

PAPER • OPEN ACCESS

Productivity and environmental performance: an empirical evidence from a furniture factory in Malang City, Indonesia

To cite this article: R Astuti *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **230** 012064

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the **collection** - download the first chapter of every title for free.

Productivity and environmental performance: an empirical evidence from a furniture factory in Malang City, Indonesia

R Astuti, P Deoranto and M M Aula

Department of Agro-industrial Technology, Faculty of Agricultural Technology,
Universitas Brawijaya, Indonesia

E-mail: retno_astuti@ub.ac.id

Abstract. The growth of furniture factories in Malang City produces large volumes of waste that potentially degrade the environment. This study aimed to analyse the level of productivity and environmental performance of a furniture factory then to determine alternative solutions for increasing productivity and improving environmental performance simultaneously. An empirical evidence was carried out from UD. JAYA ABADI using 3 stages of Green Productivity (GP) approach. The first stage was measurement of mass balance and analysis of the production process by mapping each process flow using Green Value Stream Mapping (GVSM) current-state. The second stage was the measurement of the environmental impact using initial condition of Green Productivity Index (GPI). The third phase was determination of alternatives solution based on the results of problem identification using the Fishbone Diagram. Contribution estimation of each improvement alternative solution then was done using Benefit Cost Ratio as financial analysis, future state GVSM, and GPI condition after improvement. The analysis result showed the initial condition of the company had the Environmental Impact (EI) of 26.003, economic indicator of 1.266 and GPI of 0.0487 for initial condition. It showed the impact on the environment was greater than the level of company productivity. The best solution alternative for increasing productivity and improving environmental performance was the recycling of solid waste become planting media that increased the value of GPI to be 0.064, the value of EI to be 19.711, and economic indicator increased to be 1.268.

1. Introduction

Wood-based furniture industries develop quite rapidly in all regions of Indonesia due to the growing of the value of wood furniture production. According to Ministry of Industry of Republic of Indonesia, the value of wood furniture production grew by 62.7%. The Ministry of Commerce of Republic Indonesia also stated that the quantity of the furniture industry grew by 7% [1]. Production process at those industries produces waste. Wood wastes (i.e. wood pieces and saw dust) are some of waste problems experienced by the furniture industries [2]. The utilization of waste wood resources is recognised as a key issue. Some wood-based furniture industries, especially the small and medium one, have some lacks of waste reduction due to the perception that there is low cost benefit in wood waste management, a lack of awareness and understanding and little or no direction about how to recycle the waste [3]. Therefore, wood waste management and practices should be done by considering its economic value, meanwhile it reduces the impact of production process on the environment. This study aimed to analyze the level of productivity and environmental performance of



a furniture factory then to determine alternative solutions for increasing productivity and improving environmental performance simultaneously.

The method of green productivity can be used as an approach to help the company to handle the existing problems. Several studies using the green productivity approaches have been carried out by some researchers. Mohan et al. [4] highlighted Green Productivity Index (GPI) of the Continuous Improvement (CI) performed in a foundry casting, which includes both economic and environmental performances. It found the approach adopted will provide a clear guidance for developing indicator and GPI to various types of industries. A casting case indicated that the GPI can be used as an actionable feedback for leadership to make effective decisions. Marimin et al. [5] designed and simulated Green Productivity improvement model in smallholder rubber plantation in ensuring products quality to customer while at the same time decrease environmental impact. The model was able to minimize environmental impact while keeping the economic aspect growth. An improvement initiative based on plantation management combined with the green productivity approach was the best improvement scenario. Aprianto et al. [6] had analyzed the value chain of green productivity in natural rubber cultivation process at Kelompok Usahatani Restu (KUR) in South Sumatera, Indonesia. The result showed that the level of productivity (current state) of natural rubber production in KUR was quite good, but there were still plenty of opportunities to increase it to a higher level. Composting the waste of natural rubber production could improve the productivity and income of the farmers. All the results of the studies showed that green productivity method could give feedback to business systems in improving economic aspect while considering environmental impacts. According to APO [7] the use of green productivity method can increase the productivity while reducing the impact of production process on the environment.

2. Material and Methods

An empirical evidence was carried out from UD. JAYA ABADI, a wood processing factory located in Malang City. The products produced by UD. JAYA ABADI includes cabinets, chairs, tables, sills, doors, ventilation frames, etc. The production system is a make to order based on a certain products form, products amount, and deliver time. Wood raw materials which are often used in the production process are teak, mahogany, *sengon*, *meranti*, and pine. The focus of this research is on the production process of door frames. The research is conducted until the implementation plan stage. The observed wastes are the largest waste produced in 1 (one) production cycle. The number of products produced in 1 (one) production cycle is 10 units which requires 3 days production time. All the manufactured door frames are assumed to be sold.

