Tanzania Journal of Science 47(5): 1689-1700, 2021
ISSN 0856-1761, e-ISSN 2507-7961

Critical Analysis of Material Consumption and Cost Reduction Techniques for the Apparel Cutting Processes

Ismail WR Taifa*, Ibrahim Twaha and Mboka A Mwakibambo
Mechanical and Industrial Engineering Department, College of Engineering and Technology, University of Dar es Salaam, Dar es Salaam, Tanzania
E-mail addresses: taifaismail@yahoo.com; itaifa@udsm.ac.tz; twahai13@gmail.com; sirmboka2005@gmail.com
**Corresponding author*
Received 12 Sep 2021, Revised 23 Oct 2021, Accepted 8 Nov 2021, Published Dec 2021
DOI: https://dx.doi.org/10.4314/tjs.v47i5.17

Abstract

Revenues generation in the garment industry is synonymous with material consumption. This study thus analysed material consumption and cost reduction techniques in the Tanzanian garment industry. The research employed quantitative (experimentation) and qualitative approaches (document review and observation technique) in the apparel cutting processes. Experimental results of material consumption from ten tests averaged efficiency of 78.67%, the wasted pieces (19.2%), and unnoticed waste (2.03%). Essential considerations to reduce material waste include: digitalising the fabric cutting processes; providing workers training; deploying appropriate practices in the cutting room (e.g. pattern engineering and pattern accuracy); considering the quality of the procured fabric and fabric efficiencies relative to different human body shapes and proportions; and considering the separation process rather than extending facings, splitting substantial components, slight reductions in a flare, and seam displacements. The study implies that apparel enterprises can benchmark their actual material consumption circa 50-70% of their total garment manufacturing costs.

Keywords: Material waste, Garment industry, Fabric losses, Cost reduction techniques, Small and medium-sized enterprises.

Introduction

The garment industry has gradually advanced through various technological innovations to improve the style, design, manufacturing processes, cost reduction, etc., to increase business profits ultimately (Mwasubila et al. 2020). Some of the factors which drive changes in the garment industry include competition for customers (retail environment) (Caridi et al. 2013), sustainability principles (Taifa 2021, Nzumile and Taifa 2021), scarce capital utilisation, global economic changes, factoring, and continuous changes. Amongst the critical inputs to operating the garment industry are raw materials: the crucial one being the fabric. Ideally, garment materials comprise fabric, buttons, interlining, lining, tickets, labels, tapes, pads, zips, packaging and hangers materials, among others (Cooklin et al. 2012). The revenue generated in the garment industry is thus synonymous with material consumption (Armstrong and Lang 2013). So, colossal fabric losses contribute to material utilisation (Ng et al. 1999).

The development of the garment industry has progressed through many changes as innovations and creativity have been taking place continuously through different industrial revolution timelines (Taifa et al. 2021a). Technology advancements are aimed at simplification of the manufacturing processes and maximising profits (Taifa et al. 2021b). However, the number of materials consumed in garment manufacturing and cost utilisation is amongst the major drawbacks to date. The garment industry invests astronomical capital and uses high energy in production lines. The apparel manufacturers need to develop standard operating rules, reduce raw material wastage, minimise waste, and optimise logistics to realise high profits as the industry faces stiff competition (Nayak and Padhye 2015).

Garment manufacturing processes require customer orders regularly. The vital phases to complete customers' garment orders include the cutting, sewing (assembly), and finishing (pressing) processes (Sellitto and de Almeida 2019) which all need massive material intakes (Naveed et al. 2019). Despite the apparel industry's complex situations, it is vital exploring the key driving force in saving the manufacturing costs: fabric consumption. Higher material consumptions can affect the profit compared to the invested capital, operation costs and energy utilised (Dumishllari and Guxho 2016). One Tanzanian garment factory (referred to as *S-Company*) experienced the problems mentioned above. Due to these problems, it was instigated to research on minimising implied costs and material waste. So, this study demonstrated how garment manufacturers, both small and medium-sized enterprises (SMEs) and large enterprises, can overcome a similar problem. This study examined the consumed materials and identified techniques to minimise the garment manufacturing costs due to material utilisation. To realise the main objective, three research questions were stated:

a) What are the fabric losses in the garment cutting processes?
b) What are the generated waste and cost implications related to the fabric cutting processes?
c) What are the cost reduction and material saving techniques in the cutting process?

Theoretical orientation

The garment industry: an overview

Taifa and Lushaju (2020) discussed and analysed the Tanzanian textile and garment (T&G) industry. Amongst the basic requirements to operate the garment industry include raw materials, machines, operational knowledge, and workforces (Taifa and Lushaju 2020). The T&G industry faces stiff competition. The high pressure is chiefly on increasing the efficiency of material consumption due to its contribution to the total garment manufacturing costs. Planning economic cutting lays, and the technique of processing cutting orders need excellent utilisation to reduce consumed materials to increase the efficiency of the cutting processes (Krsteva and Demboski 2011). Ideally, the better utilisation of material and time costs should be through optimising the overall cutting processes (Beazley and Bond 2003, Sellitto and de Almeida 2019). It is vital to consider the cut order planning processes, spreading, and cutting processes to realise better material utilisation to make garments (Krsteva and Demboski 2011). The T&G industry also faces workforces increase and operation costs with a gradual decrease in the garment selling prices (Wong and Leung 2008). This requires adopting robust response strategies to make and deliver garments to customers whilst utilising fabric consumption and optimising labour and production costs (Wong and Leung 2008).

