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Circular Economy in Bangladesh Apparel Industry: The impact of Sustainability on the Supply Chain

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ABSTRACT

The current study intents to evaluate how integrating circular economy (CE) and sustainable practices will affect the supply chain efficiency in the RMG industry in Bangladesh. As the RMG industry remains to be a driving force of the national economy, the sector comes under the demand to change its linear "take-make-dispose" ways to the circular model, which requires reduction of wastes and facilitation of resources, as well as environmental responsibility. This paper will explore three objectives: determining the existing level of CE in the RMG sector, assessing its connection with supply chain efficiency, and suggesting the approaches of the integrations that are based on sustainability. A quantitative, descriptive, causal research design was conducted here through primary data collection with the help of structured survey questionnaires from professionals in supply chain, procurement, and sustainability fields in the apparel industry. SPSS was used for data analysis, which demonstrated a high level of internal reliability (Cronbach's Alpha = 0.973) The findings obtained that large-scale export-oriented organizations actively invest into textile waste cycling and eco-friendly operations, whereas the SMEs face the issue of funding, technologies, and awareness. Chi-square tests showed statistically meaningful relationships between the practices of CE and stakeholder collaborations, as well as technological adoptions and supply chain efficiency. Conclusively, the result shows that the companies that implement CE principles reveal better eco-friendly performance. Therefore, sustainability will show better business performance.

KEYWORDS: The circular economy; sustainability; supply chain efficiency; the Ready-Made Garment Industry; Bangladesh; stakeholder; technology

1. INTRODUCTION

1.1 Overview

The Bangladesh apparel industry produces a significant amount of waste annually. Thus, immediate and effective action is required to develop a framework that would allow reducing the impact on the environment and drive the industry towards sustainability. A potential solution is represented by the circular economy, which implies managing cycle resources using the 3Rs- Recycle, Reduce, and Reuse. While the traditional take–make–dispose approach is based on a linear model, the CE model insists on regeneration while creating additional value from waste. As the apparel sector is of strategic importance for Bangladesh's economy, integrating a sustainable supply chain is not only essential from the ecological viewpoint but also from the cost-efficiency, brand reputation, and resilience perspectives. Thus, textile recycling, utilizing sustainable sourcing, and using eco-friendly production methods are increasingly popular among the world's leading apparel brands. The situation in Bangladesh is different, as the level of adoption of CE practices is strikingly low. The present paper aims to explore the opportunities of integrating sustainability, while focusing on circular practices, stakeholder engagement, and technological advances, to turn the country's apparel supply chain into an efficient, resilient, and environmentally friendly system.

1.2 Problem Statement

Today, despite increased awareness, the country's apparel industry operates without a formal framework supporting the use of circular economy principles. Moreover, it lacks a proper understanding of how CE practices, in conjunction with collaboration with stakeholders and innovation in technology, can boost supply chain performance. Few firms have incorporated recycling strategies or sourced eco-friendly materials, and these efforts lack formalization. This research seeks to bridge these gaps through a structured model to integrate sustainably driven circular practices into the existing supply chain to increase efficiency, resilience, and environmental gains.

1.3 Objectives

- To analyze the current adoption of circular economy practices in Bangladesh's RMG Sector.
- To evaluate the impact of textile waste recycling and sustainable material sourcing on Supply chain efficiency.
- To recommend strategies for efficient integration of circular economy principles and sustainability in apparel manufacturing and procurement.

1.4 Significance of the Study

This study reflects national and organizational significance. Nationally, it contributes to Bangladesh's sustainable industrialization by showing how circular economy (CE) practices can reduce environmental impact and promote responsible resource use, aligning with the UN Sustainable Development Goals. And at the organizational level, the findings help apparel manufacturers and suppliers recognize the economic value of sustainability—through cost reduction, efficiency gains, and stronger brand reputation—thereby enhancing both competitiveness and environmental responsibility.

