV				R 393.76	R 664.53	R 451.79
Depreciation		Actual Depreciation cost	Asset residual value	R500 000	R800 000	R 1 923	R 3 077	R 5 000

Lease or rental		Actual Lease cost	Square meter of space	150	60	R 10 714	R 4 286	R 15 000
Insurance		Actual Insurance cost	Policy cost per item	R350	R150	R 350	R 150	R 500
Interest		Actual Interest cost	Capital expenditure per product	R10 000	R20 000	R 50	R 100	R 150
Taxes		Actual Tax cost	Tax Type (Product Tax) – Production Units	4000	1200	R 115	R 35	R 150
Total Fixed Cost	TFC	Sum of all fixed cost				R 13 153	R 7 647	R 20 800
Fixed Cost per product	FCpp	= FC ÷ TPV				R 59.79	R 127.45	R 74.29

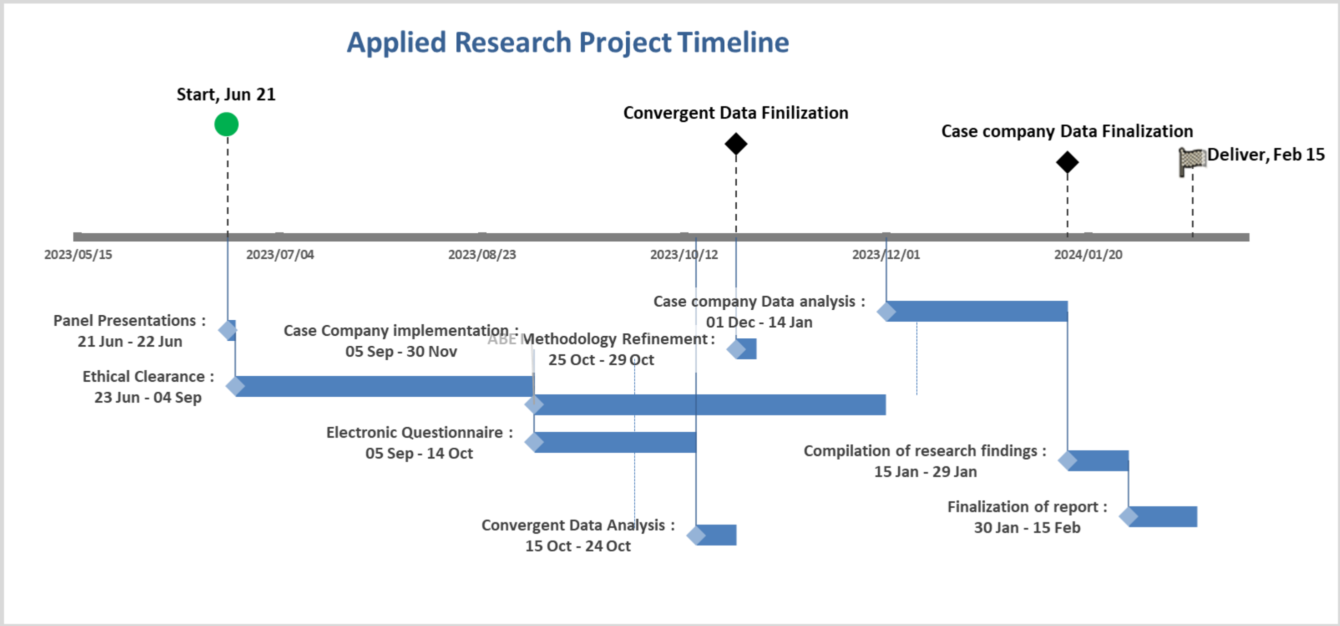
Total Cost	TC	= sum of MC and FC				R 99 781	R 47 519	R147 300
Absorption Cost	AC	= sum of MCpp and FCpp				R 453.55	R 791.99	R 526.07
		= TC ÷ TPV				R 453.55	R 791.99	R 526.07

ANNEXURE E: ACTIVITY BASED EFFECTIVENESS MODEL

Table 15: Activity Based Effectiveness (ABE) theoretical example

		OEE		ABE	
Item	**Abbr.**	**Time**	**Unit**	**Calculation**	**Cost**
Total Available Time per Day	TT	1440	minutes		
Planned Non-Operating Time / Excluded Time	ET	60	minutes	Opportunity Loss – Economies of scale	R 10 739
Marginal Cost Per product					R 393.76
Planned Operating Time / Scheduled Time	ST	1380	minutes	=MCpp x Maximum production	R 246 998
Planned Downtime	PDT	90	minutes	= (PDT ÷ DS)*MCpp	R 16 109
Unplanned Downtime	UPDT	470	minutes	= (UPDT ÷ DS)*MCpp	R 84 122
Downtime	DT	560	minutes	= (DT ÷ DS)*MCpp	R 100 231
Operating Time / Uptime	UT	820	minutes	= (UT ÷ DS)*MCpp	R 146 767
Design Speed	DS	2.2	minutes/unit		
Actual Speed	AS	2.9	minutes/unit		
Total Production Volume	TPV	280	units		
Speed Loss Time	SL	204	minutes	= (SL ÷ DS)*MCpp	R 36 513
Quality Loss Volume	QLV	10	units		
Net Production Volume	NPV	270	units		
Quality Loss Time	QL	22	minutes	= (QL ÷ DS)*MCpp	R 3 938
Effective Operating Time / Effective Production Time	EPT	594	minutes		R 106 316
OEE		43.04%	%		43.04%

ANNEXURE F: APPLIED RESEARCH PROJECT TIMELINE



Tasks

Start	End	Duration	Task
2023/06/21	2023/06/22	2	Panel Presentations
2023/06/23	2023/09/04	74	Ethical Clearance
2023/09/05	2023/10/14	40	Electronic Questionnaire
2023/10/15	2023/10/24	10	Convergent Data Analysis
2023/10/25	2023/10/29	5	ABE Methodology Refinement
2023/09/05	2023/11/30	87	Case Company implementation
2023/12/01	2024/01/14	45	Case company Data analysis
2024/01/15	2024/01/29	15	Compilation of research findings
2024/01/30	2024/02/15	17	Finalization of report

Figure 34: Applied Research Project Timeline

ANNEXURE G: ELECTRONIC SURVEY AND INTERVIEW QUESTIONNAIRE

<u>Consent</u>

Q0: Dear Sir / Madam,

My name is Elmarie David, I am a Masters student in the Faculty Commerce, Law and Management at the University of the Witwatersrand, Johannesburg, currently studying towards a Master of Business Administration. As part of my course, I have to undertake an applied research project, under the supervision of Dr. Ademola E. Ayodele.

I am conducting a research study about the development of a structured costing approach to Overall Equipment Effectiveness (OEE). The aim of this research topic is to gain insight into the current understanding of Overall Equipment Effectiveness (OEE), and the perceived impact of being able to express Overall Equipment Effectiveness as a monetary value. The study title is Cost Performance of OEE in Manufacturing: The Activity-Based Effectiveness Approach.

I am inviting you to take part in this survey. If you decide to take part, your participation survey will take approximately 10 minutes.

During the research activity, I will ask demographic information, including age group and gender, and professional information, including current level in your organization, functional area, and highest level of education.

The survey will be completely confidential and anonymous with no questions seeking identifying information.

This research study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you. If you have any questions during or afterwards about this research study, feel free to contact me on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,

Elmarie David

Researcher:

Elmarie David, 1303297@students.wits.ac.za

Supervisor:

Dr. Ademola E. Ayodele, ademola.ayodele@wits.ac.za

Demographic Information

Q1

What is your organizational level within the company?

- ○ Senior / Top ManagementExecutive/Leadership (e.g., CEO, CTO, Vice President)
- ○ Manager/Supervisor
- ○ Team Leader/Coordinator
- ○ Individual Contributor/Specialist
- ○ Employee/Operational level
- ○ Other (Please specify)

Q2

In which functional area do you primarily work within the organization?

