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Sustainability in Textile Manufacturing Processes by Waste Reduction: A Case Study from Bangladesh

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As the level of automation is increasing among industries, the increasing amount of waste has become one of the main barriers to having a sustainable environment. That's why the sustainable manufacturing concept came to bring economic benefits while focusing on minimizing negative environmental impacts. The purpose of this study is to show the importance of waste reduction in manufacturing processes to achieve a higher level of sustainability. This work uses the production processes of a textile garment factory located in Bangladesh as a case study to examine how waste reduction can be achieved. First, the major steps of the production process are mapped and visualized to identify improvement opportunities by using the Business Process Modeling Methodology and discrete event simulation. Second, after the production process is improved, an experimental test was conducted to see how much waste reduction can be achieved by the proposed solution. The research found that the in-sewing wastage in the factory was too much and used compressed air as a suggested solution to minimize this problem. The final result of the test showed that the in-sewing fabric wastage percentage had been reduced almost by 75 %, indicating the possible benefits of this solution regarding sustainability, if applied on a larger scale within the factory.

1. Introduction

Since the beginning of modernization, as automation gained speed, the environment started to lose its balance. (Ching et al., 2022). That is why the United Nations came up with 17 Sustainable Development Goals (SDGs) to end poverty, protect the planet, and ensure prosperity, which is to be achieved by the end of 2030 (Bhatnagar et al., 2022). Moreover, the fast reduction of natural resources due to increased manufacturing processes and a higher percentage of ecological imbalance has attracted the governments and respective authorities to call for sustainable development in manufacturing (Hariyani et al., 2022). The development of a green economy has also become a popular concept around the world in recent times (Sharma et al., 2022).

Based on Nazrul and Rahman (2021), Bangladesh has been a great manufacturing location for a long time and the readymade garments manufacturing industry is the biggest among all of them and contributes more than 80 % of foreign earnings. According to Centobelli et al. (2022), Bangladesh is the second-largest manufacturer of readymade clothing exporting clothing for leading and world-famous fast fashion brands such as H&M, ZARA, and C&A. With environmental issues rising up around the world and sustainability concepts being discussed frequently, the manufacturers like Bangladesh are having requests from their buyers to implement an environment-friendly system or transform the conventional clothing manufacturing process into a sustainable one. But, changing the conventional manufacturing processes into sustainable ones is time-consuming. To mitigate this issue, Industry 4.0 came as a combination of several advanced technologies to help manufacturers to have improved decision-making abilities while organizing their resources quickly and efficiently (Dixit et al., 2022). It deals with green technologies, renewable energy, sustainable fission, and fusion power in a flexible and reversible way and can lead to the final point of achieving full pledged sustainability (Hasan et al., 2020).

Textile and clothing is currently one of the biggest manufacturing industries. According to Wren (2022), the global revenue from the apparel market might reach the $2 trillion threshold by the end of 2026. The bigger the industry is, the higher the amount of waste generation. In the case of the clothing industry, it involves high volumes of synthetic or petroleum-based components which is leading to an increasing amount of greenhouse

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gasses and landfill wastes (Elmogahzy, 2020). In general, clothing and textile wastes can be classified into two types. Pre-consumer wastes which are process waste, damaged/unsold clothing waste, cut-sew waste, end-roll waste, and sampling yardage waste (Jamshaid et al., 2021). Post-consumer waste starts generating once the product is sold (Enes and Kipoz, 2020).

To cope with the buyer's requirements, ready-made garment (RMG) factories in Bangladesh are trying to adopt cleaner and improved manufacturing technology to reduce the amount of pre-consumer waste (Khandaker et al., 2022). Bangladesh mainly manufactures readymade garments which especially generates dry textile waste coming mostly from the cutting, sewing, and finishing sections of a garment factory (Rahman and Chowdhury, 2020). Hence, these have become the major wastage generation points needing attention in the case of the country (Akter et al., 2022). Attempts are being taken to re-design the existing manufacturing process by studying the existing manufacturing process while trying to identify the root cause behind the waste generation and the inclusion of some assistive technology to bring the required innovation (Moorhouse, 2020). Thomé and Scavarda (2015) highlighted the importance of process integration to increase sustainability, and Sompák et al. (2013) suggested a new logistical approach for waste reduction. Halim and Hawlader (2017) showed that using sewing aids within the garment production processes can significantly reduce the production time and hence increase the worker's efficiency. Ahmed et al. (2018) published a paper where they used different types of sewing work aids in a manufacturing line and did a time study to show the overall improvement of productivity and reduced sewing waste of that sewing line. Tilahun (2020) worked on a topic where he used several folders as work aids to improve the quality of the clothes and the productivity of the sewing line.