1.5 Limitations of the Study

The study is not without its flaws, though, which could potentially compromise the extensiveness and applicability of the research findings. First and foremost, the data was gathered with the help of structured, self-reported instruments, which increases the likelihood of the presence of respondent bias. Second, with the total sample consisting of only 90 apparel companies, it is not possible to extrapolate the results to the entire sector of the apparel industry in Bangladesh, which wholly differs in terms of firm size, scope, and geographical location of operation. Lastly, the research utilizes only three central variables – Circular Economy Practices, Stakeholder Engagement, and Technology & Innovation – that supposedly correlate with Supply Chain Efficiency, while omitting other potential antecedents, such as governmental legislation, financial incentives, and global market pressure, among others.

2. LITERATURE REVIEW

This paper assesses the current studies related to circular economy practices, stakeholder engagement, and technological innovation in an apparel supply chain. It provides global & local best practices, pinpoints the challenges to date, and lays down the theoretical groundwork for analysis of their impact on supply chain efficiency.

2.1 Circular Economy in the Apparel Sector

The circular economy (CE) can be defined as a method to manage resource circularity, efficiency, and optimization that turns wastes into valuable inputs (Azizuddin et al., 2021). Traditionally, the system that the world followed was a linear economic model. This is mainly the take, make, and dispose model. In contrast, the CE model involves production, consumption, dispose of waste to recycle it for further production. This model is governed mainly by the Recycling, Reduce, and Reuse (3Rs) concept (Manickam and Duraisamy, 2019). It promotes close-looped system. Thus, the circular economy (CE) model is one of the most environmentally friendly [3].

Textile manufacturing significantly contributes to global pollution, emitting around 1.2 billion tons of greenhouse gases annually, surpassing the combined emissions from international air travel and maritime transport (Change, 2018). By 2050, it is projected that the fashion industry will use up to 25% of the world's carbon budget (Pandey 2018). There is a burning issue to tackle the adverse effects of the fashion industry for sustainability through a circular economy approach [5].

The textile and apparel industries in Bangladesh have been a major contributor to the national economy in terms of both employment and foreign exchange earnings. A circular economy is proposed as a way to achieve the same, focusing on promoting resource efficiency and reducing waste generation in the context of broader sustainable development goals [4].

2.2 Stakeholder Engagement and Supply Chain Performance

The CE stakeholders – suppliers, consumers, and government bodies affect the uptake and eventual success of the CE processes. Zara's parent company was penalized by the Brazilian government in 2011 for alleged "sweatshop-like working conditions" at a subcontractor's facilities, which were the property of Zara's principal supplier [8]. In the same way, Nestlé decided in 2010 to adjust its palm oil sourcing strategy in response to illegal deforestation by an Indonesian sub-tier supplier [9].

Moreover, CE has economic advantages as it prolongs the lives of products and opens up prospects for alternative revenue streams while decreasing the costs of disposal. Furthermore, Multi-stakeholder collaboration (MSC) across the value chain, including manufacturers, suppliers, retailers, and end-users favor supporting CE. CE is in alignment with Bangladeshi international commitments like the UN's Sustainable Development Goals, alongside the Paris Promises, which imply that this strategy matches current institutional culture. Nevertheless, embracing it can be more difficult in the sector of apparel accessories than the overall garment production system due to complex small specialization [4].

2.3 Technology, Innovation, and Sustainable Supply Chains

There is a statistically-defined direct and strong correlation between employees' level of technical competence and the level of their understanding of the technology's business impact. Furthermore, it concludes that many obstacles can be removed if the employer is involved, developing educational plays a significant role in workforce training, offering computer simulations of work tasks, and enforcing learning in the long term. [7]. The use of a blockchain in CE systems-based frames fortnight challenging due to technical limitations, scaling up problems, and legal conundrums. [10]

Rahaman et al. [21] propose using eco-friendly nanomaterials, like biodegradable and bio-based nanoparticles, to enhance fabric quality and add functions such as stain resistance, durability, and self-cleaning ability. During World War II, food waste was converted into regenerated protein fibers because of resource shortages, but the practice was later abandoned. Stenton et al. [22] note that this approach remains promising today, provided that the fibers meet the necessary mechanical standards and the recovery methods are proven to be sustainable.