Materials used in the garment industry and the related costs

Long term survival of enterprises relies upon the accrued profits. The cost category is based on the *behavioural aspects*: fixed costs (FCs) and variable costs (VCs), whereas the basis of *traceability*, contains direct costs (DCs) and indirect costs (ICs) (Singh and Nijhar 2015). Costs for the apparel industry include FCs and VCs. FCs remain unchanged irrespective of the order quantities (number of produced garments), while the variable costs increase proportionally to the total manufactured apparel (Singh and Nijhar 2015). Examples of FCs for the apparel industry include machine and rental costs, whereas, for VCs, these include raw material costs and other related accessories to make apparel. The analysis of material consumption and cost reduction techniques should thus reduce VCs rather than the FCs.

DCs can be traced relative to the manufactured products, e.g., the DCs of raw materials (cost of trims, yarn, fabric, hooks, zippers, fabric fillings, buttons, and labels) and DCs of labour(s) (Singh and Nijhar 2015). ICs cannot easily be quantified, e.g., the wages or salary of the designer based on the time spent to design, inspecting the designed patterns and the designs, thus making it challenging to quantify the accrued costs (Singh and Nijhar 2015). Figure 1 depicts cost elements to manufacture apparel: the sum of all the costs and the profit margin dictates the product selling price quoted by the factory.

Costing methods

Costing consists of pre-costing and final costing procedures. *Pre-costing* (predictive, cost estimating, pre-production or sample costing) involves estimating all costs early in the development stages (Kennedy et al. 2020). The designers record the material costs on a worksheet. Later, the costing department can estimate the wholesale cost to determine whether the attire fits into the line's price structure (Kennedy et al. 2020). The final costing involves the cost of the manufactured garment once all the required style details are finalised and the labour, trimming, and fabric costs are also identified. The *final cost (determined, standard,* or *production costing)* includes transportation, overhead, duties, and customs clearance (Kennedy et al. 2020). The final cost should be recorded on a cost sheet.

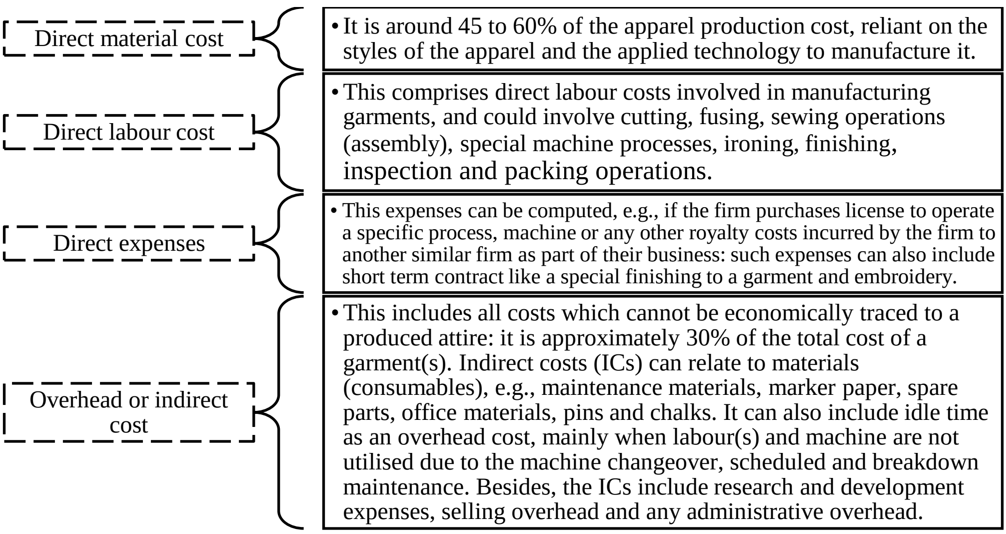

Figure 1: Cost elements to make apparel (Jeffrey and Evans 2011, Cooklin et al. 2012, Singh and Nijhar 2015).