Input used in this research are raw material in the form of wet teak, direct labor consisting of 2 employees, and electrical energy used for machines and equipment. These three input variables are chosen because these three variables give a significant direct influence on the company's production process and can be quantitatively measured. The output used in this study is the quantity of products produced in 1 cycle production process.

The stages of data analysis conducted in this study are as follows [7]:

- a. Creating a Process Flow Diagram (PFD) that describes the sequence of work activities along with the flow of energy or material in a particular process.
- b. Creating a mass balance to determine the amount of material loss in order to increase the efficiency of raw material use and to know the possibility of developing the process to achieve zero waste process (no waste is produced). The basic concept of the mass balance is that the amount of material entering into a process unit is the same number as that which exits from the unit, according to the application of the law of mass conservation.
- c. Creating a current-state Green Value Stream Mapping (GVSM) to identify activities that have an effect on the achievement of green productivity level of furniture business. The identification of seven sources of waste generation comprising the use of energy, water, materials, waste, transportation, emissions, and biodiversity serves as the basis for initial green productivity measurement.

- d. Calculating initial Green Productivity Index (GPI). Environmental impacts are determined by the sum of GP indicators. The weight and GP indicators are determined based on the results of expert judgment analysis summarized in the Environmental Sustainability Index (ESI). The environmental impact of GP indicators is calculated by equation [8]:

$$EI = (w1 \times GWG) + (w2 \times LC) + (w3 \times SWG) \quad (1)$$

where:

EI : environmental impact (kg)

w1, w2, w3 : variable weights

GWG (*Gaseous Waste Generation*): the amount of gas waste (kg)

LC (*Land Contamination*) : the use of land (m²)

SWG (*Solid Waste Generation*) : the amount of solid waste (kg)

The environmental impact calculation formula is conditional, which means it can be adjusted according to the conditions in the object of research.

The value of economic indicators or productivity is the ratio of output and input. The value of output in this study is the selling price of output multiplied by the amount of output produced, while the input value is the cost of production so that economic indicators can be calculated by the following formula:

$$\text{Economic indicator} = \frac{\text{Revenue}}{\text{Cost}} \quad (2)$$

After obtaining the value of environmental impact and economic indicators then GPI is calculated using the following formula [8]:

$$GPI = \frac{\text{economic indicator}}{EI} \quad (3)$$

where:

GPI: value of Green Productivity Index EI: environmental impact

- e. Identifying the factors causing the problems related to the productivity. The impact of the process on the environment and its causes are also identified in this stage. The relationship between the problem and the causes are identified using the Fishbone Diagram.
- f. Preparing alternative solutions to solve existing problems. The method used in this stage are studying the literature and consulting with experts in providing appropriate alternatives solution.
- g. Calculating Revenue Cost Ratio (RCR). The selection of alternative improvements is based on the highest RCR value. RCR comparison value shows the value of profit to be obtained by the company compared to expenses charged in implementing alternative solution RCR is calculated using the following formula:

$$\text{Revenue Cost Ratio (RCR)} = \frac{\text{Total Revenue (TR)}}{\text{Total Cost (TC)}} \quad (4)$$

- h. Creating a Future Green Value Stream Mapping (GVSM) as the basis for calculating alternative GPI solutions as future state GVSM illustrate the conditions of potential sources of waste generation after implementing the solution.
- i. Calculating GPI of the selected solution to find out the estimated GPI increase if the selected solution is applied. The calculation of GPI of selected solution uses environmental impacts and economic indicators according to the estimation result of selected solutions.

3. Results and Discussion

3.1. A general description of the company

Production system implemented by UD. JAYA ABADI is make-to-order. It means that the production process is done if there is an order from customer and the products made are based on customer order. The frequently ordered products at UD. JAYA ABADI are a teak-wood based door frame with a length of 1 meter and 2 meters high. There are two employees for production process at UD. JAYA ABADI with production capacity of 4 door frames per day. However, if there are many orders requiring short time production then the production is done by adding the employees using bulk system. The production stages of door frame production process at UD. JAYA ABADI consists of the process of measuring, cutting, sawmilling, perforating, assembling, gluing, recognizing, smoothing, sanding 1, blowing, sanding 2, welding, and putting into storage.