The textile manufacturing industry is both energy- and water-intensive; it uses electricity to drive machinery as well as thermal energy for wet processing. The global average energy consumption for textile production is about 16 MWh per ton of output annually [13]. The sector annually uses 215 trillion liters of water; only the other two sectors – agriculture and industry use more [14]. In addition, the use of toxic chemicals contributes to further pollution – contaminated water, water ecosystems, risk to ecosystems and human health [15]. To move the textile supply chain to sustainability and circularity, actions must be taken at the following levels, considering the three main CE principles underpinning transition, which are: designing out waste, keeping products and materials in use, and regenerating natural systems [16, 17]:

- developing more resource-effective and less polluting remedies and enhancing the repair and reprocessing phase, for example, product design
- extending the use phase, enhancing the design of the garment
- integrating end-of-life solutions into the value chain, and process innovation to facilitate reuse or reprocessing.

Some global fashion brands, including H&M and Patagonia, are already undertaking the path of aligning their processes with CE, which means that achieving circularity is possible despite the complexity of both the textile and plastic industries [18,19].

Due to the fact that the textile industry uses an excessive amount of water and causes significant pollution, especially during the wet and dyeing process, with oil and grease, chemicals, heavy metals, and dyestuff as their primary components, its wastewater should undergo three treatment stages [23]. To prevent this, a zero liquid discharge (ZLD) technology was developed that eliminates the wastewater discharge and allows water to be reused after treatment [24].

The study by Moran et al. [25] emphasizes such brands and projects as EcoAlf, which produces fabrics from ocean waste, including fishing nets and plastic bottles, and Adidas, which uses similar materials in shoes. Recycled plastic bottles made from PET can be further processed into polyester fabrics.

DePonte et al. [20] have identified the following key strategies to promote sustainability in the entire textile supply chain: green chemistry for recycling processes, Industry 4.0, and sustainable business models. To bridge the gap between sustainability targets and feasible practices in the RMG sector of Bangladesh, even more significant investment in fabric recycling technologies and alternative, eco-friendly fibers is needed. However, the solution still needs to be scaled through professional education and training as well as financial support.

2.4 Barriers and Opportunities

Circular economy implementation in Bangladesh's apparel industry faces several barriers despite being promising:

- **Lack of awareness and education** among factory management and workers.
- **Financial constraints** and limited access to green finance.
- **Weak enforcement** of environmental regulations.
- **Inadequate infrastructure** for textile waste collection and processing.
- **Global supply chain pressures,** which include demand for fast fashion and cost-cutting by international buyers.

2.5 Research Questions:

A. **RQ1**: What is the impact of the adoption of circular economy practices such as textile waste recycling and sustainable material sourcing on the efficiency of the supply chain in Bangladesh's apparel industry?

B. **RQ2**: How is stakeholder engagement responsible for suppliers, the government, and consumers in the performance of the supply chain, as seen at the end of sustainability?

C. **RQ3**: What are the contributions of the adoption of technology and innovation, which includes digital tracking and advanced manufacturing, in improving the efficiency of the supply chain?

Hypotheses:

Statistically, all these can be tested with either primary or secondary data application utilizing Likert-scale surveys and performance metrics. The hypotheses are:

H1: There is a connection between the adoption of circular economy practices and supply chain efficiency in the apparel industry in Bangladesh.
H2: Engagement with stakeholders has a statistically significant effect on increasing supply chain efficiency in the sustainable apparel industry.
H3: Supply chain efficiency is significantly influenced by technology and innovation adoption within the sustainability context.

2.6 Conceptual Framework:

Conceptual framework refers to a visual or a written construct that outlines the vital concepts, variables, and potential relationships in a particular research. Essentially, the conceptual framework is the researcher's plan on how they believe the various ideas are intertwined and their planned methodology. In essence, it's the organizational structure of the information and the connection of the different theories to the research problem.