- ○ Operations/Production
- ○ Industrial Engineering
- ○ Engineering/Technician
- ○ Quality Assurance/Control
- ○ Maintenance
- ○ Supply Chain/Logistics
- ○ Sales/Marketing
- ○ Finance/Accounting
- ○ Human Resources
- ○ Information Technology
- ○ Other (Please specify)

Q3

How many years of experience do you have?

- ○ Less than 1 year
- ○ 1-2 years
- ○ 3-5 years
- ○ 6-10 years
- ○ 11-15 years
- ○ 16-20 years
- ○ 21-30 years
- ○ More than 30 years

Q4

What is your highest level of education?

- National Senior Certificate (Grade 12)
- National Diploma
- Trade School Certification
- Bachelor's degree
- Master's degree or higher education
- Other (Please specify)

Q5

Do you have a degree in Industrial Engineering?

- Yes
- No

Q6

What is your gender?

- Male
- Female
- Non-binary / third gender
- Prefer not to say

Q7

What is your age group?

- 18-24 years
- 25-34 years
- 35-44 years
- 45-54 years
- 55-64 years
- 65 years and above
- Prefer not to say

Understanding of Overall Equipment Effectiveness

Q8

Please rate your level of understanding for each of the following statements:

	Strongly Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I am familiar with the concept of Overall Equipment Effectiveness (OEE)	○	○	○	○	○
I understand the key components of OEE (Availability, Performance, Quality)	○	○	○	○	○
I can accurately calculate and interpret OEE values	○	○	○	○	○
I am aware of the benefits of improving OEE for an organization	○	○	○	○	○
I feel confident in explaining OEE to others	○	○	○	○	○

Q9

Please indicate the extent to which the following factors have affected your understanding of OEE:

	Not at all	Slightly	Moderately	Very much	Significant
Lack of training or education on OEE	○	○	○	○	○
Complexity of OEE calculations and metrics	○	○	○	○	○
Insufficient documentation or resources on OEE	○	○	○	○	○
Lack of communication or explanation from management	○	○	○	○	○

Q10

In your experience are there any other barriers apart from the ones above that affect how you or others understand OEE?

Q11

In your opinion, what is the portion of employees in your organization that understand the concept of OEE?

- ○ 0% to 25%
- ○ 25% to 50%
- ○ 50% to 75%
- ○ 75% to 100%
- ○ I am unsure

Q12

How effectively do you think your organization communicates and explains OEE to its employees?

- ○ Not effective at all
- ○ Slightly effective
- ○ Moderately effective
- ○ Very effective
- ○ Extremely effective

Q13

In your experience, is it easy to understand and communicate the impact of low OEE to all levels of the organization?

Financial Calculation of OEE

Q14

Does your organization follow a structured way of calculating the cost impact of OEE? If yes, please elaborate.

- ○ Yes
- ○ No
- ○ I am unsure

Q15

Please rate the extent to which your organization considers the cost aspect when analyzing and improving OEE (e.g. when considering which area to assign resources to for improvement)

- ○ Low Consideration
- ○ Some Consideration
- ○ Moderate Consideration
- ○ High Consideration
- ○ Very High Consideration

Q16

Please indicate your agreement with the following statement: "The cost approach applied to OEE (expressing OEE as a monetary loss) is an essential factor in making informed decisions regarding equipment improvement"

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

Q17

How would you rate the level of cost visibility and tracking in your organization's OEE analysis?

- ○ Extremely inadequate
- ○ Somewhat inadequate
- ○ Neither adequate nor inadequate
- ○ Somewhat adequate
- ○ Extremely adequate

Q18

Has there been challenges or obstacles that your organization has faced in implementing the cost approach in relation to OEE? If yes, please elaborate on those challenges and their impact.

- ○ Yes
- ○ No

Q19

Would you say that your cost approach to OEE can be replicated in other industries? If yes, please elaborate.

- ○ Yes
- ○ No

The Cost-centric approach to OEE

Q20

Rate the extent to which the following statements is applicable to your organization

	Not at all	Minimal	Moderate	High	Significantly
Expressing OEE as a cost will improve understanding	○	○	○	○	○
Expressing OEE as a cost will lead to improved decision making	○	○	○	○	○
Expressing OEE as a cost will lead to increased focus on low productivity equipment or areas	○	○	○	○	○
Expressing OEE as a cost will improve cost management and resource allocation within your organization	○	○	○	○	○
Expressing OEE as a cost will lead to better budgeting and financial planning for your organization	○	○	○	○	○

ANNEXURE H: OEE AND ABC ASSOCIATION

Table 16: OEE and ABC Association

OEE			Cost					
OEE Element	**Downtime (DT) Category**	**Reference**	**Labour**	**Material**	**Depreciation**	**Utilities**	**Support services**	**Maintenance Services**
Availability	Planned DT	Lunch & Break	✓	by machine	✓	✓	✓	
Availability	Planned DT	Equipment Start-up	✓	by machine	✓	✓	✓	
Availability	Planned DT	Planned Maintenance (PM)	✓	✓	✓	✓	✓	✓
Availability	Planned DT	Size Change	✓	✓	✓	✓	✓	by machine
Availability	Planned DT	Material Change	✓	✓	✓	✓	✓	
Availability	Planned DT	Other Planned Downtime	✓		✓	✓	✓	
Availability	Unplanned DT	Exceeded Time of Lunch & Break	✓		✓	✓	✓	
Availability	Unplanned DT	Exceeded Time of Start-Up & 2C	✓		✓	✓	✓	
Availability	Unplanned DT	Exceeded Time of PM	✓		✓	✓	✓	✓
Availability	Unplanned DT	Exceeded Time of Size Change	✓		✓	✓	✓	by machine
Availability	Unplanned DT	Exceeded Time of Material Change	✓		✓	✓	✓	
Availability	Unplanned DT	Exceeded Time of Other PDT	✓		✓	✓	✓	
Availability	Unplanned DT	Undefined	✓		✓	✓	✓	
Availability	Unplanned DT	Machine Breakdown	✓		✓	✓	✓	✓
Availability	Unplanned DT	Process Failure	✓		✓	✓	✓	✓
Availability	Unplanned DT	Material Shortage	✓		✓	✓	✓	
Availability	Unplanned DT	Material Quality	✓	input material	✓	✓	✓	
Availability	Unplanned DT	MHE	✓		✓	✓	✓	
Availability	Unplanned DT	Man	✓		✓	✓	✓	
Availability	Unplanned DT	Technical	✓	✓	✓	✓	✓	
Availability	Unplanned DT	Power Failure	✓	✓	✓		✓	
Availability	Unplanned DT	Other UPDT	✓		✓	✓	✓	
Speed	Speed	Speed Loss	✓		✓	✓	✓	✓
Quality	Quality	Quality Loss	✓	✓	✓	✓	✓	