Fabric losses in the garment cutting processes

To eliminate fabric waste necessitates identifying different types of wastes, segregating them into essential and non-essential wastes, and creating methods to minimise or eliminate these wastes. The total fabric losses comprise the *external wastage* (comprising splice losses, width losses and end losses) and the *internal wastage* such as marker fallout (Ng et al. 1999). Other considerations can include roll length of fabrics, remnant, number of splice lines, and marker length. Types of material losses when manufacturing a garment include end of ply losses (Equation 1), edge losses, fabric joint losses, remnant losses, splicing overlap losses, ticket length losses, cutting edge losses and stickering losses (The ITJ 2008, Karthik et al. 2017).

$$End\ loss\ wastage = \sum[(Lay\ length - Marker\ length) \times Actual\ number\ of\ plies] \quad (1)$$

Cutting room operations at S-Company

The cutting room operations include fabric delivery, fabric inspection, Grams per square meter (GSM) measurement, marker making, spreading and fabric cutting method. Rolls of fabric (each weighing 18-22 kg) are received from the mill reliant on the customers' orders. S-Company follows standard fabric inspection procedures: the often-observed defects are holes, stains, and oil, while other defects appear rarely. The S-Company also has a defect rating during the inspection processes (Table 1). Q3 and Q4 ratings are due to oil and stain defects. Sometimes human errors resulting from lack of focus caused the defective rolls to pass to the cutting table: those rolls can be noticed during or after cutting, which lead to wastes.

Table 1: Defect rating

Number of defects	Rating	Results awarded
1-7	Q1	Pass
7-14	Q2	Pass
14-21	Q3	Fail
21 and more	Q4	Fail

There are two ways of GSM measurements: the use of an instrument: includes a Round GSM cutter and weighing balance; and the use of Equation (2). For instance, a square piece of fabric with a length of 8 cm and a weight of 2 g; its weight per square meter is obtained using Equation (2), thus giving 312.5 g/cm^2. The S-Company uses the instrument in determining GSM.

$$Weight\ per\ square\ meter = \frac{Weight\ of\ sample\ in\ grams \times 10000}{Area\ of\ the\ sample\ in\ cm^2} \quad (2)$$

At S-Company, a marker is prepared for each design using Computer-Aided Design (CAD) software–Red Tree, which designs patterns and prepares the marker depending on the width and length of the lay. Equations (3) and (4) compute the marker efficiency. It was also observed that the S-Company has several wastes which are generated due to a poor marker.

$$Marker\ efficiency = \frac{Area\ of\ marker\ used\ for\ garments}{Area\ of\ the\ total\ marker} \times 100\% \quad (3)$$

$$Marker\ efficiency = \frac{Weight\ of\ the\ fabric\ to\ be\ consumed\ by\ pattern\ pieces\ in\ a\ marker}{Total\ weight\ of\ the\ fabric\ under\ the\ marker\ area} \times 100\% \quad (4)$$

Spreading can be performed manually or automatically. Manual spreading takes place at the S-Company. Usually, two workers are involved in spreading the fabric on the cutting surface. Two key drawbacks characterise this: time-consuming and tension of fabric varies. Manual and/or computerised methods are used to cut fabrics in the garment industry. The S-Company uses the manual cutting method. The equipment includes a tape cutter, scissor, round knife, die-cutting, band knife, drill, and straight knife.

Related studies

Several studies critically analysed material consumption and cost reduction techniques for the apparel cutting processes. Wong and Leung (2008) developed a genetic optimisation decision-making model through adaptive evolutionary robust strategies to manage cut order planning. Their study showed at least 50% for the manufacturing costs. Jeffrey and Evans (2011) explored the associated costs for the fashion industry and found the costs ranging between 45% and 60%. Dumishllari and Guxho (2016) determined the lay plan's optimal result(s) and its impacts in the cutting section: their study found 50% to 80% being the associated costs. Krsteva and Demboski (2011) provided extra required information on cut order planning, the T&G waste and material utilisation in the Macedonian apparel industry, 75% of the production expenditure due to the raw material costs. The ITJ (2008) discussed the fabric usage and several fabric losses in the cutting section: the associated garment material costs tallied between 40 and 60%. Since up to 75% of manufacturing apparel can be due to material costs, thus by critically analysing and optimising the raw materials costs can increase profits. It is thus vital to critically analyse the proportions of the garment generated waste and the general costs.

Materials and Methods

This study involved quantitative and qualitative approaches. Qualitative approaches included document review and observation approaches. The document review highlighted how garment industries perform their operations in cutting rooms based on currently available techniques. Subsequently, the study involved an industry visitation in collecting data on garment material consumption at S-Company (one of the T&G industries in Tanzania). The study also used a quantitative approach because it focused on quantifying and analysing the material consumption data from the cutting room. Quantitative research is formed from deductive reasoning (deductive approach) because the prominence is positioned on testing theory, shaped by positivist and empiricist philosophies (Taifa 2020).

A larger sample can yield more accurate results but can be much more expensive. Therefore, the amounts of samples used were based on the number of rolls per design in this case. This study considered the designs for t-shirt making processes as this was the only design under production during the data collection processes. Data collection processes included the following aspects: (a) A single fabric roll weighed 18 to 20 kg with a length of about 60 to 80 meters. (b) Depending on the lay length, the number of lays can be determined, which in most cases they are between 18 and 20 lays. (c) The lay lengths were between 300 cm to 500 cm. (d) The samples collected were from 5 lays of waste and pattern pieces for a single lay. (e) The collected samples were then weighed on the balance scale to determine weights.

