

DOCTORAL (PHD) DISSERTATION

EFFECTS OF GREEN TECHNOLOGY ADAPTATION AND GREEN INNOVATION ON CIRCULAR ECONOMY PERFORMANCE OF MINING SECTOR IN MONGOLIA

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TABLE OF CONTENTS

1. INTRODUCTION	
1.1 Background of this study	04
1.2 Justification for the study and Research Gap	07
1.3 Research questions and objectives	09
1.3.1 Research Questions	09
1.3.2 Research Objectives	09
2. LITERATURE REVIEW	
2.1 Theoretical Background	10
2.2 Green Technology Adaptation	12
2.3 Green Innovation	14
2.4 Circular Economy	17
2.5 Circular Economic Performance	19
2.6 Circular Economy in Mining sector	23
2.7 Mining Sector in Mongolia	25
2.8 Circular Economy Performance in Mongolian Mining sector	33
3. HYPOTHESES DEVELOPMENT AND CONCEPTUAL MODEL	
3.1 Green technology adaptation and circular economic performance	41
3.2 Green technology adaptation and green innovation	45
3.3 Green innovation and circular economic performance	48
3.4 Green Innovation as a Mediator	51
3.5 Conceptual Model of this study	53
4. METHODOLOGY	
4.1 Introduction to Methodology	54
4.2 Research Design	54
4.2.1 Research Nature	54
4.2.2 Data Sources	55
4.3 Population and Sample Design	55
4.3.1 Population and Sampling Frame	56
4.3.2 Sampling Design	56
4.3.3 Sample Size	57
4.3.4 Unit of Analysis	57
4.4 Research Instruments	58
4.4.1 Green Technology Adaptation	59
4.4.2 Green innovation	60
4.4.3 Circular economy performance	60
4.5 Pre-Test	61
4.6 Pilot Study	62
4.7 Data Collection Techniques	63
4.8 Data Analysis Techniques & Tools	64
4.9 Approaches of Structural Equation Modeling	65
4.10 Evaluation of PLS Path Model Results	67
4.10.1 Measurement Model	67

4.10.2	Structural Model	69
5. FINDINGS OF THE ANALYSIS		
5.1	Introduction to Findings	71
5.2	Response Rate	71
5.3	Profile of Respondents	72
5.4	Prevention from data collection bias	73
5.5	Goodness of Measurement Model	75
5.6	Assessing Measurement Model	76
5.6.1	Convergent Validity	76
5.6.2	Discriminant Validity	80
5.7	Assessing Structural Model	82
5.7.1	Direct Effect	82
5.7.2	Indirect Effect	86
5.8	Summery of the Results	87
5.9	Discussion	87
6. IMPLICATION, LIMITATION, AND CONCLUSION		
6.1	Theoretical Contributions	105
6.2	Managerial Implications	106
6.3	Limitations	108
6.4	Conclusion	109
7. NOVEL FINDINGS		111
SUMMARY		112
REFERENCES AND APPENDICES		
References		116
List of Abbriviations		136
List of Tables		137
List of Figures		138
List of Publications		139
Declaration		141
Acknowledgement		142
APPENDICES		143

1. INTRODUCTION

1.1 Background of this study

The circular economy process has gained enormous attraction nowadays to achieve sustainability through green technologies (ALNOOR ET AL., 2024). The term “circular economy” diverges from traditional systems and offers potential to enhance value by diminishing resource flow, decelerating or terminating resource loops (LI ET AL., 2024). Additionally, if the performance in the organizational level is focused on the circular economy, it accelerates in minimizing input waste, decreasing environmental harm, and establishing a system that considers the interests of stakeholders (ZHENG ET AL., 2024). However, attaining circular economy performance necessitates the creation of distinctive business models through the integration of innovative thinking and the execution of operational activities (ABDALLAH ET AL., 2024). Pertinently, in their research, ABDALLAH ET AL. (2024) termed these activities a restorative and regenerative paradigm designed to enhance production and consumption efficiency through the application of essential reduction principles, reuse, and recycling. While the adoption of circular economy practices is advantageous, the benefits are amplified when integrated with an organization.

On the other hand, green technology encompasses methods and innovations that reduce material and energy consumption (HONG ET AL., 2024). In this context, green technology adoption refers to how businesses incorporate green technology into their operations, particularly when developing new products, production procedures, and human resource training programs (AMIN ET AL., 2019A; ULLAH ET AL., 2024; MOHAIMEN ET AL., 2025). In their study, HONG ET AL., (2024) explained that the implementation of green technology can be shaped by external factors such as environmental policies, suppliers, consumers, competitors, non-government corporations, financial departments, and research centers; as well as internal factors including enterprise characteristics, organizational structures, technology, and environmental strategies, alongside the inherent characteristics of the technology itself.

However, ASAD ET AL. (2024) indicated that the implementation of green technology by small and medium-sized firms will be hindered by deficiencies in education, training, organization, and coordination capabilities. The researchers also contended that the implementation of advanced wastewater treatment technologies can be affected by factors at both the corporate and community levels, with the former encompassing knowledge assets, environmental technology, and industry

partnerships, and the latter comprising citizen input and governmental environmental regulations. In another similar study, YANG ET AL. (2024) asserted that the senior management and customers of an organization significantly influence the adoption of green technology in organizations. Additionally, YANG ET AL. (2024) focused their research on medium and micro-enterprises, concluding that market forces propel the green concern, green entrepreneurship, green technology, and green innovation as intrinsic motivators for small and emerging markets to adopt the circular system. In another study on entrepreneurial intention, scholars (for example, SHAHNEAZ ET AL., 2020; KARIM ET AL., 2024; ALSHEBAMI ET AL., 2025) discussed entrepreneurial behavior and technical innovation, where they suggested many facilitators involved in the process of green technology adoption.

The embrace of green innovation concepts and applications has provided enterprises with a competitive advantage. The current research addresses the firm's comprehension of the appropriate productivity and resource maximization through green innovation. Green innovation can be utilized to enhance the effectiveness of sustainability management in response to the necessity of environmental protection. To mitigate environmental costs, companies might employ green innovation to enhance resource efficiency. Moreover, enterprises that advance in emerging markets will gain the first mover advantages, enabling them to set elevated prices for environmentally sustainable products, improve their brand reputation, promote their eco-friendly offerings, and potentially access new markets (ASHRAF ET AL., 2024). It has been asserted that green innovation provides a sustainable and advantageous benefit to organizations, thereby enabling them to maintain a robust presence in the market (TARIQ ET AL., 2024; HUANG ET AL., 2024; ASHRAF ET AL., 2024). Nonetheless, in their study, other additional advantages that businesses gained from the use of green innovation have been acknowledged by scholars.

Notably, adopting sustainable practices can enhance environmental protection by mitigating the adverse effects of mining. These practices include integrating renewable energy sources, improving water and waste management, and restoring land after utilization (MA ET AL., 2024A). By adopting green technologies such as automation and electrification, enterprises can reduce carbon emissions and improve resource efficiency. Moreover, the environmental impact can be further reduced through methods such as selective mining and waste material recycling (ONIFADE ET AL., 2024a). This research emphasizes the Mongolian mining sector as a prime

example of environmental sustainability and the use of green technologies within a circular economy. The mining sector significantly impacts municipal policy on the adaptation of green technologies. Initially, residents in rural regions perceived mines as harmful to the environment, pasturelands, and winter habitats, although they also provided considerable benefits to the local economy. Later, nomadic and rural populations pushed the companies off their land to safeguard their communities from the environmental devastation caused by mining operations. They convinced the mining companies to preserve their longstanding way of life rather than be enveloped in black smoke that obscures the azure sky.

Another notable point is that if the mines deplete the wells, the nomads and their herds will be forced to relocate, and the local flora and fauna will perish and migrate. This will encourage local mining enterprises to become more environmentally conscious, and only then will these investors be attracted to invest more in this productive sector to contribute to domestic economic growth. If nomads are forced to relocate due to mining-related water depletion, it could raise social and environmental concerns that attract public and regulatory attention. This pressure may push mining companies to adopt more green technology and innovation to maintain their reputation, operational stability, and ultimately circular economic performance. As a result, environmentally responsible behavior could make this sector more appealing to green technology-focused investors. Therefore, while relocation itself may not directly drive investment, its consequences can influence investors' priorities and decisions to transform green technology and innovation.

Over time, local people have found several benefits from mining in their area. Mining provides a crucial supplementary revenue stream for nomadic herders, who are susceptible to catastrophic weather events that could kill their cattle. For herders who have lost all their livestock, mining is a last resort that will allow them to survive. Many people from the surrounding regions work for large-scale mining. Because of their impact on regional employment rates, mining firms have become powerful players in local policymaking. Many Mongolians, even those who were formerly herders, have resorted to "ninja mining," or small-scale artisanal mining, to ensure their own existence. In regulated venues, this labor may give an income that is much more than the national minimum wage. The service industry has grown in response to the mining boom and the new cities that have sprung up around it. As a result, formerly nomadic people might find jobs indirectly by meeting the demands of the mining crew.

In search of employment and a better life for their families, many nomadic people relocate to the towns and cities that spring up around mining sites. Public services are sometimes lacking in rural locations, yet this helps some people get the help they need. According to MA ET AL. (2024A), Families in mining regions tend to spend more on medical care. Residents' access to healthcare and health expenditures have increased, even while overall health indicators have declined in certain areas. Better educational opportunities for children of nomads were funded by the growth and influx of wealth in mining regions. Educational attainment in mining communities is still improving, and education spending is decreasing. While local communities may be the intended beneficiaries of new infrastructure projects, such as roads, the improved transit linkages they provide are really a boon to the whole community.

1.2 Justification for the study and Research Gap

The adoption of green technology in the operational sector is a multifaceted decision-making process that engages both internal and external stakeholders. Policy planners and organizations encounter the problem of identifying potential enablers, the influential dissemination pathway, and the transfer network of green technology among internal and external operational stakeholders (HONG ET AL., 2024). However, the study of HONG ET AL. (2024) was on green technology adoption predominantly emphasizes the individual level; while the present study indicates that there is a lack of concentration on the organizational operational level; and still there is a requirement of concentration on the implementation of green technology and resource utilization. The impact of external factors on enterprise operational activities and the existence of correlations among the adoption of green technology and circular economy oriented organizational performance remain unresolved issues. This gap of the study motivates additional empirical efforts by the researchers, policy designers, and operational experts with sustainability initiatives. Consequently, it is essential to investigate a comprehensive framework for activating and enhancing external public opinion to sustainably operate firms with circular performance through green technology.

The present research indicates that green innovation is another underscored factor that has been done limited research; however, it has a significant contribution to influence on performance within a circular economic system. In this regard, KHAN ET AL. (2024) demonstrated a correlation and significant association between green innovation and environmental performance

within a circular economy-based production process. The authors illustrated that green innovation is advantageous for fostering a green economy, thereby enhancing global circular economy performance. In another similar study, YAOTENG & XIN (2022) indicated that performance in the circular economy depends on the quality of green innovation and ecological sustainability. The study further confirmed the substantial correlation between green innovation and performance in the circular economy, which provides organizations with a competitive edge. Similarly, ABDALLAH ET AL., (2024) advocated that the efficacy of green innovation is attributable to the priorities established by company leaders, and it enhances organizations' initiatives to engage in the circular economy. In addition to that, ABDALLAH ET AL., (2024) emphasized the relationship between green innovation and environmental efficiency within a circular economy-based system.