ANNEXURE I: ABC DETAILED ANALYSIS OF CASE COMPANY

ABC	Classification	Cost Driver	M1	M2	M3	T1	T2	T3	T4	T5	T6	S1
Electricity	Utilities	Consumption (Kilo Watt per Hour)	11134249	9474407	7360794	3696676	2289478	2493107	9913803	11636917	750168	9412
Water	Utilities	Consumption (Cubic meters)	32963	34356	32127	252417	353498	33080	360627	391059	146803	0
Air	Utilities	Consumption (m3/hr)	35831	80620	8958	39595	39595	39595	39595	39595	13858	0
Property & Facility Management	Support services	Floorspace (Square Metres)	230029	246927	326517	343959	116816	141298	133504	195196	84021	24516
Long Term Ills	Support services	Total Headcount (Adjusted)	28720	21228	21228	22477	21005	14984	14984	14984	7492	4579
Maintenance Services	Maintenance Services	Value of Spare Parts	1192984	1326986	1083092	761590	453661	365306	1150862	1202834	835667	170461
Medical	Support services	Total Headcount (Adjusted)	44006	32526	32526	34440	32185	22960	22960	22960	11480	7015
Cafeteria	Support services	Total Headcount (Adjusted)	210220	155380	155380	164520	153748	109680	109680	109680	54840	33513
Management	Support services	Insurance [Acquisition Value as per Asset Register]	341681	168027	461574	162100	144182	134239	124614	136205	10310	14424
Finance	Support services	Value of budget excluding utilities, allocated to workcentres based on headcount	164354	121479	121479	81243	75924	54564	63324	63324	23236	16590
Industrial Relations	Support services	Total Headcount (Adjusted)	98706	72956	72956	77248	72190	51499	51499	51499	25749	15736
Information Systems	Support services	Number of IT Users in a cost centre, allocated to work centres based on headcount	0	0	0	0	0	0	0	0	0	0
Training	Support services	Total Headcount (Adjusted)	397221	293598	293598	310869	290514	207246	207246	207246	103623	63325
Payroll	Support services	Total Headcount (Adjusted)	109225	80731	80731	85480	79883	56987	56987	56987	28493	17413
Human Resources	Support services	Total Headcount (Adjusted)	288006	212874	212874	225396	210638	150264	150264	150264	75132	45914
Procurement	Support services	Spare Part Orders	209499	188315	138612	173781	91734	76389	72462	88582	38920	15918
Machine Shop	Support services	The value of forklifts that service specific machines, adjusted for future rental of forklifts	223646	223646	223646	182936	182936	649734	469033	469033	0	27337
Fleet	Support services	Total Headcount (Adjusted)	19244	14224	14224	15061	14075	10040	10040	10040	5020	3068
General Stores	Support services	Spare Part Orders	238169	214087	157581	197564	104288	86843	82379	100705	44246	18096
Factory Instrumentation	Support services	Total spare parts per machine	723991	966103	1027808	156161	215366	55126	67307	88703	53666	52519
Salvage & Idle Equipment	Support services	The capital value of the moulds.	0	0	0	0	0	0	0	0	0	0
Security	Support services	Floorspace (Square Metres)	378349	351694	426254	449674	228542	217337	210036	267829	121195	48929

Industrial Engineering	Support services	Total Headcount (Adjusted)	107428	107428	107428	107428	107428	107428	107428	107428	107428	107428
Logistics & Scheduling	Support services	Total Headcount (Adjusted)	270504	270504	270504	220058	220058	220058	220058	220058	209358	270504
Waste Control	Support services	Directly into the M at an even allocation	1340363	1340363	1340363	0	0	0	0	0	0	0
Laboratory & Testing	Support services	Directly into the M & B at an even allocation	1590275	1590275	1590275	0	0	0	0	0	0	0
Technical Services	Support services	Total Headcount (Adjusted)	436216	436216	436216	568053	568053	568053	568053	568053	568053	270339
Quality Assurance	Support services	Total Headcount (Adjusted)	51073	51073	51073	51073	51073	51073	51073	51073	51073	51073
Process Control Passenger	Support services	Total Headcount (Adjusted)	7505	7505	7505	7505	7505	7505	7505	7505	7505	7505
Raw Material Stores	Support services	Raw material usage	5906544	5906544	5906544	0	0	0	0	0	0	0
Steam	Support services	Steam Usage per KG cured	0	0	0	0	0	0	0	0	0	0
General Engineering	Support services	Total spare parts allocation per machine	984224	724301	562680	548378	258721	174569	140717	157788	76970	43756
Maintenance Services Direct	Maintenance Services	Spare parts value per machine	6027460	3670238	5319794	3032619	1798248	1942831	702489	1559765	1980704	333069
Mould Shop	Maintenance Services	Kgs of rubber cured	0	0	0	0	0	0	0	0	0	0
Green Tyre Storage	Support services	Cure Time	0	0	0	0	0	0	0	0	0	0
General - Leads	Support services	Total Headcount (Adjusted)	1969022	1455364	1455364	318626	297764	616389	1027316	1027316	299114	175826
TMA	Support services	TMA Origin	0	0	0	386142	407467	287131	409752	421176	0	0
Direct Labour	Labour	Total Headcount	3617112	2411408	2411408	3127584	2922802	2220287	1906936	1906936	445612	502623
Depreciation	Depreciation	Book value per work centre	3560534	610627	3744528	425243	759227	709587	2241841	523338	33257	88534
Capex Budget Per WC	Depreciation	Capex budget per WC	0	0	0	0	0	0	0	0	0	0
Indirect Labour	Labour	Total Headcount (Adjusted)	6980794	5159717	5159717	3844726	3592988	2164016	2622216	2622216	1141174	971104
Material Cost	Material	Total KG	128450001	66396952	64662821	4064087	7122162	3608728	7254726	4510910	3452141	11876401
TOTAL COST/ANNUM			177400151	104418683	105278181	24134708	23283753	17647933	30571314	28987202	10806310	15286929

ANNEXURE J: DETAILED OEE AND ABC CORRELATION: ABE CALCULATION

Table 17: Detailed OEE and ABC correlation: ABE Calculation

M1 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 4 426.17
Start-up & 2C	4	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 746.32
Planned Maintenance (PM)	20	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R 51 698.32	R 16 991.44
Size Change	0	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R 49 594.12	R -
Material Change	75	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R 49 594.12	R 61 668.67
Other PDT	30	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 6 046.24
Exceeded Time of Lunch & Break	7	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 1 419.89
Exceeded Time of Start-Up & 2C	3	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 542.30
Exceeded Time of PM	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R 14 265.15	R -
Exceeded Time of Size Change	12	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 2 339.41
Exceeded Time of Material Change	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R -
Exceeded Time of Other PDT	7	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 1 463.31
Undefined	4	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 911.24
Machine Breakdown	99	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R 14 265.15	R 23 455.87
Material Shortage	30	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 6 177.42
Material Quality	11	R 3 088.46	R 1 721.30	R 1 037.62	R 3 264.81	R 4 770.06		R 13 882.25	R 2 560.49
MHE	1	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 281.55
Man	49	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 9 894.75
Technical	20	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R 49 594.12	R 16 271.29
Power Failure	24	R 3 088.46	R37 433.16	R 1 037.62		R 4 770.06		R 46 329.31	R 18 864.17
Other UPDT	58	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 11 657.00
Rate Loss	91	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R 12 160.96	R 18 444.12
Quality Loss	0	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R 49 594.12	R -
TOTAL LOSS	566								**R 204 161.65**

M1 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 4 390.63
Start-up & 2C	1	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 119.24
Planned Maintenance (PM)	30	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R51 698.32	R 26 219.18
Size Change	0	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R49 594.12	R -
Material Change	83	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R49 594.12	R 68 490.53
Other PDT	28	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 5 620.86
Exceeded Time of Lunch & Break	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 24.37
Exceeded Time of Start-Up & 2C	3	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 531.55
Exceeded Time of PM	3	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R14 265.15	R 814.56
Exceeded Time of Size Change	17	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 3 529.87
Exceeded Time of Material Change	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Exceeded Time of Other PDT	4	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 742.46
Undefined	22	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 4 544.27
Machine Breakdown	46	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R14 265.15	R 10 922.54
Material Shortage	1	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 213.20
Material Quality	16	R 3 088.46	R 1 721.30	R 1 037.62	R 3 264.81	R 4 770.06		R13 882.25	R 3 759.74
MHE	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Man	88	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 17 787.55
Technical	9	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R49 594.12	R 7 754.70
Power Failure	32	R 3 088.46	R37 433.16	R 1 037.62		R 4 770.06		R46 329.31	R 24 757.44
Other UPDT	73	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 14 751.18
Rate Loss	55	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 11 083.29
Quality Loss	0	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R49 594.12	R -
TOTAL LOSS	533								**R 206 057.18**