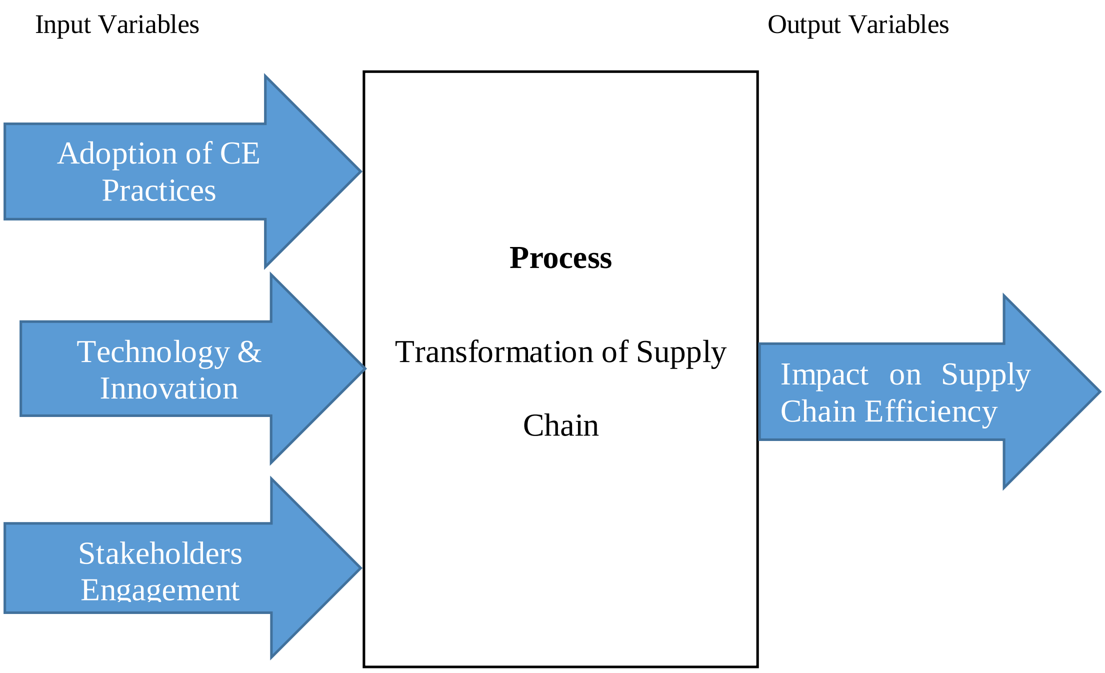

Figure 2.1: Conceptual Framework

3. RESEARCH METHODOLOGY

3.1 Research Philosophy

A positivist philosophy is being used in the study to focus on quantifiable data to delve into the relationship between circular economy practices, stakeholder engagement, technology, and supply chain performance in Bangladesh's RMG sector. The accuracy, reliability, and absence of bias are upheld by using the structured questionnaires and statistical analysis to navigate the study.

3.2 Research Design

The design employed in the study can be described as quantitative, descriptive, and causal. This design correlates and uniformly relates the statistical data and 1-5 scale responses to relate between the current extent of adoption of circular economy, stakeholder engagement, and technology in the Bangladeshi RMG sector, and how it affects efficiency in the sector. A cross-sectional strategy is used in the study. The era of data collection entailed in the study included one point in time use of the strategy, hence a single generation of data collected from professionals in the apparel sector.

This is to understand current practices and their impacts through short-term observation.

3.3 Sample Size Determination

The sample size for this study was determined using the finite population correction formula **(**Cochran's formula, 1977), which provides a statistically reliable method for estimating an appropriate number of respondents when the population size is known and limited. The formula is expressed as follows:

$n' = n / [1 + (n - 1) / N]$

Where:

n' = adjusted sample size for a finite population

N = total population size

$n = (z^2 \times \hat{p} \times (1 - \hat{p})) / \varepsilon^2$

z = z-score corresponding to the desired confidence level (e.g., 1.96 for 95%)

$\hat{p}$ = estimated population proportion (commonly 0.5 when unknown)

ε = acceptable margin of error (commonly 0.05). Using a 95% confidence level ($z = 1.96$), an estimated proportion ($\hat{p} = 0.5$)**,** and a 5% margin of error ($\varepsilon = 0.05$)**,** the computed sample size for an approximate population ($N = 20$) was found to be 19 respondents.

Given the time and constraints on access, the study managed to fetch 13 valid responses that represent 68% of the target population. Despite its small size, the sample is appropriate for an exploratory study as it is useful for calculating reliability and a chi-square. It was a statistically valid sample that reflected the objectives of the research feasibility within the agreed study limits.