In collecting data, the tools and equipment comprised pens, pencils, papers, fabric, cutting machines, laying the table, balance, and a scientific calculator. The collected data were presented in terms of the pattern weight, waste pieces weight: these data assisted in computing the average of each data category (Tables 2 to 5). Costs of each meter of fabric were noted and helped estimate loss(es) from meters of fabric lost in the cutting processes. Data were thus tabulated and plotted to determine several parameters associated with costs.

Results

Table 2 presents the ticket data, as recorded during the data collection period, whereas Tables 3 and 4 contain the weight of patterns (gram) and waste pieces (gram), respectively. Table 5 depicts the calculated values to determine efficiency, actual consumption, standard consumption and waste outcome from dust and unnoticed pieces (kg). Equations (5) to (7) computed the results in Table 5. Similarly, Equation (8) can calculate fabric utilisation.

$$Weight\ of\ patterns\ (kg) = average\ of\ patterns\ \times\ total\ number\ of\ layers \tag{5}$$

$$Weight\ of\ patterns\ (kg) = average\ of\ waste\ \times\ total\ number\ of\ layers \tag{6}$$

$$Efficiency\ (\%) = \frac{Weight\ of\ waste\ pieces}{Delivered\ weight} \times 100 \tag{7}$$

$$Fabric\ utilisation\ (\%) = \frac{The\ fabric\ used\ in\ garments}{The\ actual\ fabric\ received} \times 100 \tag{8}$$

The first five tests were performed from the first day of the new knife changing of the cutting machine (Tables 3 and 4). The other tests from six to ten were conducted after changing the knife of the cutting machine (Tables 3 and 4). This was performed to examine the effects of the knife's sharpness on the amounts of produced wastes.

Table 2: The ticket data

Parameters	Performed tests (PT)									
	1	2	3	4	5	6	7	8	9	10
Delivered weight (kg)	19.8	40	20	60.7	19.1	19.8	40	20	60.8	19
Width (inches)	38	24.5	38	38	20.5	38	24.5	38	38	20.5
Length of lay (cm)	316	495	316	376	760	316	495	316	376	760
Number of pieces per one layer	6	4	5	6	8	6	4	5	6	8
Number of layers	20	35	20	43	20	20	35	20	43	20
Number of pieces	160	140	100	258	160	120	140	100	25	160

Table 3: Weight of patterns (gram)

Performed tests (PT)	Sample number					Total	Average
	1	2	3	4	5		
PT1	760.0	767.2	770.4	744.3	778.9	3820.8	764.16
PT2	826.0	813.6	842.4	804.0	803.2	4086.8	817.36
PT3	727.5	729.2	730.3	732.4	731.3	3650.7	730.14
PT4	1200.4	1199.6	1199.3	1201.1	1198.9	5999.3	1199.86
PT5	849.0	847.2	848.4	847.8	848.0	4240.4	848.08
PT6	754.1	763.7	760.2	740.3	779.9	15192	759.64
PT7	810.8	802.9	815.4	810.1	800.1	4039	807.86
PT8	721.1	720.2	730.3	727.4	728.3	3627.3	725.46
PT9	1197.2	1194.0	1192.1	1193.4	1197.5	5974.2	1194.84
PT10	841.8	837.4	840.7	834.7	831.4	4186.0	837.2

Table 4: Weight of waste pieces (gram)

Performed tests (PT)	Sample number					Total	Average
	1	2	3	4	5		
PT1	212.1	215.2	216.2	216.0	211.5	1071	214.2
PT2	314.5	318.7	308.0	310.8	300.4	1552.4	310.5
PT3	257.4	261.0	260.3	261.2	260.7	1300.6	260.1
PT4	198.4	199.7	201.6	200.4	202.8	1002.9	200.6
PT5	93.9	94.2	94.0	94.3	93.7	470.1	94.0
PT6	211.2	214.3	216.1	213.0	210.5	1065	213.0
PT7	312.2	317.6	307.1	311.9	310.4	1559.2	311.84
PT8	247.2	261.1	258.2	260.3	258.4	1285.2	257.04
PT9	196.6	198.8	200.4	199.2	200.8	995.8	199.16
PT10	94.8	96.4	97.3	98.7	94.2	481.4	96.28

Table 5: The computed values

Parameters	Results for the performed tests									
	1	2	3	4	5	6	7	8	9	10
Weight of patterns (kg)	15.3	28.6	14.6	51.6	16.9	15.2	28.2	14.5	51.3	16.7
Weight of waste pieces (kg)	4.3	10.9	5.2	8.6	1.9	4.3	10.9	5.1	8.6	1.8
Efficiency (%)	77.3	71.5	73	85	88.4	76.7	70.5	72.5	84	87.8
Actual consumption (kg): X	19.6	39.5	19.8	60.4	18.8	19.5	39.1	19.6	59.9	18.5
Standard consumption (kg): Y	19.8	40	20	60.7	19.1	19.8	40	20	60.8	19
Waste result from dusts and unnoticed pieces (kg) = Y - X	0.2	0.5	0.2	0.3	0.3	0.3	0.9	0.4	0.9	0.5

From Table 2, the total ticket weight of tests 1 to 5 (the delivered weight) is 159.6 kg. The fabric used for patterns (efficiency) equals 79.60%. Similarly, the wasted pieces in percentage comprised 19.40%, whereas the other unnoticed waste was 1.0% (Figure 2(a)).

