VOL. 16, NO. 9, MAY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

HOW GREEN ERGONOMIC MEET ECO-EFFICIENCY IN THE BATIK INDUSTRY?

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ABSTRACT

Batik is a genuine Indonesian product and has been its cultural heritage for several decades. The production process is mostly conducted manually by many small industries in different cities such as Solo, Yogyakarta, Pekalongan, Cirebon, Madura, and others. The small batik industry, however, has some limitations including simple production technology, marketing, human resources, and the knowledge of the impact of batik production on the environment. The purpose of this study was to recommend a workstation design for wax removal in the batik production process in order to improve the Eco-Efficiency Index (EEI) and provide comfort to the workers (ergonomic). This involved the application of the Eco-Efficiency analysis method and the Green Ergonomic concept in this study. The EEI analysis conducted on 2 Batik SMEs showed SMEs using firewood has a lower EEI compared to those using used oil while Green Ergonomic was used to recommend the change from the initial use of firewood in the furnace to used oil while designing a wax removal workstation. This new design is also expected to provide comfort to the workers.

Keywords: batik, eco-efficiency, green ergonomic, design, environmental impact.

1. INTRODUCTION

Batik was designated as an intangible cultural heritage or Indonesian Cultural Heritage by the United Nations Educational Scientific and Cultural Organization (UNESCO) on October 2, 2009 [1]. It was also included in the representative list due to its fulfillment of the criteria required by the Indonesian Life philosophy and contribution to the preservation of the country's culture [2]. The vision of Solo this year is "Becoming the capital of Indonesian batik in 2020" and the formation of the Solo batik industrial cluster apparently pioneered the strategy being implemented to achieve this goal [3]. Moreover, the development of batik motifs in the city is increasing and always changing based on customer preferences [4], thereby, making entrepreneurs put more effort to satisfy their customers' desires as well as initiated government intervention towards encouraging better development. Meanwhile, the batik industry has been practically able to survive the changes in the external environment due to the fact that its development is also driven by entrepreneurs and not only by the market. The industry is very creative with several indigenous batik artists and has been reported to have developed over time [5].

Kampoeng Batik Laweyan is the largest and popular batik production center in Indonesia [6]. It is located in the western part of Solo which is a strategic place and the best asset for the batik trade and industry with full support from the local government [7].

Most of the Small and Medium Enterprises (SMEs) producing batik are home scale industries with almost every house observed to be engaging in the production process simply due to the limited resources. There is, however, no consideration for the environmental impact of the wastes disposed from the process and this is related to the situation in Malaysia where the disposal is mostly into the river adjacent to their houses [8]. It is, however, important to discuss the importance of public awareness on the environmental impact attached to the batik industry[9] mainly due to the fact that SMEs are considered more about the economic aspects without paying attention to the environmental ones. They also have constraints in terms of labor with the knowledge of matters relating to cleaner production systems such as energy-efficient and environmentally friendly technologies and this is associated with the lack of time, insufficient capital, and highly competitive market. It was reported that most of their time is spent on marketing products, fulfilling orders, negotiating prices, and maintaining delivery schedules [10]. However, batik production has a very close relationship with environmental pollution due to the wastes produced, especially because of the synthetic dyes used in the process [11] [4]. Moreover, the increase in batik production has been reported to have numerous effects on the surrounding environment, and several studies conducted on the industry have reported a quite high impact with the SME owners observed not to be concerned.

The production activities of SMEs are always targeted on obtaining maximum profits regardless of the environmental impact and this trend has been observed in many countries [12] such as Malaysia where the batik industry has been reported to be contributing significantly to environmental pollution. The main problem was reported to be the inappropriate disposal of wastewater produced during soaking and flushing [13]. Consumers are starting to have an awareness of the importance of environmental sustainability and this has led to a shift in their product selection considerations from the focus on the price and quality to the negative impact of raw materials and manufacturing processes on the environment

[14]. Meanwhile, each stage in the batik production process has different impacts on human health, ecosystem quality, and resources depending on the raw materials used [15]. This, therefore, means the industry should also focus on environmental problems instead of only the production quantities.