On a sewing floor of a clothing manufacturing plant, the major wastage yields from overlock operation which is done by an overlock sewing machine because of the fabric trimmer associated with it which cuts the edges of the fabric during sewing (Ramkalaon and Sayem, 2020). This is identified as cut-and-sew fabric wastage. Minimizing the percentage of such waste will not only positively affect the profit of the manufacturing plant but also will improve the concept of sustainability (Jaouachi et al., 2019). Compressed air is one of the appropriate technologies that have the ability to reduce this sort of cut-and-sewn waste from the sewing floor (Sarwar et al., 2021). For example, in the case of knit fabrics, there is always a tendency for the fabric ends to curl. During stitching attempts of such fabrics in the overlock machine, results in excess fabric edge trimming by the trimmer on the machine to remove curliness and smoothen the operation (Ansari et al., 2019). Compressed air can help to minimize this curliness by being blown off from above and below the fabrics and hence the edges will flatten up and the operation will be smooth, sewing wastage will be less (Jana, 2015). That's how the inclusion of a simple technology within the existing manufacturing process can help to achieve the ultimate goals of sustainability.

The purpose of this study is to show an improved manufacturing process of a product within a factory which is focused to eliminate in process waste in order to achieve a higher level of sustainability in the production line. While several previous researches approached the garment industry aiming to increase productivity and efficiency, this study is particularly focused on reducing waste from a certain area that was not widely explored yet, aiming to contribute to increased productivity at the same time. That is why, this research uses the production processes of a chosen product from a textile factory located in Bangladesh as a case study to examine and show how in-process waste reduction can be achieved. While doing so, the major steps of the whole production process were mapped and visualized to identify improvement opportunities by using the Business Process Modeling Methodology and discrete event simulation at first. Then, the whole process was modified to an extent and tested in an experimental setup to see how much waste reduction could be achieved by the proposed solution.

2. Problem Description

The research idea came from the sense of minimizing pre-consumer (dry in-sewing) waste within the plants of Bangladesh. A clothing manufacturing plant was selected. The manufacturing process of a product line was studied and observed to find out the major waste generation point. After that, the existing manufacturing process was analyzed and then re-engineered according to the requirement with the inclusion of the appropriate technology after several trials. New data were collected to compare with the existing data and analyze further to find improvements (Figure 1).

The research aims to answer the following questions: why excessive sewing wastage is being generated in the selected clothing manufacturing plant and how the re-engineering of the usual manufacturing process can bring an optimized sustainability level within the plant? What can be the estimated cost of the process re-engineering and what are the potential benefits that can be achieved through this?

The selected product line was a Kid's Top (solid dyed). Fabric construction: 100 % cotton, Single Jersey, 160 grams per sq. meter (GSM). While reviewing the whole operation process of the aforementioned style, it was seen that the excessive sewing wastage was coming out mainly from the overlock machine during the body side seam operation. It was happening because of the edge-neatening task done by the knife associated with the machine, cutting down the curly edges of both sides of the product. This is because the knit fabric has the general tendency of being curled on the sides. However, when the operator was careful with the task, the wastage percentage remained within the approved tolerance limit. But, in order to keep up the pace and maintain the specified standard minute value (SMV), the operator was not doing the task carefully most of the time, and hence a lot of unwanted sewing waste was coming out each time. Moreover, due to the excessive waste generation from the body side seam overlock operation, the pattern maker needed to adjust the pattern each time and had to add more waste percentage in the final pattern than the approved tolerance limit, increasing the overall fabric consumption for each product and finally, leading to a lesser amount of profit. In the research, Technomatix Plant Simulation (version 15) was used to find the appropriate layout and a simulated result.

