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ARTICLE

Integrating Circular Economy Principles into Lean Management: A New Paradigm for the RMG Sector

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Abstract

The Ready-made Garments (RMG) sector has played the most significant economic role in Bangladesh, as well as many other developing countries. But the RMG sector faces severe pressure to ensure sustainable practices. The global competition to manufacture high-quality textile goods is increasing day by day. This study explores the use of Circular Economy principles (CE) into the Lean Management (LM) frameworks, which enhances resource efficiency while minimizing the environmental impact. Lean management follows a linear model, which focuses on waste reduction and process efficiency. CE emphasizes resource regeneration and reuse. By the combination of these frameworks, it could be easy to make a sustainable model that minimizes waste, extends the product life cycle, and optimizes resource use. This study suggests that integrating CE into LM can enhance both environmental sustainability ability and operational efficiency in the RMG sector.

Keywords: Lean Management, Circular Economy, Product life cycle, RMG sector, Textile Industry, Sustainability.

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1 Introduction

The RMG industries are the key contributor to Bangladesh's economy and also shares approximately 6.4% of the global apparel market. The ready-made garments (RMG) industry is the number one export earner of Bangladesh [1]. RMG sectors contributed 16% of GDP, over five million direct jobs, and over 81% of foreign exchange revenues [2]. But, this sector faces critical challenges, with fabric wastage reaching 25-35% during production. Lean management, used by 70% of RMG industries, aims to decrease production waste while increasing efficiency. Considering these efforts, over 85% of textiles end up in dumps, practicing the need for more sustainable procedures. There are different sections of a garment industry like sample, cutting, sewing and finishing section, where for different cause's fabric wastage's are happened. During cutting there are two different fabric wastage's like one for marker efficiency and another for panel checking followed by different types of fabric faults [3]. The quantity of textile waste arises from different stages of production phases which affects the industries growing as well as the environment. During bulk production there's a various reason of wastage like, sewing mistake, Pattern and Marker making mistakes, Dyeing and Printing uneven shades, process breakdown, excessive use of chemicals, yarn and knitting oversights. So, it is difficult for the

textile/RMG sectors to efficiently manage waste since a large amount of textile materials ends up in dumps without recycle. The pie chart shows the percentage

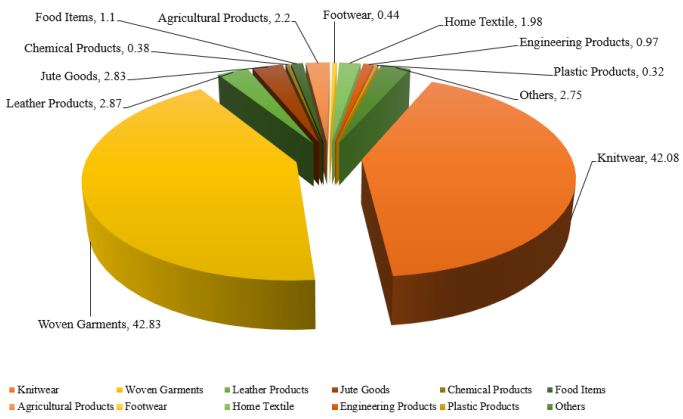

Figure 1. Export Pie of Bangladesh (FY 2023-24, August)

distribution of Bangladesh's export item. The total export income for Bangladesh in the first half of the 2023-2024 fiscal year (July 2023-June 2024) was $27.54 billion, which is a 0.84% increase from the previous year [13]. The EPB reported that exports in the first nine months of the fiscal year were $43.55 billion, a 4.39% increase. The growth was largely due to the demand for ready-made garments, which totaled $37.20 billion in July-March. [CrossRef] Approximately 577,000 tons of waste is reported to be generated from the apparel industry and fabric mills of Bangladesh, of which 250,000 tons, almost half of the total, is 100% recyclable cotton waste valued at approximately 100 million USD [4]. LM basically focus on waste reduction and process optimization, has been a key strategy in improving productivity. However, LM does not fully address environmental issues like resource depletion and waste. The CE framework deals with closed-loop systems, recycling, and resource efficiency, complementing lean's focus on minimizing operational waste. The combination of CE and LM can focus on waste reduction through recycling and resource effective process. IT helps to reduce fabric waste by 10-15% which improve operational efficiency and cost effectiveness. This new paradigm can lead major outcomes in RMG sector like, Waste Reduction, Resource efficiency, Cost Savings, Sustainability Compliance, Innovation, Long-term Resilience, Enhanced collaboration. Overall, this integration not only improves operational efficiency but also contributes to a more sustainable and responsible RMG sector. [*Figure 1*] Source: BGMEA, EPB [CrossRef]

