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CURRENT STATE OF INNOVATION AND MANAGEMENT CONTROL, READY MADE GARMENTS INDUSTRY TOWARDS CIRCULAR ECONOMY

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ABSTRACT
This study investigates the impact of innovative strategies and management control systems (MCS) on the implementation of circular economy (CE) practices within Bangladesh's ready-made garment (RMG) sector. Utilizing the Resource-Based View (RBV), Natural Resource-Based View (NRBV), and Stakeholder Resource-Based View (SRBV), the study constructs a comprehensive framework that differentiates between internal innovation capabilities and externally acquired knowledge. Data were gathered from 142 management-level professionals using a standardized questionnaire and analyzed using PLS-SEM. The results indicate that open innovation and management control systems significantly enhance CE adoption, but green product and process innovation have favorable yet statistically negligible correlations. Moreover, MCS does not substantially influence the link between innovation and CE. The results indicate that, in buyer-driven and compliance-intensive sectors, the adoption of a circular economy is predominantly influenced by institutional factors rather than by organizational capabilities. The research enhances theoretical understanding by illustrating the contextual constraints of NRBV in low-autonomy supply chain settings and emphasizing the preeminent influence of external collaboration and compliance-driven governance. The findings indicate that organizations ought to prioritize strategic relationships and organized control systems rather than solitary internal innovation efforts to expedite circular transformation.
Keywords*: Circular Economy (CE), Resource-Based View (RBV), Management Control Systems (MCS), Open Innovation and Green Innovation.*

1. Introduction

Bangladesh's ready-made garment (RMG) sector accounts for 82% of exports, 10% of GDP, and over four million jobs, mostly women, making it vital to the global textile and apparel supply chain (Bashar et. al. 2021). Despite its economic importance, the sector relies on a linear production model with high resource use, waste, and environmental externalities. Sustainable manufacturing systems are needed due to rising expectations from global buyers, regulatory authorities, and environmentally conscious customers, especially younger ones (Ahmad et al., 2020; Peña et al., 2023).

Reuse, recycling, remanufacturing, and eco-design have made the circular economy (CE) a viable alternative to the linear model by improving resource efficiency, reducing waste, and creating closed-loop systems (Geissdoerfer et al., 2023; Prieto-sandoval et al., 2018). The transition to a circular economy requires changes in manufacturing processes, business models, and supply chain stakeholder participation (Korhonen et al., 2018 ; Milios, 2021). Through effective innovation management, companies can create circular-focused ideas to accelerate the circular economy transition (Johnson, 2022; Qurtubi et al., 2026).

Innovation is a key enabler of circular economy implementation, cleaner production methods and waste-to-resource solutions, improves resource efficiency, while organizational innovation, such as new business models and open innovation, helps implement circular strategies (Awan & Arnold, 2020; Perotti et al., 2025; Rosalin et al., 2025). Recent studies show that stakeholder integration and green investments significantly benefit environmental sustainability of Bangladeshi textile sector, especially when assisted by green technology (Hossain et al., 2022). However, limited collaborative frameworks, inadequate circular infrastructure, and a lack of consistency between business strategy and sustainability goals may hinder CE (P. K. Saha et al., 2025).

Innovation is essential, but it cannot assure CE deployment. Organizations need internal frameworks to align innovation with sustainability goals and overcome uncertainty. Management control systems (MCS) help organizations make decisions, coordinate stakeholders, and include sustainability (Lill et al., 2021; Guo et al., 2018). MCS can boost innovation by reducing uncertainty, enhancing knowledge transfer, and ensuring sustainability-focused operations. However, innovative management and management control systems' role in circular economy adoption is understudied, especially in developing nations like Bangladesh.

Companies can gain a competitive advantage by possessing rare, valuable, and distinctive resources through innovation from a Resource-Based View (RBV) perspective. If these resources include environmental competencies such as pollution prevention, product stewardship, and sustainable development, they are esteemed within the Natural Resource-Based View (NRBV). Furthermore, resources acquired through collaboration with external stakeholders' knowledge, assets, and creativity towards sustainability objectives align with the Stakeholder Resource-Based View (SRBV). These viewpoints are significant; yet, prior research has seldom integrated them to elucidate how internal capabilities, environmental limitations, and stakeholder interactions influence the adoption of a circular economy (Hughes et al., 2024; Perotti et al., 2025).

Despite the growing need for circular economy adoption in the Bangladesh RMG sector, there is no empirical data on how innovation management affects CE practices and how management control systems effect this relationship. Innovation, sustainability, and stakeholder involvement are usually studied individually, ignoring their synergistic benefits and mechanisms in developing economies.

The textile sector is focusing more on circular economy and sustainability, but three major gaps remain. First, Early evidence of circular economy techniques in Bangladesh's ready-made clothing industry is rare. Second, Management control systems' role in encouraging innovation and CE adoption has not been thoroughly studied. Third, Resource-Based View (RBV), Natural Resource-Based View (NRBV), and stakeholder theories have rarely been used to explain how internal competencies and external affiliations affect circular transformation. This study examines how innovation management affects Bangladesh RMG industry circular economy adoption and how management control mechanisms moderate this relationship. The study improves theoretical and practical understanding on emerging economies' firms' linear-to-circular production system transition by synthesizing RBV, NRBV, and stakeholder theories.

2. Literature Review

2.1 Circular Economy and Industrial Transformation

Circular economy (CE) is a systematic solution to the linear "take–make–dispose" model that reduces resource consumption, waste, and environmental harm (Geissdoerfer et al., 2023). Recent research shows that Circular Economy (CE) requires a complete transformation of production systems, consumption patterns, and institutional frameworks, not just recycling or reuse. (Suchek et al., 2021; Prieto-sandoval et al., 2018). This transformation involves limiting, delaying, and tightening resource cycles to restructure value creation (Bocken et al., 2016).

Even while CE is theoretically appealing, actual study shows that structural and behavioral barriers make its implementation unreliable. Cultural hostility, low consumer knowledge, and organizational slowness as major impediments (Kirchherr et al., 2018), whereas regulatory, financial, and technological limitations also hinder CE implementation (Jesus & Mendonça, 2018). The CE transition is impacted by institutional forces, market dynamics, and firm-level capabilities, not only technology competence. Organizations implement circular economy performance using the 3R principles—reduce, reuse, and recycle—and measures including resource efficiency, pollution reduction, and product lifecycle extension (Shaharudin et al., 2024). However, measurement and implementation differences among research suggest that corporations employ CE differently, especially in emerging nations.

In Bangladesh's ready-made garment (RMG) sector, rapid industrial expansion has worsened water pollution, energy use, and textile waste. Global buyers are pressuring RMG firms to adopt sustainable practices, but many lack the technology, finances, and skilled labor (P. K. Saha et al., 2025). Thus, CE adoption demands a revolution driven by skills and institutions, which necessitates harmonization between global standards and local industrial realities.

2.2 Innovation as a Catalyst for Circular Economy

Innovation is widely recognized as a key enabler of circular economy (CE), however research on how different types of innovation effect CE is scattered and inconsistent. Eco-innovation (EI) drives Circular Economy (CE) by reducing environmental impact in innovative products, processes, and business models (Cainelli et al., 2020; Prieto-sandoval et al., 2018). It includes product, process, managerial, and business model innovation (Suchek et al., 2021).

Recent research reveals that not all innovations improve circular economy outcomes. Process innovation prioritizes resource efficiency and waste reduction, while product innovation emphasizes lifecycle effects and sustainable design. Management innovation increases organizational routines and technical change implementation (Shaharudin et al., 2024).

This suggests that CE adoption is higher when innovations are complementary rather than independent. However, empirical evidence is unclear on whether innovation promotes CE best. Breard and Llorente-Gonzalez (2022) argue that emotional intelligence's role in the circular economy transition is still unclear due to a lack of causal mechanisms (Breard & Llorente-gonzález, 2022). Engez et al. (2021) note that prior studies focused on outcomes rather than innovation strategy and management approaches (Engez et al., 2018).

Contemporary literature adopts a resource-based view (RBV) to overcome these limitations, arguing that a firm's green innovation ability depends on its internal resources and capabilities, such as technological expertise, financial resources, and human capital (Jové-Llopis & Segarra-Blasco, 2018). The Resource-Based View (RBV) is insufficient since organizations often rely on external information and collaboration. Open innovation has become more popular since it increases access to external resources, reduces risk, and speeds up invention (Perotti et al., 2025).