3.2. The Current state GVSM

The waste source that can be used as a variable in GVSM is only waste generated during the production process. GVSM current state in this research is made based on 1 cycle of production process producing 10 door frames. The results of green waste analysis on 1 cycle of production process in UD. JAYA ABADI can be seen in Table 1. Stages of the production of door frames that potentially produce residual or waste are cutting, sawmills, perforating, gluing, acting, smoothing, sanding 1, paving, sanding 2, and welding.

Table 1. Analysis result of the current state of green waste.

Type of waste	Production Process										Total
	Cutting	Angle Sawmilling	Perforating	Gluing	Acting	Smoothing	Sanding 1	Paving	Sanding 2	Welding	
Energy (KWh)	20.790	10.395	2.079	0	0	8.217	0	0	0	0	41.481
Water (m ³)	0	0	0	0	0	0	0	0	0	0	0
Material (kg)	29	4.2	0.2	0	0	38.6	0.2	0	0.1	0	72.30
Waste (kg)	0	0	0	0.1	0	0	0.16	1.5	0.16	4	5.92
Transportation (m)	0	0	0	0	0	0	0	0	0	0	0
Emission (kg CO ₂ /KWh)	12.183	6.091	1.218	0	0	4.815	0	0	0	0	24.308
Biodiversity (m ²)	0.5	0.04	0.015	0	0	1.875	0.005	0	0.0025	0	2.4375

Source: Primary data of UD. JAYA ABADI collected in 2016

3.3. Current state green productivity index (GPI)

The results of waste analysis on current-state GVSM are the basis for measuring environmental performance or environmental impact which shows that door frame production process by UD. JAYA ABADI is classified into 3 GPI environment variables, namely solid waste generator (SWG), gas waste generator (GWG), and land contamination (LC) during the production process. GWG is in the form of material waste of 72.30 kg and garbage of 5.92 kg. SWG during production process is emission (indirect CO₂) of 24.308 kg. LC is in the form of land area used as a waste disposal of 2.4375 m². In order to determine the weight of the 3 GPI environment variables, the three variables must be synchronized with the ESI indicator. The environmental impacts resulting from the production process calculated using formula (1) is 26.003.

The costs used in 1 cycle of door frame production process consist of cost of raw materials and supporting material variables. The cost spent on the use of wood, nails, wood glue, thinner, putty, and politer is IDR 7,090,000, followed by labour costs which the company spent for employees' wages for

IDR 35,000 / unit resulting in total labour costs of IDR 350,000, and energy costs that the company spent for energy use required during the production process of IDR 60,864.242. The selling price of 1 unit of door frames is IDR 950,000 / unit so the revenue for the sale of 10 door frame units is IDR 9,500,000. The value of economic indicators calculated using formula (2) is 1.266. An economic indicator with a value more than 1 indicates that the production process is profitable for UD. JAYA ABADI. GPI values calculated on the basis of environmental impact and economic indicators using the formula (3) is 0.0487. GPI value less than 1 indicates that the environmental impact is greater than the level of company's productivity. In other words, the ability of UD. JAYA ABADI in producing environmental friendly product is low. According to Marimin et al. [4], GPI depicts ability of producers in production of environment friendly products.

3.4. Identifying the problem and its causes

The problems are analyzed based on observation on the production process and brainstorming with UD JAYA ABADI's owner and employees. Detailed information about the door frame production process of UD. JAYA ABADI is needed in this analysis. Most waste generated on 1 cycle of door frame production process at UD. JAYA ABADI is a solid waste in the form of saw dust and wood pieces that become the main focuses in analyzing the root cause of the problem. The potential causes of the problem graphically is depicted in Fishbone Diagram shown in Figure 1. According to Kenkere and Saoud [9], Fishbone Diagram provides a systematic way of looking at effects and the causes that create negative effects on activity or process. It is very useful in identifies many possible causes for an effect or problem, especially in structuring a brainstorming session.

