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Designing Jewellery Manufacturing Industry Productivity Improvement using DMAIC Method

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***Abstract*— Indonesia's exports of jewellery trends that continue to rise are not in line with the increase in Production Output Trends from companies in Indonesia's industri. This research uses one of jewellery manufacturing company in Bali province as a case study. This research used a Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) method which the objective is to improve productivity through integrated DMAIC phase of a project. On the Define phase, this research used a SIPOC (Supplier-Input-Process-Output-Customer) Diagram. On the following Measure phase, a questionnaire used to collect primary data and company data for the secondary data. The questionnaires obtained from 4 Experts in Continuous Improvement and 5 Experts in Jewellery Manufacturing Industry. On the Analyze phase, a combination of Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)-Analytic Hierarchy Process (AHP), and Decision Tree are used to be able to see a result from different approach. Lastly, at the Improve and Control phases, a Perfomance Indicator approach were used. The obtained result from this research, are the most important Productivity Factor for a jewellery manufacturing company which is Labor Producitvity with the ranked order of 9 alternatives based on Ideal Solution on the increase of productivity. The chosen alternative with the highest priority ratio is the Implementation of the daily activity planning system for all employees, with an estimated increase in productivity at the level of 47%. To support the success of alternatif implementation Overall Worker Efficiency (OWE) performance indicator were being proposed.**

***Keywords*— Productivtiy, Jewellery Industry, DMAIC, TOPSIS-AHP,Decision Tree, OWE**

I. INTRODUCTION

Indonesia's jewellery industry is ranked in the second position among 8 other industries of potential export products, following Processed Food Industry on the first position. In the past 5 years, Indonesia's jewellery industry has increasing export trend with the average annual value growth of 30% [6]. This research will be focus on the Silver based Jewellery Industry, with a case study of a Silver based Jewellery manufacturing company in the province of Bali. Each region has its own uniqueness in terms of motifs, which usually associated with the historical background each area. Most craftsmen run for generations, using the expertise and heritage in terms of design and manufacturing methods [7]. This background is strongly related to the production output of jewellery manufacturing which is tend to be unstable, because the productivity of craftsmen is closely related with the skills of craftsmen, the difficulty level of design and cultural habits.

II. LITERATURE REVIEW

A. Productivity

The definition of productivity may vary based on the point of view, referring to earlier research in the field of technology, technique and economy, the three scientific knowledge which represent the fairly broad industrial categories, are giving slightly different point of views [11].

Productivity is the relationship (usually a ratio or index) between the amount of output (goods and / or services) generated by the organization system to the number of inputs (resources) used by the organization system to generate the output [15].

The European Association of National Productivity Centres [1] defines productivity as "how efficient and effective a product or service can be produced". Efficiency in this context can be seen as "doing something right", or use of resources to achieve the desired result [8]. Thus, it can be concluded that the effectiveness highlights the importance of achieving the desired objectives, while focusing on process efficiency or involvement [14].

The meaning of "resource", are all human and physical resources, namely those that produce goods or provide services, and assets which people can produce goods or provide services using these assets [3].

Thus, a high productivity can be achieved if the activities and resources in the process of manufacturing transformation adds value to the goods produced. An important conclusion of waste reduction in order to improve productivity: waste can be considered as the opposite of what is symbolized by productivity [21].

B. Total Productivity

Total Productivity is the most comprehensive productivity concept because it is defined as the total output to total inputs used to produce that output. In calculating the Total Productivity, it is should be on the state monetary equivalence or using one of mutually agreed exchange rate as the base price to eliminate the effects of inflation. Generally, this measurement method used in the business unit level [9].

$$\text{Total Prductivity} = \frac{\text{Total Output}}{\text{Total Input}} \qquad (2.1)$$

Although the definition of productivity appears to be very targeted, but the output usually shows the results of various types of input, which sometimes has a different unit of measurement when the output has only one unit of measurement. Productivity ratio of 0.75 is considered of little value, except when compared with the previous achievement whose value is smaller. Meanwhile, total productivity can be calculated from the aggregation of partial productivity [22].

C. Productivity Improvement (Hickman, 1995)

In a company, the increase in productivity is quite complex and requires a specific approach. This is because in a company generally has a tiered hierarchy of leadership, accompanied by a communication flow hierarchy. So in the effort to increase productivity in a company, it can be done through 2-way approach, which is top-down or bottom up [10].