M1 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	30	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 6 080.48
Start-up & 2C	5	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 1 013.41
Planned Maintenance (PM)	20	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R51 698.32	R 17 232.77
Size Change	0	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R49 594.12	R -
Material Change	100	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R49 594.12	R 82 656.87
Other PDT	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Exceeded Time of Lunch & Break	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Exceeded Time of Start-Up & 2C	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Exceeded Time of PM	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R14 265.15	R -
Exceeded Time of Size Change	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Exceeded Time of Material Change	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Exceeded Time of Other PDT	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Undefined	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Machine Breakdown	116	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06	R 2 104.20	R14 265.15	R 27 579.30
Material Shortage	0	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R -
Material Quality	16	R 3 088.46	R 1 721.30	R 1 037.62	R 3 264.81	R 4 770.06		R13 882.25	R 3 701.93
MHE	5	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 1 013.41
Man	80	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 16 214.61
Technical	10	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R49 594.12	R 8 265.69
Power Failure	20	R 3 088.46	R37 433.16	R 1 037.62		R 4 770.06		R46 329.31	R 15 443.10
Other UPDT	10	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 2 026.83
Rate Loss	138	R 3 088.46		R 1 037.62	R 3 264.81	R 4 770.06		R12 160.96	R 27 980.72
Quality Loss	57	R 3 088.46	R37 433.16	R 1 037.62	R 3 264.81	R 4 770.06		R49 594.12	R 46 734.19
TOTAL LOSS	607								**R 255 943.31**

M2 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 043.65
Start-up & 2C	4	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 344.59
Planned Maintenance (PM)	20	R 1 287.27	R11 289.08	R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 17 753.68	R 5 835.02
Size Change	0	R 1 287.27	R11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R -
Material Change	75	R 1 287.27	R11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R 21 019.62
Other PDT	30	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 791.67
Exceeded Time of Lunch & Break	7	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 655.59
Exceeded Time of Start-Up & 2C	3	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 250.39
Exceeded Time of PM	0	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R -
Exceeded Time of Size Change	12	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 1 080.15
Exceeded Time of Material Change	0	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R -
Exceeded Time of Other PDT	7	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 675.64
Undefined	4	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 420.74
Machine Breakdown	99	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R 10 629.61
Material Shortage	30	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 852.24
Material Quality	11	R 1 287.27	R37 433.16	R 103.82	R 1 630.43	R 2 593.44		R 43 048.12	R 7 939.94
MHE	1	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 130.00
Man	49	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 4 568.61
Technical	20	R 1 287.27	R11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R 5 546.03
Power Failure	24	R 1 287.27	R11 289.08	R 103.82		R 2 593.44		R 15 273.61	R 6 219.04
Other UPDT	58	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 5 382.27
Rate Loss	335	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R 36 047.28
Quality Loss	0	R 1 287.27	R11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R -
TOTAL LOSS	809								**R 114 432.08**

M2 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 027.24
Start-up & 2C	1	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 55.06
Planned Maintenance (PM)	30	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 17 753.68	R 9 003.91
Size Change	0	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R -
Material Change	83	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R 23 344.83
Other PDT	28	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 595.27
Exceeded Time of Lunch & Break	0	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 11.25
Exceeded Time of Start-Up & 2C	3	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 245.43
Exceeded Time of PM	3	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R 369.14
Exceeded Time of Size Change	17	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 1 629.81
Exceeded Time of Material Change	0	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R -
Exceeded Time of Other PDT	4	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 342.81
Undefined	22	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 098.18
Machine Breakdown	46	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R 4 949.82
Material Shortage	1	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 98.44
Material Quality	16	R 1 287.27	R 37 433.16	R 103.82	R 1 630.43	R 2 593.44		R 43 048.12	R 11 658.76
MHE	0	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R -
Man	88	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 8 212.87
Technical	9	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R 2 643.17
Power Failure	32	R 1 287.27	R 11 289.08	R 103.82		R 2 593.44		R 15 273.61	R 8 161.91
Other UPDT	73	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 6 810.92
Rate Loss	115	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R 12 399.12
Quality Loss	0	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R -
TOTAL LOSS	593								**R 96 657.94**

M2 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 027.24
Start-up & 2C	1	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 55.06
Planned Maintenance (PM)	30	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 17 753.68	R 9 003.91
Size Change	0	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R -
Material Change	83	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R 23 344.83
Other PDT	28	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 595.27
Exceeded Time of Lunch & Break	0	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 11.25
Exceeded Time of Start-Up & 2C	3	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 245.43
Exceeded Time of PM	3	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R 369.14
Exceeded Time of Size Change	17	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 1 629.81
Exceeded Time of Material Change	0	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R -
Exceeded Time of Other PDT	4	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 342.81
Undefined	22	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 2 098.18
Machine Breakdown	46	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R 4 949.82
Material Shortage	1	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 98.44
Material Quality	16	R 1 287.27	R 37 433.16	R 103.82	R 1 630.43	R 2 593.44		R 43 048.12	R 11 658.76
MHE	0	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R -
Man	88	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 8 212.87
Technical	9	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R 2 643.17
Power Failure	32	R 1 287.27	R 11 289.08	R 103.82		R 2 593.44		R 15 273.61	R 8 161.91
Other UPDT	73	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44		R 5 614.96	R 6 810.92
Rate Loss	145	R 1 287.27		R 103.82	R 1 630.43	R 2 593.44	R 849.65	R 6 464.61	R 15 590.02
Quality Loss	56	R 1 287.27	R 11 289.08	R 103.82	R 1 630.43	R 2 593.44		R 16 904.04	R 15 716.22
TOTAL LOSS	679								**R 115 565.06**

M3 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 1 950.35
Start-up & 2C	1	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 52.97
Planned Maintenance (PM)	30	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 16 622.94	R 8 430.45
Size Change	0	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58		R 15 611.95	R -
Material Change	83	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58		R 15 611.95	R 21 560.44
Other PDT	28	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 2 496.83
Exceeded Time of Lunch & Break	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 10.82
Exceeded Time of Start-Up & 2C	3	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 236.12
Exceeded Time of PM	3	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 366.19
Exceeded Time of Size Change	17	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 1 568.00
Exceeded Time of Material Change	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R -
Exceeded Time of Other PDT	4	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 329.81
Undefined	22	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 2 018.60
Machine Breakdown	46	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 4 910.29
Material Shortage	1	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 94.70
Material Quality	16	R 1 195.45	R 37 433.16	R 591.24	R 1 168.72	R 2 446.58		R 42 835.16	R 11 601.08
MHE	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R -
Man	88	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 7 901.37
Technical	9	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58		R 15 611.95	R 2 441.14
Power Failure	32	R 1 195.45	R 10 209.96	R 591.24		R 2 446.58		R 14 443.23	R 7 718.17
Other UPDT	73	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 6 552.59
Rate Loss	131	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 13 954.84
Quality Loss	0	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58		R 15 611.95	R -
TOTAL LOSS	609								**R 94 194.75**

M3 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 1 950.35
Start-up & 2C	1	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 52.97
Planned Maintenance (PM)	30	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 16 622.94	R 8 430.45
Size Change	0	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58		R 15 611.95	R -
Material Change	83	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58		R 15 611.95	R 21 560.44
Other PDT	28	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 2 496.83
Exceeded Time of Lunch & Break	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 10.82
Exceeded Time of Start-Up & 2C	3	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 236.12
Exceeded Time of PM	3	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 366.19
Exceeded Time of Size Change	17	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 1 568.00
Exceeded Time of Material Change	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R -
Exceeded Time of Other PDT	4	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 329.81
Undefined	22	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 2 018.60
Machine Breakdown	46	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 4 910.29
Material Shortage	1	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 94.70
Material Quality	16	R 1 195.45	R 37 433.16	R 591.24	R 1 168.72	R 2 446.58		R 42 835.16	R 11 601.08
MHE	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R -
Man	88	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 7 901.37
Technical	9	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58		R 15 611.95	R 2 441.14
Power Failure	32	R 1 195.45	R 10 209.96	R 591.24		R 2 446.58		R 14 443.23	R 7 718.17
Other UPDT	73	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 6 552.59
Rate Loss	47	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 5 031.01
Quality Loss	0	R 1 195.45	R 10 209.96	R 591.24	R 1 168.72	R 2 446.58		R 15 611.95	R -
TOTAL LOSS	525								**R 85 270.92**