The present research is significant for a nation where nearly half of the population lives as nomads and where the bulk of economic exports originate from the mining industry. Significant urbanization has occurred in the country in recent decades whereas the resources are notably very limited; both government and people of the country are feeling the urge to use circular system as much as possible in all their production processes even in mining sector (SODNOMDARJAA ET AL., 2024). Notably, a numerous number of Mongolian nomads relocating from the steppes and abandoning herding to seek employment in mines and metropolitan areas. Because the government and corporations are boosting the skill development of local population to be capable of working through more green innovation, green technology, and circular-oriented production systems. At the same time, organizations are adopting green technologies with the help of green innovation, and at the end they are attaining circular economy-oriented performance (MA ET AL., 2024B). However, finally the much important research concern is that there is no such prior study has been considered on Mongolia mining before. Thus, based on the above literature support, this study aims to fulfill the mentioned research gap and claims a justification for the conduction of this research.

1.3 Research questions and objectives

To contribute to the academic debate and to provide useful insights to practitioners, the present study aims at evaluating the effect of green technology adaptation and green innovation on circular economic performance. In the present model, green technology adaptation presents as exogeneous construct, circular economy performance as the endogenous construct, whereas green innovation applied as a mediating factor. Based on this, the current study indicates the following research questions represented in section 1.3.1 and research objectives in section 1.3.2.

1.3.1 Research Questions

RQ1: Does green technology adaptation have a relationship with circular economic performance?

RQ2: Has green technology adaptation a relationship with green innovation?

RQ3: Does green innovation have an association with circular economic performance?

RQ4: Has green innovation a mediating effect on the relationship between green technology adaptation and circular economy performance?

1.3.2 Research Objectives

RO1: To assess the impact of green technology adaptation on circular economic performance.

RO2: To evaluate the effect of green technology adaptation on green innovation.

RO3: To measure the relationship between green innovation and circular economic performance.

RO4: To investigate the mediating effect of green innovation on the relationship between green technology adaptation and circular economy performance.

2. LITERATURE REVIEW

2.1. Underlying Theory

GHADGE ET AL. (2019) asserted that the resource-based view (RBV) is one of the most appropriate theories for forecasting circular performance and sustainable performance within an organizational perspective. In this context, PENG (2001) asserted that a significant benefit of the resource-based view is its heightened focus on firm-specific resources in relation to corporate success. This contrasts with the conventional features often analyzed at the industry level. Contrary to the perspective of industrial organizations, the resource-based view posits that competitive advantage is more efficiently attained using internal resources rather than external ones (BARNEY & HESTERLY, 2010). The resource-based view posits that organizations include a disparate array of resources, characterized by enduring inequities in their distribution throughout time. Moreover, enterprises with resources that meet the resource-based view criteria—valuable, rare, imperfectly imitable, and non-substitutable—can attain enduring advantages in the market (BARNEY, 1991).

TEECE (2007) posited that the resource-based view approach regards firms as inherently different due to the varied resources they have. This compels enterprises to implement diverse strategies based on their distinct resource combinations. The resource-based view has faced criticism for neglecting the biophysical and natural environment, as well as the substantial constraints imposed by natural resources, which provide the fundamental context for a company's inventive capacity. LILLIS ET AL. (2015) asserted that contemporary management studies have shifted the focus of academic study from physical to intangible resources. Intangible assets are expected to be recognized from a strategic viewpoint since they include the essential elements for a sustained competitive advantage (LILLIS ET AL., 2015).

HART (1995) initiated the development of the resource-based view concept by examining the organization's interaction with the natural environment. On the other hand, the National Resource-Based View (NRBV) concept posits that enterprises must emphasize their environmental relationships and commit to sustainable development while maintaining a competitive advantage through three interrelated strategies: pollution prevention, product stewardship, and sustainable development (HART, 1995). The organizations should also value their ecological connections. The NRBV delineates three tactics and elucidates their relationship to sustainable competitive advantage and improved organizational performance. This is achieved by adopting circular and

sustainable practices and innovations, which can yield significant benefits in terms of cost, reputation, legitimacy, future positioning, and long-term growth.

This study adapted the Resource-Based View (RBV) theory to develop its model. Resource-Based View (RBV) theory provides a strong theoretical foundation for this study by conceptualizing green technology adaptation and green innovation as strategic resources that contribute to superior firm performance. According to RBV, organizations achieve a sustainable competitive performance when they possess resources that are valuable, rare, inimitable, and non-substitutable (ABBASI ET AL., 2025). Recent scholars (for example, BAAH ET AL., 2024; ESPOSITO ET AL., 2024; ABBASI ET AL., 2025) emphasize that RBV continues to be relevant in explaining firm performance in dynamic contexts, particularly in technology, innovation, circular economy, and sustainability.

In this study, green technology adaptation can be regarded as a dynamic capability that enables firms to acquire and deploy environmentally friendly technologies, while green innovation reflects a knowledge-intensive capability that is difficult for competitors to replicate. Both resources align with RBV's criteria to achieve the best circular economy focused performance. However, circular economic performance results from effectively leveraging such resources, consistent with RBV's central proposition that firm performance differences arise from internal capabilities (ESPOSITO ET AL., 2024).

Empirical evidence also supports green technology adaptation drives eco-innovation and efficiency—mechanisms directly aligned with RBV concept. Similarly, BAAH ET AL. (2024) argues that resource availability, organizational capabilities, and technology adoption are central to implementing circular economy strategies, underscoring RBV's relevance in this domain. Thus, the use of RBV in this study is justified as it explains how firm-specific resources—such as green technology adaptation and innovation—can be mobilized to enhance circular economic performance.

The present study indicates that green technologies are a resource for companies; along with green innovation, they can achieve circular economic performance. Moreover, circular economic performance is sustainable and can accelerate the company's competitive advantage. Previous research has explored this theory from a similar perspective, for example, SINGH ET AL. (2020),

SHAHZAD ET AL. (2020), MASOUMIK ET AL. (2014). The scholars also indicated that there were analogous requests to broaden the resource-based view to explain circular economic performance, which would entail potential interactions with external stakeholders, including the government and supply chain partners. The organization may innovate and achieve a competitive advantage by prioritizing environmentally circular economic and sustainable practices across all operations and committing them to sustainable development.

2.2 Green Technology Adaptation

Traditional industries are harming the environment, resulting in pollution and resource depletion (NKETIAH ET AL., 2024). Global environmental consciousness is increasing, prompting companies to adhere to sustainable development principles. The UN's 2030 plan advocates for the sustainable use of natural resources to avert depletion (CHAURASIA ET AL., 2022). Sustainability may provide businesses with a competitive advantage. Numerous prominent organizations have tried to achieve sustainability, although with less success (ISLAM ET AL., 2024A). Conversely, small and medium firms have achieved notable advancements in sustainability via the use of green technology (AMIN & ISLAM, 2009; BRUCE ET AL., 2022; MOLLAH ET AL., 2025B; HASSAN ET AL., 2025A; HOSAIN ET AL., 2025A; HOSAIN ET AL., 2025C; SONY ET AL., 2025). On the other hand, REN ET AL. (2023) attribute 51% of industrial greenhouse gas emissions, but only 25% of state-owned enterprises can do so internationally.

Enterprises are now thriving due to green technology's enabling efficient resource use and mitigating the environmental impacts associated with extensive supply chains. The inadequate adoption of green technology, managerial inefficiency, and scarcity of geographical resources impede the sustainable development of countries with emerging economies, as stated by ISLAM ET AL. (2024B). Therefore, it is essential to assess the factors that facilitate the initiation and advancement of these green technologies, since sustainability enhances competitiveness across all enterprises (BRUCE ET AL., 2022). Green technology assists social and environmental groups in achieving sustainability (IKRAM ET AL., 2021; AMIN & SALEHIN, 2022; RAHMAN ET AL., 2025). IKRAM ET AL. (2021) advocated for prioritizing green initiatives via the use of green technology to tackle environmental challenges, based on eco-innovation that provides comprehensive implementation guidance for practitioners.

XIA ET AL. (2022) characterized green technology adoption as the use of green technologies by enterprises in new product creation, manufacturing processes, employee training, and promoting environmentally conscious customer behavior. Xia et al. (2022) advocated for the promotion of these distinctive green innovations outside the organization to engage more stakeholders. Energy-efficient technology advantages people, the environment, and society (OLAJIGA ET AL., 2024). An inefficient heating system consumes more energy to deliver the same amount of heat (AHMED ET AL., 2025). Investing in such technology enables firms to save energy, reduce costs, and reduce CO₂ emissions. The optimal outcome of adopting green technology would be for factories to invest more in cost-effective, energy-efficient options to enhance profitability (RAHAMAN ET AL., 2023). Inadequate energy efficiency and savings impact environmental safety. In literature, this is referred to as the adaptation of green technology to enhance energy efficiency (SHAHZAD ET AL., 2022).

Researchers have proposed many reasons for enhancing energy efficiency through green technology to achieve sustainability. ZENG ET AL. (2022) identified structural and behavioral constraints as a factor contributing to the sluggish adoption of green technology for energy efficiency. Proposed structural constraints include inaccessible funding, fuel price distortions, and government fiscal and regulatory policies. Consumers are unable to surmount these obstacles. Additional advantages of green technology include energy efficiency, informational support, and fuel price regulation. Policymakers and implementers must also account for the intricacies of customer behavior, which complicates energy market regulation. Energy-efficient heating systems entail a substantial initial investment; nevertheless, they significantly reduce energy consumption and lower future energy expenses (DEY ET AL., 2021; CHOWDHURY ET AL., 2024). The behavioral obstacles complicate the assessment of adoption costs, resulting in an underestimation of the profitability of energy saving projects. Green technology has the potential to overcome these obstacles to domestic energy-efficiency expenditures.

According to prominent engineering research by MING ET AL. (2022), green technology has the capacity to fully realize energy investment capabilities. They contended that obstacles to energy efficiency and the implementation of green technologies might decrease annual energy consumption. Nonetheless, appropriate green technology remains contentious. MING ET AL. (2022) suggested that emerging green technology may have unrecognized costs, opportunity costs,

and training expenses that might hinder its adoption. Consumer heterogeneity may render green technology investment inappropriate for some individuals. This complicates the assessment of the efficacy and viability of such green technologies. Certain businesses may choose not to invest if the hidden expenses are substantial, despite apparent profitability.

In comparable research, USMAN (2023) determined that the installation of an energy-efficient heat pump, a sustainable technology, may decrease a factory's energy expenses, enhance interior environment, and provide a more consistent temperature. These provide private advantages to the corporation. The environmental benefits derived from alternative energy use make this green technology investment advantageous for society. The primary source of energy is hydroelectricity. The renewable nature of water resources results in lower emissions from electricity generation. Residential energy conservation may not promptly reduce greenhouse gas emissions. Reducing residential energy use allocates resources for sectors with more potential for emission reductions. Undoubtedly, green technology may assist firms and many stakeholders.