One of the stages in the production process is the wax removal which involves removing wax from batik cloth by dipping it into heated water and mostly conducted with a furnace using firewood. This has a negative impact on the surrounding environment and also affects the ergonomic aspects of the workers due to the uncomfortable position such as squatting and bending they maintain while preparing the firewood. This study was focused on an Eco-Efficiency analysis of the wax removal in the batik production process and redesigning the station based on ergonomic aspects. Meanwhile, studies are being currently conducted to make the production process to be environmentally friendly due to the significance of this aspect for the development of small industries, especially batik.

Eco-efficiency is a practical method of analyzing the business sector with the focus on achieving economic and environmental goals through the use of more efficient resources to have lower pollution. It is an embodiment of the efficiency concept which involves minimizing the resources used in producing a unit of outputs, improving productivity, and economic activities to generate added value and reduce waste production. The World Business Council for Sustainable Development (WBCSD) showed the concept is beneficial to the company's operations by reducing resource consumption and impact on the natural environment as well as increasing the value of products or services [16]. The term eco-efficiency is derived from combining the economic and ecological efficiency. Meanwhile, environmentally friendly businesses are those producing lesser wastes, pollution, and emissions as well as inputting effort to maximize economic growth with minimal environmental degradation. Basically, eco-efficiency connects economic benefits such as turnover, production, etc. with environmental impacts such as energy consumed, tons of carbon dioxide emitted, waste produced, packaging consumed, etc. The ratio provides a quantitative measure of progress in key sustainability indicators such as energy, wastewater, and packaging[17]. Meanwhile, the Eco-Efficiency Index (EEI) determines the affordability and sustainability of a product and also used in comparing profit and eco cost or costs due to environmental impacts [18].

An eco-efficiency analysis was conducted in Tianjin China and a relationship was established between environmental impacts and economic growth from 2001 - 2013 and the results were also able to significantly reduce water and air pollution emissions [19]. Another study was conducted on 19 Small and Medium Enterprises (SMEs) in Portugal and eco-efficiency was found to have been implemented as a management strategy to ensure sustainable development due to its ability to improve the companies' economic and ecological efficiency by using minimal input, material, and energy to obtain maximum output and reduced waste. The approach aimed to reduce costs and improve the environmental product profile towards producing a higher value for the company and increasing its competitiveness, especially the SMEs, and this usually achieved using the Cleaner Production even though it is in a different context [20]. Moreover, eco-efficiency is used to minimize energy, water, and waste intensity, reduce resources by half but does not have the ability to individually reduce the absolute quantity of pollutant accumulation and biodiversity loss. This is important due to the need for effective use of resources in production and consumption [21]. There is, however, the need to apply eco-efficiency analysis in batik SMEs to assess the damages caused at every stage of production to the environment as well as the eco cost attached to these impact and the results are expected to aid material consideration towards efficient use of raw materials and reduction of environmental impacts [22].

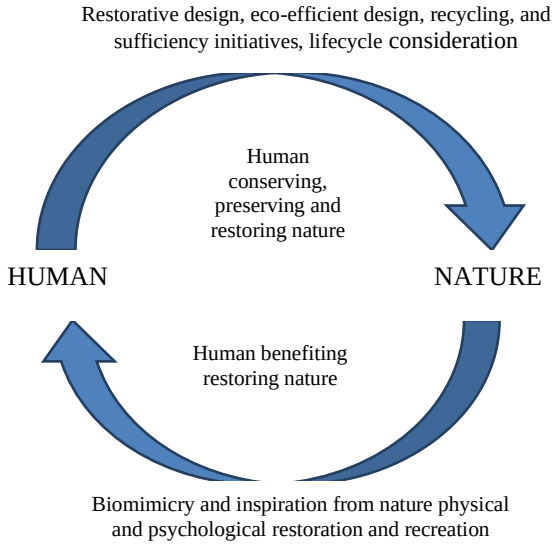

Figure-1. Bi-directional impacts between human and natural systems [23].