M3 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 1 950.35
Start-up & 2C	1	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 52.97
Planned Maintenance (PM)	30	R 1 195.45	R10 209.96	R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R16 622.94	R 8 430.45
Size Change	0	R 1 195.45	R10 209.96	R 591.24	R 1 168.72	R 2 446.58		R15 611.95	R -
Material Change	83	R 1 195.45	R10 209.96	R 591.24	R 1 168.72	R 2 446.58		R15 611.95	R 21 560.44
Other PDT	28	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 2 496.83
Exceeded Time of Lunch & Break	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 10.82
Exceeded Time of Start-Up & 2C	3	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 236.12
Exceeded Time of PM	3	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 366.19
Exceeded Time of Size Change	17	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 1 568.00
Exceeded Time of Material Change	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R -
Exceeded Time of Other PDT	4	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 329.81
Undefined	22	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 2 018.60
Machine Breakdown	46	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 4 910.29
Material Shortage	1	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 94.70
Material Quality	16	R 1 195.45	R37 433.16	R 591.24	R 1 168.72	R 2 446.58		R42 835.16	R 11 601.08
MHE	0	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R -
Man	88	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 7 901.37
Technical	9	R 1 195.45	R10 209.96	R 591.24	R 1 168.72	R 2 446.58		R15 611.95	R 2 441.14
Power Failure	32	R 1 195.45	R10 209.96	R 591.24		R 2 446.58		R14 443.23	R 7 718.17
Other UPDT	73	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58		R 5 401.99	R 6 552.59
Rate Loss	184	R 1 195.45		R 591.24	R 1 168.72	R 2 446.58	R 1 010.99	R 6 412.98	R 19 637.09
Quality Loss	62	R 1 195.45	R10 209.96	R 591.24	R 1 168.72	R 2 446.58		R15 611.95	R 16 057.57
TOTAL LOSS	724								**R 115 934.57**

T1 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 3 909.97
Start-up & 2C	1	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 106.19
Planned Maintenance (PM)	30	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 12 823.53	R 6 503.55
Size Change	0	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 12 823.53	R -
Material Change	83	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 14 955.99
Other PDT	28	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 3 953.38
Exceeded Time of Lunch & Break	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 17.14
Exceeded Time of Start-Up & 2C	3	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 373.86
Exceeded Time of PM	3	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 602.26
Exceeded Time of Size Change	17	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 3 061.45
Exceeded Time of Material Change	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R -
Exceeded Time of Other PDT	4	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 522.20
Undefined	22	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 3 196.17
Machine Breakdown	46	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 8 075.75
Material Shortage	1	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 149.95
Material Quality	16	R 3 663.97	R11 289.08	R 223.47	R 2 096.07	R 2 569.80		R 19 842.38	R 5 373.93
MHE	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R -
Man	88	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 12 510.72
Technical	9	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 1 693.36
Power Failure	32	R 3 663.97	R 2 276.36	R 223.47		R 2 569.80		R 8 733.59	R 4 667.05
Other UPDT	73	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 10 375.11
Rate Loss	-151	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	-R 26 618.88
Quality Loss	0	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R -
TOTAL LOSS	327								**R 53 429.16**

T1 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 3 909.97
Start-up & 2C	1	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 106.19
Planned Maintenance (PM)	30	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 12 823.53	R 6 503.55
Size Change	0	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 12 823.53	R -
Material Change	83	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 14 955.99
Other PDT	28	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 3 953.38
Exceeded Time of Lunch & Break	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 17.14
Exceeded Time of Start-Up & 2C	3	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 373.86
Exceeded Time of PM	3	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 602.26
Exceeded Time of Size Change	17	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 3 061.45
Exceeded Time of Material Change	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R -
Exceeded Time of Other PDT	4	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 522.20
Undefined	22	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 3 196.17
Machine Breakdown	46	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 8 075.75
Material Shortage	1	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 149.95
Material Quality	16	R 3 663.97	R 11 289.08	R 223.47	R 2 096.07	R 2 569.80		R 19 842.38	R 5 373.93
MHE	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R -
Man	88	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 12 510.72
Technical	9	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 1 693.36
Power Failure	32	R 3 663.97	R 2 276.36	R 223.47		R 2 569.80		R 8 733.59	R 4 667.05
Other UPDT	73	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 10 375.11
Rate Loss	-25	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	-R 4 440.93
Quality Loss	0	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R -
TOTAL LOSS	453								**R 75 607.11**

T1 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 3 909.97
Start-up & 2C	1	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 106.19
Planned Maintenance (PM)	30	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 12 823.53	R 6 503.55
Size Change	0	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 12 823.53	R -
Material Change	83	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 14 955.99
Other PDT	28	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 3 953.38
Exceeded Time of Lunch & Break	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 17.14
Exceeded Time of Start-Up & 2C	3	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 373.86
Exceeded Time of PM	3	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 602.26
Exceeded Time of Size Change	17	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 3 061.45
Exceeded Time of Material Change	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R -
Exceeded Time of Other PDT	4	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 522.20
Undefined	22	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 3 196.17
Machine Breakdown	46	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R 8 075.75
Material Shortage	1	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 149.95
Material Quality	16	R 3 663.97	R 11 289.08	R 223.47	R 2 096.07	R 2 569.80		R 19 842.38	R 5 373.93
MHE	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R -
Man	88	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 12 510.72
Technical	9	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 1 693.36
Power Failure	32	R 3 663.97	R 2 276.36	R 223.47		R 2 569.80		R 8 733.59	R 4 667.05
Other UPDT	73	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80		R 8 553.30	R 10 375.11
Rate Loss	0	R 3 663.97		R 223.47	R 2 096.07	R 2 569.80	R 1 993.87	R 10 547.17	R -
Quality Loss	24	R 3 663.97	R 2 276.36	R 223.47	R 2 096.07	R 2 569.80		R 10 829.66	R 4 288.55
TOTAL LOSS	502								**R 84 336.59**

T2 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 2 426.98
Start-up & 2C	1	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 65.91
Planned Maintenance (PM)	30	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15	R 719.75	R 7 441.87	R 3 774.20
Size Change	0	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15	R 719.75	R 7 441.87	R -
Material Change	83	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 9 283.40
Other PDT	28	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 2 054.86
Exceeded Time of Lunch & Break	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 8.91
Exceeded Time of Start-Up & 2C	3	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 194.32
Exceeded Time of PM	3	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 294.96
Exceeded Time of Size Change	17	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 1 499.36
Exceeded Time of Material Change	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R -
Exceeded Time of Other PDT	4	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 271.43
Undefined	22	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 1 661.28
Machine Breakdown	46	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 3 955.13
Material Shortage	1	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 77.94
Material Quality	16	R 2 082.55	R 11 289.08	R 242.66	R 857.39	R 1 263.15		R 15 734.84	R 4 261.48
MHE	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R -
Man	88	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 6 502.72
Technical	9	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 1 051.09
Power Failure	32	R 2 082.55	R 2 276.36	R 242.66		R 1 263.15		R 5 864.73	R 3 133.99
Other UPDT	73	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 5 392.69
Rate Loss	-262	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	-R 22 556.07
Quality Loss	0	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R -
TOTAL LOSS	216								**R 23 354.57**

T2 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 2 426.98
Start-up & 2C	1	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 65.91
Planned Maintenance (PM)	30	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15	R 719.75	R 7 441.87	R 3 774.20
Size Change	0	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15	R 719.75	R 7 441.87	R -
Material Change	83	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 9 283.40
Other PDT	28	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 2 054.86
Exceeded Time of Lunch & Break	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 8.91
Exceeded Time of Start-Up & 2C	3	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 194.32
Exceeded Time of PM	3	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 294.96
Exceeded Time of Size Change	17	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 1 499.36
Exceeded Time of Material Change	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R -
Exceeded Time of Other PDT	4	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 271.43
Undefined	22	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 1 661.28
Machine Breakdown	46	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 3 955.13
Material Shortage	1	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 77.94
Material Quality	16	R 2 082.55	R 11 289.08	R 242.66	R 857.39	R 1 263.15		R 15 734.84	R 4 261.48
MHE	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R -
Man	88	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 6 502.72
Technical	9	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 1 051.09
Power Failure	32	R 2 082.55	R 2 276.36	R 242.66		R 1 263.15		R 5 864.73	R 3 133.99
Other UPDT	73	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 5 392.69
Rate Loss	-165	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	-R 14 222.72
Quality Loss	0	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R -
TOTAL LOSS	313								**R 31 687.92**