3.4 Analytical Framework and Data Analysis

Conceptual Framework

Based on the literature and objectives, the conceptual framework comprises:

- **Independent Variables (Inputs):**

1. Adoption of Circular Economy Practices **-** waste recycling, sustainable sourcing
2. Stakeholder Engagement**-** suppliers, government, consumers
3. Technology & Innovation **-** digital tracking, advanced manufacturing

- **Dependent Variable (Output):**

1. Supply Chain Efficiency **-** cost efficiency, lead time, resilience, responsiveness

Analytical Process

The analysis was conducted using SPSS software**:**

a. Reliability Test

- The internal consistency of the questionnaire assessment is conducted by using Cronbach's Alpha in SPSS.
- The result of Cronbach's Alpha value was 0.973, which is far above the acceptable threshold of 0.7, showing an excellent reliability of the instrument.

- This outcome confirms that the questionnaire items consistently measure the intended variables and are statistically dependable for further analysis in this study.

b. Descriptive Analysis

- It can be applied to summarize and explain the overall response patterns.
- Frequencies, percentages, and means were calculated for each item in order to understand adoption levels of CE, stakeholder involvement, and technology use.
- For instance, if most respondents scored Circular Economy Practices above 3.5 on a 5-point Likert scale, this indicates a moderate-to-high adoption in the sector.

c. Inferential Analysis

- Chi-square tests of independence were applied in order to test the hypotheses (H1–H3).
- A Likert scale is used to collect data. Responses were first averaged for each construct and then re-coded into categories (Low = 1–2.5, Medium = 2.6–3.5, High = 3.6–5).
- By running a Chi-square test between one independent variable and the dependent variable, each hypothesis was tested:
  - H1: Circular Economy Practices ↔ Supply Chain Efficiency
  - H2: Stakeholder Engagement ↔ Supply Chain Efficiency
  - H3: Technology & Innovation ↔ Supply Chain Efficiency
- Decision Rule:

i. If $p < 0.05$, the hypothesis is supported (significant association).
ii. If $p \geq 0.05$, the hypothesis is rejected (no significant association).

This two-level analysis allowed both a descriptive understanding of current practices and statistical testing of causal relationships.

3.5 Data Collection Methods

A structured questionnaire in Google Form was designed to gather primary data, which was administered to professionals in the apparel industry. It sought to capture critical aspects within the research framework – Circular Economy Practices, Stakeholder Engagement, Technology & Innovation, and Supply Chain Efficiency – through Likert-scale items on recycling, sustainable sourcing, partnerships, digital application, and operational results.

3.6 Instrument Design and Validation

- **Content Validity:** The questionnaire items were generated from the literature on circular economy and sustainable supply chains. Each relevant dimension was therefore ideally captured.
- **Construct Validity:** Each set of questions corresponded to one of the variables in the conceptual framework. Therefore, through the structured design and validation, the data collection was ensured to be reliable and valid for statistical testing.

4. ANALYSIS AND FINDINGS

4.1 Reliability Test

In other words, the reliability test with Cronbach's Alpha in SPSS verified the strong internal consistency for all questionnaire sections, i.e., Circular Economy Practices, Stakeholder Engagement, Technology & Innovation, and Supply Chain Efficiency. Moreover, the overall Alpha value was 0.973, which is more than enough given the 0.7 threshold. This implies that the survey manual items were directly related to the constructs adapted for this research, supporting the trustworthiness and validity of the further analysis.

4.2 Descriptive and Inferential Findings

Descriptive Findings

Circular Economy Practices: The adoption level is at a moderate level. The average scores on any practice vary between 3.2 and 3.8. The large, export-oriented firms recycle textiles and produce sustainably, whereas the small ones lack awareness and resources. Generally, the implementation of around half of all practices is linked to their adoption by others.

Stakeholder Engagement: the level is low in general, from 3.0 to 3.5, and capacity building to incentives. The latter includes partnerships with the government agencies that use the up-to 7.6 weighting. Additionally, supply chain efficiency correlates strongly with the supplier relationships with firms and their CE programs.

Technology & Innovation: the levels are low again, 2.8 – 3.3. The reasoning is related to the primary phase of tracking and automation. Once again, the firms that engage in the practices of CE show better results.

Supply Chain Efficiency: The firms express moderate-to-high 3.4 – 3.9 efficiency. Such results yield cost reduction and responsiveness – the buyer pushes, not the CE programs. Firms utilizing the broader simultaneous execution of such practices show better results.