2 Circular economy principles

Circular Economy (CE) is an economic system which deals with eliminating waste and increase product life cycle. Unlike the traditional linear model of "take, make, dispose", CE focuses on designing products and processes that extend the life cycle of materials through reuse, recycling, and regeneration. The objective of Circular Economy is to create a closed-loop structure that maximizes resource utilization. The economy of a product depends on the production and consumption of products and services as well as financial activities. Money, Production and Consumption habits have traditionally influenced international relations, but creating sustainable global economic systems is a difficult task. Biological and technological phases are the focus of the circular economy [5]. Global industries such as electronics, plastics, and textiles are adopting circular economy models to lessen their environmental impact and reduce resource depletion. Countries that have accepted innovation in waste management and product design, such as the Netherlands and Japan, have established national strategies centred around the circular economy. Adopting CE principles creates new business opportunities and helps the environment, giving businesses a competitive edge in a global marketplace. CE can encourage the development of a more robust and sustainable economic system by reevaluating conventional production and consumption patterns. Under the themes of equity, transparency, and resilience, the 7 Pillars of the Circular Economy concentrate on recycling materials, using renewable energy, managing water sustainably, supporting biodiversity, preserving society and culture, improving health and wellbeing, and creating value beyond finances.

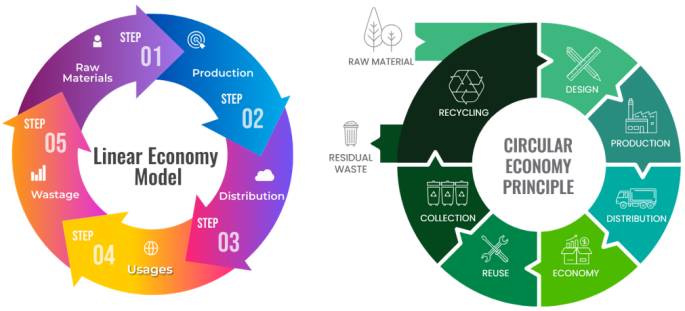

Figure 2. Visualization of Linear Ecomony and Circular Economy model.

The CE concept, as a paradigmatic framework for sustainability, is based on the following three

fundamental principles [6] (1) Preserve and improve the natural capital; (2) optimize the resource performance; and (3) enhance the effectiveness. Its natural principles are [7] :Design without waste; develop the resilience from the diversity; use resources and renewable energies; employ system thinking; and make use of cascade effect thinking. [*Figure 2*]

3 Lean Management & Lean tools

Lean management is an approach of continuous improvement to achieve smooth work flow by minimizing element of waste and incorporating a flexibility to change [8]. In the highly competitive manufacturing climate of today, businesses are always seeking for methods to improve [9]. The Ready-Made Garments (RMG) industry uses lean management to reduce waste, increase production, and optimize processes. Just-in-Time (JIT) production, Kaizen, Kanban, Value Stream Mapping (VSM), and the 5S methodology are illustrations of common Lean tools. Lean tools like VSM, 5S, JIT and cellular manufacturing aid in visualizing wastes in an organization and their potential for elimination or reduction [10].