Open innovation is important for circular economy (CE) solutions since they often require inter-organizational collaboration and systemic change (Konietzko et al., 2019). Data shows that working with suppliers, customers, and institutions helps companies embrace circular processes. Enterprise absorptive capacity and institutional environment vary greatly(Salam et al., 2019).

Global supply chain dynamics and technology diffusion drive Bangladesh RMG innovation. Buyers and worldwide collaboration promote wealthy nations' innovations and sustainable practices (Park-poaps et. al., 2026). Global buyer needs, certifications, and regulatory frameworks are propelling RMG companies toward sustainable innovation. Mimetic pressures encourage adoption, while coercive forces improve awareness (Alinda & Kaawaase, 2025). This shows that innovation in this business is institutionalized, emphasizing the need to analyze how internal and external influences determine CE outcomes.

2.3 Management Control Systems and Innovation Alignment

Management control systems (MCS) are crucial to Circular Economy (CE) because they help organizations coordinate, monitor, and synchronize innovative initiatives. Management Control Systems (MCS) help innovation, however different conceptual frameworks and circumstances lead to inconsistent conclusions (Chenhall & Moers, 2015).

Simons' (1995) Levers of Control (LOC) framework shows how belief systems, boundary systems, diagnostic controls, and interactive controls can help management control systems (MCS) balance innovation and regulation. These systems create a dynamic conflict between creativity and discipline, which is essential for innovation in uncertainty (Lill et al., 2021).

Research shows that Management Control Systems (MCS) influence innovation from ideation to commercialization by fostering knowledge development, information sharing, and performance evaluation (Bisbe & Malagueño, n.d.,2015). Interactive controls promote learning and flexibility, whereas diagnostic controls boost efficiency but limit originality. This tension distinguishes enabling and coercive management control system designs. Enabling systems promote innovation through flexibility, autonomy, and learning, while coercive systems emphasize compliance and control (Bernd & Beuren, 2022). Literature increasingly suggests that MCS promotes process and organizational innovation, especially in uncertain circumstances.

Despite these advances, MCS-innovation interactions to improve CE results are still poorly understood. Most study on MCS–innovation linkages do not consider sustainability or circularity aims. Bangladesh's RMG sector is significantly affected by this imbalance. Companies must increasingly follow worldwide sustainability standards and certifications, which require strict monitoring, reporting, and management. MCS can help operational and strategic decision-making incorporate sustainability by measuring performance, allocating resources, and following global standards (P. K. Saha et al., 2025). In limited-capability organizations, coercive limits may hinder innovation.

2.4 Theoretical Underpinning of Resource-Based Perspectives on Innovation and Circular Economy

Study uses resource-based view (RBV) and shows how valuable, scarce, unique, and irreplaceable resources can provide organizations an edge (Barney Jay, 1991). Traditional RBV focuses on internal business resources, giving little insight into environmental sustainability and interorganizational challenges. This study synthesizes the natural resource-based view (NRBV) and the stakeholder resource-based view (SRBV) to explain how enterprises employ internal and external resources to embrace a circular economy (CE) and overcome these restrictions.

The NRBV defines strategic decision-making with environmental boundaries and skills including pollution avoidance, product stewardship, and sustainable development (Hart et al., 2011). Product stewardship and sustainable development involve supplier and supply chain collaboration, but pollution avoidance is mostly done internally. Empirical studies show that enterprises are increasingly using supplier integration and technical collaboration for environmental innovation and sustainability (Jum & Alkhodary, 2025). NRBV alone cannot explain relational and governance frameworks that enable collaboration beyond environmental necessity.

With this restriction, the SRBV views stakeholders as strategic resources that create value and provide a company an edge over competitors (Freeman & Phillips, 2021). SRBV requires enterprises to access and share value with stakeholders to maintain long-term partnerships. Environmental skills are NRBV's focus. Since access to external information, technology, and skills typically involves trust-based and mutually beneficial cooperation, enterprises participate in collaborative innovation. NRBV and SRBV increase sustainability-oriented collaboration by merging environmental concerns with stakeholder-driven resource mobilization (Bouguerra et al., 2023; Hughes et al., 2024).

NRBV-based green innovation improves eco-design, waste minimization, and process optimization internally (Albort-morant et al., 2016). Open innovation, which follows SRBV thinking, emphasizes how outside aid and collaboration can help you overcome resource constraints (Bogers et al., 2018; Bertello et al., 2022). External collaboration promotes knowledge and CE implementation's systemic transformation, while internal capabilities raise absorptive ability (Perotti et al., 2025; Khanra et al., 2022).

Organizational frameworks are needed to turn resources into CE concepts and practices. MCS encourage strategic goals, information sharing, and new concept uncertainty (Chenhall & Moers, 2015). Facilitating MCS adaptability, knowledge acquisition, and interactive engagement improves green and open innovation coordination and information distribution, while excessive constraints may hinder experimentation (Bedford, 2015). MCS boost creativity and CE-promoting innovation.

Resource-Based View (RBV), augmented by Natural Resource-Based View (NRBV) and Social Resource-Based View (SRBV), explains how does firm access and mobilize internal and external resources, innovation drives transformation, and Management Control Systems (MCS) aids transformation.

2.5 Conceptual Framework

Literature indicates that innovation, organizational capabilities, and control mechanisms affect CE adoption, however they are frequently analyzed in isolation. Innovation is a crucial facilitator of Circular Economy. Nonetheless, its processes, especially the auxiliary roles of various forms of innovation, remain ambiguous. Secondly, the Resource-Based View (RBV) and open innovation frameworks emphasize internal and external resources but fail to elucidate how organizations align and integrate them. The impact of MCS on CE innovation is uncertain, particularly in underdeveloped countries. The issues are exacerbated by significant institutional pressures, resource limitations, and reliance on global supply chains encountered by Bangladesh's RMG enterprises. This paper presents an integrated framework in which green and open innovation drives circular economy performance, but management control systems moderate this relationship by aligning innovation activities with strategic and sustainability objectives, grounded in resource-based view and institutional context.

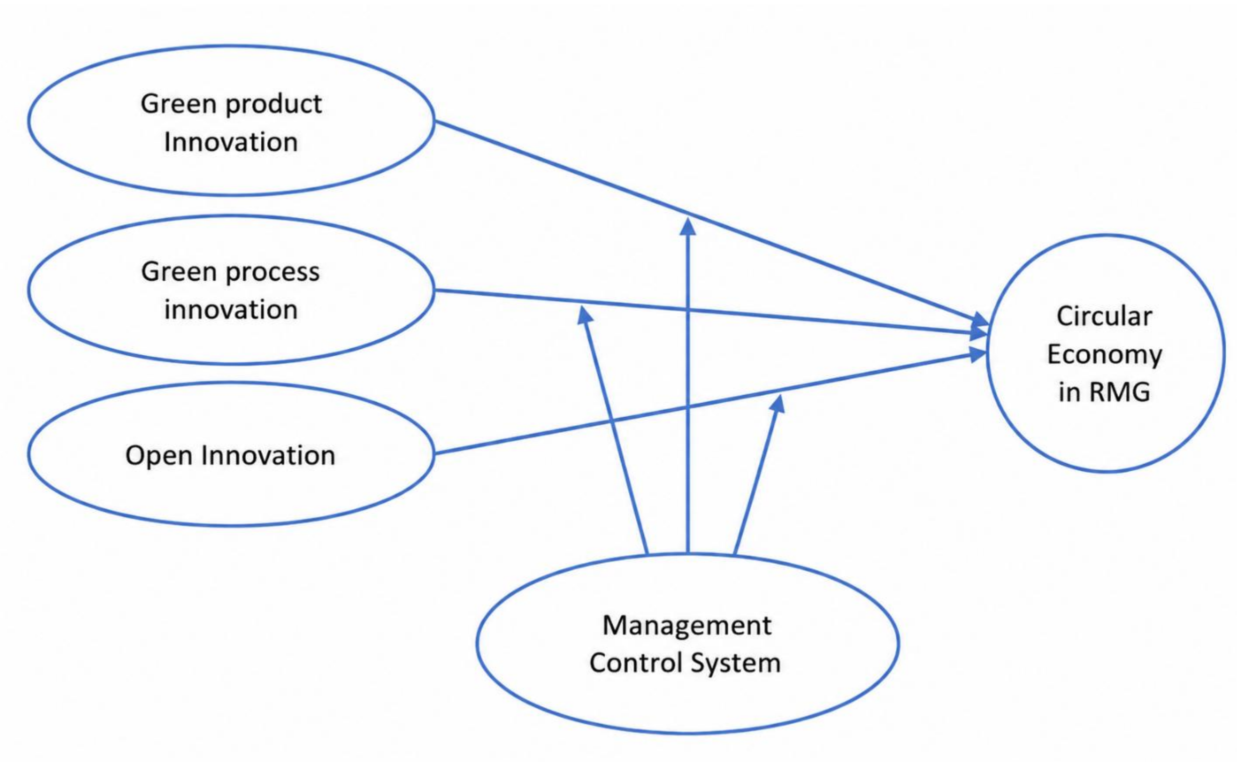

Fig. 1. Conceptual Framework

2.6.1 Green Product Innovation and Circular Economy

Green Product Innovation (GPI) decreases environmental impact from material selection to end-of-life recovery (Abdallah et al., 2024). Without incremental environmental measures, GPI substantially modifies product architecture by using recyclable materials, eliminating hazardous compounds, and boosting durability and disassembly for reuse, reproduction, and recycling. According to the natural resource-based view (NRBV), such innovation shows firms' ability to reorganize resources to meet environmental restrictions, turning sustainability concerns into competitive benefits (Hart & Dowell., 2011; Anders, 2021).

The closed-loop circular economy (CE) prioritizes resource efficiency, waste minimization, and lifecycle extension over linear "take–make–dispose" paradigms (Geissdoerfer et al., 2023). This transformation demands circular material flow technology and product design innovation (Hinojosa, 2022 ; Prieto-sandoval et al., 2018). The relationship between green innovation and CE acceptance is philosophically underexplored and experimentally inconsistent, despite universal agreement. Eco-innovation increases circular behavior in certain studies (Triguero et. al, 2022), whereas systemic or product-level innovations have limited or context-dependent effects (Kiefer et al., 2021); (Jesus et al., 2019). his paradox suggests context-specific research is needed to comprehend GPI's CE role. Product design affects textile and garment sector circularity; therefore, this distinction is clear. Production creates 15%–25% of material waste, while material intricacy and product longevity hamper technological and economic post-consumer recycling (Khairul et al., 2022). Fiber composition, modularity, and durability affect downstream circular activities like recycling and reuse, making GPI an important upstream mechanism (Rahaman & Khan, 2025). Very few circular economy ideas can be profitable without product-level innovation.

GPI is essential for Bangladesh RMG to meet global buyer sustainability standards despite resource and technology constraints. Growing acceptance of LEED, GOTS, and OEKO-TEX certifications indicates a shift toward eco-friendly production, especially product creation (Islam & Halim, 2022). Issues include recycling infrastructure, material efficiency, and circularity (P. K. Saha et al., 2025). GPI helps manufacturers use sustainable materials, improve product durability, and design for recyclability to meet circular economy and international market norms (Khan et al., 2022).

This research suggests that GPI is necessary for linear to circular manufacturing processes based on NRBV and industry concerns. Eco-friendly product design helps organizations develop circular practice technical and organizational skills. Thus, green product innovation should increase CE adoption in Bangladesh's RMG business, where technological and structural obstacles hinder circularity. Therefore, it can be hypothesized that

H1: Green product innovation has a positive impact on the adoption of circular economy practices in RMG firms.

2.6.2 Green Process Innovation and Circular Economy

Green process innovation (GPrI) reduces manufacturing environmental impact through cleaner technologies, resource efficiency, and waste reduction (Liu et. al., 2024). GPI changes industrial resource flow by addressing operational activities like energy, water, chemical inputs, and waste, unlike product-oriented innovation. These process-level advancements reveal firm-specific pollution mitigation and resource optimization capabilities, laying the groundwork for natural resource-based sustainability initiatives (Albort-morant et al., 2016). These skills help companies reduce emissions, increase efficiency, and satisfy sustainability goals (Shahzad et al., 2020).

GPrI improves resource recovery, process efficiency, and waste reduction (Perotti et al., 2025) and closed-loop methods improve material recovery and resource conservation (Kirchherr et al., 2018). Although there is theoretical consensus, data on process innovation's impact on circular economy implementation is limited and often ignores industry-specific constraints (García-Quevedo et. al., 2020). Research shows that cutting, dyeing, and finishing waste a lot of raw materials, and resource-intensive procedures waste water and emit carbon (Abbate et al., 2024; K. Saha et al., 2024). Downstream circular solutions like fiber-to-fiber recycling are technologically constrained and unprofitable (Silva et al., 2026). Improving industrial processes promotes circularity since decreasing waste and resource consumption at the source is easier than reclaiming resources later.

Limited resources, poor technology, and worldwide buyer pressure to comply with environmental regulations increase Bangladesh's RMG sector's problems. LEED and other sustainability frameworks have encouraged corporations to engage in greener manufacturing, energy-efficient equipment, and waste management (Islam & Halim, 2022). GPrI seems to be a reaction to market and institutional conditions, not just an operational improvement. When recycling and reverse logistics fail, process innovation reduces material losses, improves resource recovery, and implements circular production. Green process innovation is essential to a circular economy, as shown by NRBV and RMG industry structural restrictions. From the above discussion it can be conclude that green process innovation could improve Bangladesh's RMG sector's circular economy. Thus, it can be said that

H2: Green process innovation has a positive and significant impact on the adoption of circular economy practices in Bangladesh’s ready-made garments (RMG) firms.

2.6.3 Open Innovation and Circular Economy

Sharing knowledge, technology, and resources across organizations accelerates innovation (Perotti et al., 2025). Companies can learn from suppliers, consumers, research institutes, and other stakeholders instead of closed innovation paradigms. Sustainability-focused innovation relies on open innovation to access diverse knowledge bases and technical solutions for complex environmental concerns (Bertello et. al., 2024).

Open innovation is needed to overcome technological, resource, and knowledge barriers to circular transition (Bocken and Ritala, 2021; Jesus & Jugend., 2021). Engaging external stakeholders can help companies acquire sophisticated recycling technology, sustainable resources, and circular process improvements (Perotti et al., 2025). Collaboration among value chain stakeholders is crucial for circular economy (Triguero et al., 2022). Despite these findings, open innovation's direct impact on circular economy adoption is rarely studied, especially in emerging economies with resource and institutional constraints.

Bangladesh RMG enterprises confront structural and technological hurdles that emphasize this difference. Despite insufficient R&D, backward connections, recycling infrastructure, and supply chain coordination, the sector is globally competitive (K. Saha et al., 2024 ; Jewel et al., 2022). Open innovation helps firms overcome internal capabilities limitations as a strategic objective. Working with overseas buyers, industry groups like BGMEA, and technology suppliers may give RMG companies foreign experience, sustainable technologies, and optimal circular transformation processes (Islam & Halim, 2022). These external links enable knowledge acquisition and upstream-downstream integration, important for value chain-wide circular material flows and implement sustainability-focused innovations (Bouguerra et al., 2023). Therefore, it can be understood that open innovation enhances circular economy implementation and strengthen RMG circular economy processes. Thus, it can be assumed that

H3: Open innovation has a positive and significant impact on the adoption of circular economy practices in Bangladesh's ready-made garments (RMG) firms.

2.6.4 **Management Control System as a moderator**

Management control systems (MCS) help resource-limited, compliance-oriented companies like Bangladesh's RMG industry innovate for circular economy. MCS improve innovative knowledge integration, coordination, and strategy alignment (Wijayanti & Cahyadi, 2024). Companies in the RMG industry must balance institutional constraints from global customers, certification authorities, and sustainability benchmarks with internal concerns including limited technological skills, cross-functional collaboration, and absorptive capacity.(K. Saha et al., 2024 ; Islam & Halim, 2022).

The firm's information, resource, and operational management impacts product, process, and open innovation initiatives. MCS blends innovation lifecycle planning, resource allocation, performance monitoring, and organizational learning (Curtis & Sweeney, 2016). Enabling and interactive MCS promote adaptation, employee involvement, and information exchange to handle circular transitions' complexity and unpredictability(Bernd & Beuren, 2022).

RMG firms use eco-friendly materials and sustainable designs to meet international customer needs and certification norms. These notions cannot develop circular patterns due to poor control systems. MCS deepens this link by integrating sustainability into decision-making, product innovation with strategic goals, and environmental performance monitoring (Hallstedt et al., 2020). Thus, MCS promote green product innovation and CE acceptance.

RMG green process innovation entails coordinating complex production processes and ensuring uniform application across operational units for energy-efficient manufacturing, waste reduction, and water recycling. Input, behavior, and output controls improve resource allocation, process standardization, and performance monitoring, allowing organizations quantify process improvements into circular results (Guo et al., 2018). Therefore, MCS promote process innovate and CE implementation.

Open innovation helps RMG enterprises access external knowledge, technologies, and sustainable materials by collaborating with global consumers, suppliers, and institutions, but its success depends on the firm's ability to absorb and integrate these contributions. Many Bangladeshi companies lack R&D and technology infrastructure, making absorption difficult. MCS helps people learn, integrate external relationships into strategy, and assess joint innovation (Curtis & Sweeney, 2016). So, MCS influences the external and internal learning and innovation for CE. Thus, it can be theorized that

H4a: Management control systems positively moderate the relationship between green product innovation and circular economy implementation in Bangladesh's RMG firms.
H4b: Management control systems positively moderate the relationship between green process innovation and circular economy implementation in Bangladesh's RMG firms.
H4c: Management control systems positively moderate the relationship between open innovation and circular economy implementation in Bangladesh's RMG firms.

3. Methodology

3.1 Research Design

Research design is necessary to address a research challenge and ensure empirical validity (Malhotra, M. and Grover, 1998). Organizational and innovation research empirically tests theoretical correlations in a large sample using cross-sectional surveys. This quantitative cross-sectional survey addressed green innovation (product, process, and open innovation), management control systems (MCS), and circular economy (CE) in Bangladesh ready-made garments (RMG) (Bryman & Bell, 2015; Hair et al., 2019). A research design organizes data collection, measurement, and analysis (Figure 2).

Many arguments support this design. Theory-based correlations and moderating effects are tested using quantitative surveys (Hair et al., 2019). Second, key informant survey data is helpful for perceptual and organizational creative practices and management control systems (Podsakoff et al., 2003). Methodological standards exclude causal inference from cross-sectional data due to temporal sequencing issues (Rindfleisch et al.,2008). So, this analysis implies correlation, not causality. Later study may demonstrate causality using longitudinal or experimental methods.

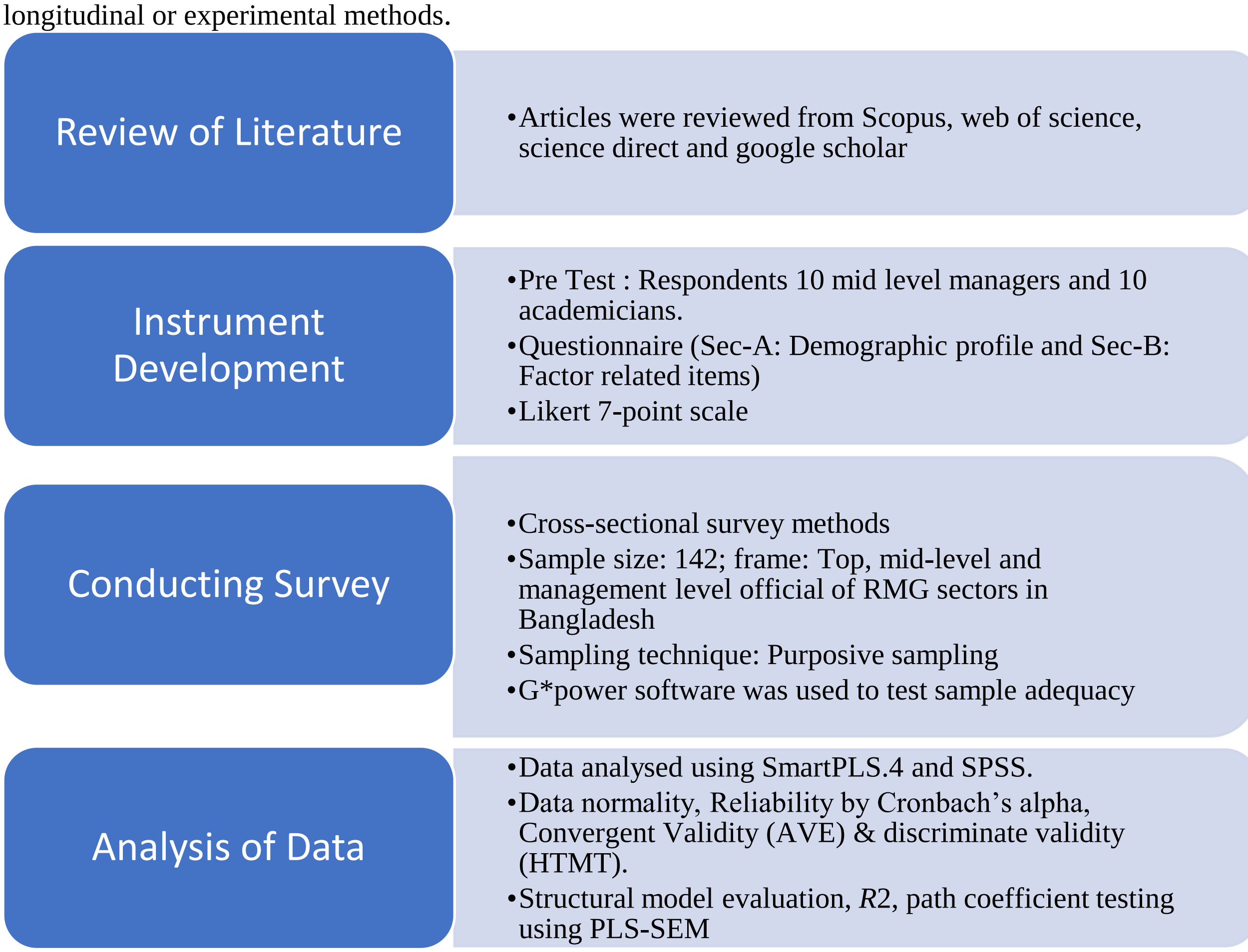

Fig. 2. Methodology Flowchart

3.2 Study Context and Population

In the Bangladesh Ready-Made Garment (RMG) sector, 4,500 producers are registered with the Bangladesh Garment producers and Exporters Association (BGMEA, 2023). As a global textile manufacturing hub, the sector has adopted circular economy and eco-friendly practices. LEED-certified factories numbered 258 in August 14, 2025 and 550 under USGBC certification (BGMEA, 2025). LEED-certified and environmentally concerned organizations have more organized green innovation and sustainability management systems, thus the research concentrates on them. Focusing on sustainability makes the study relevant to sustainability-oriented operations but may limit its usefulness to RMG enterprises, especially non-certified ones. The study's purpose of examining advanced sustainability strategies and practices across major organizations permits and justifies this constraint (Hair et al., 2019).

3.3 Sample Size Determination

The requisite minimum sample size was ascertained via G*Power (Faul et al., 2009). According to a medium effect size ($f^2 = 0.15$), a statistical power of 0.80, and a significance level of 0.05, the minimal sample size needed was 103, however a more rigorous significance threshold of 0.01 necessitated 134 observations. The resulting dataset included 142 valid responses, surpassing the thresholds and fulfilling the criteria for partial least squares structural equation modelling (PLS-SEM) (Hair et al., 2019). This sample size is deemed sufficient for identifying statistically significant correlations and ensuring the analysis's robustness.

3.4 Data Collection Procedure

From July to September 2025, a standardized online questionnaire was used to collect data, enhancing response efficiency and data quality (Dillman et. al., 2024). Two hundred twenty questionnaires were sent to selected firms with frequent reminders to boost response rates. This technique returned 153 questionnaires, a 71.06% response rate. After data screening, 142 responses were valid (effective response rate: 64.54%), while the others were eliminated due to missing data (>15%) or disengaged response patterns such little variation or straight-lining (Hair et al., 2019). To protect data integrity, mode imputation was used for missing values in the retained. Research ethics were carefully considered. Before data collection, all participants gave informed consent with optional participation. Individuals were kept anonymous and no personal information was collected. The Research Ethics Committee of Universiti Kebangsaan Malaysia approved the research (Ref: JEP-2023-914), ensuring ethical conduct (Podsakoff et al., 2003).

3.5 Questionnaire Design and Measurement Development

To verify reliability and validity, the questionnaire used measurement scales from previous investigations (DeVellis, 2016). Green product and process innovation were measured using items four and six respectively extracted from (Perotti et al., 2025) and (Wong et al., 2020) and open innovation was measured by using six items from (Cheng & Huizingh, 2014) and (Perotti et al., 2025). Management control systems were operationalized using five items from (Zhor, 2018a) and (Dreyer, B. and Grønhaug, 2004) scales, while circular economy practices were measured using six items from (Perotti et al., 2025), (Di Maria et al., 2022), (Khan et al., 2022), and (Zhu et al., 2012). Each construct was measured using numerous items and all items were slightly reworded to fit the Bangladesh RMG context while retaining their significance (*Appendix A)*. A seven-point Likert scale from 1 (strongly disagree) to 7 (strongly agree) was adopted for higher measurement sensitivity and advanced multivariate analysis (Hair et al., 2006 ; DeVellis, 2016).

Experts evaluated face and content validity to assure measurement validity (Zikmund et al., 2013 ; DeVellis, 2016). To assess clarity, relevance, and comprehensibility, 20 academics and RMG professionals participated in a pilot survey. Minor phrasing changes were made based on their suggestions to reduce ambiguity. English is commonly utilized in managerial communication in the Bangladesh RMG sector, hence the questionnaire was administered in English with reduced phrasing to avoid misinterpretation.

3.6 Common Method Bias

Both procedural and statistical interventions were used to reduce method bias since the data were self-reported (Podsakoff et al., 2003). The study carefully developed the questionnaire to reduce ambiguity and item redundancy, ensured respondent anonymity, and reduced evaluation fear. Harman's single-factor test showed that the first component accounted for 43.79% of variance, below the 50% threshold (Harman,1967). A detailed collinearity investigation found that all variance inflation factor (VIF) values were below 3.3, indicating that common technique bias is improbable (Kock, 2015).

3.7 Data Analysis Techniques

Data analysis was done using SPSS and SmartPLS 4 in two steps: measurement model assessment and structural model evaluation (Hair et al.,2017). Data screening included missing value management, outlier identification, and skewness and kurtosis evaluation before analysis (Tabachnick, & Fidell, 2013). PLS-SEM was chosen for its robustness to non-normality and suitability for complex models with limited sample numbers (Hair et al.,2017).

The structural model was evaluated using bootstrapping with 5,000 resamples to analyze collinearity (VIF < 5), path coefficients (β), and significance (Hair et.al., 2017). Convergent validity was confirmed using factor loadings (≥ 0.70) and average variance extracted (AVE ≥ 0.50) (Fornell, and Larcker, 1981). Discriminant validity was assessed using the Fornell–Larcker criterion, cross-loadings, and the heterotrait–monotrait (HTMT) ratio, with threshold values below 0.85–0.90 (Henseler et al., 2015).

The structural model was assessed by analyzing collinearity (VIF < 5), path coefficients (β), and their significance using bootstrapping with 5,000 resamples (Hair et al., 2017). The coefficient of determination (R^2) and effect sizes (f^2) were used to assess the model's explanatory capacity (Chin & Newsted, 1998), and determine the relative impact of exogenous elements (Cohen, 1988). Evaluation of predictive relevance (Q^2) was done using blindfolding (Stone, 1974; Geisser, 1974), and model fit was assessed using SRMR $<$ 0.08% (Henseler et al., 2015).

The product indicator approach in SmartPLS was used to construct an interaction term to assess management control system moderating effects (Hen;.seler & Chin, 2010). Bootstrapping was used to assess moderation effects, determining their significance based on interaction coefficient direction, magnitude, R^2, and effect size (f^2). MCS alters the relationship between green innovation and circular economy strategies.

4. Results and Discussion

A total of 142 valid responses were recorded, comprising 10.56% female and 89.44% male participants. 57% of respondents were Assistant Managers, Planning Officers, or Assistant Production Managers; 28% were Merchandisers or Quality Managers; 12% were Merchandising Managers or Assistant General Managers; and 3% were General Managers.

4.1 Measurement Model Evaluation and Interpretation

Beyond procedural validation, the measurement model evaluation revealed construct quality and theoretical strength. Figure 3 and Table 1 reveal 0.718–0.890 indicator loadings, indicating satisfactory to robust dependability (Hair et al., 2019). GPRODI3 (0.890) and MCS5 (0.880) are Bangladesh's RMG sector's most reliable indicators of product innovation and management control. CE5 (0.718) and OI4 (0.721), however near the threshold, enhanced content validity without reducing composite reliability or AVE. Staying with these elements preserves theoretically relevant dimensions, especially CE procedures operational complexity(Kline, 2023).

All constructs had AVE values above 0.50 (Table 2), confirming convergence. The RMG industry's high AVE (0.702) indicates well-organized and formalized management control systems. Previous CE and innovation studies demonstrated high internal consistency reliability, with Cronbach's alpha and composite reliability exceeding 0.80 across constructs (Perotti et al., 2025). Fornell–Larcker (Table 4) and HTMT criteria (Table 3) showed discriminant validity, with the maximum HTMT value of 0.842, below 0.85 (Henseler et al., 2015). These measurement features mirror empirical studies with factor loadings between

0.70 and 0.90 and AVE over 0.50(Hair et al., 2019 ; Perotti et al., 2025). This consistency supports the external validity of recognized constructs in an emerging country and suggests that CE and innovation scales apply to Bangladesh RMG.

Table 1 - Factor Loadings

	CE	GPRODI	**GPROCI**	**MCS**	**OI**
CE1	0.774				
CE2	0.796				
CE3	0.844				
CE4	0.837				
CE5	0.718				
GPRODI1		0.783			
GPRODI2		0.725			
GPRODI3		0.890			
GPRODI4		0.821			
GPROCI1			0.746		
GPROCI2			0.853		
GPROCI3			0.791		
GPROCI4			0.782		
GPROCI5			0.839		
GPROCI6			0.770		
MCS1				0.773	
MCS2				0.834	
MCS3				0.847	
MCS4				0.851	
MCS5				0.880	
OI1					0.757
OI2					0.753
OI3					0.736
OI4					0.721
OI5.					0.790
OI6					0.766

Table - 2 Relevant Indicators of the Measurement Model

Latent Construct	**Cronbach's alpha >0.700**	**Composite reliability (rho_a) >0.700**	**Composite reliability (rho_c) >0.700**	**Average variance extracted (AVE) >0.500**
Circular Economy	0.854	0.858	0.895	0.632
Green Process Innovation	0.885	0.886	0.913	0.636
Green Product Innovation	0.825	0.862	0.881	0.651
Management Control System	0.894	0.899	0.922	0.702
Open Innovation	0.849	0.855	0.888	0.569

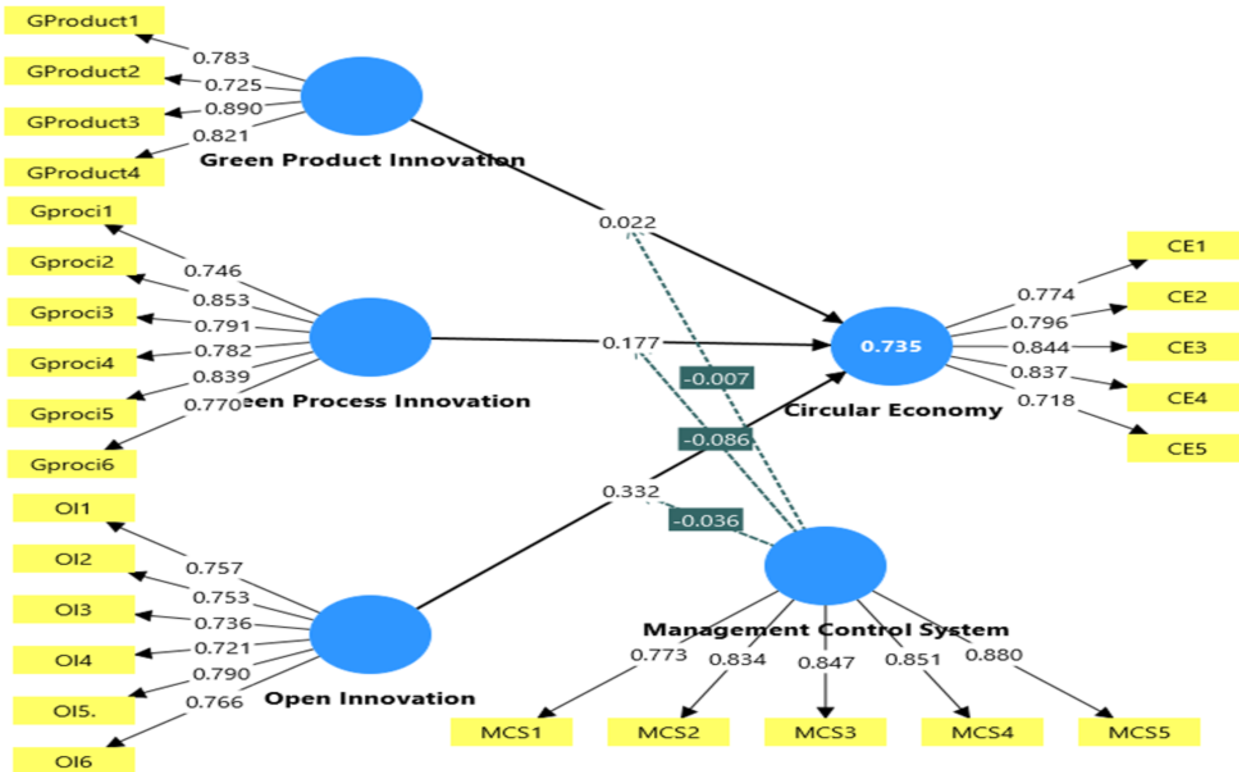

Fig. 3. Overall Measurement Model

Table - 3 Discriminate Validity HTMT Ratio

	CE	GPROCI	GPRODI	MCS	OI
CE					
GPROCI	0.806				
GPRODI	0.669	0.802			
MCS	**0.842**	0.672	0.617		
OI	0.818	0.657	0.530	0.643	

Table - 4 Discriminate Validity Fornell Larcker Criterion
(Square Root of the AVEs, Correlation Among Constructs)

	CE	GPROCI	GPRODI	MCS	OI
CE	**0.795**				
GPROCI	0.706	**0.798**			
GPRODI	0.593	0.717	**0.807**		
MCS	0.744	0.597	0.543	**0.838**	
OI	0.704	0.572	0.479	0.563	**0.754**

4.2. Structural Model Results and Interpretation

The structural model explains a considerable portion of CE adoption variance ($R^2 = 0.735$), exceeding the threshold for robust explanatory power in sustainability and management research (Hair et al., 2019). The predictors explained 73.50% of CE implementation variance, demonstrating a substantial connection. According to Hair et al. (2019), bootstrapping with 5000 re-samples was performed, and Table 5 shows the findings. This shows that open innovation and management control systems provide a complete CE justification (Hair et al., 2019).

Open innovation has a significant positive influence on CE adoption ($\beta = 0.332$, $p < 0.01$), with a modest effect size ($f^2 = 0.244$). This finding supports stakeholder theory and the wider resource-based perspective that sustainability transitions require external information and resources (Bogers et al., 2018).

Internal R&D capabilities dominate research in developed economies (Perotti et al., 2025), but external collaboration drives circular transformation in the Bangladesh RMG sector, which has limited internal innovation capacity. This supports prior research demonstrating inter-organizational collaboration increases CE adoption through knowledge exchange and competence building (Awan & Arnold, 2020).

CE adoption is most significantly influenced by management control systems (β = 0.416, $p < 0.01$; $f^2 = 0.333$), indicating a considerable effect size. This suggests that organized control systems are necessary to implement sustainable goals. Simons (1995) characterizes MCS as facilitating strategic control and innovation (Letmathe & Christian, 2026), but current data imply that RMG MCS are compliance-driven systems impacted by buyer needs and regulatory pressures. Based on past research, formal control systems may serve as implementation instruments rather than innovation facilitators in undeveloped economies.

Green product innovation has a non-significant positive connection with CE adoption (β = 0.022, $p > 0.05$; $f^2 = 0.001$). This contradicts prior study showing significant benefits (e.g., Bag et. al., 2022; Kiefer et al., 2021). The buyer-driven production model of the RMG industry limits product design autonomy. Product innovation is generally incremental rather than revolutionary, limiting its circularity impact. This study highlights a key boundary condition of the natural resource-based strategy (Hart., 1995), strategic autonomy and design capability determine green product creation success. Green process innovation proves beneficial but statistically insignificant (β = 0.177, p = 0.074; $f^2 = 0.033$). Process innovation is a key catalyst for circular economy (CE) (Triguero et al., 2022), but compliance-oriented innovations rather than fundamental transformation limit its impact. RMG process innovations often priorities efficiency improvements like energy-saving devices over resource loop closure, limiting their circular economy impact.

Table - 5 Structure Model (Path coefficients, Mean, STDEV, t Values, and P Values)

	Path coefficients (β)	**Standard deviation (STDEV)**	**T statistics**	**P values**	**f-square**	**Significance (p < 0.05)**	**R-square**
GPRODI->CE	0.022	0.071	0.316	0.752	0.001	Not Supported	0.735
GPROCI-> CE	0.177	0.099	1.789	0.074	0.033	Not Supported	
OI -> CE	0.332	0.127	2.610	0.009	0.244	Supported	
MCS -> CE	0.416	0.117	3.547	0.000	0.333	Supported	
MCS x GPROCI-> CE	-0.086	0.085	1.014	0.310	0.020	Not Supported	
MCS x GPRODI -> CE	-0.007	0.073	0.097	0.923	0.000	Not Supported	
MCS x OI -> CE	-0.036	0.100	0.361	0.718	0.005	Not Supported	

4.3 Moderation analysis and discussion

The study evaluated how management control systems (MCS) regulated the relationships between green product, green process, open innovation, and RMG sector CE adoption. These effects were analyzed using bootstrapping with 5,000 resamples and bias-corrected and accelerated confidence intervals according to PLS-SEM criteria (Hair et. al., 2016). Minor moderating effects of MCS are observed in all posited linkages, with coefficients and p-values indicating modest interaction effects (H4a: β = -0.007, p = 0.923; H4b: β = -0.086, p = 0.310; H4c: β = -0.036, So H4a, H4b, and H4c are unsupported.

According to Simons (1995), interactive control systems stimulate discourse, encourage experimentation, and facilitate strategic renewal, promoting innovation. (Simons, 1995). Results contradict this. MCS do not increase innovation-CE adoption correlation in Bangladeshi RMG. MCS may be compliance-focused because the industry relies on buyer-driven standards and external regulations. These strategies promote operational efficiency and compliance over grassroots originality. International clientele influence RMG innovation, decreasing internal control system mediation. In these contexts, compliance drives organizational innovation, not strategy. Many RMG organizations' hierarchical structures limit knowledge sharing and interactive controls, which require clear communication and decentralized decision-making (Willekes & Wagensveld, 2016). This structural rigidity may hinder MCS's ability to promote innovation-CE practice interactions.

Graphical studies reveal subtle interaction patterns despite insignificant statistical results. Green process innovation is more positively correlated with circular economy adoption in participatory (bottom-up) control systems than in rigid, top-down frameworks. These effects are too minor for statistical significance (Figure 4.2). Green product and open innovation vary little among control system designs, indicating MCS's modest moderating influence (Figures 4.1 and 4.3).

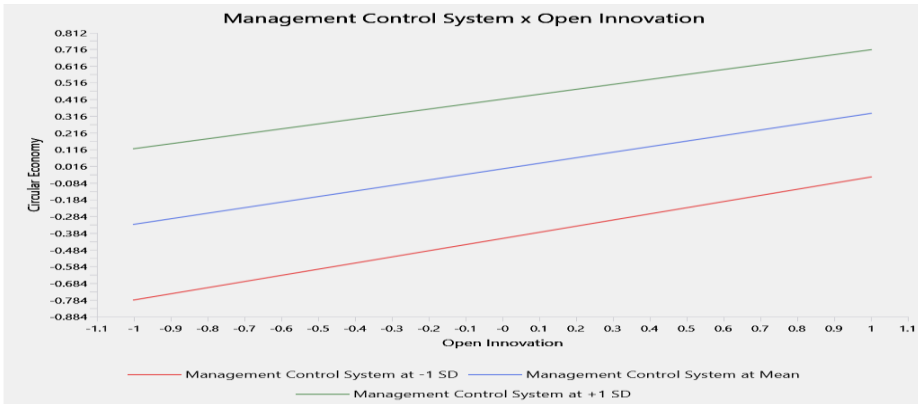

Fig. **Error! No text of specified style in document.**.1. Moderating Effect of Management Control System on the Relationship Between Open Innovation and CE implementation

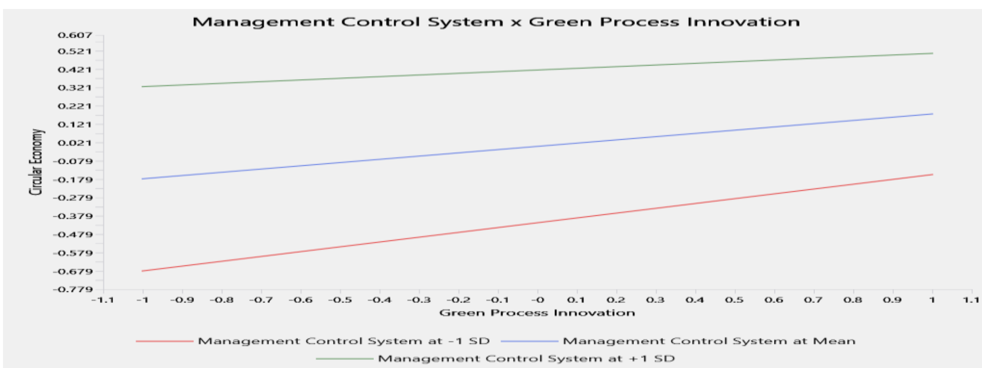

Fig. **Error! No text of specified style in document.**.2. Moderating effect of Management Control System on the Relationship Between Green Process Innovation and CE implementation

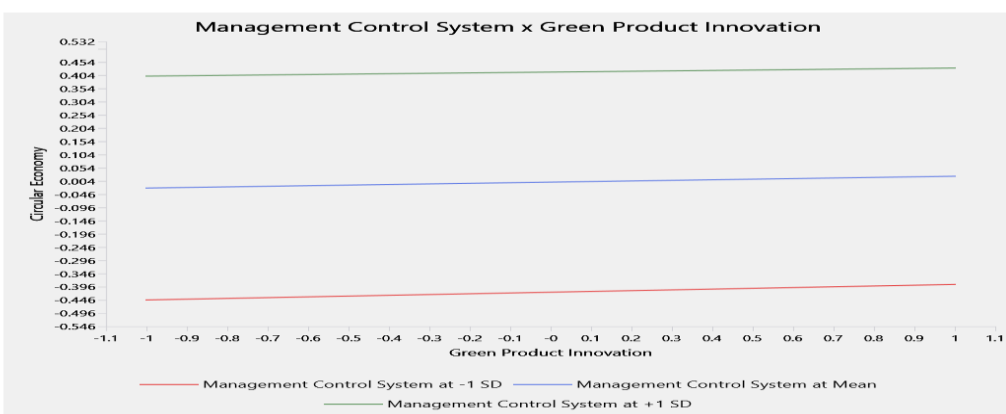

Fig. **Error! No text of specified style in document.**.3. Moderating effect of Management Control System on the Relationship Between Green Product Innovation and CE implementation

The results contradict past empirical investigations that revealed interactive MCS moderates alternative scenarios. Interactive control systems increased organizational resources and innovation (Zhor, 2018b). Interactive controls promote organizational learning, communication, and opportunity identification (De Haan-hoek et al., 2020 ; Ruiter et al., 2022). In contrast to prior studies, new findings emphasize context. Interactive management control systems' moderating effectiveness in the RMG industry is limited by institutional pressures, compliance requirements, and decreased organizational autonomy. The findings show that MCS in the Bangladeshi RMG industry largely facilitate CE adoption rather than moderate innovation consequences. This challenges MCS's "pure moderator" (Sharma et al., 1981) role and indicates their structural and facilitative nature. To support cyclical transitions, Management Control Systems (MCS) should change from compliance-oriented frameworks to learning-centric control mechanisms that stimulate experimentation, knowledge sharing, and grassroots innovation. MCS would be better linked to dynamic CE deployment skills in developing economies.

4.4 Integrated Discussion

Thus, our study reconciles contradicting evidence and shows that the innovation–CE link is context-dependent. The results reveal that CE adoption in Bangladesh RMG is challenging. CE is driven by external collaboration (open innovation) and formal control systems (MCS), unlike prior studies in developed contexts (Perotti et al., 2025). Since green innovation is limited, buyer dominance, cost pressures, and capacity restrictions matter. Thus, our work reconciles conflicting results and indicates that innovation–CE is context-dependent. RBV, NRBV, stakeholder theory, and MCS frameworks are needed to explain CE adoption in emerging economies.

5.Implication of the Study

5.1 Theoretical Implications

This study applies the resource-based view (RBV), natural resource-based view (NRBV), stakeholder theory, and management control systems (MCS) literature to the Bangladesh ready-made garments (RMG) industry, a buyer-driven, export-oriented sector with limited design autonomy, strict compliance requirements, and high cost pressures.

First, RBV and NRBV assumptions about internal innovation capacity are not universally applicable. Although previous research has identified green product and process innovation as critical drivers of CE (Hart et al., 2011 ;Jia et al., 2020), this study demonstrates positive but insignificant benefits for both (β = 0.022; β = 0.177). In the Bangladesh RMG industry, low strategic autonomy, customer domination, and compliance-oriented production structures impede the conversion of internal green capabilities into CE outcomes. This shows that environmental capabilities alone are insufficient; their success requires on organizational control over design and innovation decisions, adding a crucial boundary condition to NRBV.

Second, the study supports stakeholder theory and resource-based view by showing that open innovation drives CE implementation significantly at 1 % level of significant with β = 0.332. Unlike automotive and electronics, where internal R&D dominates sustainability innovation, buyers, international NGOs, certifying agencies, and technology providers supply information, standards, and process enhancements to the Bangladesh RMG sector(Giuliani et al., 2020). Global value chain (GVC) partners support open innovation with eco-friendly materials, cleaner technology, and circular practices. The research makes stakeholder contact a strategic resource, especially in resource-constrained environments. It also demonstrates that unequal authority and knowledge reliance organizations priorities inter-organizational collaboration over internal competence (Pietrobelli & Rabellotti, 2011).

Third, Simons' (1995) paradigm of MCS is revisited and found to strongly effect CE adoption but not innovation-CE relationship. In developed countries, MCS especially interactive controls—enable innovation and organizational learning (Bedford, 2015). Buyer audits, social compliance (BSCI, WRAP), and environmental certifications affect Bangladesh RMG MCS. Monitoring, reporting, and standardization are prioritized over invention and experimentation (Ekonomi & Islam, 2025).

Fourth, a context-sensitive theoretical framework was created by merging green innovation, open innovation, and MCS into a single model, explaining a significant percentage of CE adoption variance (R^2

= 0.735). External forces, collaborative networks, and compliance-oriented governance structures drive CE adoption in Bangladesh's RMG industry, not skills. Innovation-driven industries value dynamic and internal skills (Teece, 2007).

The analysis shows that industry structure and global value chain dynamics greatly affect sustainability transition drivers, adding to CE literature. Purchaser dominance, institutional compliance restrictions, and firm-level autonomy affect CE adoption in developing economies, making theory context-specific. Industry-specific and GVC-sensitive interpretations are needed for emerging economy RBV, NRBV, and MCS research.

5.2 Practical Implications

This study result shows that Management control systems (MCS) had the highest impact on CE adoption at 1% significant level with $\beta = 0.416$ and $f^2 = 0.333$, surpassing other variables. This shows that CE implementation technique in the Bangladesh RMG sector is mostly formalized control and compliance rather than discretionary creativity. Implement CE-related targets in compliance audits (BSCI, WRAP), environmental certifications (ISO 14001, LEED), and buyer and regulator-required internal KPI dashboards. The MCS effect states that monitoring, traceability, and reporting accelerate CE results over uncertain innovation processes. This shows Bangladeshi RMG enterprises choose external compliance over volunteer sustainability (Ekonomi & Islam, 2025 ; Egels-Zanden & Lindholm, 2015).

Second, open innovation exhibits a statistically significant and moderate-to-strong impact on CE adoption ($\beta = 0.332$, $p < 0.01$; $f^2 = 0.244$), positioning it as the second most influential factor in the model. This finding should not be construed as a general appeal for collaboration, but rather as substantiation for focused, resource-specific partnerships. These may collaborate on sustainable raw materials, wastewater treatment, and circular design abilities. This path's magnitude and relevance show that targeted external engagement can compensate for poor internal R&D.

Third, Practitioners should be careful as green product and process innovation has non-significant benefits ($\beta = 0.022$, $p = 0.752$ and $\beta = 0.177$, $p = 0.074$). This shows that Bangladesh RMG innovation is not producing any major CE results. Most enterprises follow buyer-specified designs and implement incremental energy efficiency and waste reduction changes without changing material flows or enabling circularity (Sinkovics et al., 2016). Therefore, managers should avoid overinvesting in individual or progressive “green” projects without CE implications. Innovation should priorities fabric recycling, industrial symbiosis, and closed-loop production. Due to limited design capacity, such transformations may necessitate customer input, proving open innovation's superiority over internal R&D.

Fourth, MCS's non-significant moderating effects ($p > 0.05$ across all interaction variables) suggest that existing regulatory mechanisms do not increase innovation-CE adoption. MCS are effective direct implementation tools, but our analysis does not support rebuilding them as innovation-enhancing or “interactive” systems. Bangladesh RMGs rely on MCS for compliance verification, not strategic learning (Bedford, 2015). Managers should avoid “more flexible” control system calls. Rules should gradually limit cross-functional feedback and coordination approaches rather than expecting interactive controls to instantly promote creativity. This interpretation is supported by the model's non-significant interaction effects.

Finally, the findings suggest two evidence-based policy changes. Evidence suggests a significant MCS impact size ($f^2 = 0.333$) between mandated sustainability reporting, audit standardization, and enforcement processes and CE adoption. While open innovation is crucial ($\beta = 0.332$), public policy should prioritize organized collaboration platforms such industry-academia partnerships, shared technology centers, and buyer-supplier knowledge exchange programs. Due to non-significant innovation variables, wide, subsidy-driven innovation initiatives without value chain limits (e.g., restricted design control, buyer dominance) may fail in this business. Researchers argue developing countries must connect policy with global value chain dynamics (Pietrobelli & Rabellotti, 2011).

6. Conclusion

This study offers empirical evidence that contests traditional beliefs about the factors influencing circular economy adoption. Contrary to prevalent beliefs, internal green innovation does not substantially facilitate the implementation of circular economy practices in Bangladesh's ready-made garment business. Conversely, externally focused innovation initiatives and structured management control systems assume a predominant role. These findings highlight the significance of industry structure and global value chain dynamics in influencing sustainability transitions. In environments characterized by significant buyer dominance and restricted strategic independence, circular transformation is mostly influenced by external collaboration and compliance mandates rather than internal capabilities. Bangladesh's buyer-driven, compliance-intensive RMG sector relies on formal compliance frameworks and externally supported collaboration to establish circular processes, rather than leveraging internal innovation capabilities. The research underscores the necessity for a transformation in both theoretical and practical approaches. Future study ought to integrate institutional and governance approaches to enhance the comprehension of sustainability adoption in emerging economies. Practitioners should emphasize collaborative networks and systematic control methods rather than solitary innovative efforts. Ultimately, attaining circularity in the RMG industry necessitates not only individual company initiatives but also synchronized efforts throughout the entire value chain.

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Appendix

Appendix A.
Items of Questionnaire for Data Collection

Factors	Items	Sources
Green Product Innovation	**GPI 1** Innovative product/service design to decrease the consumption of materials and energy in RMG industry.	Perotti, et. al. (2024). Wong, Wong, and Boonitt (2020).
	GPI 2. Innovative product/service design to minimize its externalities on the environment (e.g., reducing pollution or waste at product end-of-life) in RMG industry.	
	GPI 3. Innovative packaging/service delivery conditions to reduce its environmental footprint in RMG industry.	
	GPI4. Using sustainable and recyclable materials for packaging in RMG industry.	
Green Process Innovation	**GPRI 1.** Sourcing raw materials from environment friendly suppliers and use nonhazardous/nontoxic materials in RMG industry.	Perotti, et. al. (2024). Wong, Wong, and Boonitt (2020).
	GPRI 2. Innovative sourcing of recycled or recovered secondary raw materials in RMG industry.	
	GPRI 3. Innovative using cleaner technology to decrease waste from all sources in RMG industry.	
	GPRI 4. Introducing new operations processes to reduce waste from all sources in RMG industry	
	GPRI 5. Employing cleaner transportation modes in RMG industry	
	GPRI 6. Carefully scheduling transportation routes to reduce emissions in transportation of RMG	
Open Innovation	**OI1.** External partners, such as customers, competitors, research institutes, consultants, suppliers, government or universities are directly involved in all our innovation projects.	Perotti, et. al. (2024). Cheng and Huizingh (2014),
	OI 2. Our firm often buys R&D-related services from external partners, such as customers, competitors, research institutes, consultants, suppliers, governments or universities**.**	
	OI 3. Our firm invests in other firms because we would like to obtain synergies that are beneficial to our innovation projects.	
	OI 4. Our firm often sells licenses, such as patents, copyrights or trademarks, to other firms so as to better benefit from our innovation efforts.	
	OI 5. Our firm exploits every possible external use of its own intellectual property to benefit from it.	
	OI 6. In innovation projects, our firm keeps internal and external partners updated about new information.	
Management Control System	**MCS1.** Regularly & interactively intervene in the decision of subordinates to control Innovation.	Smiklou, Z. (2018). Dreyer, B., & Grønhaug, K. (2004).
	MCS2. Circular economy related innovation system receives regular attention from operating managers	
	MCS3. Reinforcing face-to-face meetings of superiors, subordinate to interpret the data of innovation	
	MCS4. Monitor the development of employees by strategic manpower system.	
	MCS5. Formalizing set of predefined objectives to optimize the employees ‘outcomes	

Circular Economy Implementation	**CEI1.** Adoption of more sustainable inputs in product development/service delivery (for instance, recycled or recovered materials).	Perotti, et. al. (2024). Di Maria et. al. (2022) and O. Khan et. al. (2021). Zhu, Geng, and Lai (2010)
	CEI2. Reduction of process-related environmental impact (for example, on air or water)	
	CEI3. Design products to be easily repaired or refurbished	
	CEI4. Designing products to be easily biodegradable or recyclable	
	CEI5. Use of waste from other companies/sectors as input in product development/service delivery.	
	CEI6. Reduction of production waste and recycling own production waste	

Appendix-B: Total Variances

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.825	43.798	43.798	11.825	43.798	43.798
2	2.362	8.749	52.547	2.362	8.749	52.547
3	1.699	6.293	58.840	1.699	6.293	58.840
4	1.230	4.554	63.394	1.230	4.554	63.394
5	1.111	4.115	67.509	1.111	4.115	67.509
6	.863	3.195	70.704			
7	.773	2.864	73.568			
8	.759	2.810	76.378			
9	.649	2.406	78.784			
10	.618	2.290	81.074			
11	.551	2.041	83.115			
12	.505	1.871	84.986			
13	.455	1.685	86.671			
14	.448	1.661	88.331			
15	.394	1.460	89.791			
16	.378	1.401	91.192			
17	.346	1.282	92.473			
18	.318	1.177	93.650			
19	.282	1.045	94.695			
20	.266	.983	95.679			
21	.221	.820	96.499			
22	.207	.765	97.264			
23	.200	.740	98.004			
24	.165	.610	98.614			
25	.139	.513	99.127			
26	.132	.490	99.617			
27	.103	.383	100.000			

Extraction Method: Principal Component Analysis.