T2 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 2 426.98
Start-up & 2C	1	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 65.91
Planned Maintenance (PM)	30	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15	R 719.75	R 7 441.87	R 3 774.20
Size Change	0	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15	R 719.75	R 7 441.87	R -
Material Change	83	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 9 283.40
Other PDT	28	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 2 054.86
Exceeded Time of Lunch & Break	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 8.91
Exceeded Time of Start-Up & 2C	3	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 194.32
Exceeded Time of PM	3	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 294.96
Exceeded Time of Size Change	17	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 1 499.36
Exceeded Time of Material Change	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R -
Exceeded Time of Other PDT	4	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 271.43
Undefined	22	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 1 661.28
Machine Breakdown	46	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 3 955.13
Material Shortage	1	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 77.94
Material Quality	16	R 2 082.55	R11 289.08	R 242.66	R 857.39	R 1 263.15		R15 734.84	R 4 261.48
MHE	0	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R -
Man	88	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 6 502.72
Technical	9	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 1 051.09
Power Failure	32	R 2 082.55	R 2 276.36	R 242.66		R 1 263.15		R 5 864.73	R 3 133.99
Other UPDT	73	R 2 082.55		R 242.66	R 857.39	R 1 263.15		R 4 445.76	R 5 392.69
Rate Loss	44	R 2 082.55		R 242.66	R 857.39	R 1 263.15	R 719.75	R 5 165.51	R 3 781.40
Quality Loss	56	R 2 082.55	R 2 276.36	R 242.66	R 857.39	R 1 263.15		R 6 722.12	R 6 297.51
TOTAL LOSS	578								**R 55 989.54**

T3 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 2 345.34
Start-up & 2C	1	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 63.70
Planned Maintenance (PM)	30	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 7 473.46	R 3 790.22
Size Change	0	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 7 473.46	R -
Material Change	83	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 8 971.14
Other PDT	28	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 2 296.15
Exceeded Time of Lunch & Break	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 9.95
Exceeded Time of Start-Up & 2C	3	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 217.14
Exceeded Time of PM	3	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 339.48
Exceeded Time of Size Change	17	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 1 725.69
Exceeded Time of Material Change	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R -
Exceeded Time of Other PDT	4	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 303.30
Undefined	22	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 1 856.36
Machine Breakdown	46	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 4 552.16
Material Shortage	1	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 87.09
Material Quality	16	R 1 856.64	R11 289.08	R 300.49	R 1 086.54	R 1 724.13		R 16 256.89	R 4 402.87
MHE	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R -
Man	88	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 7 266.31
Technical	9	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 1 015.74
Power Failure	32	R 1 856.64	R 1 528.21	R 300.49		R 1 724.13		R 5 409.47	R 2 890.71
Other UPDT	73	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 6 025.93
Rate Loss	64	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 6 341.60
Quality Loss	0	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R -
TOTAL LOSS	542								**R 54 500.88**

T3 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 2 345.34
Start-up & 2C	1	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 63.70
Planned Maintenance (PM)	30	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 7 473.46	R 3 790.22
Size Change	0	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 7 473.46	R -
Material Change	83	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 8 971.14
Other PDT	28	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 2 296.15
Exceeded Time of Lunch & Break	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 9.95
Exceeded Time of Start-Up & 2C	3	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 217.14
Exceeded Time of PM	3	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 339.48
Exceeded Time of Size Change	17	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 1 725.69
Exceeded Time of Material Change	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R -
Exceeded Time of Other PDT	4	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 303.30
Undefined	22	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 1 856.36
Machine Breakdown	46	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 4 552.16
Material Shortage	1	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 87.09
Material Quality	16	R 1 856.64	R 11 289.08	R 300.49	R 1 086.54	R 1 724.13		R 16 256.89	R 4 402.87
MHE	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R -
Man	88	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 7 266.31
Technical	9	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 1 015.74
Power Failure	32	R 1 856.64	R 1 528.21	R 300.49		R 1 724.13		R 5 409.47	R 2 890.71
Other UPDT	73	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 6 025.93
Rate Loss	58	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 5 747.45
Quality Loss	0	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R -
TOTAL LOSS	536								**R 53 906.73**

T3 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 2 345.34
Start-up & 2C	1	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 63.70
Planned Maintenance (PM)	30	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 7 473.46	R 3 790.22
Size Change	0	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 7 473.46	R -
Material Change	83	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 8 971.14
Other PDT	28	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 2 296.15
Exceeded Time of Lunch & Break	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 9.95
Exceeded Time of Start-Up & 2C	3	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 217.14
Exceeded Time of PM	3	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 339.48
Exceeded Time of Size Change	17	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 1 725.69
Exceeded Time of Material Change	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R -
Exceeded Time of Other PDT	4	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 303.30
Undefined	22	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 1 856.36
Machine Breakdown	46	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 4 552.16
Material Shortage	1	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 87.09
Material Quality	16	R 1 856.64	R 11 289.08	R 300.49	R 1 086.54	R 1 724.13		R 16 256.89	R 4 402.87
MHE	0	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R -
Man	88	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 7 266.31
Technical	9	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R 1 015.74
Power Failure	32	R 1 856.64	R 1 528.21	R 300.49		R 1 724.13		R 5 409.47	R 2 890.71
Other UPDT	73	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13		R 4 967.81	R 6 025.93
Rate Loss	16	R 1 856.64		R 300.49	R 1 086.54	R 1 724.13	R 977.44	R 5 945.25	R 1 546.09
Quality Loss	0	R 1 856.64	R 1 528.21	R 300.49	R 1 086.54	R 1 724.13		R 6 496.02	R -
TOTAL LOSS	494								**R 49 705.37**

T4 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 1 605.27
Start-up & 2C	1	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 43.60
Planned Maintenance (PM)	30	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85	R 286.94	R 4 733.13	R 2 400.44
Size Change	0	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85	R 286.94	R 4 733.13	R -
Material Change	83	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 6 140.28
Other PDT	28	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 1 535.91
Exceeded Time of Lunch & Break	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 6.66
Exceeded Time of Start-Up & 2C	3	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 145.25
Exceeded Time of PM	3	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 206.13
Exceeded Time of Size Change	17	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 1 047.83
Exceeded Time of Material Change	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R -
Exceeded Time of Other PDT	4	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 202.88
Undefined	22	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 1 241.73
Machine Breakdown	46	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 2 764.05
Material Shortage	1	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 58.26
Material Quality	16	R 701.22	R 11 289.08	R 347.09	R 1 596.84	R 677.85		R 14 612.07	R 3 957.40
MHE	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R -
Man	88	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 4 860.47
Technical	9	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 695.22
Power Failure	32	R 701.22	R 1 123.20	R 347.09		R 677.85		R 2 849.35	R 1 522.63
Other UPDT	73	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 4 030.78
Rate Loss	-26	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	-R 1 564.31
Quality Loss	76	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 5 631.84
TOTAL LOSS	528								**R 36 532.31**

T4 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 1 605.27
Start-up & 2C	1	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 43.60
Planned Maintenance (PM)	30	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85	R 286.94	R 4 733.13	R 2 400.44
Size Change	0	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85	R 286.94	R 4 733.13	R -
Material Change	83	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 6 140.28
Other PDT	28	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 1 535.91
Exceeded Time of Lunch & Break	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 6.66
Exceeded Time of Start-Up & 2C	3	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 145.25
Exceeded Time of PM	3	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 206.13
Exceeded Time of Size Change	17	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 1 047.83
Exceeded Time of Material Change	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R -
Exceeded Time of Other PDT	4	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 202.88
Undefined	22	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 1 241.73
Machine Breakdown	46	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 2 764.05
Material Shortage	1	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 58.26
Material Quality	16	R 701.22	R 11 289.08	R 347.09	R 1 596.84	R 677.85		R 14 612.07	R 3 957.40
MHE	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R -
Man	88	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 4 860.47
Technical	9	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 695.22
Power Failure	32	R 701.22	R 1 123.20	R 347.09		R 677.85		R 2 849.35	R 1 522.63
Other UPDT	73	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 4 030.78
Rate Loss	7	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 392.94
Quality Loss	95	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 7 074.65
TOTAL LOSS	580								**R 39 932.36**