This study combines eco-efficiency and green ergonomics to provide adequate production equipment with the ability to save energy and resources. The focus of this approach was to develop ergonomic interventions for a pro-natural focus and the principles include evaluation, design, and innovation for eco-efficiency, eco-effectiveness, eco-productivity, ecological resilience, solutions, and natural system [24].

Some of the studies reaffirmed the significant role of ergonomics in solving environmental problems of the industry and the field related to this is known as Green Ergonomic Approach which is applied to develop and evaluate industries sustainability and also to ensure human system and nature are in a good reciprocal relationship as shown in Figure-1 [24].

Ergonomic studies can identify designs evaluation parameters that help designers, buyers and users to choose product solutions and processes [25]. Human factor or ergonomics is highly related to

sustainability in solving problems comprehensively and thoroughly. Moreover, globalization requires a broader perspective which incorporates sustainable development and it is not possible to release this without ergonomics [26]. One component of Green Ergonomic is eco-efficiency and it was considered in the study to minimize environmental impacts while workstation design was also recommended to support its effectiveness.

2. METHODS

Eco-efficiency and workstation analysis with Green Ergonomics were used in this study and the production data in terms of the fuel used for the wax removal process were obtained from 2 different SMEs. The eco-efficiency analysis was initiated with the Damage Assessment by considering the raw materials and using SimaPro 9.0.0.4.8 to determine the categories and environmental impacts such as (1) Human Health with DALY (Disability Adjustment Life Years) units, (2) Ecosystem Quality with PDF * m2yr units (Species Fractions that may be missing per square meter per year), and (3) Resources with MJ Surplus units (Mega Joule) [27]. Furthermore, the Damage Assessment was also used to calculate the eco-cost which is the amount of money incurred due to environmental damage while the Eco-Efficiency Index (EEI) was derived from comparing total profits from sales with thee eco-cost [28]. The SMEs with the highest EEI were selected to determine the workstation to be designed in order to ensure the concept of ergonomics is satisfied by having a comfortable work posture. Moreover, the recommended design was analyzed using Ovako Working Posture Analysis (OWAS), Rapid Upper Limb Analysis (RULA), and Low Back Analysis (LBA).

3. RESULTS AND DISCUSSIONS

The study started by comparing the Eco-Efficiency Index (EEI) of two different batik SMEs with respect to the fuel usage at the wax removal workstation which requires the use of heated water to rinse the batik cloth. SME A used a furnace with firewood while SME B with used oil and the Damage Assessment results are shown in Table-1.

Table-1. Damage assessment of wax removal.

Damage category	Unit	SME A	SME B
		firewood	used oil
Human Health	DALY	0.009813556	0.001238317
Ecosystem Quality	PDF*m2yr	241.74543	59.951388
Resources	MJ surplus	220.93956	3184.1369

Table-1 shows the Human Health and Ecosystem Quality with the SME B observed to have a lower value compared to SME A and this indicates the damage caused by a furnace with used oil is lesser than with firewood.

Further analysis was conducted with SimaPro 9.0.0.4.8 to determine the eco-cost required for the calculation of the Eco-Efficiency Index (EEI) and the results are presented in the following table. The EEI was calculated by comparing profits obtained from the difference between total sales and production costs in 1 year with eco-costs.

The results showed the SME B with used oil has a higher Eco-Efficiency Index (EEI) than SME A with firewood and this means its wax removal process was more efficient and environmentally friendly.

Table-2. Total eco cost.

Damage Category	Unit	Eco Cost (IDR) SME A	Eco Cost (IDR) SME B
Human Health	DALY	74,403,791.4	88,970,918.7
Ecosistem Quality	PDF*m2yr	1,210,793,135.4	1,675,632,608.7
Resources	MJ surplus	1,815,206.83	2,733,854.03
Total		1,287,012,133.6	1,767,337,381.5

Table-3. Eco Efficiency Index (EEI).

