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Impact of Total Productive Maintenance and Overall Equipment Effectiveness on Productivity in Saudi Arabian Manufacturing Company

Abdulaziz Tobaigi and Mohammed Alamoudi
Department of Industrial Engineering, Faculty of Engineering,
King Abdulaziz University, P.O. Box 80204, Jeddah 21589,
Saudi Arabia.

***Abstract*— This study investigates the interplay between Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE), and operational performance in vegetable oil manufacturing company in Saudi Arabia, with a focus on aligning with Vision 2030 objectives for industrial improvement. Utilizing a quantitative methodology incorporating descriptive statistics and stepwise regression analysis performed in Minitab (α = 0.05 entry/removal). Drawing on empirical data from 31 industry professionals using a 20-item questionnaire, this research contributes to both academic and practical understandings of how TPM and OEE can be leveraged to improve manufacturing output. The regression model explains 59.14% of the variance in productivity (R^2 = 0.5914, adjusted R^2 = 0.5285, $p < 0.001$), with the current role, working experience in manufacturing industry, degree of employee involvement in TPM programs and agreement with the term that states that the implementation of TPM and OEE causes productivity improvements.**

Keywords—Total Productive Maintenance; Overall Equipment Effectiveness; Stepwise Regression; Productivity; Manufacturing; Saudi Arabia Vision 2030.

I. INTRODUCTION

In today's competitive industrial landscape, Total Productive Maintenance (TPM) and Overall Equipment Effectiveness (OEE) are increasingly recognized as strategic tools for enhancing operational performance and production efficiency. TPM is a comprehensive maintenance approach that aims to maximize equipment productivity by involving all employees across the organization. Its core philosophy revolves around proactive and preventive maintenance to achieve zero breakdowns, zero defects, and zero accidents. OEE, on the other hand, is a widely accepted performance metric used to quantify the effectiveness of manufacturing equipment.

The manufacturing industry in Saudi Arabia faces recurrent challenges including equipment failure, unscheduled downtime, and poor production flow. These problems lower efficiency and sustainability, causing firms to seek ways to enhance equipment effectiveness. Although TPM is recognized globally for enhancing OEE and decreasing operational costs, limited research has been conducted on Saudi industries. This research addresses this gap by examining the relationship between TPM pillars, OEE components, and productivity in the Saudi manufacturing environment.

II. THEORETICAL FRAMEWORK

Total Productive Maintenance (TPM) is a predictive maintenance technique with the ultimate goal of increasing equipment effectiveness by eliminating lost time due to equipment failures, product faults, and accidents. TPM differs from conventional maintenance practices because it involves operators and expects employees to be responsible for the equipment [1].

A. TPM Pillars

The TPM framework consists of several key pillars:

1. Autonomous Maintenance: Increases engagement and accountability of operators regarding machine health [2].
2. Planned Maintenance: Minimizes machine downtime and increases lifespan through proactive component replacement [3].
3. Quality Maintenance: Removes equipment conditions that may cause product defects, guaranteeing product quality and minimizing rework [4].
4. Focused Improvement: Small-group activities aimed at eliminating losses and improving equipment efficiency [1].
5. Training and Education: Ensures staff are well-prepared to manage and maintain equipment properly [5].
6. Early Equipment Management: Involves designing and installing new equipment with minimal lifecycle cost and rapid start-up [6].
7. Safety, Health, and Environment: Ensures a safe working environment and eliminates accidents [7].
8. Office TPM Improves administrative processes by reducing inefficiencies and supporting overall operational performance.

B. Overall Equipment Effectiveness (OEE)

OEE is a comprehensive metric that helps companies understand their operational efficiency and prioritize improvement initiatives [4, 8, 9]. It comprises three components:

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1. Availability: The proportion of planned production time for which equipment is available for use, including time for planned and unplanned maintenance and equipment failure [10].
2. Performance: Encompasses slowdowns, micro-stops, and bottlenecks that TPM seeks to eradicate through constant surveillance [11].
3. Quality: Captures losses arising from defects, ensuring that TPM's quality management approaches reduce rework and scrap [12].

C. *Productivity Trends*

Year-over-year analysis from 2020 to 2023 revealed a steady increase in productivity from 44 metric tons per employee in 2020 to 69 metric tons per employee in 2023, representing a 57% improvement over four years. This upward trend aligns with TPM implementation, which likely contributed to reduced downtime and enhanced production efficiency. See figure 1 below.