In the book of "Productivity Game" [10] also emphasized the need for Change Agents who are responsible for the transformation. Therefore, the choice of approaches to improve productivity is divided into three, which are top-down approach, in which case the productivity improvement starts from the leaders (board of management); bottom-up, where the productivity improvement starts from improving all employee's productivity; and the last is to increase productivity or rather ensure the quality of the productivity of the Change Agents before it leads the productivity improvement program of the entire company. In this section, we can see the different approaches of productivity improvement [10].

Fig. 1 below is the picture of Productivity Improvement Approaches in the Company which have been summarized from the book of "Productivity Game" as a brief description of the focus areas in the productivity improvement.

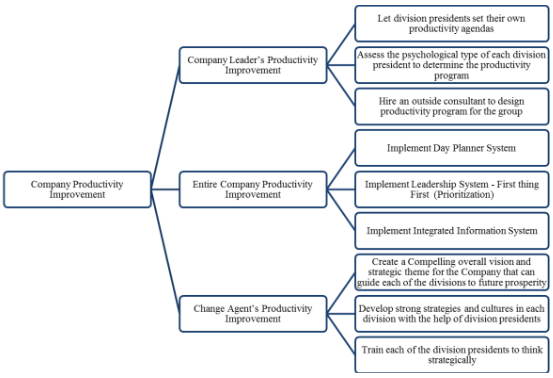

Fig. 1. Productivity Improvement Approaches in the Company [10]

D. DMAIC

To achieve Six Sigma, one of the most widely used methodology is DMAIC approach. In the last few decades, Six Sigma has been supported by many companies worldwide with many successful cases. In addition, the Six Sigma program can also improve operational performance in order to increase customer satisfaction with the products and company services. Although there are many criteria for assessing the performance of Six Sigma projects, for example, Net Cost Savings, the Cost of Poor Quality, Capacity and Customer Satisfaction [13], However, [16] suggest that a good Six Sigma project should have some characteristics that are connected with a very important business priority for the organization, with reasonable scope, and so on.

In the explanation about the definition of each stage of the DMAIC method [5], it is stated that the use of the methods in each stage of the DMAIC is quite flexible, but there are methods which are commonly used. The definition of Define phase is to define the purpose of a project with the commonly used methods are SIPOC Diagram and CTQ (Critical to Quality) Tree [5,18], while the Measure phase objective is to measure or assess the ongoing condition with the commonly used of used methods of Pareto Analysis [5,19] and Descriptive Statistics [13,18]. Later in the Analyze phase is to analyze the current condition in order to find new ways to achieve the goal wich commonly used a Fishbone Diagram, Failure Mode Effect Analysis (FMEA) [5] and Cause and Effect Diagram [19]. Followed by Improve phase which serves to implement an action or a new measurement method which is generally supported by Matrix Diagram [5] and Design of Experiment (DOE) [18]. The final phase of the DMAIC process is Control which serves to ensure the sustainable improvement implementation, which generally using Performance Measurement (KPI) [5,19] and Statistical Process Control [13] method.

E. Key Performance Indicator (KPI)

Many people when discussing about productivity actually see a wider problem, which is performance. Performance, on the other hand, is a broader term that covers both the operational and the overall economy aspects. This includes almost all the objectives of competition and manufacturing excellence whether it is related to cost, flexibility, speed, reliability or quality. Below are the description of a high-performing operating activities to be achieved by each company [21]:

- High quality operation should not waste time or effort to do the job repeatedly
- Rapid operation will reduce the level of inventory Work in Process (WIP) between micro surgery, and reduce administrative activities
- Reliable operations, can be relied upon to result delivery exactly as planned.
- Flexible operations which can easily adapt to changing circumstances quickly and without disturbing the rest of the operations.

An example of a commonly used measurement of productivity in the manufacturing industry is OEE. The original definition of OEE developed by Nakajima, consists of six large losses which are divided into three categories such as inventory, performance and quality. OEE is the abbreviation for Overall Equipment Effectiveness, instead of Overall Equipment Efficiency. However, basically the real purpose of OEE measurement is more to measure the efficiency of internal rather than external effectiveness, therefore, a more precise definition is Overall Equipment Efficiency [2].

III. RESEARCH METHODOLOGY

Data collected from both primary data and secondary data will begin to be prepared and processed based on the DMAIC method. DMAIC method used in this study are described in **Table 1** as follows.