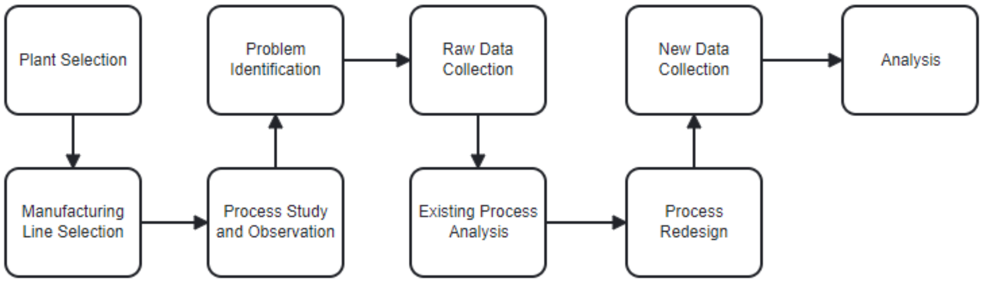

Figure 1: Flowchart of the Research Process

3. Methodology

After studying the existing manufacturing process, and carefully reviewing the identified problems and all the available options within the plant, the idea was to implement compressed air as the assistive technology within the production line to minimize the sewing waste to an optimized level matching to the sustainability standard. This is because the curliness of the fabric was the root cause behind such wastage and compressed air has the ability to eliminate such curliness if used properly. To examine the current process of the sewing line more precisely discrete event simulation were applied with the help of the Technomatix Plant Simulation software (Figure 2).

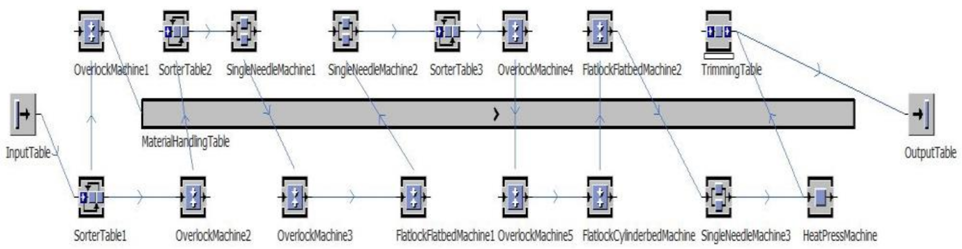

Figure 2: Simulation of the Existing Manufacturing Process

The very first issue raised with using compressed air as the manufacturing assistant was technical, as the application area was small and required preciseness. So, a small device was made to apply compressed air during the overlock sewing process in that small, specific area of the machine, and it was built in a way so that it could be attached to the presser foot of the machine. The device was made as per design specifications confirmed by the research team, and a factory technician made it accordingly. The device was made of copper, having a length of 7 cm with a diameter of 0.6 cm. A small round-shaped hook was welded to the device in such a way that it could be attached to the presser foot of the machine with a small screw.

From the central air compressor of the factory, the air came into the sewing floor through the horizontal overhead pipes. Then, via vertical steel pipes, the air is entered into loading points in each sewing line, and each point has an on/off switch to control airflow. From the loading point, via horizontal pipes, the central compressed air is connected to each machine into an air meter, which is connected to the pedal of the machine. To bring the compressed air connection from the air meter to the actual operation area of the overlock machine, an additional connection was added after discussing the feasibility and going through several trials. The other side of this extended connection was attached to the circular (top) part of the air-flowing device. The device was then attached to the presser foot of the sewing machine. When the operator started sewing by pressing the pedal down with a foot, compressed air started to come out of the air-flowing device. To examine the improved process of the sewing line more precisely, discrete event simulations were also applied again during the design process (Figure 3).

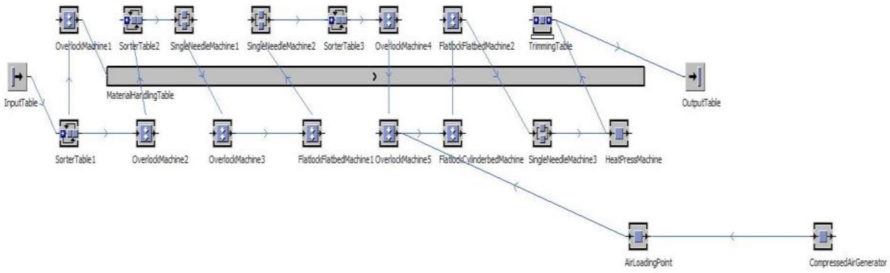

Figure 3: Simulation of the Improved Manufacturing Process

After successful application, the high-speed compressed air flow straightened the curly edges of the garment during sewing. As a result, the fabric wastage was reduced as the machine knife did not have a lot of excessive fabric edges to cut down, and the operator also did not have to put much effort into straightening out the fabric edges while sewing.