T4 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 1 605.27
Start-up & 2C	1	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 43.60
Planned Maintenance (PM)	30	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85	R 286.94	R 4 733.13	R 2 400.44
Size Change	0	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85	R 286.94	R 4 733.13	R -
Material Change	83	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 6 140.28
Other PDT	28	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 1 535.91
Exceeded Time of Lunch & Break	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 6.66
Exceeded Time of Start-Up & 2C	3	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 145.25
Exceeded Time of PM	3	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 206.13
Exceeded Time of Size Change	17	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 1 047.83
Exceeded Time of Material Change	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R -
Exceeded Time of Other PDT	4	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 202.88
Undefined	22	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 1 241.73
Machine Breakdown	46	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 2 764.05
Material Shortage	1	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 58.26
Material Quality	16	R 701.22	R 11 289.08	R 347.09	R 1 596.84	R 677.85		R 14 612.07	R 3 957.40
MHE	0	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R -
Man	88	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 4 860.47
Technical	9	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R 695.22
Power Failure	32	R 701.22	R 1 123.20	R 347.09		R 677.85		R 2 849.35	R 1 522.63
Other UPDT	73	R 701.22		R 347.09	R 1 596.84	R 677.85		R 3 322.99	R 4 030.78
Rate Loss	27	R 701.22		R 347.09	R 1 596.84	R 677.85	R 286.94	R 3 609.93	R 1 640.73
Quality Loss	0	R 701.22	R 1 123.20	R 347.09	R 1 596.84	R 677.85		R 4 446.19	R -
TOTAL LOSS	505								**R 34 105.50**

T5 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 1 588.29
Start-up & 2C	1	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 43.14
Planned Maintenance (PM)	30	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 862.60	R 2 466.10
Size Change	0	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 862.60	R -
Material Change	83	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 6 075.35
Other PDT	28	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 1 683.57
Exceeded Time of Lunch & Break	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 7.30
Exceeded Time of Start-Up & 2C	3	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 159.21
Exceeded Time of PM	3	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 234.45
Exceeded Time of Size Change	17	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 1 191.79
Exceeded Time of Material Change	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R -
Exceeded Time of Other PDT	4	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 222.38
Undefined	22	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 1 361.11
Machine Breakdown	46	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 3 143.80
Material Shortage	1	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 63.86
Material Quality	16	R 759.76	R 11 289.08	R 87.79	R 2 024.33	R 770.58		R 14 931.55	R 4 043.92
MHE	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R -
Man	88	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 5 327.76
Technical	9	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 687.87
Power Failure	32	R 759.76	R 756.70	R 87.79		R 770.58		R 2 374.84	R 1 269.07
Other UPDT	73	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 4 418.30
Rate Loss	-62	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	-R 4 242.76
Quality Loss	0	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R -
TOTAL LOSS	416								**R 29 744.52**

T5 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 1 588.29
Start-up & 2C	1	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 43.14
Planned Maintenance (PM)	30	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 862.60	R 2 466.10
Size Change	0	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 862.60	R -
Material Change	83	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 6 075.35
Other PDT	28	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 1 683.57
Exceeded Time of Lunch & Break	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 7.30
Exceeded Time of Start-Up & 2C	3	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 159.21
Exceeded Time of PM	3	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 234.45
Exceeded Time of Size Change	17	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 1 191.79
Exceeded Time of Material Change	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R -
Exceeded Time of Other PDT	4	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 222.38
Undefined	22	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 1 361.11
Machine Breakdown	46	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 3 143.80
Material Shortage	1	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 63.86
Material Quality	16	R 759.76	R 11 289.08	R 87.79	R 2 024.33	R 770.58		R 14 931.55	R 4 043.92
MHE	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R -
Man	88	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 5 327.76
Technical	9	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 687.87
Power Failure	32	R 759.76	R 756.70	R 87.79		R 770.58		R 2 374.84	R 1 269.07
Other UPDT	73	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 4 418.30
Rate Loss	17	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 1 138.09
Quality Loss	0	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R -
TOTAL LOSS	495								**R 35 125.36**

T5 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 1 588.29
Start-up & 2C	1	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 43.14
Planned Maintenance (PM)	30	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 862.60	R 2 466.10
Size Change	0	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 862.60	R -
Material Change	83	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 6 075.35
Other PDT	28	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 1 683.57
Exceeded Time of Lunch & Break	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 7.30
Exceeded Time of Start-Up & 2C	3	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 159.21
Exceeded Time of PM	3	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 234.45
Exceeded Time of Size Change	17	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 1 191.79
Exceeded Time of Material Change	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R -
Exceeded Time of Other PDT	4	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 222.38
Undefined	22	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 1 361.11
Machine Breakdown	46	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 3 143.80
Material Shortage	1	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 63.86
Material Quality	16	R 759.76	R 11 289.08	R 87.79	R 2 024.33	R 770.58		R 14 931.55	R 4 043.92
MHE	0	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R -
Man	88	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 5 327.76
Technical	9	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R 687.87
Power Failure	32	R 759.76	R 756.70	R 87.79		R 770.58		R 2 374.84	R 1 269.07
Other UPDT	73	R 759.76		R 87.79	R 2 024.33	R 770.58		R 3 642.47	R 4 418.30
Rate Loss	25	R 759.76		R 87.79	R 2 024.33	R 770.58	R 463.43	R 4 105.90	R 1 739.36
Quality Loss	0	R 759.76	R 756.70	R 87.79	R 2 024.33	R 770.58		R 4 399.18	R -
TOTAL LOSS	504								**R 35 726.64**

T6 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 1 580.91
Start-up & 2C	1	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 42.94
Planned Maintenance (PM)	30	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 5 922.18	R 3 003.48
Size Change	0	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 5 922.18	R -
Material Change	83	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 6 047.11
Other PDT	28	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 1 149.43
Exceeded Time of Lunch & Break	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 4.98
Exceeded Time of Start-Up & 2C	3	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 108.70
Exceeded Time of PM	3	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 230.14
Exceeded Time of Size Change	17	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 1 169.85
Exceeded Time of Material Change	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R -
Exceeded Time of Other PDT	4	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 151.83
Undefined	22	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 929.28
Machine Breakdown	46	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 3 085.92
Material Shortage	1	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 43.60
Material Quality	16	R 869.61	R11 289.08	R 18.23	R 499.16	R 1 099.85		R 13 775.92	R 3 730.95
MHE	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R -
Man	88	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 3 637.45
Technical	9	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 684.67
Power Failure	32	R 869.61	R 1 891.88	R 18.23		R 1 099.85		R 3 879.56	R 2 073.16
Other UPDT	73	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 3 016.53
Rate Loss	554	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 37 208.25
Quality Loss	68	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 4 996.52
TOTAL LOSS	1101								**R 72 895.69**

T6 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 1 580.91
Start-up & 2C	1	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 42.94
Planned Maintenance (PM)	30	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 5 922.18	R 3 003.48
Size Change	0	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 5 922.18	R -
Material Change	83	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 6 047.11
Other PDT	28	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 1 149.43
Exceeded Time of Lunch & Break	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 4.98
Exceeded Time of Start-Up & 2C	3	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 108.70
Exceeded Time of PM	3	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 230.14
Exceeded Time of Size Change	17	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 1 169.85
Exceeded Time of Material Change	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R -
Exceeded Time of Other PDT	4	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 151.83
Undefined	22	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 929.28
Machine Breakdown	46	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 3 085.92
Material Shortage	1	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 43.60
Material Quality	16	R 869.61	R11 289.08	R 18.23	R 499.16	R 1 099.85		R13 775.92	R 3 730.95
MHE	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R -
Man	88	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 3 637.45
Technical	9	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 684.67
Power Failure	32	R 869.61	R 1 891.88	R 18.23		R 1 099.85		R 3 879.56	R 2 073.16
Other UPDT	73	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 3 016.53
Rate Loss	189	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 12 678.45
Quality Loss	0	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R -
TOTAL LOSS	667								**R 43 369.37**