Figure 3. Lean Management Structure

These tools help organizations in improving quality, cutting expenses, and streamlining operations—all of which promote a competitive global market. RMG companies can achieve a more sustainable operation, increase efficiency, and decrease waste by implementing these tools into practice. Lean manufacturing prioritizes minimizing the non-value-added component of lead time while attempting to maximize the value-added component by practicing various lean techniques [9]. [*Figure 3*]

4 Purpose and Significance of the study

The study aims to investigate how the combination of these two approaches can create a more sustainable and efficient production process that solves the industries most important issues, including resource optimisation, waste reduction, process breakdown, and environmental impact. The study also looks at the benefits and difficulties of combining CE and LM in the attempt to create an innovative structure for the RMG sector that maintains a balance between sustainability and economic efficiency criteria. Textiles emit greenhouse gas methane during their breakdown process, and they also release harmful chemicals and dyes into our land and groundwater.Bangladesh and other developing nations are recognized for having serious environmental problems with solid waste management. Massive textile and apparel production produces a lot of solid wasteland depletes raw materials supplies [11]. By reducing the specific amount of waste, the garments industry will highly benefit [11]. This inquiry is particularly important because there is a lack of literature on the integration of LM and CE in the RMG industry. By providing insights into how manufacturers might minimise waste, develop circular production cycles, and limit demand resources, it closes a crucial gap and eventually helps to build a more resilient and sustainable industry.

5 Textile and RMG industries cluster in Bangladesh

The textile industries in Bangladesh are primarily concentrated in Various Zones. In the Dhaka zone, major textile and apparel industrial hubs include Tongi, Gazipur, Savar, DEPZ, AEPZ, Mirpur, Narshingdi and Narayangonj. The Chottogram zone encompasses CEPZ and KEPZ. In the Sylhet zone, industries are found in Hobigonj, while in the Mymensingh zone, Bhaluka is a notable industrial area.

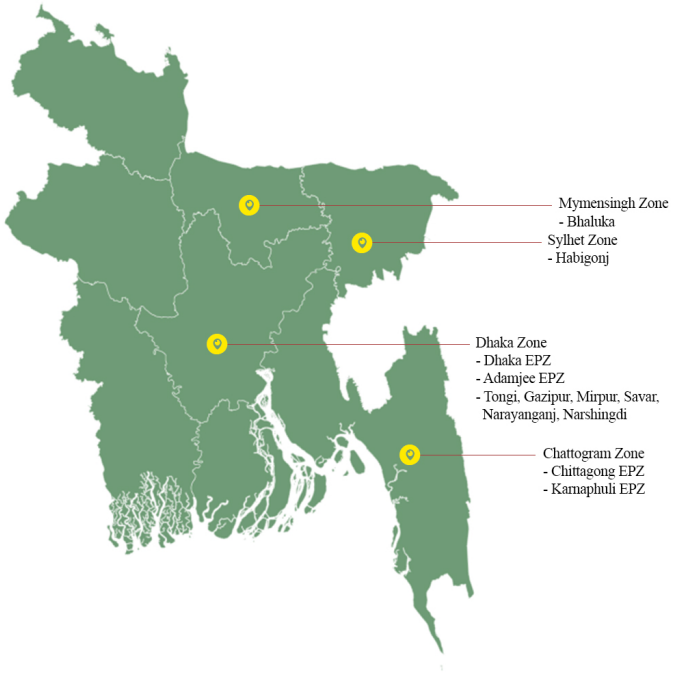

Figure 4. Textile and RMG industries cluster in Bangladesh

The textile sectors in these zones generate large amounts of solid waste, including fabric off-cuts, packaging materials, and unused dyes, which contribute greatly to the degradation of the environment. Thus, this waste goes almost invariably to landfills, therefore adding to pollution and resource depletion. To contribute to the solution of these challenges, the principles of Circular Economy (CE) emphasize a shift towards the reuse and recycling of materials, waste minimization, and development of sustainable production cycles. Additionally, Lean Manufacturing (LM) approaches call for process optimization with a view on removing inefficiencies and perfecting resource use. Given the common goals of CE and LM, these two streams could offer a union justice approach to waste reductions and environmental sustainability in the textile sector of Bangladesh. [*Figure 4*]