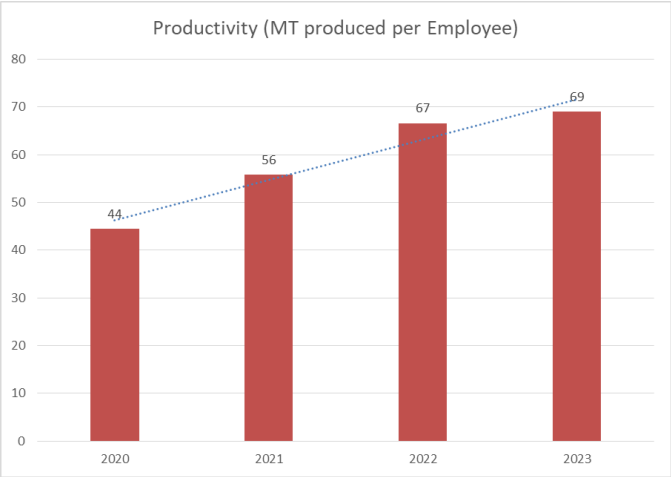

Fig. 1. Productivity trend (2020-2023)

Analysis of production line utilization revealed significant improvements across all processes:

1. Refinery: Increased from 62% (2020) to 87% (2023), a 25% improvement
2. Shortening: Rose from 46% to 78%, achieving a 32% gain
3. Margarine: Increased from 34% to 47%, a 13% growth

These improvements provide contextual evidence of operational gains potentially attributable to TPM.

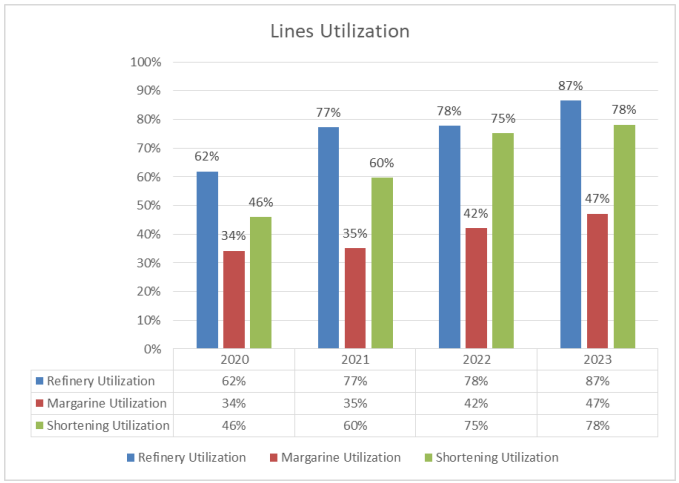

Fig. 2. Line Utilization Improvements

III. METHODOLOGY

This study employed a quantitative research design incorporating both survey and document review methods to collect primary and secondary data for comprehensive assessment of TPM and OEE influence on productivity [15].

A. *Research Instrument: 20-Item Questionnaire*

A structured questionnaire comprising 20 items was developed to capture perceptions on TPM implementation, OEE awareness, and productivity outcomes. The questionnaire was divided into eight sections as shown in Table I. The items were adapted from established TPM literature and refined through expert review.

B. *Sampling Strategy*

A stratified sampling technique was employed to capture diverse perspectives across organizational roles. Target respondents included Maintenance Managers, Production Managers, Quality Managers, Continuous Improvement/Lean Managers, Engineers, and Operators. Data was collected from 31 respondents across a specific manufacturing firm in Saudi Arabia's vegetable oil sector.

IV. DATA ANALYSIS

Stepwise regression analysis was performed using Minitab statistical software to identify the most influential TPM variables affecting productivity. The dependent variable was the productivity index, while independent variables included the 19 variables. Stepwise selection used α-to-enter = 0.05 and α-to-remove = 0.05, ensuring that only predictors with p-values below 0.05 were retained in the final model. Model adequacy was assessed using R^2 and adjusted R^2.

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TABLE I. 20- ITEM QUESTIONNAIRE

Section	Question Number (Q)	Question	Number of levels/options
General Information	1	What is your current role in the company?	7 options
	2	How long have you been working in the manufacturing industry?	4 options
Implementation of TPM and OEE	3	Has your company implemented a Total Productive Maintenance (TPM) program?	3 options
	4	How familiar are you with the concept of Overall Equipment Effectiveness (OEE)?	3 options
Impact of TPM on Performance and Productivity	5	On a scale of 1 to 5, how would you rate the impact of TPM on your company's overall performance?	5 scores
	6	Which TPM component had the greatest impact on improving productivity?	5 options
	7	To what extent do you agree with the statement: "Implementing TPM has led to a significant increase in our production line's productivity"?	5 scores
	8	How often has unplanned downtime due to equipment failures decreased since TPM was implemented?	5 options
Impact of OEE on Equipment and Process Performance	9	How would you rate the impact of OEE factors on productivity improvement?	3 factors 5 levels
	10	Which OEE factor had the most significant impact on productivity in your organization?	3 options
Impact on Employee Workload	11	To what extent has implementing TPM reduced the workload on employees?	5 options
	12	Has TPM reduced the need for overtime hours or extra shifts?	4 options
Waste Reduction and Equipment Loss Prevention	13	To what extent do you agree with the following statement: "TPM has helped reduce waste and equipment-related losses in our company."	5 levels
	14	Which TPM component has been most effective in reducing machine breakdowns and equipment losses?	4 options
TPM Pillars and Employee Involvement	15	How important is employee involvement for the success of the TPM program?	5 levels
	16	To what extent do you agree with the following statement: "Employee training has improved the effectiveness of TPM and OEE implementation."	5 levels
	17	Which TPM pillar has had the greatest impact on employee skills and confidence development?	4 options
Ov erall Performance and Conclusion	18	How would you rate the overall performance of your company after implementing TPM and OEE?	5 levels
	19	To what extent do you agree with the statement: "The implementation of TPM and OEE has met our expectations in terms of productivity improvement."	5 levels
	20	What is the biggest challenge your company has faced in sustaining TPM and OEE programs?	5 options

V. RESULTS AND DISCUSSION

A. Respondent Demographics

The survey collected responses from diverse organizational roles: Maintenance Managers (10%, n=3), Production Managers (6%, n=2), Quality Managers (3%, n=1), Continuous

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Improvement/Lean Managers (35%, n=11), Engineers (16%, n=5), Operators (3%, n=1), and other roles (26%, n=8). The majority of respondents had more than 5 years of industry experience (68%).

B. Stepwise Regression Results (α = 0.05)

Stepwise regression analysis in Minitab with entry/removal criteria set at α = 0.05 on the selected variables. The model explains 59.14% of the variance in productivity, with a high adjusted R^2 confirming model stability. The predicted R^2 of 59.14% suggests good predictive capability. The overall model F-statistic is highly significant ($p < 0.001$), confirming that the selected variables collectively explain a significant portion of productivity variation. See Table 2 below for the Minitab statistical software output. Table 3 shows the Model Summary.

TABLE II. SIGNIFICANT FACTORS COEFFICIENTS

Coefficients					
Term	**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Constant	**1.051**	**0.723**	**1.45**	**0.158**	
1-What is your current role in	**0.119**	**0.0487**	**2.44**	**0.022**	**1.19**
2-How long have you been working	**-0.2237**	**0.0864**	**-2.59**	**0.016**	**1.07**
15-How important is employee in	**0.376**	**0.122**	**3.1**	**0.005**	**1.15**
19-To what extent do you agree	**0.43**	**0.131**	**3.27**	**0.003**	**1.18**

TABLE III. SIGNIFICANT FACTORS COEFFICIENTS

Model Summary			
S	R-sq	R-sq(adj)	R-sq(pred)
0.463647	59.14%	52.85%	31.11%

The fitted linear Regression Equation to estimate the TPM productivity index is shown below:

$$Q7=1.051+ 0.1190\ Q1- 0.2237\ Q2+ 0.376\ Q15+ 0.430\ Q19 \ldots. \textit{Equ.}\ (1)$$

C. Discussion of Findings

The stepwise regression results demonstrate significant factors which contribute to productivity enhancement in Saudi Arabian vegetable oil manufacturing. This includes; The Role of the employee, working experience, employee involvement in TPM and employees positive expectations regarding TPM.

Employee involvements are essential elements for the success of TPM. The variable Question 15, "How important is employee involvement for the success of the TPM program?" have a positive effect on the implementation of TPM, this indicates that employee involvement is considered highly critical for successful TPM implementation. Also, the diversity in job roles (Question 1) ensures a broad perspective on TPM and OEE effectiveness and is reflected on different functions within the organization. For Question 19 "To what extent do you agree with the statement: “The implementation of TPM and OEE has met our expectations in terms of productivity improvement”." this affects the implementation of TPM which is reflected in the reduction of employee workload and overtime hours. The Annual Productivity per employee has increased from 44 Metric Tons in 2020 to 69 Metric Tons in 2023 under the presence of TPM programs. The question regarding number of years in the manufacturing industry (Question 2) shows that the highly experienced staff may be against the implementation of TPM programs. This is explained that they prefer traditional manufacturing protocols.

The results shows that it is important to involve employees in the implementation of TPM programs by assigning them responsibilities and authorities for specific TPM tasks, also to try to rotate that tasks among employees, while they also should be involved in updating the key performance indicators for mean times between failures and the mean number of failures.

VI. CONCLUSION AND RECOMMENDATIONS

This study provides empirical evidence that TPM and OEE significantly enhance productivity in Saudi Arabian manufacturing, aligning with Vision 2030 objectives for industrial improvement. Stepwise regression with α = 0.05 identified significant factors on the implementation of TPM in manufacturing firms including; Role of the Employee, manufacturing working experience, employee involvement and positive expectations regarding the benefits of the implementation of TPM in the working industry.

Future research should explore TPM implementation across diverse Saudi industries, investigate the integration of Industry 4.0 technologies with traditional TPM practices, and employ longitudinal designs with larger samples to confirm causal relationships.

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Conflicts of Interest: The authors declare no conflict of interest.

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