Using Figure 2(a), the total amount of wasted pieces and other wastes were obtained by calculating the respective percentages of wasted pieces and other wastes, as presented in Figure 2(b). The average amount of fabric that was cut per day in the cutting room was 2972.04 kg. The total daily consumption of fabric in kg was thus as follows: the used fabrics to make patterns are 2377.63 kg, wasted pieces (564.69 kg) and other unnoticed waste (29.72 kg); therefore, leading to a total waste of 594.41 kg (Figure 2(b)).

From Table 3, the total ticket weight of tests 6 to 10 (the delivered weight) is 159.6 kg. The fabric used for patterns (efficiency) equals 78.80%. Similarly, the wasted pieces in percentage comprise 19.20%, whereas the other unnoticed waste is 2.0% (Figure 3(a)).

The average amount of fabric that was cut per day in the cutting room was 2972.04 kg. Using Figure 3(a), the total amount of wasted pieces and other wastes were obtained by calculating the respective percentages of wasted pieces and other wastes, as presented in Figure 3(b). Thus, the total daily consumption of fabric in kg was as follows: the consumed fabrics to make patterns are 2347.9 kg, wasted pieces (564.7 kg) and other unnoticed waste (59.4 kg); thus, leading to a total waste of 624.1 kg (Figure 3(b)).

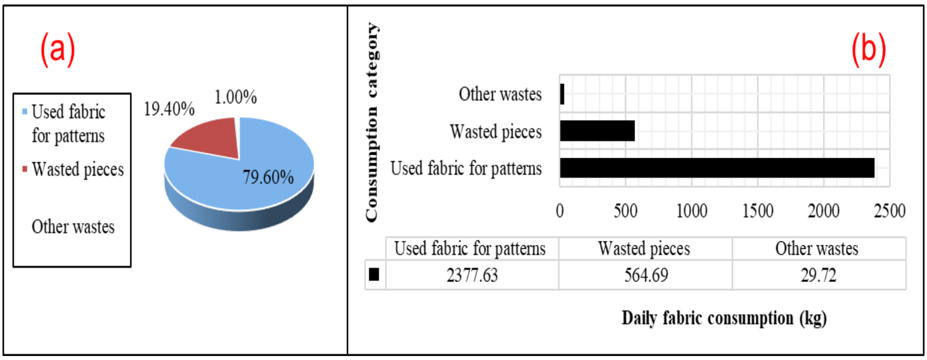

Figure 2: (a) Pie chart for the results of the first five tests. (b) Daily fabric consumption for the results of the first five tests.

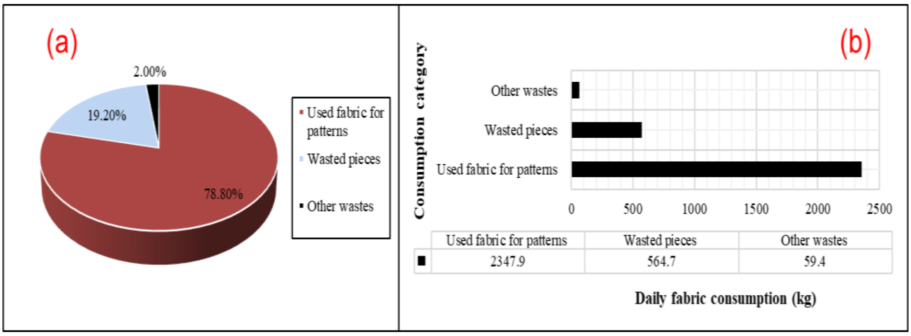

Figure 3: (a) Pie chart for the last five tests. (b) Daily fabric consumption for the results of the last five tests (6^{th} to 10^{th}).

Discussion

General overview and the fabric utilisation proposal

A typical fabric-cutting unit involves order receiving, cut order planning, marker planning, spreading, cutting and assembly (sewing) processes (Wong and Leung 2008). Other materials required can include buttons, shanks, sewing threads, labels, hangers, rivets, hangtag, carton box, elastics, laces, and polybags. Despite the garment industry consisting of other several activities, properly utilised fabric cutting processes with saving to the consumed materials is necessary to increase the profit (Wong and Leung 2008). This is because cut order planning of fabrics is the initial phase in the manufacturing workflow of the exemplar garment industry. Figure 4 shows a typical T&G framework to reduce material waste.