6 Identification of textile wastage

The textile industry has wastage's that can be broadly divided into two parts: fabric wastage and process wastage. Each of these has telling effects on sustainability and cost-efficiency. The main sources of fabric wastage are inefficient cutting, excess usage in the sewing section, and poor management of storage. Process wastage generally occurs at dyeing, washing, printing, embroidery, and finishing stages due to over utilization of water, energy, and chemicals. In dyeing, there is excess water and chemical discharge, whereas wrong handling of chemicals and trims in finishing produces waste. An indispensable part of waste reduction strategy implementation is fitted to the principles of Circular Economy and Lean Management for the indicated cases.

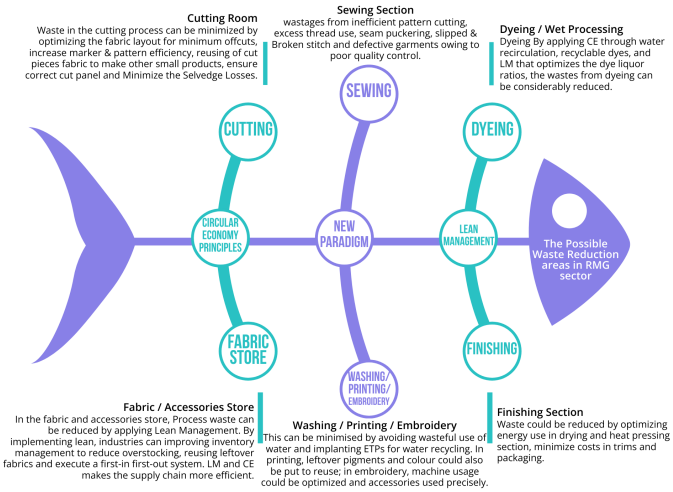

Figure 5. FISHBONE diagram of possible waste reduction areas in Textile industries.

The EPA estimates that in 2018, the most recent year for which data is available, 14.7% of all textile waste was recycled in the United States, amounting to 2.5 million tons of materials. More than 11 million tons of textile waste was sent to landfills, or nearly 8% of all MSW land filled that year [**?**]. A factor that most people don't ever consider is the impact our clothes have on the environment. Textile production requires significant amounts of chemicals, water, energy and other natural resources. According to the World Resources Institute, it takes 2,700 liters of water to make one cotton shirt. And when consumers throw away clothing in the garbage, not only does it waste money and resources, but it can take 200+ years for the materials to decompose in a landfill. During the decomposition process, textiles generate greenhouse methane gas and leach toxic chemicals and dyes into the groundwater and our soil [**?**]. In some contemporary approaches, fabric is utilized by usingrectangular and triangular shapes that easily fit together like ajigsaw puzzle [**?**]. Fabric waste for adult outerwear varies onaverage from 10 to 20 percent, with the estimation of 10 per-cent for trousers or pants and greater percentages for blouses,jackets, and underwear [13]. [*Figure 5*]