4. Application and Results

After collecting real production data before and after the implementation of the improved process, it was possible to compare the previously existing and the improved manufacturing processes with each other (Table 1).

Table 1: Comparison between Existing and Improved Manufacturing Processes

Existing Manufacturing Process				Improved Manufacturing Process			
Date	Shift	Sewing Waste (gram)	Output (pieces)	Date	Shift	Sewing Waste (gram)	Output (pieces)
26-June-	Morning	145.7	116	24-July-	Morning	36.3	144
2022	Afternoon	139.2	121	2022	Afternoon	36.1	139
27-June-	Morning	148.6	115	25-July-	Morning	35.9	141
2022	Afternoon	144.1	118	2022	Afternoon	38.1	140
28-June-	Morning	140.8	122	26-July-	Morning	37.2	145
2022	Afternoon	138.9	119	2022	Afternoon	35.6	137
29-June-	Morning	146.5	110	27-July-	Morning	36.9	137
2022	Afternoon	148.9	117	2022	Afternoon	35.4	142
30-June-	Morning	138.5	116	28-July-	Morning	37.7	145
2022	Afternoon	142.4	109	2022	Afternoon	36.5	144
Average		143.36	116.3	Average		36.56	141.8

According to the results in the previously existing working process, when the operator was doing the body side seam operation in the overlock machine, the knife associated with the machine was cutting the edges even more than the allowance because of the tendency to curl at the edges. But in the re-engineered manufacturing process, the highly speedy compressed air was coming out of the device during the sewing operation, minimizing the curliness, and hence, sewing wastage came down to a minimum level.
Table 2 shows an overall summary of the improvements. The data in the table illustrates that the existing operational process had an hourly average production of 116 pieces of garments while generating an average waste of 143 g/h. On the other hand, the modified production process showed a higher hourly average output of 142 pieces while reducing the waste level to 36.5 g/h on average. Hence, the calculation of the collected data indicates that 74.49 % of waste was reduced in the updated process compared to the existing method, and 17.98 % was increased in total output compared to the existing process.

Table 2: Comparison between Existing and Improved Manufacturing Processes

Method	Average Waste (gram)	Average Output (pieces)
Existing Method	143.36	116.3
Updated Method	36.56	141.8
	Reduction= 106.8	Increase= 25.5

Compared to all the improvements, the cost of the improved process is very small. A calculated $ 15 is the cost of compressed air per overlock machine each day. In addition, $ 3 is the estimated cost of the air-flowing device and set-up cost (Table 3).

Table 3: Estimated Achievable Profits from the Improved Manufacturing Process

Current Hourly Output on the Specified Body Side Seam Overlock Operation	125 pieces
Average Output from Other Tasks	145 pieces
Can achieve Hourly Output (according to the modified process described in this study)	140 pieces
Calculated Hourly Increase in the Final Output	15 pieces
Price Per Garment	$ 3
Net Hourly Increase in Revenue	(15x3)= $45

In addition to this, the current panel dimension (44 cm x 31.5 cm) has been reduced to (44 cm x 31 cm) which indicates a 0.5 cm of width-wise reduction in dimension. As the compressed air was flattening the curly edges, the pattern maker didn't have to give additional waste tolerance to the pattern. This can actually lead to reduced fabric consumption per garment and ultimately bring higher profit.

5. Conclusion

Sustainable production processes have key importance in meeting current daily needs without compromising the ability of future generations to meet their own needs. The sustainable manufacturing system is an idea that can integrate product and process design issues with manufacturing, planning to effectively control, reduce, and manage the flow of waste. Considering the above statements, this study was carried out to show an improved way of performing the regular garment manufacturing process of a selected product with the help of compressed air, blown on an experimental setup via an air blower device. The results showed that the process waste percentage was reduced by almost 75 % compared to what it was before. At the same time, the productivity improvement was almost 18 %. Moreover, the estimated calculation showed that the process modification cost is very small compared to the estimated benefits (benefits achieved through higher productivity and panel dimension adjustment). However, as it was only applied in one sewing line, the research can be extended further by implementing the same within multiple sewing lines on a large scale within the same plant following the success of this study to understand the result from a bigger perspective and modify further if needed. Moreover, the same can be applied to products that use heavy fabrics as their base (e.g., denim jeans, jackets) and then go through trials to make it work.

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