Tabel 1. Method used in the DMAIC Framework

DMAIC	Method Used	Explanation
Define	- SIPOC Diagram	- Define phase is the problem statement of a project or research [20]
		- Through SIPOC Diagram, initial problem identification can be performed, after detail manufacturing process is explained
Measure	- Pareto Diagram - Histogram	- Encourage the evaluation of input, process and output based on the key steps for each process [20]
		- Generally, data collection and presentation is conducted to indicate the current ongoing state [20]
		- By using the Pareto diagram and histogram, it can help to show trends or the source of the problem based on quantitative data
Analyze	- TOPSIS-AHP - Decision Tree	- Looking for problem gap (gap analysis) and root cause analysis of the problem [5]
		- In this case study, the root cause of the problem is defined as high level which need the help of Expert Judgment to see through decision-making method
		- TOPSIS-AHP is used to see the importance level of the existing alternatives, and the Decision Tree method used to select the best alternative (in other words eliminating other options)
Improve	- Based on Analyze Method	- Analyze the data and determine the current state for improvement opportunities [20]
		- The solution of this stage should also be practical and feasible to implement
		- An alternative is selected from the Analyze phase would be the base to design improvement actions for the following Improve phase
Control	- Performance Measure (KPI, Balance Score Card)	- Generally at this phase occurs drafting processes standard and procedures as well as the transfer of ownership of the project to the user [20]
		- In this research, the selection of the KPIs will be adapted based on the chosen alternative, in order to guarantee the sustainability of the results of monitoring and the implementation of the selected alternative

A. Define

This research was conducted with the case study of a company engaged in the field of Jewellery Manufacturing Industry in Bali, Indonesia. It is necessary to understand business processes or operations related to the Jewellery Industry itself. SIPOC diagram in **Fig. 2** below will show more clearly about the business or operating process which takes place at the location of the study.

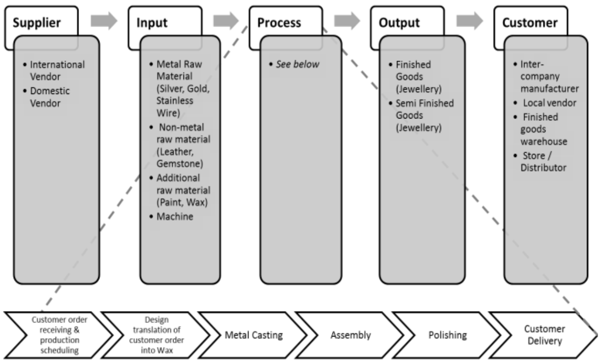

Fig. 2. SIPOC Diagram of Business Process Flow

Associated with total productivity input factor, then the above problems mapped in **Table 2**.

Table 2. Problem Mapping towards Total Productivity Input Factors

Total Productivity Input Factor	Identified Problem
Labor Productivity	- Problems in delay delivery of goods towards the schedule requested by the customer, due to unstable labor productivity
	- Fluctuative production output
Material Productivity	High Inventory Cost (WIP & RM)
Capital Productivity	High number of repair product, as the result of low performing degrading machine
Energy productivity	N/A

B. Measure

In this phase, both primary and secondary data will be processed based on the information obtained from the problems defined in the Define phase.

Total Productivity Ratio

In the case of Total Productivity Ratio which tend to be decreasing with the average range at the level of 0.74 or still far below the ideal ratio of 1. This statement refers to [22] which says that the ratio of 0.75 is considered as small value for the ratio of total productivity.

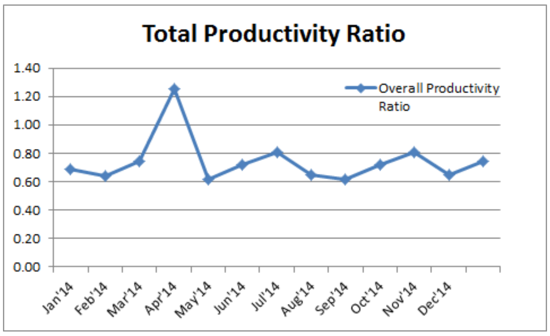

Fig. 3. *Total Productivity Ratio*

Contributors to Low Total Productivity Ratio

Through the following Pareto Chart below, we can see that the largest contributors in terms of value is the Cost of Work In Progress (inventory) and followed by Raw Material Cost. Followed by employee costs (labor) and fixed capital costs.