7 Methodology

In our thesis focused on Lean Manufacturing and Circular Economy, we have chosen MASCO Picasso Ltd's production line within the Ready-Made Garments (RMG) sector. After reviewing the production floor, we identified several types of waste, including , over-processing, backtracking, excessive work-in-process (WIP) inventory, and transportation issues. These factors contribute to an increase in Non-Value-Added Time while simultaneously decreasing Value Added Time, resulting in low productivity levels. Our goal is to enhance productivity by increasing Value Added Time and minimizing Non-Value-Added Time also reduce overall wastage. We use a mixed-method research methodology to examine how circular economy (CE) principles can be blended with lean management (LM) in the ready-made garments (RMG) sector. The study combined a mixed-methods approach, using data from surveys, interviews, case studies and literature review. Exploratory research of the type is descriptive in nature and it is to find out how CE implemented at various managerial practices (LM) that could be enriched by adopting these especially in RMG. To do that we visited one of the leading textile companies of Bangladesh, MASCO Group an observed their operational procedures. To get an understanding of the practical operations of MASCO Group with respect to wastage and recycling at source, we examined how things were being done. Major Concerns in the RMG Sector — RMG sector is heavily wasting its raw materials, mainly fabric, water and energy. At some factories this can be as high as 15% with cut-offs and faulty garments contributing most to the waste. The excessive water use in dyeing and finishing processes also results in environmental degradation and higher production costs. Another key concern is that factories tend to consume a lot of electricity due to the use of older technologies and processes. It is important to tackle these areas of wastage so that we can improve sustainability and optimize operational efficiencies. Initially, the data collection started with a comprehensive review of literature tells us about the subject area focusing on waste reduction, close loop system and resource efficiency connecting CE and LM to get better understanding of these concepts. Then few surveys and questionnaires were distributed among factory managers, production engineers, and sustainability officers in Masco Group as well as some other RMG factories. The questions aimed at how the extant LM syndrome has been navigated and what opportunities exist to fit with CE principles.

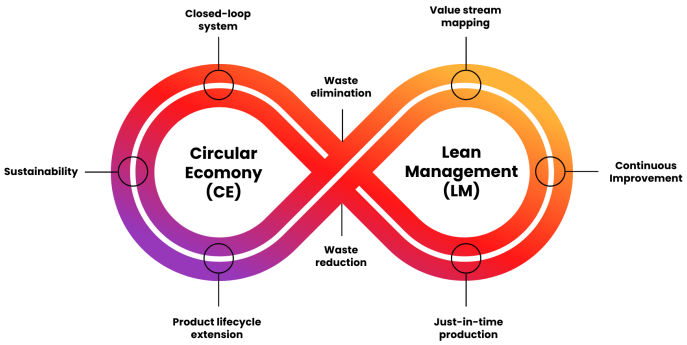

Figure 6. Infinity diagram representing the integration of circular economy and lean management principles.

Possible benefits outcomes of this could be with an example of how the RMG industry can achieve its mentioned objectives by incorporating CE principles into LM are:

1. The reduction of garbage: A closed loop system of using the remaining material will directly result in turning waste materials over far less. Reusing wastage or using them in new product cycle and CE & LM supported the progress of resource productivity progresses.

2. Improved Resource Efficiency: Implementation of lean processes that facilitate in minimizing the water and energy consumption, by deploying CE technologies like a wastewater recycling plant and steam-efficient equipment's will reduce operational overheads drastically with least impact on environment.

3. In the end, beating products are products that possess longevity adequacy's to be repurposed or up cycled and this directly correlates down with productivity of resources.

4. Closed-Loop Supply Chain Development: By encouraging the usage of circular practices from suppliers and customers, the creation of a closed-loop supply chain will result in considerable decreases on material and energy inputs in every stage of production.

Upon the basis of these findings, a conceptual model was developed in order to integrate CE principles into LM. Industry professionals then audited the framework for validation and revised it accordingly. Insights from Masco Group and others provided a practical dimension to the shaped model, aimed at sustainability and efficiency enhancement in the RMG sectors.

The limitations of the study are also recognized,

more particularly focusing on a small number case studies may not be able to generalize results for the whole sector diversity RMG. However, the results should provide a clear understanding on how CE and LM can be integrated to support sustainable practices in RMG sector. This allows industries to meet tough sustainability targets without compromising on productivity or costs. [*Figure 6*]

8 Experiments

Segregated cotton from the cutting unit The flow diagram explains the recycling process of segregated cotton wastes collected from the cutting unit for producing the same as recycled yarn for garment manufacturing. Segregated cotton wastes are first collected and pressed into compact bales with the help of a bale press machine. Cotton shredded and blended to ensure uniform quality. Opening and cleaning take place in the blow room where the blended cotton gets processed. Carding aligns the fibers into a continuous strand. Further layering of the cotton is done by lapping, drawing combines and stretches the fibers for uniformity, and roving refines the fiber strands to the point where they can be spun. Finally, ring spinning produces the final product of recycled yarn, which is used in garment manufacturing. The final product, during this process, involves 30% post-consumer recycled and 70% virgin cotton to guarantee high-quality and sustainable products.