Variable	SME A	SME B
Sales (IDR)	561,600,000.00	88,970,918.73
Production cost (IDR)	371,379,600.00	1,675,632,608.77
Profit (IDR)	1,815,206.83	2,733,854.03
Eco Cost(IDR)	1,287,012,133.64	1,767,337,381.54
Eco Efficiency Index (EEI)	0,147	0,178

Therefore, the method is recommended because it is more efficient and better for the environment and this means ergonomic wax removal workstation is required to improve eco-efficiency.

Figure-2. Initial design wax removal workstation.

Wax removal is one of the stages in the entire batik production process and, as previously stated, it starts with boiling water in a tub with fire from firewood, for about 2.5 hours after which the fabric is inserted and wax is removed by twisting and moving the fabric up and down repeatedly using a stick and drained afterward. This is usually followed by the transfer of the fabric to the washing bath. However, this process is observed to have an activity which is considered not to be ergonomic and this involved the workers bending and squatting to pick and place the firewood into the furnace due to the location of the furnace as shown in Figure-3. This posture was discovered from interviews not to be comfortable for workers and also to present a risk of injury. Therefore, the workstation needs to be redesigned to provide ergonomic comfort for the workers.

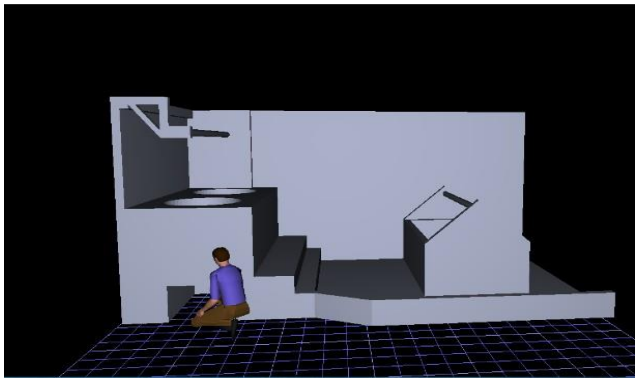

Figure-3. Initial design work posture in preparing the furnace at the wax removal workstation.

Redesign wax removal workstation is to eliminate squatting and bending postures when preparing water heating furnaces with due consideration for the eco-efficiency aspects using which involves using used oil fuels as previously discussed. Figure-4 shows the replacement of the wood-burning furnace with a used oil-fired furnace and the bending and squatting in the previous method have been eliminated because the new design requires the worker to be in a standing position to ensure comfortability. This is considered necessary because the reduction of bending and squatting postures at work has been a challenge for entrepreneurs, employees as well as the occupational safety and health community, and this has been achieved through the ergonomic interventions [29].

Some previous studies have shown the difficulty associated with improving the work posture of a worker whose job role requires moving from one activity to another and the transformation of the squatting posture into optimal alternatives to reduce costs and minimize workload has also been evaluated by [30]. Moreover, oxygen consumption and heart rate in lifting activity using this posture were considered higher than others but the Maximum Accepted Weight Limit (MAW) was significantly lower [31]. This means squatting postures are not recommended for several activities. Products are designed based on specific functions that are useful and convenient for users [32].

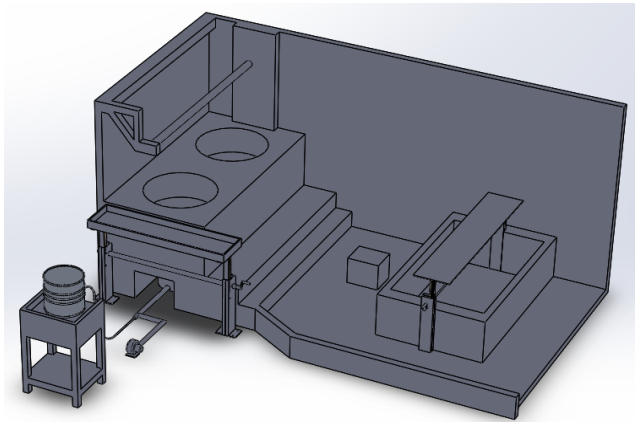

Figure-4. Redesign of wax removal workstation.