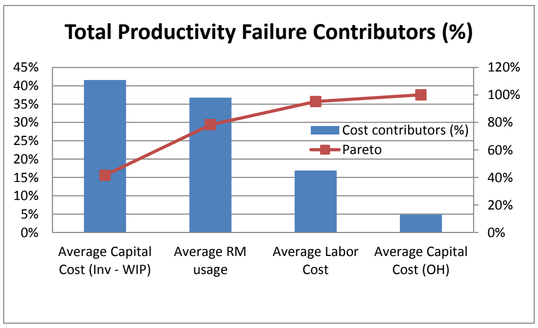

Fig. 4. Contributors to Low Total Productivity Ratio

C. Analyze

To determine the factors that affect productivity at the level of productivity of the Manufacturing Industry, an initial interview with the Expert was conducted. From the results of the initial interviews it was decided that 3 out of 4 input factors of Total Productivity have influence on the performance of Productivity Manufacturing Industry performance, which will be the criterions in the following decision making process, which are:

K1: Labour Productivity

K2: Material Productivity

K3: Capital Productivity

Meanwhile, the alternatives chosen for the following decision making process are referring to Productivity Improvement by [10], with adjustments based on the Expert Judgments made earlier in the interview. Followed by arrangement for both Criteria and Alternatives in hierarchy structure shown in Fig. 5.

A1: Create a compelling high level vision and strategic theme for the Company (based on Customer Value)

A2: Develop strong strategies and cultures in each Division/Team based on the respective requirement

A3: Develop the strong Strategic and Continuous Improvement Thinking for Division/Team Leaders, through Training

A4: Design a Productivity Improvement Framework through third party Expert Judgement/External Consultant. (Best practice approach)

A5: Design a Productivity Improvement Framework through Internal Expert Judgement or Division/Team Leaders. (Internal requirement approach)

A6: Design a Productivity Improvement Framework through employee character/divisional or team culture adjustments

A7: Implementation of Priority Management System

A8: Implementation of Daily Planning System (Daily Activity Planning) for all Employee

A9: Implementation of Integrated Operational Planning Information System (e.g ERP).

The Output of AHP Method

The calculation of weighted priority using AHP Method were conducted with the support of Expert Choice software. The output of the calculation are obtained with the following results: (K1) Labor Productivity weighs 0.458, (K2) Material

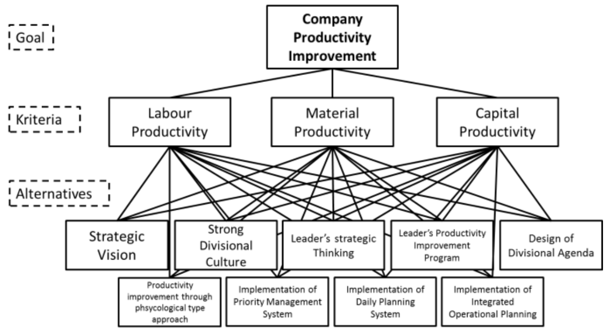

Fig. 5. Hierarchy of Alternative Selection Methods for Improving Productivity

Productivity weighs 0.368, (K3) Capital Productivity weighs 0.174.

The output of TOPSIS Method

TOPSIS method of calculates the farthest distance from the Ideal Negative Solution because the purpose of this research was to maximize productivity. The results of which have been sorted are as follows:

A8: Implementation of Daily Planning System (Daily Activity Planning) for all Employee, with the score of 0.94

A7: Implementation of Priority Management System, with the score of 0.74

A3: Develop the strong Strategic and Continuous Improvement Thinking for Division/Team Leaders, through Training, with the score of 0.72

A5: Design a Productivity Improvement Framework through Internal Expert Judgement or Division/Team Leaders. (Internal requirement approach), with the score of 0.42

A1: Create a compelling high level vision and strategic theme for the Company (based on Customer Value), with the score of 0.41

A2: Develop strong strategies and cultures in each Division/Team based on the respective requirement, with the score of 0.40

A9: Implementation of Integrated Operational Planning Information System (e.g ERP), with the score of 0.30

A6: Design a Productivity Improvement Framework through employee character/divisional or team culture adjustments, with the score of 0.30

A4: Design a Productivity Improvement Framework through third party Expert Judgement/External Consultant. (Best practice approach), with the score of 0.14

The output of Decision Tree Method

Decision Tree final results obtained from the processing of 2 (two) questionnaires of Implementation Success Probability of Each Alternative and Impact of each Alternative towards each Productivity Improvement Criterion.

Decision Tree yield only 1 (one) selected alternative with the greatest value. This value is the estimated value of

Productivity Improvement from the implementation of one of the alternative, which obtained through a theoretical calculation results with inputs from the expert's judgment. The chosen alternative is the Implementation of Daily Planning System (Daily Activity Planning) for all Employee with an estimated value of increase in productivity by 0.47 or 47%.