Figure 7. Recycling process of wastage segregated cotton

The recycling process follows principles of Circular Economy and Lean Manufacturing. The CE principles are minimization of waste and closed-loop recycling. Thus, in converting the textile waste into a raw material product, the life cycle of the cotton is extended and further development brings about reduced environmental impact. Lean Manufacturing is all about the eradication of wastes for the betterment of a process; therefore, implementation at every step reduces the wastage of resources and ensures a smooth workflow for recycling. Thus, CE and LM collectively contribute to an environment-friendly and economical model of cotton waste utilization that supports environmental and operational sustainability in the textile industry. [*Figure 7*]

Cutting Section's Data: Data display the deviation in marker efficiency, showing whether fabric use is as booked. In this case, the negative deviation means that the garment uses less than booked fabric, and efficiency is higher. Therefore, a positive deviation would imply that it takes more fabric than expected, indicating inefficiency. For example, "Buyer – KappAhl, Style No. – Babblarn a Pyjamas ser" indicates a -1.68% deviation, which signifies efficient usage, whereas "Buyer –Benetton, Style No. – 3J68G10E3" indicates a +2.10% deviation, signifying excess usage.

Buyer	Style	Item	Marker type		Dia		GSM	Marker Eff. (%) = 1.59%		
					Booking	Rcvd		Booking	Act.	Dev.
H&M	Havana pj	Top Btm	Solid	Complete	60	59	190	82.0%	82.0%	**0.02%**
H&M	Anthea	Top	Solid	Short	64	64	180	83.8%	85.1%	**1.27%**
Benetton	39m2c502y	Tee	Exception	-	0	63	240	89.2%	88.2%	**-1.01%**
Benetton	3J68G10E3	Vk+Cuff+Btn	Solid	Complete		47	350	95.3%	97.4%	**2.10%**
KappAhl	EDITPJMG	pant/cuff	Solid	Complete		31	240	82.0%	82.1%	**0.13%**
KappAhl	Babblarna Pyjamas ser	Pant	All X 1Way	Short	70	72	160	65.2%	63.5%	**-1.68%**
Ostin	MT6612	top	Solid	Complete	72	78	160	82.2%	83.9%	**1.65%**
Ostin	MT4659	top	All X 1Way	Complete		77	160	80.3%	82.4%	**2.05%**
Otto	13645021	top	Solid	Complete	76	71	160	81.2%	85.3%	**4.07%**
Otto	13645021	top	Solid	Short	76	71	160	83.7%	85.1%	**1.39%**
Others	67622398	Pant	Solid	Complete	74	73	260	79.7%	83.9%	**4.16%**
Others	67622398	Pant	Solid	Complete	74	73	260	79.7%	84.7%	**4.94%**

Figure 8. Daily Marker efficiency report

This table shows the marker efficiency after the implementation of CE and LM. The values denote that there are minimal deviations within items. For instance, KappAhl's " Babblarn a Pyjamas ser" and H&M's "Havana pj" have a deviation of +0.12% and +0.02%, respectively, which postulates that the items were efficiently aligned with booked fabric usage. Items such as "AW-23 WOMENS", on the other hand, have a -2.00% deviation, meaning that this item can now be optimally produced with less fabric than booked, therefore making production more economical.

Embroidery Section's Data: Regular training of operators, strong quality control measures, and a proper maintenance routine will result in achieving the DHU-Defects Per Hundred Units. target at 12.50% and rejection at 25%. Proper check on quality raw material and effective improvement in team communication will enable sorting out the defects and identify them as early as possible to ensure better embroidery.