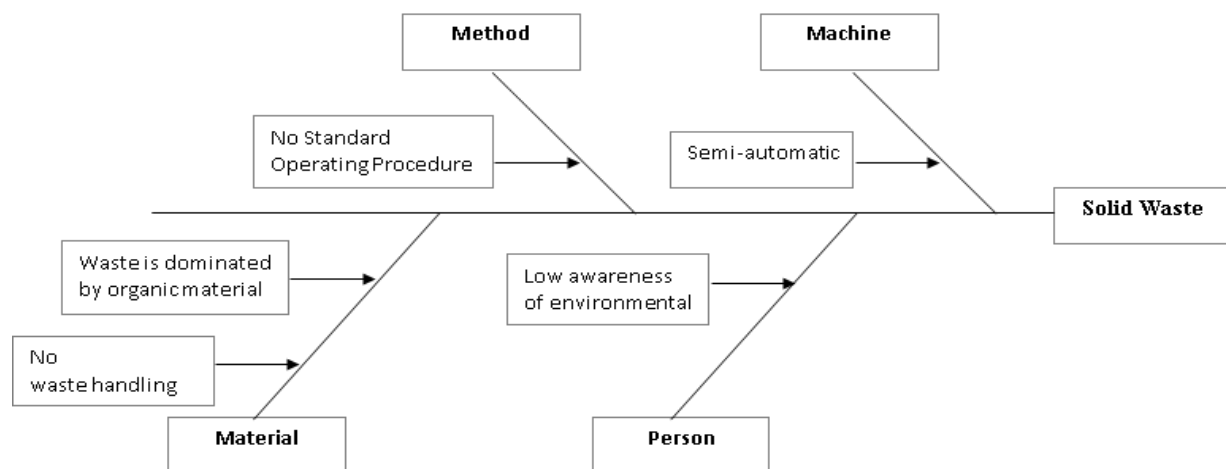


Figure 1. Fishbone Diagram of the solid waste problem in UD. JAYA ABADI.

Tools / machines used in the production process is semi-automatic without a certain waste disposal so that the waste from the production process are scattered not in one place. Waste water materials are largely organic in nature to decay and become the media for pathogenic bacteria degeneration. Waste handling is also not done so the production area is less healthy for employees. Employees who are less aware of the environment hygiene contribute to less conducive working environment as the waste is scattered everywhere. It seems the management of the company does not really pay attention to the health and safety of its employee. According to Derecichei et al. [10], wood waste pollution has as a consequence on changing the normal water surface and spreading dust in the atmosphere. UD. JAYA ABADI management also has no Standard Operating Procedure (SOP) so that its employees work irregularly and they are less orderly.

3.5. Preparing and selecting alternative solutions

The preparation of alternative solutions is done by considering the financial aspects and their impact on environmental performance. An alternative solution that can be considered is the processing of solid waste into planting medium. Saw dust and wood pieces can be utilized as one of the good planting medium. Saw dust as planting medium is usually used if the plants are planted using a pot or polybag. Saw dust is chosen because of its light texture so that the roots can grow faster. The utilization of solid waste as a planting media can be done by packaging it using plastic having 2kg per pack in size. Plastic materials used as packaging is PP (*polypropylene*) plastic which is thick using the dimensions of 20 cm x 30 cm x 0.3 cm. Planting medium resulting from the utilization of 72.3 kg of wood and saw dust waste are 36 packs with a selling price of IDR 1,000 / packaging. The Total production cost of planting medium is IDR. 18,300, while the income obtained from the processing of saw dust and wood pieces into a planting media is IDR 36,000

Another alternative solution can be applied on the cultivation of oyster mushrooms. Oyster mushroom is a type of mushrooms which is quite easy to cultivate and its demand for culinary fields is quite high in Indonesia. The utilization of solid waste of 72.3 kg needs 7.23 kg bran, CaCO_3 lime of 2.169 kg, 0.3615 kg of urea fertilizer, TSP fertilizer of 0.3615 kg, and water of 36.15 kg with total cost of IDR 142,342.625. Processing 72.3 kg solid waste can produce mushrooms mycelium as many as 85 *baglog* with selling price IDR 2,500 / *baglog* so the total *baglog* of oyster mushroom is IDR 212,500.

The selection of the best solution is based on the highest RCR value. The RCR calculation results show the feasibility of feasible alternative solutions and estimate the value of profits derived from the application of selected solutions. The alternative RCR of this solution calculated using formula (4) is 1.967, meanwhile RCR of oyster mushroom cultivation is 1.493. RCR value of planting medium is higher than RCR value of oyster mushroom cultivation so that alternative solution chosen is utilizing solid waste into planting medium.

3.6. Future state GVSM

Future state GVSM is used to determine the impact of selected solution on environmental performance. The selected solution is able to reduce the solid waste in the form of reprocessed materials and can reduce the use of land as a waste disposal site so that the GVSM map changes as shown in Table 2.