IV. Result and Discussion

A. *Improve*

From both approaches we might see one thing in common with the results of the selected alternative with both the biggest priority ratio and values of the largest productivity increase. The selected alternative is the Implementation of Daily Planning System for all employees. In other words, this alternative was considered the best to be implemented for the Company in the Indonesia Jewellery Industry.

By adopting the concept of Daily Planning System covered by [10] that the daily planning is required to regulate the activities (event) better, and not merely set the time. The basic concept of daily planning includes time management, activities setting, the importance of planning, organizing, prioritizing of activities, and understanding of productivity.

Daily Planning System is now supported by a variety of software, both for the Daily Planning System of a general day-to-day office operation such as Franklin Time Management System [10], as well as the Daily Planning System for operations and manufacturing, such as Enterpirse Resource Planning (ERP) and the more recent Advance System Planning for Supply Chain overall system settings, where the manufacturing process and management Resources are also in it [12]. This research is also consistent with previous studies [23] about the importance of implementation of the Integrated Information System for the manufacturing process, in which he emphasized the importance of good planning on Labour, monitoring on purchasing and raw material losses. Highlighting the importance of a good planning on Labour, he stressed the importance of production management. In the jewellery manufacturing information systems, production module is designed with special features to handle production control and scheduling functions. This includes the determination of the work and listing fees that are used to record information such as time spent on the production of a worker to produce, workers who are responsible for a particular job, and the quantity of the raw materials that were or are used throughout the production process [23].

B. *Control*

To monitor the overall performance of the company, the characteristics of an enterprise performance management system should be established based on the company's strategy [14] related to the business target and financial condition of the company. By doing a benchmark with the similar character of labour intensive industry, such as the Construction Industry or Small and Medium Enterprises Industry, the main focus of human productivity needs to be improved.

Small and Medium Enterprises Industry, which also has a high intensity in the use of Human Resources, has led to the measurement of Labor Productivity performance indicators, called Overall Worker Efficiency (OWE) [17].

Here is the detail calculation of three components of OWE:

Availability Efficiency (Aeff)

$$Aeff\,(\%) = \frac{Available\ Hours}{Scheduled\ Hours} \qquad (2.17)$$

Where:
Available Hours is the number of available working time (8 hours) minus unscheduled downtime or absenteeism, while Scheduled Hours is the amount of working time (8 hours) after deducted with scheduled downtime.

Performance Efficiency (Peff)

$$Peff\,(\%) = \frac{Actual\ Output}{Planned\ Output} \qquad (2.18)$$

Where:
Actual output is the amount of actual production yields of a worker as compared to planned output or confirmed by the workers.

Quality Efficiency (Qeff)

$$Qeff\,(\%) = \frac{\text{Accepted quantity produced right at first time during a spesified time}}{\text{Total Output Produced in that time}} \qquad (2.19)$$

To support the implementation of system Control through the above performance indicators, several supporting strategies need to be done prior implementing the Performance Indicators, referring to earlier research in a dairy industry manufacturing process [4] with the adjustment to Jewellery Manufacturing Industry as follows:

- Designing an appropriate flow of business processes, which also pay attention to mapping the skills and abilities of each worker.
- Improve and develop the existing ERP system which should be adapted to business processes and other supporting data, such as the mapping of the skills and abilities of each worker.
- Creating a notification system, in the form Health check Notification system, due to lack minimum automation within the production process.
- Fix the new policy towards the need for performance indicators and standardized work.
- Designing a new tool of performance indicators, such as supporting tools to process data that can be created using Excel, to then be designed to be made automation integrated in the ERP system.

V. Conclusion

The result of this research is the design of company productivity improvement for Jewellery Manufacturing Industry, using DMAIC method. The design of productivity improvement is based on the selected alternative which has been chosen out of the 3 criteria and 9 alternatives to increase productivity. The most important criteria to increase productivity is Labour Productivity, thus, it becomes imperative that for a company in Jewellery Manufacturing in

Indonesia need to be focus on the area of Labour Productivity Improvement.

The selected alternative was obtained from the data processing between the criteria and alternatives through analysis of the Analyze phase, using the results of the comparison between the combination of AHP-TOPSIS and Decision Tree method. Among 9 alternatives, the obtained result was Alternative 8, which is the Implementation of Daily Planning System Implementation for all employees through the combination of AHP-TOPSIS method which output is a weighted priority score of 0.94, and Decision Tree method which provides the estimated impact value of the company's productivity improvement as much as 0.47 or 47%.

Future studies may perform validation through the implementation of the selected alternative in the respective industry, in the area where expert judgments were widely used, such as impact and success probability of an alternative..

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