We collect the embroidery defect and rejection summary from the embroidery quality section. Most

Buyer	Style	Item	Marker type		Dia		GSM	Marker Eff. (%) = 0.77%		
					Booking	Recvd		Booking	Act.	Dev.
Benetton	3YL9L200O	Top	Solid	Complete	76	79	340	84.2%	86.2%	**1.95%**
Benetton	3I1XS103J	TOP	Solid	Short		77	140	81.3%	81.4%	**0.05%**
KappAhl	EDITPJMG	pant/cuff	Solid	Complete		31	240	82.0%	81.9%	**-0.14%**
KappAhl	Babblarna Pyjamas ser	Pant	All X 1Way	Short	70	72	160	65.2%	65.3%	**0.12%**
H&M	Havana pj	Top Btm	Solid	Complete	60	59	190	82.0%	82.0%	**0.02%**
H&M	Anthea	Top	Solid	Short	64	64	180	83.8%	87.1%	**3.27%**
Ostin	MT6612	top	Solid	Complete	72	78	160	82.2%	82.9%	**0.65%**
Ostin	MT4659	top	All X 1Way	Complete		77	160	80.3%	80.2%	**-0.15%**
Otto	13645021	top	Solid	Short	76	77.5	160	83.5%	84.5%	**1.00%**
Otto	13645021	top	Solid	Short	76	77.5	160	86.5%	88.0%	**1.50%**
Others	AW-23 WOMENS	Nk+Cuff+B tm	Solid	Complete		49	380	87.9%	90.9%	**3.00%**
Others	AW-23 WOMENS	Nk+Cuff+B tm	Solid	Complete		52	380	92.3%	90.3%	**-2.00%**

Figure 9. Daily Marker efficiency report

Daily Quality Inspection Report									Date:- 23 July, 2024
Floor	Total Check	Okay Qty.	Defect Qty.	Defect %	EMB Reject Otv.	EMB Reject %	Fabric Reject Otv.	Fabric / Print Reiect	Goal For 2024
Ground	37,286	34,659	2,289	6.14%	208	0.56%	130	0.35%	DHU: 12.50%; Rejection:0.25 %
First	27,943	22,767	2,074	7.42%	88	0.31%	14	0.05%	

Figure 10. Daily Embroidery Quality Inspection Report

of the rejections are due to slip of stitch, position mistake of the sequins, cord, and designs. Follow up the buyer Lindex, Champion, Hurley, Puma, C&A, and some others, found out the problems. In embroidery, there's a huge amount of process losses due to design change and grading change. Although the whole embroidery production process is generated by automatic embroidery m/c, the industry can reduce the process loss and time loss by implementing the Lean tool. The summary highlights areas for

Noticeable Defect and Reject Summary (Embroidery)

Floor	Buyer	Style	Color	Total Check QTY	Defect Qty	Defect%	Reject QTY	Reject%
Ground	Lindex	3004663-001	Light Green	2,975	894	30.05%	14	0.47%
Ground	Champion	306897	NRN	987	3	0.30%	10	1.01%
Ground	Hurley	08759-681	Teal Tinted	4,870	404	8.30%	42	0.86%
Ground	Lc Waikiki	ESULER	ECrU RJ9	2,057	366	17.79%	37	1.80%
Ground	Hugo Boss	50534947	001 Black	1,944	0	0.00%	10	0.51%
Ground	PUMA	682373	18 Pink	776	0	0.00%	31	3.99%
1st	Benetton	3NPDC10OL	60W	2,620	7	0.27%	14	0.53%
1st	C&A	2232209	Gardenia	29,988	3,077	10.26%	158	0.53%
1st	Hurley	16892	Black	4,133	329	7.96%	38	0.92%
1st	TAO	S MC BNOEUD AC	Lily Pad	2,774	949	34.21%	41	1.48%
1st	Mayoral	7537 / 854	80 Hibiscus	1,034	788	76.21%	11	1.06%
1st	Pepe Jenas	PL506016VIVITH	Blue	610	116	19.02%	11	1.80%

Figure 11. Noticeable Defect and Rejection summary of buyerwise embroidery goods.

improvement in defect and reject rates, including color-coding risk factors and mitigation measures. Focusing on specific training, quality control measures, and communication can reduce defects, improving product quality, and bringing closer to meeting the target value of DHU.

Apparel Garments Industry: We have visited an apparel garments industry for this wastage recycling process. Its gives us a overall concept about the implementation of Circular economy. Figure 12 shows the conceptual model that integrates the application of the CE principle in the RMG industry. Figure 12: material and product journey through different stages of the apparel lifecycle explain how waste is at a minimum and repurposed. With bulk production in the RMG sector, there are two major routes that follow from the figure, namely: approved garments move to shipment, while rejected goods take other routes for other uses. The rejected items will be either sold at local markets or transformed to other materials like mats, further extending the usability of the item. It portrays waste fabrics, locally known as "Jhut" or scrap fabrics, that undergo sorting and processing. A certain portion of the waste is turned into recycled yarn, which, once processed, can enter the supply chain again as raw material in textile production. Remaining fabrics are fed as raw materials in local garment productions. These defective garments are re-processed by re-cutting and sewing, after which they become products for local markets, reducing disposal problems and encouraging sustainable consumption.

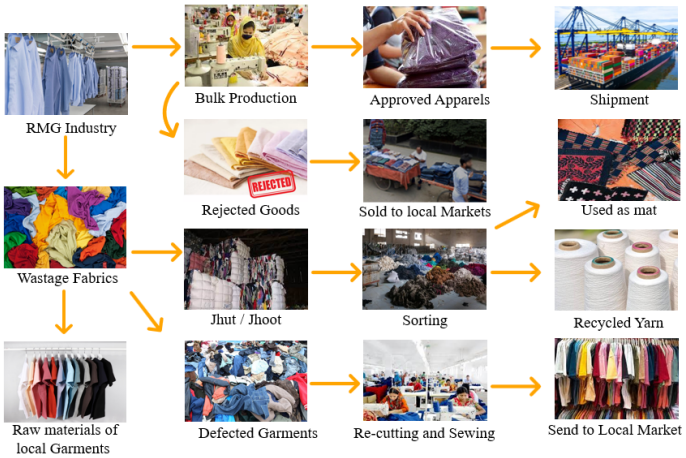

Figure 12. A conceptual model of waste management in the circular economy

Figure 12 represents how the principles of the CE are translated into taking the concept of waste to resource and how local markets can act as a prime motivator for continued cycles. A model like this not only will reduce the environmental footprint of the RMG sector but also will contribute to the growth of a local economy, hence showcasing a structured methodology toward the realization of sustainability objectives through waste and resource valorization across industries. [Figure concept: CrossRef]

9 Conclusion

Zero waste concept is not new in RMG industry. A lot of investigations are done by the designers to

make zero wastage garments. Inclusion of Circular Economy principles into Lean Management is a transformation approach toward the sustainability challenges faced by the sector in Bangladesh's Ready-Made Garments. Integration of CE principles, such as waste elimination, extension of product life cycles, and closed-loop production systems, into Lean methodologies enables RMG manufacturers to competitively drive operational efficiencies along with reduced environmental impacts. This synthesis represents a pathway to reducing high-impact areas of waste in fabric, water, and energy within textile production. Sustainable practices, involving the adoption of an integrated approach, require a conceptual shift in decision-making by the industry to closed-loop processes that enhance resource efficiency with emphasis on durability and recyclability of the products. Besides strategic technology investments in-waste management systems, workforce training in sustainable practices is core. These will not only help the environment but also enhance competitiveness in Bangladesh's RMG sector for the global marketplace and offer a model for sustainable growth that marries economic objectives with ecological stewardship. Integration of the CE principles into LM is ultimately the step toward a resilient and sustainable textile industry. In this light, it is perceived that the RMG sector in Bangladesh will be setting a bench for eco-innovation, dependency on virgin resources would be minimized, and all in contribution to a global revolution toward greener economic growth.

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