T6 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 1 580.91
Start-up & 2C	1	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 42.94
Planned Maintenance (PM)	30	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 5 922.18	R 3 003.48
Size Change	0	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 5 922.18	R -
Material Change	83	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 6 047.11
Other PDT	28	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 1 149.43
Exceeded Time of Lunch & Break	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 4.98
Exceeded Time of Start-Up & 2C	3	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 108.70
Exceeded Time of PM	3	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 230.14
Exceeded Time of Size Change	17	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 1 169.85
Exceeded Time of Material Change	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R -
Exceeded Time of Other PDT	4	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 151.83
Undefined	22	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 929.28
Machine Breakdown	46	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 3 085.92
Material Shortage	1	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 43.60
Material Quality	16	R 869.61	R 11 289.08	R 18.23	R 499.16	R 1 099.85		R 13 775.92	R 3 730.95
MHE	0	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R -
Man	88	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 3 637.45
Technical	9	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R 684.67
Power Failure	32	R 869.61	R 1 891.88	R 18.23		R 1 099.85		R 3 879.56	R 2 073.16
Other UPDT	73	R 869.61		R 18.23	R 499.16	R 1 099.85		R 2 486.85	R 3 016.53
Rate Loss	250	R 869.61		R 18.23	R 499.16	R 1 099.85	R 1 543.45	R 4 030.30	R 16 780.61
Quality Loss	0	R 869.61	R 1 891.88	R 18.23	R 499.16	R 1 099.85		R 4 378.72	R -
TOTAL LOSS	728								**R 47 471.53**

S1 Sep-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 400.25
Start-up & 2C	1	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 10.87
Planned Maintenance (PM)	30	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 2 859.24
Size Change	0	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R -
Material Change	83	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 7 785.88
Other PDT	28	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 512.40
Exceeded Time of Lunch & Break	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 2.22
Exceeded Time of Start-Up & 2C	3	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 48.46
Exceeded Time of PM	3	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 63.30
Exceeded Time of Size Change	17	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 321.79
Exceeded Time of Material Change	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R -
Exceeded Time of Other PDT	4	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 67.68
Undefined	22	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 414.26
Machine Breakdown	46	R 562.02		R 33.76	R 3.59	R 509.24	R 192.03	R 1 300.63	R 995.87
Material Shortage	1	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 19.44
Material Quality	16	R 562.02	R 2 278.04	R 33.76	R 3.59	R 509.24		R 3 386.64	R 917.21
MHE	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R -
Man	88	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 1 621.53
Technical	9	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 881.54
Power Failure	32	R 562.02	R 4 529.16	R 33.76		R 509.24		R 5 634.18	R 3 010.79
Other UPDT	73	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 1 344.74
Rate Loss	36	R 562.02		R 33.76	R 3.59	R 509.24	R 192.03	R 1 300.63	R 771.27
Quality Loss	0	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R -
TOTAL LOSS	514								**R 22 048.74**

S1 Oct-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 400.25
Start-up & 2C	1	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 10.87
Planned Maintenance (PM)	30	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 2 859.24
Size Change	0	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R -
Material Change	83	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 7 785.88
Other PDT	28	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 512.40
Exceeded Time of Lunch & Break	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 2.22
Exceeded Time of Start-Up & 2C	3	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 48.46
Exceeded Time of PM	3	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 63.30
Exceeded Time of Size Change	17	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 321.79
Exceeded Time of Material Change	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R -
Exceeded Time of Other PDT	4	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 67.68
Undefined	22	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 414.26
Machine Breakdown	46	R 562.02		R 33.76	R 3.59	R 509.24	R 192.03	R 1 300.63	R 995.87
Material Shortage	1	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 19.44
Material Quality	16	R 562.02	R 2 278.04	R 33.76	R 3.59	R 509.24		R 3 386.64	R 917.21
MHE	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R -
Man	88	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 1 621.53
Technical	9	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 881.54
Power Failure	32	R 562.02	R 4 529.16	R 33.76		R 509.24		R 5 634.18	R 3 010.79
Other UPDT	73	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 1 344.74
Rate Loss	264	R 562.02		R 33.76	R 3.59	R 509.24	R 192.03	R 1 300.63	R 5 730.75
Quality Loss	0	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R -
TOTAL LOSS	743								**R 27 008.22**

S1 Nov-23	OEE	Labour	Material	Depreciation	Utilities	Support services	Maintenance Services	TOTAL	ABE
Lunch & Break	22	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 400.25
Start-up & 2C	1	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 10.87
Planned Maintenance (PM)	30	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 2 859.24
Size Change	0	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R -
Material Change	83	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 7 785.88
Other PDT	28	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 512.40
Exceeded Time of Lunch & Break	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 2.22
Exceeded Time of Start-Up & 2C	3	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 48.46
Exceeded Time of PM	3	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 63.30
Exceeded Time of Size Change	17	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 321.79
Exceeded Time of Material Change	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R -
Exceeded Time of Other PDT	4	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 67.68
Undefined	22	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 414.26
Machine Breakdown	46	R 562.02		R 33.76	R 3.59	R 509.24	R 192.03	R 1 300.63	R 995.87
Material Shortage	1	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 19.44
Material Quality	16	R 562.02	R 2 278.04	R 33.76	R 3.59	R 509.24		R 3 386.64	R 917.21
MHE	0	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R -
Man	88	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 1 621.53
Technical	9	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R 881.54
Power Failure	32	R 562.02	R 4 529.16	R 33.76		R 509.24		R 5 634.18	R 3 010.79
Other UPDT	73	R 562.02		R 33.76	R 3.59	R 509.24		R 1 108.61	R 1 344.74
Rate Loss	249	R 562.02		R 33.76	R 3.59	R 509.24	R 192.03	R 1 300.63	R 5 395.15
Quality Loss	0	R 562.02	R 4 529.16	R 33.76	R 3.59	R 509.24		R 5 637.77	R -
TOTAL LOSS	727								**R 26 672.62**

ANNEXURE K: RESEARCH OBJECTIVES, QUESTIONS, GAPS AND HYPOTHESIS

Table 18: Research Objectives, Questions, Gaps and Hypothesis

	Objective	Question	Gap	Hypothesis
1	Gauge the current proportion of professional that understand OEE and its implications on organizational effectiveness.	What is the current proportion of employees in the manufacturing sector who understand OEE and its impact on overall organizational effectiveness? Furthermore, how is this understanding influenced by adopting a cost-centric approach to OEE?	Despite extensive research on Overall Equipment Effectiveness, there is a research gap in terms of understanding the impact of OEE in manufacturing operations (Contextual Gap).	The proportion of employees in a manufacturing organization that understand OEE is directly affected by the organization following a structured way of calculating OEE as a cost-centric metric.
2	Develop a methodology for expressing OEE as a cost-centric approach to facilitate equipment benchmarking.	Can a structured, replicable cost-centric approach to OEE be developed based on the key strengths and findings in current methodologies, to improve benchmarking of equipment?	The lack of precise benchmarking mechanisms between equipment and organizations impedes the accurate assessment of performance (Methodological Gap).	Implementing Activity-Based Effectiveness (ABE) will yield clear cost allocations for each loss, thus improving benchmarking of equipment.
3	Implement the deduced structured cost application to OEE and contrast the results to the traditional OEE to confirm the impact on decision-making.	How does the performance optimization differ when utilizing the OEE and ABE approaches within an organization, and does it support effective decision making?	The absence of a structured and replicable costing approach to OEE results in incomplete consideration of all associated costs, thus undermining the accuracy of decision-making processes (Methodological Gap).	Implementing Activity-Based Effectiveness (ABE) will yield different results than traditional OEE, thus improving effective decision making.