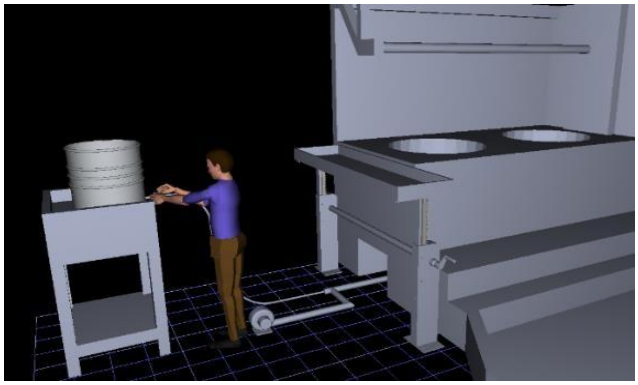

Figure-5. Redesign work posture to prepare the furnace.

The OWAS, RULA, LBA, and PEI analysis showed a change in the score of the actual station assessment with the squatting posture and the recommended workstation with the standing posture. Moreover, a smaller score indicates a safer work posture with the risk of spinal injury also getting reduced.

Table-4. Work posture assessment.

Assessment	Initial design	Redesign	Conclusion
OWAS	3	1	A smaller score leads to a lesser risk of injury and this indicates a safer work posture.
RULA	4	3	
LBA	995	640	
PEI	1,85	1,04	

It is important to note that the PEI scores are an accumulation of OWAS, RULA, and LBA and the small score recorded was due to the upright body posture which led to a relative reduction in the risk of injury to the spine and musculoskeletal system for the workers [33].

Table-5. Comparison of the designs.

Initial Design	Redesign
Boiling water using a furnace with firewood and kerosene Working posture in preparing and inserting firewood into the furnace involves squatting and bending.	Boiling water using a furnace with used oil fuel. Working posture in preparing the furnace by standing reduces the risk of injury to the spine.

The redesign workstation provides workers the convenience to do other activities more easily due to the standing position and reduces the risk of injury compared to previous work postures which involve squatting or bending. The recommended design is also more ergonomic by providing comfort and convenience in working as well as using a furnace with used oil fuel which has been proven to have a better EEI compared to the use of firewood.

These result showed Green Ergonomics is needed to meet the goals of eco-efficiency and sustainability which involves minimizing environmental impact and ensuring workers convenience. This is in line with its implementation in product design, work, and systems towards reducing their negative impacts on the environment. With an ergonomics-based work station design will affect work posture and work time which will increase worker performance [34]. Moreover, ergonomics concepts have also been applied in Sustainable Development and Human Factor [35] which comprehensively covers economic and social needs as well as sustainability [36]. Sustainability is doing good things for environmental, social and community for increased energy conservation, human life as well economic development [37]. It also focuses on safety, health, quality of life, efficiency, and productivity and this means the concept has a close association with all aspects of the environment [38]. Therefore, effective synergy is required between ergonomics and sustainability and this is achievable through workstation or ergonomics product designs [39].

4. CONCLUSIONS

Green Ergonomic with its design tools has the ability to ensure eco-efficiency by making the production process more efficient and environmentally friendly. Moreover, replacing the firewood furnace with used oil was also able to increase the Eco-Efficiency Index while the improvement in the workstation design makes the workers work comfortably, safely, and ergonomically. Therefore, green ergonomic tools were able to integrate environmental consciousness into workstation design in order to achieve better eco-efficiency.

ACKNOWLEDGEMENTS

This study was facilitated and funded by LPDP, Republic of Indonesia. The researchers would like to thank the students and who have helped to collect data.

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