Nevertheless, plant managers or supervisors may refrain from investing if they lack awareness of energy savings. This may impede the uptake of green technologies. In accordance with the 2016 Paris Agreement on Climate Change, Norway intends to reduce all emissions by at least 50% by 2030 using innovative green technologies (HOUELAND ET AL., 2021). Consequently, by adopting green technologies, enterprises might reduce energy consumption in production facilities, significantly influencing overall electricity demand and helping other sectors conserve energy.

2.3 Green Innovation

Environmental degradation and climate change, driven by elevated hazardous emissions and pollutants, constrain the global sustainable economy (KHAN ET AL., 2022). Green innovation has the potential to enhance a sustainable global economy. Green innovation refers to ecological or environmental advancements that enhance the environment (TU & WU, 2021). Green innovation encompasses the environmental, social, and economic dimensions of sustainable innovation (LI ET AL., 2023). Green innovation, a burgeoning industry, is expanding swiftly owing to its impact on environmental and economic outcomes (TU & WU, 2021). Green innovation examines the development of products, processes, marketing strategies, organizational frameworks, and novel or improved institutional arrangements that mitigate environmental effects

(YOUSAF, 2021). Modifications may range from minor to significant throughout production or in the final product (TAKALO & TOORANLOO, 2021).

ZHANG ET AL. (2022) characterized green innovation as inventive manufacturing methodologies that advantage both customers and corporations while mitigating environmental effects. CHIEN ET AL. (2021) characterized green innovation as the development, incorporation, or application of an innovative product, production process, service, or management method that mitigates environmental risk, pollution, and other adverse impacts of resource consumption, including energy utilization, throughout its life cycle in comparison to pertinent alternatives. QIU ET AL. (2023) characterized green innovation as the development of innovative and competitively priced products, processes, systems, services, and procedures that fulfill human needs and enhance quality of life, while reducing natural resource consumption (including energy carriers and land area) per unit of output and diminishing hazardous substance emissions. ULLAH ET AL. (2023) describes green innovation within industrial dynamics as market innovations that generate green rents.

Green innovation is diverse and inventive; hence, companies pursue it for various motivations. Green innovation is propelled by legislative frameworks and market demand (ULLAH ET AL., 2023), with improvements in efficiency, expansion of market share, stakeholder collaboration, and technological transformations within the sector. Certain firms embed green innovation into their identity and competitive advantage, whereas others adhere only to environmental regulations to attain legitimacy (TU & WU, 2021). Green innovation is both exhilarating and challenging. Initial categories include progressive, radical, and systemic alteration (ZHANG ET AL., 2020). The need for coordination in innovation projects complicates operations at the firm level (ULLAH ET AL., 2023).

The challenges associated with green technology may hinder comprehension and dissemination (CHIEN ET AL., 2021). Companies must cooperate to develop and implement green innovation, as value chain participants must synchronize to provide value to customers. Inter-organizational complexity may need collaboration to exchange information, manage disputes, acquire knowledge, and sustain connections (SHAH ET AL., 2021). Non-cooperation may obstruct the diffusion of innovation by fostering corporate competition, while inadequate communication might hinder the comprehension of the value of new ideas (SHAHNEAZ ET AL., 2013; QIU ET

AL., 2023). Green technology and regulatory regulations are essential for overseeing and fostering green innovation and sustainability (ISLAM ET AL., 2024A).

Green innovation necessitates inventive organizational methods to transition from traditional to innovative and sustainable production (GAZI ET AL., 2024H). The transition to sustainable operations is complex and unclear, posing challenges for companies (ZHANG ET AL., 2022). Numerous industries and organizations have embraced sustainable practices via the use of green technology. Amin et al. (2024) observed that environmental, social, and economic factors influence sustainable organizational performance. In case of operational activities in organizations, several departments generating green innovation for their green activities, for example green workforce management (AMIN & SALEHIN, 2021; GAZI ET AL., 2024B); management of green production (AMIN ET AL., 2019B; HE ET AL., 2021); sustainable financial management (MOLLAH ET AL., 2024A); supply chain management (MUSTAFA ET AL., 2024); knowledge management and leadership (KARIM ET AL., 2023B; MOLLAH ET AL., 2024B); information technology management (MOLLAH ET AL., 2024C; RABBI ET AL., 2024); employee grievance management (ISLAM & AMIN, 2011; TIRNO ET AL., 2020; GAZI ET AL., 2024A; RAHAMAN ET AL., 2025; GAZI ET AL., 2025A; HOSAIN ET AL., 2025B; MOHAIMEN ET AL., 2025); crisis management (YU ET AL., 2024); employee citizenship behavior (TANCHI ET AL., 2025; GAZI ET AL., 2025C; GAZI ET AL., 2025E; GAZI ET AL., 2025F) energy and renewable energy management (HASAN ET AL., 2023, RAHAMAN ET AL., 2023); and corporate social activities (MAHMUD ET AL., 2023; GAZI ET AL., 2024C; SONG ET AL., 2025).

Green innovation by the enterprises has garnered interest from specialists and scholars (LI ET AL., 2023). Researchers have identified several factors and facilitators of green innovation in manufacturing companies (YOUSAF, 2021). According to YOUSAF (2021), green innovation may facilitate the adoption and application of green technologies. Green innovation refers to the potential for communities or companies to endorse novel technology (LI ET AL., 2023). The 1980 World Conservation Strategy of the International Union for Conservation of Nature and Natural Resources advocated for sustainable development. Sustainable development integrates conservation and development to ensure that environmental changes safeguard all people, according to the study. The Brundtland report, commissioned by the UN, defined "sustainable development" as fulfilling "the needs of the present without compromising the ability of future

generations to meet their own needs" (SCHLEPER, 2019). Sustainable development may be attained via innovative green technologies, contemporary social organizational frameworks concerning environmental resources, and the biosphere's capacity to absorb human influences (SHAHZAD ET AL., 2022).

Nonetheless, green innovation is intricately linked to competitiveness and does not ensure environmental sustainability. TAKALO & TOORANLOO (2021) proposed that green innovation needs to emphasize the integration of environmental considerations into economic operations. Comparable studies conducted by TU and WU (2021) corroborated this perspective. Green innovation facilitates the development or execution of novel or enhanced products (goods and services), processes, marketing strategies, organizational structures, and institutional arrangements that provide environmental benefits compared to pertinent alternatives, as stated by TU & WU (2021). SHAHZAD ET AL. (2022) said that green innovation is crucial for corporations and policymakers in two respects. Innovations that exhibit reduced environmental effect compared to alternatives. SHAHZAD ET AL. (2022) characterized green innovations as both technical and non-technological, including organizational, institutional, and commercial innovations (ISMAEL ET AL., 2025). Green innovations may arise from commercial or environmental incentives. The former encompasses objectives to enter the global market for environmentally sustainable goods and to reduce costs associated with resource use, pollution, and waste management.

2.4. Circular Economy

Economics has become more environmentally aware due to its interconnection with the environment. Economic theories are used to address environmental challenges in the emerging ecology-focused economy. The circular economy conceals the influence of environmental factors on conventional economic theories. The 3R principles of the circular economy—reducing, reusing, and recycling resources—illustrate the significant connection between environmental sustainability and economic considerations (AMIN ET AL., 2024; AMIN ET AL., 2025). Pearce and Turner introduced the concept of the circular economy in 1989, which was further elaborated upon by Turner and his associates in 1993. Pearce and Turner articulated the concept of the circular economy through the lens of natural resources, their interrelationships, and economic activities. The writers examined the environment as both a resource and a repository of waste. As the

environment functions as a linear, open-ended system without a recycling mechanism, its rejection parallels the dismissal of the economy.

The first law of thermodynamics states that energy and matter cannot be created or destroyed, and that this principle is analogous to environmental waste. Turner and his colleagues proposed an economic concept positing that Earth functions as a closed economic system, in which the economy and environment are interrelated, and all components serve as inputs. Boulding expands Pearce and Turner's economic and environmental model to include the natural environment's capacity for waste absorption, the disposal of non-recyclable resources, and the management of non-renewable or exhaustible resources. This perspective aims to identify the prerequisites for economic and environmental equilibrium. Another academic, CORVELLEC ET AL. (2022) criticised the circular economic theory for favoring price theory above materiality. He advised reestablishing the connection between the material and value perspectives but prioritizing the material approach.

The rapid deterioration of the global environment has necessitated methods to mitigate the adverse impacts of production and consumption on ecological systems. Numerous nations have laws to enforce circular-economy recycling. Germany initiated the circular economy in 1996. The 'Closed Substance Cycle and Waste Management Act.' The Act promotes closed cycle waste management and environmentally suitable rubbish disposal and absorption. Japan exemplifies a circular economy strategy. Japan has enacted a comprehensive legislation to promote recycling (MONTAG, 2023). The 2002 recycling legislation sets measurable recycling objectives and seeks to dematerialize Japanese society (MONTAG, 2023).

China is the third country to implement a circular economy. In contrast to the German and Japanese governments, the Chinese government intends to first implement the circular economy framework through numerous pilot projects to more effectively evaluate its comprehensive adoption. Economic liberalization began with the establishment of coastal free economic zones. Sweden and several European nations use long-term incentive schemes. They also offered public education to guarantee continued and effective growth in recycling rates (FARKAS ET AL., 2024). The policy was enacted with the support of politicians and environmentalists. Consequently, Sweden, Germany, and several European countries have effectively included green political parties into their political frameworks and decision-making processes, promoting a circular economy.

The European Commission's manifesto urges industry, labor, and civil society leaders to emphasize resource efficiency and the transition to a circular economy (CASTILLO-DÍAZ ET AL., 2024). This plan delineates a strategy for a resource-efficient Europe and the revitalization of the circular economy. The circular economy strategies of these nations emphasize mitigating environmental degradation and saving resources by optimizing the use of renewable energy and controlling production and consumer waste, particularly via integrated solid waste management. Limited evidence about the use of the circular economy in China and elsewhere indicates a consensus supporting the idea, which aligns with industrial ecology.

This concept advocates the recycling and repurposing of waste materials. It encompasses energy, water, diverse byproducts, and knowledge (RABBI & AMIN, 2024). The concept of industrial symbiosis holds that economic and environmental factors can yield synergistic benefits. Sustainable corporate performance, as stated by ISLAM ET AL. (2024B), arises from the aggregation of firms inside a circular system that consolidates capital, labor, energy, materials, and infrastructure to reduce unit costs and enhance factor productivity. Proximity in business lowers personal commuting expenses (AL AMIN ET AL., 2024B). It also reduces transaction costs and spillovers in technology across firms. Minimizing waste and conserving virgin resources benefits the environment, and it reduces the transaction costs, along with technology spillovers across organizations (AZAD ET AL., 2012; AMIN ET AL., 2012; AZAD ET AL., 2023; ALI ET AL., 2024; HAMADA ET AL., 2024).

ZHU ET AL. (2019) conducted another research on the circular economy using a three-dimensional framework including social, economic, and environmental aspects. Experts assert that an ecological economy is essential to transforming open, linear growth. The three pillars enhance competitiveness via the optimization of resource allocation, the augmentation of productivity via the reconfiguration of industrial structures, the mitigation of negative externalities, and the advancement of social well-being. The linear economy or consumption model absorbs resources for production and consumption in a unidirectional manner, without alternatives for reuse or proactive regeneration of natural systems. It depletes resources and adversely affects the environment.

2.5 Circular Economic Performance

Numerous approaches have been devised and executed to mitigate resource constraints, population pressures, and environmental degradation resulting from consumption patterns. The circular economy concept emerged after the linearity concept. Concluding resource cycles and reestablishing connections at various nodes diminishes and eradicates waste, fostering economic expansion (ESPOSITO ET AL., 2024). Certain writers suggest that MARRUCCI ET AL. (2021) may have conceptualized the circular economy. The circular economy originated from industrial ecology. The circular economy lacks a single originator. The following sections will examine the origins. AMIN & OLÁH (2024) propose that circular economic performance fosters economic development and enhances industrial efficiency by enabling optimal resource use.

Circular economic performance aims to transform production networks, consumption patterns, and industrial processes (ESPOSITO ET AL., 2024). Circular economic principles need the reconfiguration of production and consumption to create a new industrial paradigm. Successful adoption of a circular economy would decouple growth from circular economic performance. The genesis of 'circular economy' remains uncertain; nonetheless, BAAH ET AL. (2024) posited that the Earth resembles a spacecraft always depleting its finite resources for survival. If the exploitation of natural resources and environmental degradation go until the point of no return, the Earth will suffer irreversible damage, like a starship. To maintain the spaceship, the consumption-based economic model must be replaced with a circular economy capable of regenerating its environmental resources.

British environmental economists Pearce and Turner presented the concept of the circular economy in "Economics of Natural Resources and the Environment." They said that the linear economy, which disregards recycling, is contributing to environmental pollution. Given environmental concerns and resource depletion, the Earth should be seen as a closed economic system characterized by a circular economic-environment link. Pearce and Turner developed the circular economy, a closed-loop model of material fluxes within the economy, via the examination of economic and ecological processes. Industrial ecology may have influenced the circular economy. Industrial ecology, a theory from the 1970s, analyzes industrial processes together with the flows of materials and energy.

Industrial ecology promotes the analysis and comprehension of industrial processes akin to biological ecosystems to integrate operations and enhance resource cycling (BAAH ET AL.,

2024). The most exemplary representation of industrial ecology is symbiosis. Industrial symbiosis enables distinct industries to exchange waste, byproducts, and energy. This biological system necessitates an industrial area characterized by industrial symbiosis (MARRUCCI ET AL., 2021). MARRUCCI ET AL. (2021) identified an ecological power plant, oil refinery, biotechnology facility, plasterboard manufacturing enterprise, and sustainable municipality that engage in the interchange of energy, materials, and waste. Despite the proliferation of Industrial Eco-Parks in China, Europe has yet to embrace this concept. The circular economy is exemplified in Suzhou New District (SND) (BAAH ET AL., 2024). This SND surpasses Denmark and expands more rapidly due to top-down policy. In 2014, the SND was used by about 16,000 organizations and 4,000 manufacturers (BAAH ET AL., 2024).

The 1996 Closed Substance Cycle and Waste Management Act in Germany was among the pioneering circular-economy legislation in developed nations. The Act included product responsibility in economic decision-making to mitigate waste (BAAH ET AL., 2024). Japan, Sweden, and the Netherlands are Western nations that enact legislation pertaining to circular economy concepts. Following several delays and stakeholder pressure, the EU Commission approved the circular economy package in 2015. The objective is to facilitate the EU's transition to a circular economy. This bundle includes ineffective laws aimed at enhancing recycling and reuse while minimizing landfilling. The circular economy is underpinned by an Action Plan that completes the product lifecycle loop, including production, consumption, repair, manufacturing, waste management, and the reintegration of secondary raw materials.

China is in the forefront of circular economy laws and practices because of its national development plan (ESPOSITO ET AL., 2024). China sees the circular economy as an innovative developmental model that would enhance economic sustainability. ESPOSITO ET AL. (2024) examines China's Circular Economy and contrasts it with Western practices. The authors said that environmental groups, civil society, and NGOs advocate for the circular economy as a grassroots microeconomic initiative in affluent industrialized nations, influencing the government to enact laws. The circular economy is a multifaceted national government initiative aimed at holistic social transformation in China (ZHU ET AL., 2019). The author contends that social and economic disparities, inadequate resource distribution, and environmental deterioration and pollution affect China's circular economy.

China regards the circular economy as a developmental paradigm that integrates environmental and economic elements to attain harmony between humanity and nature. The absence of indicators, policy frameworks, and grassroots involvement obstructs the implementation of a circular economy (ZHU ET AL., 2019). China embraced the circular economy in the 1990s, drawing inspiration from European and Japanese models of cleaner production, industrial ecology, and ecological modernization. The Circular Economy Promotion Law, enacted in 2009, serves as China's principal legislation on circular economy. Numerous papers illuminate China's Circular Economy framework (RASHID ET AL., 2024; ESPOSITO ET AL., 2024).

The circular economy model for organizational performance was designed to tackle pollution, enhance energy efficiency, optimize resource use, and handle other environmental challenges. In this context, China's rapid industrial and commercial growth has compromised the environment, necessitating a new paradigm that reconciles progress with ecological considerations. China faced challenges in reconciling economic expansion with social and environmental issues. In contrast to its European equivalent, the Chinese circular economy amalgamates materials, resources, and trash, emphasizing pollution reduction and resource efficiency (RASHID ET AL., 2024).

Chinese regulations disregard purchasing behaviors, whereas the European model encourages consumption. Mongolia emphasizes manufacturing efficiency, waste minimization, and pollution abatement. Consequently, Mongolian firms are progressively embracing circular economic production. Mongolia prioritizes size and geography, but Europe and China do not. Mongolia's circular economy policy prioritizes resource distribution and the establishment of provinces, cities, zones, and industrial parks. The circular economy approach in land-use planning illustrates Mongolia's rural-urban transition (ERDENEBAT & GANBOLD, 2021).

Mongolian circular economy plans prioritize business performance and results derived from commercial possibilities and resource efficiency. The circular economy, first conceived in Europe and later embraced by China, has gained traction in Mongolia amid concerns about rising commodity prices. Mongolia emphasizes materials, resources, and waste above environmental degradation (ERDENEBAT & GANBOLD, 2021). Mongolia's approach was influenced by Chinese consumerism and product design ideals. Mongolia is developing a comprehensive eco-design framework for many home products, facilitating the incorporation of circular economy principles.

2.6. Circular Economy in Mining sector

The current global economic systems are heavily reliant on economic growth and the continuous expansion of industrial output. This has led to a steady rise in the material footprint of the global economy during the last century. Most of these basic materials come from primary sources, including mining. The enormous extraction activities underpinning this economic system have revealed significant negative social and environmental impacts, which are now subject to scrutiny and denunciation. In 2023, primary mineral and metal production was projected to account for over 10% of total energy-related greenhouse gas (GHG) emissions, with an expected increase (DE HAES & LUCAS, 2024). Mining constituted 7% of global deforestation and is the fourth-largest contributor to forest habitat degradation and its associated climate impacts (SARKHEIL ET AL., 2024).

This research demonstrates that the adverse impacts of mining on biodiversity and its use of dwindling freshwater supplies must be comprehensively recorded. A crucial method for tackling this problem is the circular economy. It promotes the shift of our economic framework from the current linear 'take-make-dispose' paradigm to a generative system that prioritizes material efficiency and reduces waste. The concept of circular economy has significantly proliferated in academic discourse and policy debates in recent years (HARTLEY ET AL., 2020). Private firms are increasingly exploring innovative business structures and strategies grounded in circular economic principles. Nonetheless, research suggests that circular economy practices are crucial for reducing societal resource needs, but they are insufficient to eliminate primary resource extraction for several reasons.

The existing reserves of most extracted raw materials are inadequate to meet the escalating needs of global development and emerging technologies (LITVINENKO ET AL., 2022). Furthermore, several potential sources of metal stocks are used for prolonged periods, and the technical requirements for materials are always evolving, hence increasing the demand for fundamental raw materials (LUNDAEV ET AL., 2023). Conversely, significant challenges remain in improving collection rates and reducing recycling losses to diminish the volume of metals lost throughout each use cycle (VAN YKEN ET AL., 2021). Consequently, the extraction of fundamental raw resources will remain vital for the functioning of contemporary civilization in the foreseeable future.

Despite this evidence, many proponents of the circular economy argue that the cessation of primary natural resource extraction should be the primary goal of the transition to a circular economy, and there is a widespread belief in circular-economy discussions that raw-material extraction may eventually become obsolete (BLOMSMA & TENNANT, 2020). As a result, mining and other raw material extraction activities in the upstream sectors of global value chains have traditionally received less attention in the circular economy literature. The BLOMSMA & TENNANT (2020) research argued that the growing acknowledgment of the need for continuous primary material extraction is a critical omission that requires correction. Furthermore, it claimed that the notion of a circular economy, together with its principles and associated strategies and practices, functions as an effective approach for improving the sustainability of raw material extraction processes.

Increasing evidence indicates that many effective circular economy techniques and practices may reduce environmental impact, material consumption, and structural waste associated with large-scale mining (BLOMSMA & TENNANT, 2020). The authors also noted that the processes in the circular economy include minimizing freshwater use, reusing mine waste for other businesses, and remanufacturing mining equipment. Nonetheless, the historical neglect of the mining sector and upstream industries in circular economy research has led to numerous circular economy frameworks, perceived as proposals or visions for circular economy practices, largely overlooking the critical role that mining and other upstream raw material extraction activities must persist in fulfilling.

Notably, the mining sector and other upstream businesses face unique challenges relative to downstream industries, necessitating techniques that enable systematic evaluation to pinpoint specific circular economy plans and practices that address their individual challenges. The current research demonstrates that existing circular economy frameworks are inadequate as tools, necessitating conceptual improvements to develop appropriate circular economy strategies and practices for upstream production systems. This study asserts that existing circular economy frameworks are a crucial conceptual element required for developing appropriate practices in the mining industry and other upstream sectors. The current research emphasized a clear delineation of the objectives and constraints of the industrial production system designed to adopt circular economy practices; an identification of the sources and categories of inputs employed by the

system; and an assessment of the resource status of these inputs and the resulting structures produced from them.

This paper contends that, due to the distinct constraints faced by the mining industry and other upstream businesses, it is imperative to have tools that provide systematic assessments to identify targeted circular economic concepts and practices that address their issues. This paper argues that current circular economy frameworks are inadequate for conducting a thorough assessment. They especially lack the contextually relevant conceptual elements required to successfully address the unique challenges of the mining sector and promote the adoption of circular economic principles, strategies, and practices within industry.

2.7. Mining Sector in Mongolia

Over the past twenty years, Mongolia has undergone a significant mining boom characterised by extensive mineral exploration and development initiatives. The Government of Mongolia implemented various policies and programs to promote foreign investment in the minerals sector in the late 1990s (BATMUNKH, 2021), leading to the identification of the sector's strategic significance, which is currently being developed further.

Notably, the mining sector of Mongolia enhances national economic security or fosters national and regional economic development, which can generate over five per cent of the country's GDP (DAVAASUREN ET AL., 2020). There are three significant strategic deposits that contribute to total GDP: copper-gold, coking coal, and copper-molybdenum. These mining projects are expected to significantly impact the country's development and complement the ongoing mining sector, the main copper producer that has operated since the 1970s.

Mongolia's economic growth is slowing, attributed to weak global commodity markets, reduced exports to Russia and China, and decreased foreign investment in the mining sector due to legal instability (DAVAASUREN ET AL., 2020). After 2009, commodity prices rebounded, leading to economic stabilisation, while the significant development of mineral resources resulted in a rapid increase in GDP (DAVAASUREN ET AL., 2020).

On the other hand, the mining sector in Mongolia has made some economic and social contributions to local people. Because of these, the provinces' governments oppose the cessation of mining operations, as it would diminish regional employment and likely prompt the local

populace to seek job opportunities (BATMUNKH, 2021). However, this occurs when numerous former nomads relocate to mining communities that emerge around mining sites to provide homes for the laborers. The former nomads relocated to these cities in search of employment in the mining industry or in service sectors catering to miners. Numerous individuals abandoned their nomadic lifestyles for economic reasons and to improve their families' living conditions. Regrettably, numerous mining businesses choose to employ personnel from external regions, particularly Ulaanbaatar, and occasionally from Darkhan, Erdenet, or even China and Russia (BATMUNKH, 2021). Companies employ individuals to reduce the likelihood of local networks forming around the mines and to promote greater discipline and work ethics.

The establishment of larger mines in often distant locations has led to the construction of villages and small cities for mining employees. The establishment of these towns or a new mine within a town will increase the local population as individuals migrate to the towns in search of work. These settlements predominantly rely on mining for economic production (GOMBODORJ & PETŐ, 2022). The towns must establish a diversified economy to mitigate volatility in commodity prices and the risk of significant economic downturns (GOMBODORJ & PETŐ, 2022). The mining towns generate a substantial demand for employment in the service industry to support the mine workers. The influx of new residents into the towns presents an opportunity to enhance infrastructure, potentially facilitating the establishment of new enterprises by leveraging the technical expertise of professionals relocating to the area (GOMBODORJ & PETŐ, 2022).

The Mongolian government has acquired a 34% stake in the mines, while several joint ventures among other corporations invest in the same mine to mitigate potential hazards. The Mongolian government's intense focus on the mining sector has led to sluggish investment in other sectors, such as traditional agriculture, which nevertheless employs a significant portion of the population. The Mongolian government possesses the authority to allocate land for private ownership only to Mongolian nationals (BATMUNKH, 2021). The land designated for privatization excludes pastures and other public or specially designated areas, including national parks. The area of land allocated to a household by the government depends on the household's location. In Ulaanbaatar, the plot size is considerably smaller than the aggregate due to high population density and land demand (BATMUNKH, 2021).

Many researchers have recognized the challenges faced by transition nations such as Mongolia in implementing effective laws within their burgeoning mining industries (DAVAASUREN ET AL., 2020; BATMUNKH, 2021; GOMBODORJ & PETŐ, 2022). Deficiencies in governmental institutions, characterized by inadequate openness in regulatory and legislative procedures and mishandling of natural resources, have impeded the sustained advancement of Mongolia's mines sector. Previous government attempts to coordinate mineral development and enhance business advantages through new legislation and regulations have been ineffective. These initiatives have created an uncertain and unattractive legal environment for overseas investors.

The Fraser Institute's assessment of Investment Attractiveness revealed that Mongolia fell to 85th position (out of 109 countries) in 2020, down from 36th (out of 79) in 2023 (AVIRMED & BOLD, 2024). The laws, rules, and restrictions that hindered the industry's expansion were eliminated after 2 years. The bill imposed a moratorium on the approval of new mineral exploration projects pending revisions to existing laws and regulations. Following the implementation of this law, multinational investors in mineral exploration withdrew from the country, and several national businesses halted operations.

Nonetheless, Mongolia is a country where one-third of the population depends solely on cattle herding for their livelihood (GOMBODORJ & PETŐ, 2022). Since the era before the vast Mongol Empire, which extended from China to Eastern Europe, these people have sustained their way of life by subsisting on the land and the cattle they tend. Since the beginning of the 20th century, many of these nomadic folks have started to change their lives. They are migrating to metropolitan regions in search of improved living conditions, motivated by factors such as economic prospects, education, employment, or secure housing. Education should be regarded as a critical aspect for every country (ISLAM ET AL., 2018; RAHMAN ET AL., 2024; AHMMED ET AL., 2025; CHOWDHURY ET AL., 2025B; GAZI ET AL., 2025D; GAZI ET AL., 2025H; MOLLAH ET AL., 2025A). Socialist planned economies made significant efforts to industrialize pastoral areas, integrating their residents into the developing social and economic system (GOMBODORJ & PETŐ, 2022). This program aims to secure the energy needed for operations in factories, mines, and other labor-intensive industries.

During the 20th century, the Soviet government enforced the establishment of agricultural collectives. In Mongolia's communal system, all herders became state-employed wage earners,

tasked with the care of single-species herds alongside their own modest private cattle (BATMUNKH, 2021). Agricultural communal arrangements constrained the migration of Mongolian nomads (GOMBODORJ & PETŐ, 2022). Notably, this circumstance is similar to that of other Asian nations, such as Malaysia (KASSIM ET AL., 2024). This led to generations of Mongolians adopting a sedentary lifestyle, conducting most of their agricultural endeavors in permanent locations, whether for livestock or crops. Furthermore, the Mongolian government mandated the relocation of residents from rural fields to urban centers and mining sites to participate in newly formed firms. This pushed nomads to forsake their way of life to participate in government enterprises. Mongolians needed education and employment in skilled professions in urban settings to attain unfettered mobility within the nation (BATMUNKH, 2021). As a result, despite urbanization and industrialization throughout the communist period of a planned economy, citizens faced limited choices for their settlement (GOMBODORJ & PETŐ, 2022). This continued until the disbandment of the agricultural collectives and the disintegration of the Soviet state in the late 20th century.

Following the dissolution of the collectives in the late 20th century, numerous former nomads returned to their ancestral territories and traditional way of life. However, the younger generation, which had never experienced a nomadic existence and had been employed in collectives or the mining and industrial sectors, encountered significant challenges in adjusting to this new lifestyle. The youthful nomads were predominantly ill-equipped to cope with natural disasters like ‘DZUD’ (an extreme weather event). During 2009-2010, Mongolia had significant DZUDs, resulting in the death of about eight million animals, including cows, yaks, camels, horses, goats, and sheep, which constituted around 17 per cent of the nation's total livestock, as reported by United Nations assistance officials (BATMUNKH, 2021).

This rendered numerous nomadic households devoid of income and financial resources (UZIR ET AL., 2025B; CHOWDHURY ET AL., 2025A; GAZI ET AL., 2025B; HASAN ET AL., 2025; HASSAN ET AL., 2025B; ISLAM ET AL., 2025). Numerous families relocated to Ulaanbaatar, the capital of Mongolia. They undertook this endeavor to discover a means of generating income for their survival. However, in the 21st century, a significant new issue has prompted an increasing number of families to abandon their nomadic lifestyle and relocate to urban areas, surpassing the impact of these DZUDs. Mining corporations have commenced unprecedented expansion,

exploiting new mines and potential mining sites. The mines restrict the remaining nomads' capacity to maintain their traditional migratory lifestyle and inflict harm on the environment upon which they depend.

The Mongolian government has been increasing permitted mining activities in the country because of their economic importance, which constitutes two-thirds of Mongolian exports (GOMBODORJ & PETŐ, 2022). The heightened presence of mining corporations has imposed a greater burden on the nomads. In the locations where these enterprises establish their operations, nomadic communities typically utilize the area for grazing cattle. When these corporations encroach on and enclose land, they compel the nomads to seek alternative territories large enough for their herds. This may provide a challenge in a province with numerous nomadic families competing for the same territory. The Mongolian government, in conjunction with mining firms, has been exerting pressure on nomads and farmers to relocate to urban centers.

Mongolian culture has inherited a unique set of concepts, tendencies, and institutions focused on rural, local, and domestic aspects, as well as on centers, elites, and political systems. State socialism significantly invested in urban and industrial centers, reinforcing the connection between political centers, elites, and the city itself (BATMUNKH, 2021). This permits people in authority to live in urban areas, while lower-class citizens must either labor in the city or remain in the countryside, facing societal disgrace. In the contemporary 21st century, characterized by globalization and mass media, Mongolia continues to engage in a significant and intriguing struggle, publicly experimenting with development policies before both its citizens and the global community (GOMBODORJ & PETŐ, 2022). In contrast to the past, when governments of several countries could formulate laws and policies without public awareness, Mongolia is currently drafting its legislation and policies in an era of readily accessible information. The Mongolian government cannot conceal the laws and policies that may be enacted or vetoed. The Mongolian populace will be informed, and the government will take their perspectives into account. This can be both advantageous and detrimental, as not all public desires may align with the nation's best interests.

Prior studies on the mining industry's effects on Mongolian nomads predominantly focus on environmental impacts, with minimal discussion of social implications. A significant number of the publications used in this study concentrate on Mongolia's transition from Soviet governance to

democratic governance. Recent studies reveal the environmental impact of mining companies on Mongolian nomads, prompting awareness of the broader implications for the traditional lifestyle of a substantial segment of the Mongolian populace (BATMUNKH, 2021). Until recently, the strong connection of a major segment of the Mongolian population to nomadic life led to a lack of emphasis on the rising issues affecting their lives. Since the 1990s, studies have examined the significant influx of nomads and residents from smaller cities and towns relocating to Ulaanbaatar in pursuit of improved living conditions or to replace lost livelihoods due to DZUDs, as is the case for many nomads. GOMBODORJ & PETŐ (2022) authored an article examining the migration of Mongolian herders to Ulaanbaatar and contrasting their current lives with their existence in the steppes. The publication discusses how Mongolians perceive Chinese, Russian, and other foreign businesspeople as individuals who are "enriching themselves at Mongolia's expense" (BATDELGER & ZAGDBAZAR, 2022).

The apprehension of foreign domination in Mongolia is not uncommon, as evidenced by the substantial investments from international corporations in Mongolian industries, particularly in mining. Mongolia's limited economy necessitates reliance on foreign businesses and aid to advance its development. A recent study in Mongolia predominantly emphasizes the environmental and economic dimensions of the mining industry, neglecting numerous other facets. The Mongolian mining industry employs significant numbers of local residents around mining sites. The mining industries exert significant influence over local policies. The provinces oppose the cessation of mining operations, as it would diminish regional employment and likely prompt the local populace to relocate to areas with job opportunities (GAZI ET AL., 2021A). This occurs when numerous former nomads relocate to mining settlements that emerge around a mining site to provide homes for the laborers.

The former nomads relocated to these cities in search of employment in the mining industry or in service sectors catering to miners. A multitude of individuals abandoned their nomadic lives for economic reasons and to improve their families' living conditions. Regrettably, numerous mining businesses choose to employ personnel from external regions, particularly Ulaanbaatar, and occasionally from Darkhan, Erdenet, or even China and Russia (BATDELGER & ZAGDBAZAR, 2022). The corporations employ personnel to mitigate the likelihood of local networks forming around the mines and to promote enhanced discipline and work ethics (BATDELGER &

ZAGDBAZAR, 2022). Additionally, inhabitants of rural areas perceive placer mines as detrimental to the environment, pastures, and winter habitats, while offering minimal benefits to the local economy (BATDELGER & ZAGDBAZAR, 2022).

Nomadic and rural inhabitants perceive firms as encroaching on their territory and observe environmental degradation following the arrival of mining enterprises. They prefer to maintain their lives as they have for many decades, rather than witness the mines open and their pasture areas transform into craters, shrouded in black smoke that obscures the blue sky. The establishment of larger mines in often distant locations has led to the construction of villages and small cities for mining employees. The establishment of these towns or a new mine will increase the local population as individuals migrate to the area in search of work. These settlements predominantly rely on economic production from mining (BATDELGER & ZAGDBAZAR, 2022). The towns must establish a diversified economy to mitigate volatility in commodity prices and the risk of significant economic downturns (BATDELGER & ZAGDBAZAR, 2022). The mining towns generate a substantial demand for employment in the service industry to cater to the needs of the mining sector personnel. The influx of new residents into towns presents an opportunity to enhance infrastructure, potentially facilitating the establishment of new sectors through the technical expertise of incoming professionals (BATDELGER & ZAGDBAZAR, 2022).

Although most of the mineral sector tax and royalty earnings now go to the state, there have been initiatives by the federal government to increase fiscal decentralization and encourage a fairer distribution of wealth from resources (AMARTUVSHIN ET AL., 2021). But thus far, attempts to control resource profits by setting up development funds have failed. In 2007, the Mongolian government established the Mongolian Development Fund. In 2009, it was supplanted by the Human Development Fund. The idea behind these funds was to save money from mineral extraction and use it to help people and the economy grow (ZANDARIYA, 2022). As a result of ineffective regulatory agencies, political parties used campaign funds to fulfil their promises of public cash transfers and child monetary programs. According to BATDELGER & ZAGDBAZAR (2022), the fund became insolvent due to excessive costs.

Since 2006, there has been a universal child monetary program. At first, parents with children under 18 received extremely low monthly cash payments per child (AMARTUVSHIN ET AL., 2021). Since then, the monetary program has led to this sum growth. The Mongolian Development

Fund oversaw this system, which successfully met the country's goals of reducing poverty and providing social protection (ZANDARIYA, 2022). Before the 2008 Parliamentary elections, political parties developed a new system for distributing monetary assistance due to the program's success (BATDELGER-ZAGDBAZAR, 2022). To win the election, the Mongolian People's Revolutionary Party promised every citizen 1.5 million Mongolian Ticks (USD 1,282 in June 2024) through the Human Development Fund (AVIRMED-BOLD, 2024). The government sought foreign loans and advance payments from mineral developers, as the commitment was far greater than the Human Development Fund's income (AVIRMED-BOLD, 2024).

Instead of promoting economic and human development, the development funds of 2007 and 2009 caused economic instability (BATDELGER-ZAGDBAZAR, 2022). In January 2017, the Future Heritage Fund took over from the Human Development Fund and continues to make a positive impact (AVIRMED-BOLD, 2024). With an anticipated savings period lasting until 2030, this fund aims to accumulate mineral income for future development initiatives. The principal sources of this fund are dividends from strategic deposit development, mineral royalties (equaling 65% of total income), and mineral revenue windfalls (equaling 20% of total revenue) (ZANDARIYA, 2022). No funds may be withdrawn from the fund until 2030. The local development funds of towns that host mining operations were enriched by amendments to the Budget Law in 2015 and 2016. This fund allowed for the extraordinary distribution of Mongolia's petroleum and mineral profits.

Indicators such as local development index, population density, remoteness, and size of the tax generation determine the amounts that are allocated from a variety of sources, including five per cent of domestic value-added tax (VAT), five per cent of mineral royalties, donations from national and international organizations, and thirty per cent of petroleum royalties. These funds are used for general local development. Apart from minerals considered strategically significant, mining taxes receive an additional 30 per cent of the mineral royalties collected from mines. Based on similar metrics, the tax distributes at least 60% of the money to lower-level Sums.

However, the following Figure 1 represents the investment rate on various sectors of Mongolia:

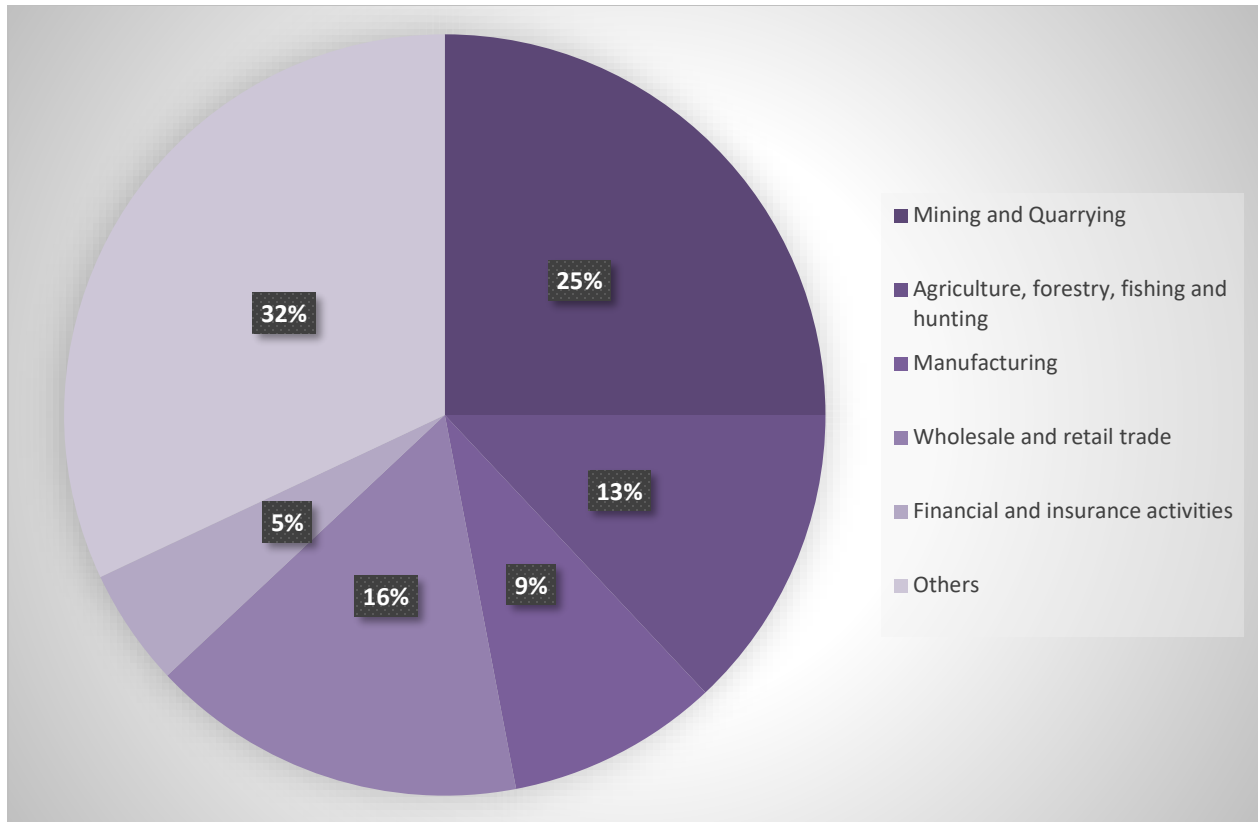


Figure 1. Investment rate in various sectors in Mongolia

Source: AVIRMED & BOLD (2024)

2.8. Circular Economy Performance in Mongolian Mining sector

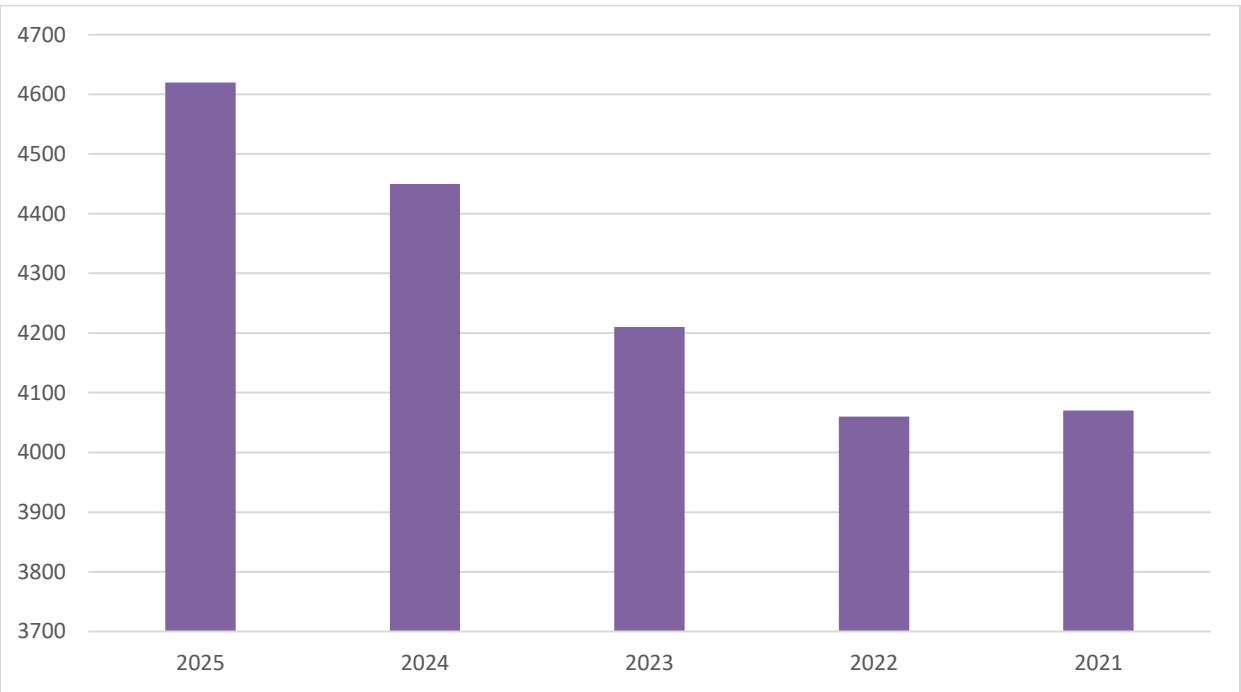
After 2009, Mongolia's mining sector began to explore. The most interesting aspect is that the Mongolian government signed a deal with the Canadian mining firm Ivanhoe Mines in October 2009 to use the Oyu Tolgoi project's copper and gold reserves. A week after the agreement, Ivanhoe Mines contributed \$100 million to the country's coffers. At the very beginning, Mr. Bayartsogt, Mongolia's minister of finance, declared in 2010 that from this year, all citizens will get a one-time incentive of 50,000 MNT, or \$35 USD (BATDELGER-ZAGDBAZAR, 2022). About three million people consider Mongolia home. This has led to several new challenges in the mining industry, as well as questions about the best international practices and the possible benefits of mining economic development. A total of 2,737,602 people call Mongolia home, and the country's 21 provinces make up its expansive territory of more than 1.5 million square kilometers. Situated in the geographic heart of Asia, the nation has borders with both China and Russia. It is home to vast, mostly unexplored natural riches and runs as a democratic country with a free-market

economy. The mining industry has so started to play a pivotal role in the country's economic destiny.

Coal, copper, fluorspar, gold, oil, and silver are only a few of the minerals that have been the subject of long-term government projects aimed at attracting investment (BATDELGER-ZAGDBAZAR, 2022). By raising the value of its vast undeveloped mineral resources and boosting mining sector revenues, Mongolia has been greatly aided by the commodities bubble in the global stock market. The Mongolian economy has taken a hit since April 2008, when the global financial crisis caused commodities prices to plummet on stock markets throughout the world. Many have drawn comparisons between this outcome and that of other Asian nations (GAZI ET AL., 2024E).

Regardless, the Mongolian economy has been booming, and in 2025, GDP per capita was 4,768 USD. To see Mongolia's GDP per capita during the last five years, look at Figure 2.

Figure 2. Last five years per capita GDP of Mongolia



Source: BAO ET AL. (2025)

However, maintaining this performance necessitates a rigorous development program within the mining sector. The Mongolian economy is poised to gain substantially from its abundant mineral resources in the forthcoming period. AVIRMED & BOLD (2024) emphasized the necessity of

advancing agreements in the mining sector and enhancing institutions required for the effective management of mineral resources.

As of 2024, the Mongolian economy experienced rapid growth, with a total production output of 2,936.7 million USD. Exports amounted to 1,369.9 million USD, while imports reached 1,566.8 million USD (AVIRMED & BOLD, 2024). Mining accounted for approximately 30% of the nation's industrial output and 60% of its export revenue, with minerals accounting for a larger share of total exports in Mongolia. In 2023, mining sector exports accounted for 78.4% of total exports, rising to 80.7% in 2024, an increase of 2.3 percentage points from the previous year (AVIRMED & BOLD, 2024). Since 2024, the mining sector has accounted for 31% of total foreign direct investment in Mongolia, and this proportion has been steadily rising since then (AVIRMED & BOLD, 2024). Therefore, the government must prioritize issues that enhance the investment climate and maintain macroeconomic stability.

Recent data shows that out of Mongolia's 1.7 million working-age citizens, over 100,000 engage in illegal, small-scale artisanal mining, mostly for gold and fluorspar, as part of the country's shadow economy. Large and medium-sized mining businesses also employ close to 100,000 people (ZANDARIYA, 2022). With a 2.8% unemployment rate in 2022, down from 3% in 2021, the country ranked 31st globally. With inflation reaching 34% in September 2022, it was the first time the nation had seen such a rate in the previous decade and the highest in East Asia (BATDELGER-ZAGDBAZAR, 2022). The persistent worldwide financial crisis is to blame for the sharp rise in unemployment.

About 18 pieces of mining legislation have been passed by the Mongolian parliament. Problems arise in pursuing legal action when the general public lacks an adequate understanding of the judicial system. Regulatory and legislative procedures are not transparent, and bureaucratic corruption is a major obstacle to the growth of Mongolia's mining sector (ZANDARIYA, 2022). To regulate the discovery, extraction, and processing of Mongolian mining materials, the Law of Materials was passed in June 1997. The changes were made in January 2009 and 2006 (BATDELGER-ZAGDBAZAR, 2022). Offering investors a clear and consistent legal framework, this legislation is considered the most successful on a worldwide scale (ZANDARIYA, 2022). A government decision endorsing fifteen (15) strategically important deposits in Mongolia is

considered a major resolution. These deposits are among the world's best-reserved and might entice investors. Several additional laws, including those pertaining to economic entities and organizational income, foreign investments, customs, and general taxes, regulate mining activities (BATDELGER-ZAGDBAZAR, 2022).

The Mongolian government has retained control of the resource and will share up to 55% of total profits with oil exploration firms under a production-sharing agreement. Government risk sharing and tax stability for up to 30 years are advantages for developers (AMARTUVSHIN ET AL., 2021). A few agreements have been inked between the Mongolian government and mining corporations to foster sustainable growth in the nation. In addition to a 5% mining royalty rate, investors must pay seven other taxes to the state coffers. Twenty separate levies, taxes, and fees have been levied on mining firms by various state and municipal governments. According to AVIRMED-BOLD (2024), the situation is expected to have a major influence on the country's salaries, quality of life, and social benefits. Nonetheless, it failed to have a major impact on the nation in the end.

There were negative effects on municipal spending, social service spending (e.g., on education and healthcare), community cohesion, and the expense of environmental restoration when mining operations were shut down (GAZI ET AL., 2025G; GAZI ET AL., 2025H). The mining industry encourages the formation of microenterprises and has a direct, favorable influence on employment. Around 2.5 million people were directly employed by large-scale mining in 2002, according to Weber-Fahr. The author also calculated that there were up to 25 jobs in associated microenterprise (microeconomy) activities for every large-scale mining job. Additional research on the paradox of plenty is required. However, according to HOQUE ET AL. (2015), access to abundant resources and technological progress may bolster the health variables. Resource reliance, on the other hand, is intrinsic to systemic causes; as a result, this might lead people astray. Contrary to expectations, the authors find that resource availability has a positive effect on both growth and institutional quality, whereas resource dependency has no effect.

Developing countries rich in natural resources face a formidable policy challenge: how to achieve and sustain rapid economic development that reduces poverty while protecting social inclusion and the environment (AVIRMED-BOLD, 2024). The interconnectedness of social, economic, and

environmental issues is fundamental to sustainable development, which includes resource maximizing as one of its essential functions (MA ET AL., 2024B). The use of natural resources demands proactive regulation and decision-making by governments, with a focus on integrating social, economic, and environmental considerations (MA ET AL., 2024B). Building an economy that is conscious of its use and preservation of natural resources requires an understanding of the importance of these resources to the economy (ESPOSITO ET AL., 2024).

The current research highlights that during comparable phases of development, resource-endowed nations performed far better than resource-rich nations, particularly those with many non-renewable resources. However, it is a fact of life that countries rich in natural resources tend to have slower economic growth rates. Case in point: oil-producing states in Venezuela, Mexico, the Gulf countries, and Nigeria have failed to attain sustainable economic growth; this is just one of many problems that MA ET AL. (2024B) found in resource-dependent countries, including problems with democratization, rent-seeking, corruption, bribery, and conflict. However, there are also examples of industrialized countries that are quite wealthy and have plenty of natural resources. The US, Venezuela, Australia, Norway, Chile, Peru, Brazil, and Botswana are all included as instances. That is why it's more important to make the most of available natural resources than to have plenty of them. They suggest that we must get to the bottom of the curse linked to natural resources.

With a few notable outliers between 2014 and 2016, Mongolia's GDP shows mostly consistent growth. The Mongolian economy felt the pinch of the worldwide economic downturn that hit in 2008 and 2009. A decline in Mongolia's GDP growth rate began in 2016 and has persisted to the current day (BAO ET AL., 2025). Reasons given for the downturn include insufficient fiscal policy changes, which led to rapid and unsustainable debt buildup, and economic difficulties that followed a period of mineral exuberance, marked by major shocks to the terms of trade and foreign direct investment (BAO ET AL., 2025). FDI in Mongolia's mining industry was the only area where the country's economic performance began to improve. Mongolia's economic growth will be greatly influenced by its renewable resources, including land, water, and forests.

Nevertheless, these sustainable resources have been significantly affected by the rapid expansion of Mongolia's mining industry over the last 20 years. According to AVIRMED-BOLD (2024), of

Mongolia's total area of 156.5 million hectares, 118.4 million hectares, or 75%, are suitable for raising cattle for agricultural and pastoral purposes. Over the last 20 years, the mining industry has grown substantially, whereas agriculture has maintained a stable second or third place ranking in terms of GDP. Notable mining enterprises with national and international investments began operations in 2024, and the Minerals Law was renewed in 2006. More than 90% of overall export profits and 30% of budget income came from the mining industry (BAO ET AL., 2025).

A country's economic development may be positively or negatively impacted by the availability of natural resources and the consequent expansion of its mining industry. If other variables stay the same, growth in the mining industry and allied fields may boost GDP and GNP with the help of rising labor and capital. But there's another side to the story that history shows. The failure to turn resource abundance into economic success is often due to ineffective macroeconomic policies and investments. In most instances, poor institutions serve as the "transmission channel" via which these judgments are made, say some academics. On the other hand, an overabundance of natural resources may become a boon rather than a ban with skillful fiscal management (BATDELGER-ZAGDBAZAR, 2022).

Many emerging nations face serious resource management challenges due to the growth of the mining industry; this is one example of the "curse of natural resources." According to this theory, nations with abundant natural resources tend to have worse economies than those with fewer (BATDELGER- ZAGDBAZAR, 2022). Despite having lower natural resources, East Asian nations experienced much higher growth rates between the 1960s and the 1990s, according to another study. Latin American economies, on the other hand, stagnated and missed growth expectations despite having ample resources (BATDELGER-ZAGDBAZAR, 2022).

According to BATDELGER-ZAGDBAZAR (2022), other production sectors are pushed out of the market due to the dominance of mining and the resulting drop in real currency strength. This leads to diminished economic growth, a phenomenon known as the Dutch sickness. A decline in GDP occurs when other export industries, such as agriculture and manufacturing, become less competitive due to a rise in the real exchange rate and the subsequent shift of workers to the expanding natural resources sector (BAAH ET AL., 2024). Because of the increasing demand for

capital and manpower in the building and mining industries, other sectors are displaced, leading to rising domestic inflation because of Dutch disease.

On a local scale, the mining industry has caused societal harm. As mining villages in Mongolia continue to grow, the local workforce is becoming more eco-conscious (AVIRMED-BOLD, 2024). Additionally, AVIRMED-BOLD (2024) found that mining might improve environmental safety and help us better use our abundant natural resources. In addition, given the heavy reliance of developing countries on extractive industries, there is a need to build human capital through training and education in circular production systems. The long-term economic consequences of a lack of human capital knowledgeable about resource-maximizing systems, also known as circular economic production, include a loss of overall productivity and a reduction in physical capital accumulation. Because of this decline, the country's economy is becoming ever more dependent on the mining industry, which it has never been able to diversify. The need for trained workers in areas such as resource optimization, innovation, green technology, and the circular economy is rising in tandem with the country's growing reliance on the resources industry, creating a negative feedback cycle. Management may put this information to use by better leveraging the natural resources that developing nations have relied on for so long. The circular economy hypothesis, which is gaining traction across many sectors, is a prime example of how natural resources can be sustainably supported.

Mongolia is falling behind other nations that have used reduced rates to entice more investors, such as the European Union and China. Before mining-related laws, rules, and regulations are approved, it is essential to raise local community awareness and expand data-gathering options for government decision-making (BAO ET AL., 2025). That is why, in the end, the policies created and put in place will work. Mongolia needs an appropriate legislative framework for its mining industry since it is a growing country with abundant natural resources. There has to be a new law enacted to address mining-related environmental concerns, circular production, waste management, resource maximization, and rehabilitation efforts; it should also strengthen environmental protection and grant more authority to local administrative bodies, make license holders more accountable, and identify strategically significant deposits. The primary step in the legal process is to get an exploration license from the Mongolian government.

This license has a three-year initial term and a two-year extension option. The exploration license may be upgraded to a mining license if promising resources are found. The mining license lasts for 30 years and can be renewed for another 20 years if needed. The mining sector is coordinated by two government agencies. Data and studies related to the mining sector are supervised by the Ministry of Energy and Mineral Resources. Its duties include formulating spending plans, mining investment planning, encouraging international collaboration, forming public-private partnerships, coordinating policies in global financial markets, and assessing rules and regulations.

It is worth mentioning that mining companies are adopting circular economy-based performance measures, such as environmental rules and resolutions. These measures aim to serve the interests of consumers and investors in the mining industry while also boosting the sector's contribution to Mongolia's economy. To demonstrate that the private mining sector is engaged with the global financial market, the Mining Association provides research, analysis, and assistance to demonstrate that it is implementing a circular system across all its activities. The production sector in Mongolia that is based on the circular economy is strategically important because it has the potential to impact the country's economic growth, social progress, and national security. The mining output via the circular system is projected to contribute at least 5% to the country's GDP and to meet the high worldwide demand.

3. HYPOTHESES DEVELOPMENT

3.1 Green technology adaptation and circular economic performance

Among the many environmental challenges that the world is facing today, from climate change to soil, water, and air pollution, the circular economy stands out for its emphasis on innovation and technology, logical management of nature, and humanitarian upkeep. Renowned international consultancies like PWC, McKinsey, Ernst & Young, KPMG, Deloitte, and KPMG have all come around to the idea of the circular economy and its great potential. Several multinational organizations have begun to incorporate circular economic principles into their business plans. These include the MacArthur Foundation, Accenture, Unilever, Statoil, Ellen, and Philips. In the new circular economy, Denmark, Scotland, and Finland are striving to be in the forefront of international efforts.

This is a region where China is actively pursuing massive development projects. The ideas of the circular economy have the support of well-known international consulting companies like PWC, McKinsey, Ernst Young, KPMG, and Deloitte because of the enormous potential it has. Many multinational organizations have begun to incorporate circular economic principles into their business plans. These include the MacArthur Foundation, Accenture, Unilever, Statoil, Ellen, and Philips. In the new circular economy, Denmark, Scotland, and Finland are striving to be in the forefront of international efforts. As part of its Belt and Road Initiative, China is carrying out massive development projects in this sector (HOSAIN ET AL., 2024B). Questions of complexity, intricacy, and manufacturability as well as the upfront expenses of implementing a circular economy are the main concerns.

It is crucial to reorganize everything ideologically and structurally, which means changing people's minds about what they buy and how they make their living. The cornerstone of circular economy are products with longer life cycles. All recyclable materials should be carefully considered during product development, which necessitates top-notch design and manufacturing. Concurrently, many manufacturers are focused on short-term advantages and want to avoid spending more money on manufacturing. This brings attention to a problem with government regulations, company policies, and tax processes. The needs of the mining sector and long-established consumer habits are two factors that reduce the likelihood of "green technologies" being developed. Since digitization is essential to the creation of environmentally friendly products, the

fast rise in the manufacturing of rare earth metals used in electronics is another example of the negative effects of the digital economy.

In contrast, according to ROZHNOV ET AL. (2020), the Russian Federation's exports of products and services per capita were rated 72nd internationally. At the same time, Russia has a lot of untapped potential in fields like nuclear power, military, and space exploration; these areas are known for their cutting-edge technology, patents, expertise, and personnel who possess the necessary skills (IVANOVA-CHIPEVA, 2021). In addition, ROZHNOV ET AL. (2020) found that by 2025, Russia might double its raw material exports and almost equal its "Industry 4.0" product exports, while also seeing a substantial growth in its non-energy, non-primary exports of goods and services.

There has been a lot of buzz around the idea of a circular economy lately. A restorative and regenerative economy would be one that prioritizes the continuous improvement of goods and their constituent parts to keep their value and utility at an optimal level, drawing clear lines between the material and biological life cycles. The idea is presented as an ongoing cycle of positive development that manages renewable flows and final stocks in a way that maintains and improves natural capital, maximizes the return of resources, and reduces systemic hazards. Regardless of the scale, it works well. The disentanglement of global economic development from final resource use is a tendency of this economic model. Strategies that enable the return of wasted materials to production for reuse in a new capacity are at the heart of the circular economy.

The impact of circularity on linear economics is growing, according to research by BAAH ET AL. (2024), and it's not only proof of concept anymore. Several companies have found success with this strategy, and politicians are beginning to see the circular economy to achieve important political goals. Innovative materials and products, such as biodegradable food packaging and easily dismantled office printers, and contracts, like those for tires, that are geared to the circular economy, are presently available in different forms. In each of these cases, the emphasis is on improving the system, not on any one part of it.

Beyond the above, the research of BAAH ET AL. (2024) created convincing commercial groundwork for a circular economy, which allowed for a rephrasing of conversation throughout the changeover. The expenses that come with a change are affected by how fast it is. Investments

in assets, new digital infrastructure, R&D, retraining, market penetration support for new goods, and interim aid for affected sectors are all examples of what may be included in transition expenditures. There will be an increase in transition costs and the creation of non-recoverable assets if we move faster than the current replacement cycle to achieve a circular economy. We need more data to determine how much these expenses are on top of other possible development scenarios and if they may cause the economy to stagnate. This kind of systemic transformation carries with it substantial dangers. Redistribution of wealth may occur because of long-standing industries' need to change their business methods. Achieving a fair distribution of benefits among consumers, companies, and nations is crucial considering the changes ushered in by a circular economy (KHAN ET AL., 2023).

Both governments and businesses play critical roles in bringing about a circular economy. Getting everyone on the same page on policy, supply, and demand is crucial for fixing the production and consumption paradigm that has been in place for 250 years. National and international governments should use their power to set market circumstances to assist the reforms that are required. This is a sign that big businesses and supply chains are adopting a circular economy model, especially in the realm of state procurement. An important finding from the UN, as brought forth by TANVEER ET AL. (2022), is that 83% of CEOs think governments should do more to create a setting where sustainability programs may thrive. For sustainability to shift from individual efforts to communal and transformational consequences, these leaders argue that more government involvement on a global, national, and local scale is necessary.

To enhance investment volume, speed up transformation, and guarantee investment stability in the long run, transparent rules and regulations are sought after. Global, national, and local sustainability should be the focus of public policy, and they want politicians and government to take the lead in this effort in collaboration with businesses. Among these initiatives are the introduction of substantial tax policies and regulatory norms (SHAH-DAS, 2024). The European Union has made great strides toward sustainable socioeconomic development by adopting circular economic practices, which are in line with the United Nations' framework for establishing goals. Circular economies, which prioritize resource efficiency and technology derived from nature, are taking root in the European Union and other industrialized nations thanks to preexisting legislative rules, state economic incentives, and investment project funding (KHAN ET AL., 2022).

In economics, a closed cycle is most often used for things like recycling old products and waste, using virtual technologies directly like books, movies, museums, and exhibitions (GAZI ET AL., 2024F); using virtual technologies indirectly like online stores and services (GAZI ET AL., 2024D; ISLAM ET AL., 2023); incorporating more participants into the cycle; using virtual financing mechanisms like public-private partnerships (GAZI ET AL., 2024D; ISLAM ET AL., 2023); allowing for flexible differentiation among participants, consumers, and financial instruments; and finally, remanufacturing and refurbishing products and components. Industry geared toward the circular economy is the only viable framework for the large-scale implementation of such operations.

According to this research, green technology can't continue without the circular economy. By providing chances to increase value via slowing down or eliminating resource cycles, the circular economy departs from conventional systems (BAAH ET AL., 2024). On the other hand, it helps implement a system that takes stakeholder interests into account, reduce emissions of greenhouse gases, and minimize input waste (ÜLKÜ ET AL., 2022). Circular economy calls for the development of unique business models by combining creative thinking with the performance of operational tasks (BAAH ET AL., 2024). But to analyze the results of the circular economy, ESPOSITO ET AL. (2024) defined these phenomena as a paradigm shift toward more efficient production and consumption based on the tenets of reduction, reuse, and recycling.

But while it's beneficial to adopt circular economic performance on its own, it's much better when combined with green technology adaptation (LIM ET AL., 2022). Furthermore, it is possible to validate optimum benefits via the establishment of a performance system based on the circular economy. To improve resource efficiency and effectiveness, organizations may provide groundwork for a paradigm shift by adopting green technologies and implementing circular economic performance (TANVEER ET AL., 2022). The company has improved its sustainability policies by adopting green technologies and implementing a circular economy (ISA ET AL., 2021). Consequently, businesses that are serious about sustainability must study how adopting green technologies affects their circular economic performance (KHAN ET AL., 2022). However, based on the above discussion, this study proposes the following hypothesis.

H1: Green technology adaptation has a positive relationship with circular economic performance

3.2. Green technology adaptation and green innovation

Numerous studies have demonstrated a correlation between technology adoption and improved innovation capabilities within firms (for example, SHAHZAD ET AL., 2022; LISI ET AL., 2020; ZHANG ET AL., 2020; WANG ET AL., 2019; WANG ET AL., 2024). The integration of new technologies facilitates green innovation by enhancing resource efficiency, minimizing waste, and enabling the development of sustainable products (WANG ET AL., 2024). In this pertinent, empirical study of LI ET AL. (2022) examined the factors influencing a firm's adoption of green innovation behavior through the adaptation of green technologies. On the other hand, LIAN ET AL. (2022) examined the impact of legislation and customer pressure on research and development expenditure, which subsequently affects the adoption of the green innovation process. The environmental management system along with the research and development wing of the organizations facilitates the process of green innovation (LIAN ET AL., 2022).

However, LIAN ET AL. (2022) additionally concluded that while environment management significantly affects the innovation process, it has an insignificant association with product innovation. Besides, environmental regulation, management tools, and organizational factors promote environmental innovation. Similarly, the study of LI ET AL. (2022) indicated that customer benefits, environmental regulations, and technological capabilities of research and innovation significantly influence the green innovation process. Similarly, the environmental factors and innovation processes have influences on market pressure, government environmental regulation, and the internal conditions of the firm (WANG ET AL., 2024; UZIR ET AL., 2025A).

In another similar study by LISI ET AL. (2020) have examined the impact of internal factors within firms and technological factors on the adoption of green innovation. On the other hand, the examination of SHAHZAD ET AL. (2022) identified environmental regulation as a determinant of green innovation adoption. Moreover, this study considers government regulation as a moderating variable, which does not directly influence adoption behavior but rather affects the relationship between technological factors and the adoption of green innovation. