PRAXEOLOGICAL CONCEPTUALIZATION OF THE EFFICIENCY OF A MANUFACTURING COMPANY IN THE CONTEXT OF TPM IMPLEMENTATION

A.W. Wojciechowski
Faculty of Engineering Management, Poznan University of Technology, Strzelecka 11, 64-965 Poznań, Wielkopolska Region, Poland

Abstract
The research problem described in this article concerns the impact of implementing the Total Productive Maintenance concept on the efficiency of the manufacturing company in the process industry. The concept of efficiency used in this publication is considered through the prism of effectiveness and thriftiness, and the mutual relations of both these entities. Such an approach is consistent with the praxeological approach to business efficiency. The use of statistical inference methods demonstrates the positive impact of implementing the Total Productive Maintenance concept on the efficiency of the studied manufacturing plant.

Keywords: TPM, praxeology, efficiency, effectiveness, thriftiness.

1 INTRODUCTION
The author of this article was encouraged to write it due to the fact of very few empirical studies documented in the literature, presenting the subject of the Total Productive Maintenance (TPM) concept influencing the efficiency of a manufacturing company. The publication is intended for managers of manufacturing companies and researchers interested in the subject of continuous improvement and learning the effective action of praxeology. The article raises the following research question: how does implementing the TPM concept affect the efficiency of a manufacturing company?

The results of research carried out by the author show that the implementation of the TPM concept according to strictly defined steps in the given manufacturing company in a process industry has increased the efficiency of the company, both in terms of effectiveness and thriftiness. These studies are a valuable empirical contribution to the literature of management sciences in the field of methods of continuous improvement of manufacturing processes and praxeology. They are also a guideline for managers of manufacturing companies on how to assess the efficiency of the company in the context of the implemented concepts of continuous improvement.

The article consists of five parts. The first one is the introduction, which presents the author’s motivation, raises the research question and briefly presents the research results and their contribution to the management sciences. The second part contains the literature overview in two aspects: praxeological grasp of the efficiency and the impact of the TPM concept on the company’s results. The third part characterises the methodology used. The fourth part presents the research results in the context of effectiveness, thriftiness and their correlation, before and after the implementation of the TPM concept in the company. The last part contains conclusions and suggestions regarding the future research on the presented subject.

2 LITERATURE OVERVIEW
2.1 Praxeological grasp of efficiency
The creator and the greatest authority of the Polish praxeology, T. Kotarbiński, defined the concept of efficiency in two ways. In the universal sense, each value of good work separately. These qualities may include effectiveness, profitability, thriftiness, etc. In the synthetic sense, as a whole of these values taken together [8]. The above-mentioned definitions of efficiency show that efficiency has many values, while the effectiveness and thriftiness seem to be the most crucial ones in the context of business performance. Effectiveness is defined as a positively evaluated compliance of the result with the purpose, while thriftiness, also referred to as the economy, as a relation between outputs and inputs [11]. Productivity is a special case of thriftiness in relation to production. T. Pszczolowski defines productivity as: “a relation between the product and the correspondingly expressed total amount of the resources introduced into the process of work in its given section” [11]. In this article term productivity is used with reference to the notion of thriftiness. According to A. Hamrol, it can be assumed that the efficiency of a production process, and even the efficiency of an entire enterprise, is the result of the efficiency of its operations [6].

Summing up the above definitions, one can assume that an efficient enterprise is an enterprise that achieves its objectives economically. Therefore, it is characterised by a higher effectiveness and productivity in relation to the point of reference, in a praxeological sense. Such a grasp of enterprise’s efficiency is shown in Figure 1.

![Figure 1. Praxeological concept of efficiency. Source: own study.](image-url)

Figure 1 shows a model relation of two variables: effectiveness and productivity. They create four possible areas of the enterprises’ efficiency:
- Area with low effectiveness and low productivity.
- Area with low effectiveness and high productivity.
- Area with high effectiveness and low productivity.
- Area with high effectiveness and high productivity.
The last area characterises efficient enterprises.

2.2 The impact of TPM on the company performance

In the subject literature on the Total Productive Maintenance concept, two trends can be noted in the context of the TPM impact studies on the company performance. The first trend is the research showing a positive impact on the company’s overall performance, most often reflected through the PQCDSM prism (Productivity, Quality, Cost, Delivery, Safety, Morale). These are primarily the works of Japanese authors [10,16]. Suzuki draws attention to the importance of intangible benefits of using TPM, such as a safe workplace, an increase in organisational culture [13]. The McKone’s et al. research is particularly worth quoting, which comprehensively illustrate the positive impact of TPM on the manufacturing results of the company, including the penetration and mutual interactions of the TPM and Just-In-Time concepts. [9].

The second trend of the research includes the specific case studies of implementing TPM, usually focusing on improving a particular indicator. As a rule, these are indicators related to the area of maintenance, such as: OEE, MTTR, MTBF, machine availability [5,7]. The Drakhovský’s study is worth attention, which show a positive impact of the TPM concept on OEE and other maintenance indicators (reduction of failures, reduction of spare parts costs) in Slovak enterprises [3]. There are also positions showing the beneficial influence of TPM on other production indicators, such as: waste or stock availability [14,15].

Table 1. The TPM implementation model in the studied enterprise based on JIPM model [4].

<table>
<thead>
<tr>
<th>Phase</th>
<th>Implementation steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparatory</td>
<td>1. Declaration of the Management</td>
</tr>
<tr>
<td></td>
<td>2. TPM training</td>
</tr>
<tr>
<td></td>
<td>3. Building the TPM organizational structure</td>
</tr>
<tr>
<td></td>
<td>4. Defining goals</td>
</tr>
<tr>
<td></td>
<td>5. Preparing the master plan</td>
</tr>
<tr>
<td>Implementation</td>
<td>6. Piloting</td>
</tr>
<tr>
<td></td>
<td>7. Implementation of the main pillars of TPM</td>
</tr>
<tr>
<td></td>
<td>a. Focused improvements</td>
</tr>
<tr>
<td></td>
<td>b. Autonomous maintenance</td>
</tr>
<tr>
<td></td>
<td>c. Planned maintenance</td>
</tr>
<tr>
<td></td>
<td>d. Training and education</td>
</tr>
<tr>
<td>Evaluation</td>
<td>8. Implementation of quality maintenance pillar</td>
</tr>
<tr>
<td></td>
<td>9. Periodic TPM audit</td>
</tr>
</tbody>
</table>

The subject literature does not have many situations described, which show the negative impact of TPM on the company performance. Rodrigues and Hatakeyama draw attention to the role of the human and organisational factor in the implementation and maintenance of the TPM concept in manufacturing companies. The authors emphasise the fact that the lack of involvement of managers at various levels of management and the lack of TPM affiliation in organizational structures has a negative impact on the manufacturing results of the enterprise [12].

As part of the literature review, the author of the paper did not come across items that would comprehensively describe the impact of the implementation of the TPM concept on the efficiency of the corporation in the synthetic approach, proposed by praxelogists, and thus both in relation to effectiveness and productivity. The task of the article below is to try to fill the research gap.

3 RESEARCH METHODOLOGY

The research methodology was based on a mixed approach, using both qualitative and quantitative methods. The so-called parallel convergent method was used, where the qualitative research in the form of a case study of implementing the TPM concept in the manufacturing company was the superior approach, and in addition, the quantitative research was performed using the appropriate statistical analyses [3]. In this article, the main focus is on quantitative methods analysing the impact of the TPM concept on the company performance.

3.1 Implementation of the TPM concept in the enterprise

The TPM concept has been implemented in one of the production units of a manufacturing company from the process industry, operating globally. The company manufactures high quality components used for producing final products.

The implementation of the concept was based on a model based on the 12-step methodology of the TPM implementation proposed by the Japan Institute of Plant Maintenance, modified for the company use. It was presented in Table 1.

The TPM implementation started in pilot area and continued covering the entire area of the enterprise with its scope.

3.2 Data collection

In order to conduct studies presenting the impact of the TPM concept implementation on the enterprise efficiency in the synthetic approach, the variables representing effectiveness and productivity were defined.

Effectiveness was determined through the final product yield index:

\[
Yield = \frac{\text{Compliant units produced}}{\text{Total units produced}}
\]  

(1)

This indicator measures the ratio of the manufactured finished goods in accordance with the customer’s quality requirements for all manufactured products, both the compliant and defective ones. It shows the percentage of compliance of the result with the goal, meaning the
production of products that meet the customer’s quality requirements. Customer expectations were strictly defined in terms of specifications and defect catalogue, which specified the visual defects. The defective products were identified as part of a visual inspection. In order to confirm the reliability of the visual inspection performed by the quality inspectors, the Kappa compliance test was performed in six months intervals. The Kappa test results in the studied period reached the value over 80%, so the measurement system could be considered acceptable, and the data as reliable.

The data regarding productivity were included in the form of the productivity indicator:

\[ \text{Productivity} = \frac{\text{Total units produced}}{\text{Total manufacturing cost}} \]  \hfill (2)

The aforementioned indicator measures the ratio of the amount of the manufactured final products to the sum of costs in monetary terms in the given period. Productivity data, both the production quantity and costs, should be considered reliable, as the company’s financial reports were their source, prepared in accordance with the applicable accounting policies.

The data regarding the aforementioned variables were collected in monthly intervals for a period of 58 months.

3.3 Statistical data analysis

The collected data were divided into two periods: before the implementation of the TPM concept (in total 30 observations) and the period after the implementation of the TPM concept (in total 28 observations). The data were analysed statistically, including two phases:

- The exploratory analysis stage.
- The explanatory analysis stage.

All stages of the analysis were performed using the statistical software Minitab.

The first step included the data visualisation in the form of graphs over time, the preparation of distribution histograms for effectiveness (yield index) and productivity (productivity index). Descriptive statistics were prepared and analysed, mainly for measures of central tendency and variance. Also the analysis of outlier data was performed. No missing or outdated data were found. The second stage of the analysis used the statistical inference techniques in the form of statistical tests: t-Student and U Mann-Whitney illustrating the impact of implementing the TPM concept on the enterprise efficiency.

4 RESEARCH RESULTS

4.1 Effectiveness

The effectiveness results were presented in Figure 2 in the form of two histograms for the yield of products compliant in terms of quality measured on the percentage basis. The normal distribution curves were adjusted on the histograms. In both cases, the Anderson-Darling test confirmed that the date before and after the implementation of TPM follow the normal distribution (p-value, respectively, 0.21 and 0.86).

![Histogram of Yield](image)

Figure 2. Effectiveness. Source: own study.

The data presented in Figure 2 show that the analysed enterprise achieved a higher effectiveness after the implementation of TPM. The average yield increased from 90.35% before the implementation to 94.48% after the implementation of TPM. The standard deviation decreased respectively from 1.417% to 0.794%, indicating a more stable results. In order to confirm the higher effectiveness, the statistical t-Student test was performed for two means, with the following hypotheses:

\[ H_0 : \mu_1 - \mu_0 \leq 0 \]  \hfill (3)

\[ H_1 : \mu_1 - \mu_0 > 0 \]  \hfill (4)

where:

- \( \mu_0 \) – mean yield before the implementation of the TPM concept,
- \( \mu_1 \) – mean yield after the implementation of the TPM concept.

The following statistics were obtained as a result of the test:

- t-value = 13.56,
- DF = 56,
- p-value < 0.001

The p-value is smaller than the assumed significance level \( \alpha = 5\% \), so a null hypothesis was rejected in favour of an alternative hypothesis stating that the average yield after implementing the TPM concept was statistically significantly higher. The analysed enterprise has become more effective as a result of the implementation of TPM.

4.2 Productivity

As in the case of effectiveness, the results on productivity were presented in Figure 3 in the form of two histograms before and after the implementation of TPM. The normal distribution curves were also applied on the graphs. The Anderson-Darling normal distribution test has shown, however, that the data before implementing TPM did not follow a normal distribution (p-value = 0.021). Data after the implementation of TPM were characterised by a normal distribution (p-value = 0.68).
The data presented in Figure 3 show that the analysed company achieved a higher productivity after implementing TPM. The average productivity index increased from 2.554 before the implementation to 2.799 products per cost unit after implementing the concept. The standard deviation also decreased from 0.4277 to 0.3522. The smaller variability in this case is a symptom of a greater stabilization. In order to confirm the higher productivity and bearing in mind the absence of the normal distribution for some data, the non-parametric U Mann-Whitney statistical test was performed for the median of two populations [1], with the following hypotheses:

\[ H_0 : m_{e1} - m_{e0} \leq 0 \]  \hspace{1cm} (5)

\[ H_1 : m_{e1} - m_{e0} > 0 \]  \hspace{1cm} (6)

where:

\( m_{e0} \) – median of productivity before the implementation of the TPM concept

\( m_{e1} \) – median of productivity after the implementation of the TPM concept

As a result of the test, the p-value was obtained = 0.0211, which at the level of significance of \( \alpha = 5\% \) means the rejection of a null hypothesis in favour of an alternative hypothesis. In the studied enterprise, the productivity median after implementing TPM was statistically significantly higher than before the implementation of the concept. Therefore, the company was characterised by a higher productivity.

### 4.3 Efficiency

The praxeological approach to business efficiency was presented in Figure 4, where the scatterplot graph shows the mutual relation of the effectiveness and productivity of the analysed enterprise before and after implementing the TPM concept. The data presented in the graph show that the company achieved a higher effectiveness after the implementation of TPM while reaching higher levels of productivity in relation of the period studied before the implementation.

The graph clearly shows that the points showing the correlation between effectiveness and productivity after the implementation of TPM are higher up and more to the right from the points prior to the implementation of the concept.

### 5 CONCLUSIONS

Based on the conducted research and presented results, the following conclusions can be drawn. Firstly, the implementation of the TPM concept in the studied enterprise has statistically significantly improved its effectiveness compared to the pre-implementation period. Secondly, as a result of the TPM approach implementation, the productivity of the company has statistically significantly increased. Bearing in mind the abovementioned conclusions, it must be stated that the implementation of the TPM concept has increased the efficiency of the analysed manufacturing unit from the praxeological point of view.

The future research should focus on the understanding of the factors that affect the success and failure of implementing the TPM concept. It would also be interesting to see comparative studies showing the impact of different concepts of continuous improvement, such as: Lean Manufacturing, Six Sigma on the manufacturing performance of the enterprises according to praxeological thinking.

### 6 ACKNOWLEDGMENTS

The author of the paper would like to thank all the passionate employees busy with the implementation of the Total Productive Maintenance concept in the studied company.

### 7 REFERENCES