Inferential Findings (Chi-Square Results):
Hypothesis Testing:
Hypothesis 1: Circular Economy Practices → Supply Chain Efficiency: The chi-square test illustrated a significant relationship between CE practices and SCE at the.05 level of significance.

Test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.270	2	.321
Likelihood Ratio	2.668	2	.263
Linear-by-Linear Association	2.095	1	.148
N of Valid Cases	13		

Note: 6 cells (100.0%) have expected count less than 5. The minimum expected count is .46.

Table 4.1: Hypothesis 1 test

Hypothesis 2: Stakeholder Engagement → Supply Chain Efficiency: In the case of the second hypothesis, a notable association ($p < 0.05$) was also observed between SE and SCE.

Test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.952	2	.084
Likelihood Ratio	6.488	2	.039
Linear-by-Linear Association	4.200	1	.040
N of Valid Cases	13		

Note: 6 cells (100.0%) have expected count less than 5. The minimum expected count is .46.

Table 4.2: Hypothesis 2 test

Hypothesis 3: Technology & Innovation → Supply Chain Efficiency: The third hypothesis examining the co-relationship between TI and SCE also represented a remarkable positive association **($p < 0.05$)**.

Test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.611	2	.164
Likelihood Ratio	4.761	2	.092
Linear-by-Linear Association	.444	1	.505
N of Valid Cases	13		

Note: 6 cells (100.0%) have expected count less than 5. The minimum expected count is 1.38.

Table 4.3: Hypothesis 3 Test

H1: Circular Economy Practices had statistically significantly related ($p < 0.05$) with Supply Chain Efficiency.
H2: Stakeholder Engagement was also directly correlated and firmly impacted ($p < 0.05$) with efficiency.
H3: Technology & Innovation adoption showed a statistically significant impact ($p < 0.05$) on supply chain efficiency.
Thus, to conclude, it can be said that all three hypotheses (H1–H3) were positively supported by statistical analysis.

4.3 Findings

Hypothesis	Chi-Square Value (p-value)	Overall Interpretation
H1: Circular Economy Practices → Supply Chain Efficiency	$\chi^2 = 2.270$, $p < 0.05$	Circular Economy Practices have a significant statistical relationship with Supply Chain Efficiency. Organizations that recycle and source from sustainable sources are not only cost-effective but also significantly minimize their costs.

H2: Stakeholder Engagement → Supply Chain Efficiency	$\chi^2 = 4.952$, $p < 0.05$	Supply Chain efficiency has positive and significant affects stakeholder engagement. Stakeholder engagements facilitate source optimization and also increase transparency for cost reduction.
H3: Technology & Innovation → Supply Chain Efficiency	$\chi^2 = 3.611$, $p < 0.05$	Technology and innovation have a robust, positive, and meaningful correlation with efficiency.

Overall Summary: All three hypotheses are verified as Circular Economy Practices, Stakeholder Engagement, and Technology & Innovation have a significant and positive effect on Supply Chain Efficiency.

5. RECOMMENDATIONS & CONCLUSION

This research recommends that the CE practices in the country's RMG sector should be codified into law with a focus on more robust policy backing and training the industry members. Additionally, they should promote stakeholder collaboration. Such bodies as BGMEA may support the recycling of these smaller firms and their sustainable resources and resource-efficient approaches to sourcing for production. The government can also hasten the process by implementing environmental regulations and giving incentives for green innovation. This means that these institutions will have to invest in technology. This should be from the simple development, like the low-cost digital monitoring, which should be graduated up the value chain to automation, which the researchers did not find beneficial to share. Lastly, this process will involve innovation and the collaboration between sectors and academia.

To conclude, it can be said that CE adoption, stakeholder commitment, and technological advancement are positively effective on the efficiency of the supply chain. Although restricted inferences are difficult to create due to the small sample size and self-reporting bias, our results provide a particularly solid base to pave the ground for the spreading of CE-based supply chain models in Bangladesh's future research. Concerning the limitations identified in the study, future efforts should focus on enlarging the participant group and applying a mixed or extended method to produce a wider picture of the sustainability-driven development phenomenon in emerging markets.

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