Future state GVSM analysis shows that application of selected solution at 1 cycle of door frame production process will produce solid waste (SWG) of 5.92 kg and waste gas (GWG) of 24.308 kg CO_2/KWh . In order to determine the weight of two GPI environment variables, the two variables must also be synchronized with the ESI indicator. The environmental impact resulting from 1 cycle of the production process after the application of selected solutions calculated using formula (1) is 19.711

The result of economic indicators after the application of alternative solutions is different from the initial calculation because there is an additional income of IDR 36,000 and a fee of IDR 18300. Total revenue after application of alternative solutions is IDR 9,536,000 and total cost of IDR 7.520.164.242 so that the value of economic indicators after the application of alternative solutions calculated using the formula (2) is 1.268.

GPI values after the implementation of selected solution calculated based on the environmental impact value and economic indicators using the formula (3) is 0.064. Although the GPI value remains less than 1, the value has increased by 0.0153 from 0.0487 to 0.064. It means that implementation of the selected solution can help the company to reduce the environmental impact resulting from 1 cycle of the production process, but the ability of UD. JAYA ABADI in producing environmental friendly product is still low.

Table 2. Analysis result of the future state of green waste.

Type of Waste	Production Process										Total
	Cutting	Angle Sawmilling	Perforating	Gluing	Acting	Smoothing	Sanding 1	Paving	Sanding 2	Welding	
Energy (KWh)	20.790	10.395	2.079	0	0	8.217	0	0	0	0	41.481
Water (m ³)	0	0	0	0	0	0	0	0	0	0	0
Material (kg)	0	0	0	0	0	0	0	0	0	0	0
Waste (kg)	0	0	0	0.1	0	0	0.16	1.5	0.16	4	5.92
Transportation (m)	0	0	0	0	0	0	0	0	0	0	0
Emission (kg CO ₂ /KWh)	12.183	6.091	1.218	0	0	4.815	0	0	0	0	24.308
Biodiversity (m ²)	0	0	0	0	0	0	0	0	0	0	0

4. Conclusion

The proposed waste handling at UD JAYA ABADI by utilizing solid waste for planting medium as a selected solution is chosen to increase productivity or economic indicators, environmental performance, and GPI value. Productivity increased by 0.002, environmental performance increased with environmental impact reduction of 6.292, and the increase of GPI value is equal to 0.0153. The application of selected solutions is able to provide an additional advantage of IDR 17,700 and decrease solid waste for 72.30 kg. Further research can be done by considering the size of the company then clustering the solution to increase productivity or economic indicators, environmental performance, and GPI value according to the size of the company.

References

- [1] Pujiati R 2017 Produksi Furnitur Indonesia (Indonesian Furniture Production) p 7-36. Badan Pengkajian dan Pengembangan Perdagangan Kementerian Perdagangan Republik Indonesia Jakarta Indonesia. [In Indonesian]
- [2] Jijin I, Rinitha P 2016 Effective Recycling and Use of Wood Carving Waste in Wood Industry Int. Conf. on Future Technology in Engineering p 20-30. College of Engineering Perumon
- [3] Daian G, Ozarska B 2009 Wood waste management practices and strategies to increase sustainability standards in the Australian wooden furniture manufacturing sector *J. Clean. Prod.* **17** 1594-1602.
- [4] Mohan Das Gandhi N, Selladurai V, Santhi P 2006 Green productivity indexing *Int. J. Product. Perform. Manag.* **55** 594-606.
- [5] Marimin, Darmawan M A, Martini S, Rahmanto A D 2014 Green productivity improvement model for pre-processed rubber (bokar): case study at rubber smallholders plantation *2nd Int. Conf. on Technology, Informatics, Management, Engineering & Environment IEEE Indonesia Bandung Indonesia* p 135-140.
- [6] Aprianto D A, Daryanto A, Sanim B 2016 Analysis value chain of green productivity in natural rubber cultivation process at kelompok usahatani restu *Int. J. Sci. Res.* **5** 1576-1581.

- [7] APO 2008 Green Productivity and Supply Chain Manual APO Tokyo Japan.
- [8] Hur T, Kim I 2004 An attempt to measure green productivity Konkuk University Seoul South Korea.
- [9] Kenkere V Y, Saoud S J 2013 Fish bone analysis: An effective tool for identifying causes for employee attrition in MNC's located in Bangalore *Conf. National Conference* Bangalore India.
- [10] Derecichei L, Marinela B, Codruta L, Dubău C G, Gavril C 2015 The sawdust and wood waste management from wood processing industry *Nat. Resour. Sustain. Dev.* 129-132.