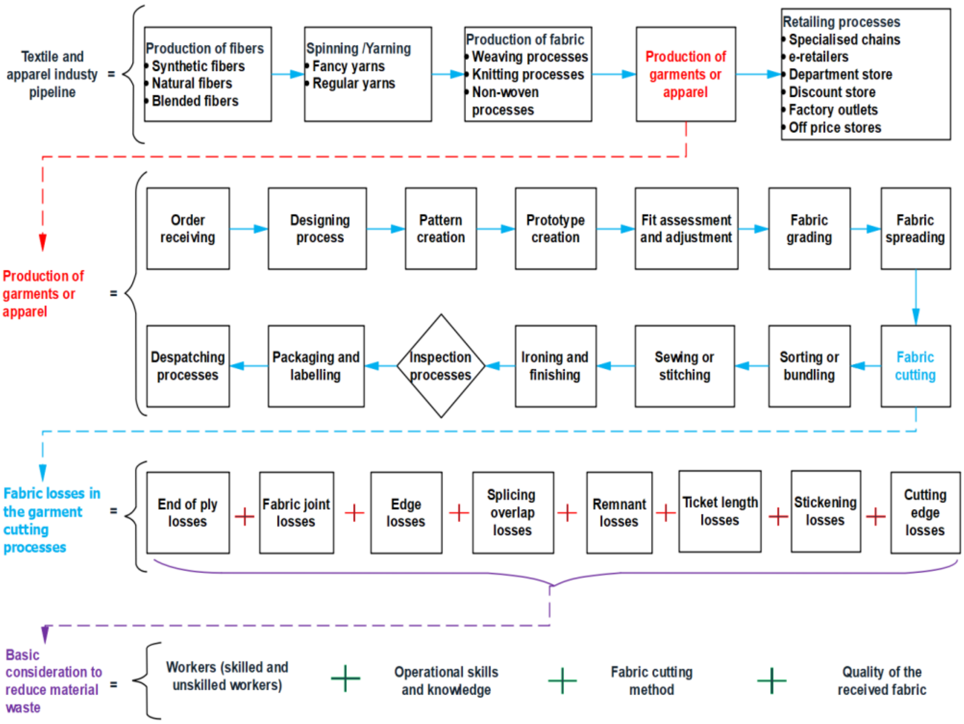

Figure 4: Typical textiles and garment conceptual framework to reduce material waste.

The following are the means of how wastes are generated when cutting fabric manually: incorrect drawing of the marker, the vibration of the knife, condition of the cutting table surface, the width of the cutting table and improper tension. The basic consideration to reduce material waste in the cutting processes are as follows:

a) *Digitalising the fabric cutting processes and other associated processes:* Industries are transforming through digitisation and digitalisation frameworks, leading to the digital transformation of vital functions or entire manufacturing processes. Researchers have proposed digitalisation through Textile 4.0, Apparel 4.0, and Fashion 4.0 (Taifa et al. 2020): these neologisms are coined with Industry 4.0 (Taifa et al. 2021a).
b) *Improving workers efficiency*: The garment industry comprises both skilled and unskilled workers. Although there is an emphasis on the digitalisation conceptual frameworks, still workers are needed to run industries. Workers must be adequately trained to update them on the newly discovered techniques and advanced technologies to deploy during the cutting and other associated processes.
c) *Deploying the best practices in the cutting room:* companies should enable the cutting section to alter the garment design to enhance fabric consumption without compromising the garment quality. The best practices could also involve pattern engineering and pattern accuracy.
d) *Quality of the procured fabric;* it is essential to procure high-quality fabric which adheres to the acceptable quality level, e.g., companies should procure acceptable fabric width, length, shrinkage in warp and weft, and other fabric parameters.
e) *The consideration of fabric efficiencies relative to different human body shapes and proportions*; e.g., Naveed et al. (2019) experimented in the garment industry at establishing the relationship between the fabric efficiencies and the different human body shapes: triangle, square, circle, and oval. They considered two order styles (the fitted shirts and the fitted trousers), which were transformed into four body shapes of men and women. Their study, via a comparative analysis of auto-generated-marker and skilled operative marker through Garment Gerber Technology (GGT) package, revealed the presence of several variations in the fabric utilisation. Naveed et al. (2019) study suggested the circle and triangle shapes for the women's and men's shirts, respectively, to be the most efficient shapes. Similarly, the least efficient shape was the oval body shape for both men's and women's shirts.
f) Other vital changes include separate instead of extended facings, splitting substantial components, slight reductions in a flare, and seam displacements (Cooklin et al. 2012).

Cost-saving techniques: an overview

Having analysed the material consumption critically, it was also essential to discuss the cost reduction techniques in general perspectives of the garment industry. Studies reveal that between 45 to 70% of the garment production costs are due to material consumption (The ITJ 2008, Wong and Leung 200), Jeffrey and Evans 2011, Krsteva and Demboski 2011, Dumishllari and Guxho 2016). Garment manufacturers require to reduce their manufacturing costs, mainly the variable costs, without compromising the acceptable quality level of garments. The garment manufacturing processes involve direct cost elements such as direct material and labour costs, direct expenses, overhead (indirect) costs, among others. The averaged costs and the profit margin dictate the product selling price quoted by the factory to customers. Thus, having factors that can be implemented successfully in the industry could reduce the total production cost to the entire garment industry's cutting process.

The highlighted essential consideration to utilise materials for garment manufacturing needs pragmatic flexibility from the designers and pattern cutters because each saving in the used materials to manufacture any garment contributes jointly to saving the total production costs for the apparel industry. Considering that this study critically analysed material utilisation within the garment industry, the industry thus needs appropriate mechanisms to use less but sufficient materials which meet customers' specifications and handle sufficient batch sizes as per the strategic plans of the industry. For the material costs, the industry should prioritise to plummet the fabric losses. So, cost reduction techniques should involve robust strategies that reduce material costs in manufacturing garments, properly optimising workforces' performance through timely and useful training, improving garment designs, applying advanced machinery for the cutting processes, and digitalising cutting processes through advanced processes technologies, among other pertinent approaches. In the long run, these techniques may potentially reduce the unitary costs before reducing the costs at large.

Benchmarking: comparing results

Textile wastes increase daily as the pre-consumer and the post-consumer textiles wastes. For the pre-consumer textiles waste, it is projected that 15% of fabric consumed in making garments is wasted (Cooklin et al. 2012). This is lower than the obtained waste in this study (19.2%) and the other unnoticed waste of 2.03%; so, S-Company has a higher loss. Further research found the textiles waste of around 10% for jeans and pants and over 10% for underwear, jackets and blouses (Abernathy et al. 1999). Similarly, the higher waste was 25–30% during garment production (Runnel et al. 2017). Materials usually encompass around 50% of the total cost of a garment, with labour charges of about 20% (Cooklin et al. 2012). So, any material cost saving influences the reduction of the production costs of a garment. In manufacturing apparel, the pattern cutter on its own cannot thwart excess materials usage in the cutting section; there are several procedures required to be deployed to optimise material demands in making the garment patterns (Cooklin et al. 2012). Although this study focused on the pre-consumer textiles wastes (the materials used in manufacturing garments), the research underpinnings indicate the post-consumer textiles waste. Such waste, including garments discarded by customers (end consumers), was approximately 60% of the circa 150 billion garments manufactured worldwide in 2012 (Kirchain et al. 2015), which were dumped within many years subsequently to production (Niinimäki et al. 2020). Thus, material utilisation for each section of the apparel industry is crucial to reduce wastes.

Conclusion

Analysing material consumption and cost reduction techniques critically for the apparel cutting processes can enhance profits. In realising that, the study's aims were achieved by the quantitative and qualitative approaches (document review and observation approaches). Experimental results of material consumption from ten (10) tests averaged efficiency of 78.67%, the wasted pieces (19.2%), and unnoticed wastes (2.03%). Theoretical underpinnings show that at least 50% to 80% are due to the manufacturing costs. To enhance profits, it is vital to analyse material consumption through waste optimisation techniques critically. Achieving that could lead to higher material utilisation to reduce garment manufacturing costs. The fabric consumptions should be noted for all the steps, including the sampling phase, to dictate an appropriate fabric costing. This can involve selecting fabric categories, fabric yields, fabric width and the fabric suppliers who follow the standard acceptable quality level.

Essential considerations to reduce material wastes in the cutting processes and other apparel industry's sections include digitalising the fabric cutting processes, improving workers' efficiency, deploying pattern engineering and pattern accuracy, considering the procured fabric quality, and considering fabric efficiencies relative to different human body shapes and proportions.

Significant modifications can also comprise the separation process instead of extending facings, splitting substantial components, slight reductions in the flare, and seam displacements. The digitalisation concepts are aligned with Industry 4.0 frameworks in transforming industries. Digitisation, digitalisation frameworks and digital transformation should forge ahead the proper material utilisation in the cutting departments to reduce and/or replace unnecessary manual operations. So, the T&G sector's operations, which depend on manual interventions, require complete transformation. Apparel factories that still experience high fabric losses should transform their operations to optimise material consumption.

Implications for research, practice, and society

This study is vital to several garment factories. SMEs can compare their actual material consumption. Findings show that the raw materials in making garments are of high proportions in the apparel industry: saving even small fabric quantities per garment can boost their profit over an extended period. Firms' management, researchers and practitioners could use the proposed framework or techniques to minimise material consumption to boost profits.

Limitations and future works

This study focused on a single industry and did not propose any optimisation technique such as a genetic optimisation decision-making model to manage cut order planning to utilise fabric in making apparel. Future studies can develop such optimisation approaches to combat fabric losses. Moreover, garments consumption increases proportionally to the population increase: this affects the material consumptions in industries. It is also essential to develop new economic models for the fashion industry to alleviate material consumption.

References

Abernathy FH, Dunlop JT, Hammond JH and Weil D 1999 A stitch in time. Lean retailing and the transformation of manufacturing-lessons from the apparel and textile industries, Oxford University Press, UK.

Armstrong CM and Lang C 2013 Sustainable product service systems: The new frontier in apparel retailing? *Res. J. Text. Appar.* 17(1): 1–12.

Beazley A and Bond T 2003 Computer-aided pattern design & product development, Wiley-Blackwell, New Jersey, USA.

Caridi M, Perego A and Tumino A 2013 Measuring supply chain visibility in the apparel industry. *Benchmarking: Int. J.* 20(1): 25–44.

Cooklin G, Hayes SG, McLoughlin J and Fairclough D 2012 Cooklin's garment technology for fashion designers, 2nd ed., John Wiley & Sons, Hoboken.

Dumishllari E and Guxho G 2016 Influence of lay plan solution in fabric efficiency and consume in cutting section. *Autex Res. J.* 16(4): 222–227.

Jeffrey M and Evans N 2011 Costing for the fashion industry, 1st ed, Berg, Oxford.

Karthik T, Ganesan P and Gopalakrishnan D 2017 Apparel manufacturing technology, 1st ed, CRC Press, Boca Raton, USA.

Kennedy A, Reyes A and Venezia F 2020 Apparel costing, 1st ed, Bloomsbury Visual Arts, London, UK.

Kirchain R, Olivetti E, Miller TR and Greene S 2015 *Sustainable apparel materials*, Materials Systems Laboratory, Massachusetts Institute of Technology, Cambridge.

Krsteva S and Demboski G 2011 Determination of generated textile waste in clothing companies of different technological level. *In: 3rd scientific-professional conference Textile science and economy, 10-11 November 2011*, Zrenjanin, Serbia, 203–208.

Mwasubila IJ, Taifa IWR and Kundi BAT 2020 An analytical study on establishing strategies for improving the productivity of the spinning industries. *Int. J. Ind. Syst. Eng*. https://doi.org/10.1504/ijise.2020.10030901

Naveed T, Hussain A, Babar AA, Naeem A, Mussana H, Xin W, Duan L and Zhong Y 2019 A comparative study on fabric efficiencies for different human body shapes in the apparel industry. *Autex Res. J.* 19(2): 104–118.

Nayak R and Padhye R 2015 Introduction: the apparel industry. In: Nayak Rajkishore and Padhye Rajiv (Eds) *Garment Manufacturing Technology* (pp. 1–17), Elsevier.

Ng SFF, Hui CLP and Leaf GAV 1999 A mathematical model for predicting fabric loss during spreading. *Int. J. Cloth. Sci. Technol.* 11(2–3): 76–83.

Niinimäki K, Peters G, Dahlbo H, Perry P, Rissanen T and Gwilt A 2020 The environmental price of fast fashion. *Nat. Rev. Earth Environ.* 1(4): 189–200.

Nzumile JM and Taifa IWR 2021 Emperical analysis of the quality infrastructure in trade facilitation within the African Continental Free Trade. *Bus. Educ. J.* I(II):1–13.

Runnel A, Raihan K, Castle N, Oja D and Bhuiya H 2017 *The undiscovered business potential of production leftovers within global fashion supply chains: creating a digitally enhanced circular economy insight from research among fabric and garment factories of China and Bangladesh.* Retrieved (October 19, 2021), https://www.reverseresources.net/about/white-paper.

Sellitto MA and de Almeida FA 2019 Strategies for value recovery from industrial waste: case studies of six industries from Brazil. *Benchmarking: Int. J.* 27(2): 867–885.

Singh A and Nijhar K 2015 Garment costing. In: Nayak R and Padhye R (Eds) *Garment manufacturing technology* (pp. 447–467), Elsevier.

Taifa IW 2020 *Domestic supply chain for UK apparel manufacturing as a digital business: A computer simulation approach*. PhD thesis, The University of Manchester.

Taifa IWR 2021 Sustainable industrialisation for luxury products: Manufacturers and retailers must commit to tackling modern slavery in Africa. In: Coste-Maniere I and Gardetti MÁ (Eds) *Sustainable Luxury and Jewelry. Environmental Footprints and Eco-design of Products and Processes* (pp. 199–228), Springer, Singapore.

Taifa IWR, Hayes SG and Stalker ID 2020 Computer modelling and simulation of an equitable order distribution in manufacturing through the Industry 4.0 framework. *In: 2nd International Conference on Electrical, Communication and Computer Engineering (ICECCE), 12-13 June 2020,* IEEE, Istanbul, Turkey, 1–6.

Taifa IWR, Hayes SG and Stalker ID 2021a Towards a digital revolution in the UK apparel manufacturing: An industry 4.0 perspective. In: Bartolo P, Silva F, Jaradat S and Bartolo H (Eds) *Industry 4.0 – Shaping the future of the digital world, 2nd International Conference on Sustainable Smart Manufacturing (S2M 2019)* (pp. 3-8), CRC Press, Taylor & Francis Group, London, UK.

Taifa IWR, Hayes SG and Stalker ID 2021b Enabling manufacturer selection and an equitable order allocation amongst textiles and apparel manufacturers. *Int. J. Manag. Decis. Mak.* 20(1): 58–87.

Taifa IWR and Lushaju GG 2020 Establishing basic requirements for textile and garment mass production units in the Tanzanian context. *Res. J. Text. Appar.* 24(4): 321–340.

The ITJ 2008 Processing, dyeing & finishing. *Indian Text. J.* Retrieved (June 30, 2020), https://indiantextilejournal.com/articles/FAdetails.asp?id=1307.

Wong WK and Leung SYS 2008 Genetic optimization of fabric utilization in apparel manufacturing. *Int. J. Prod. Econ.* 114(1): 376–387.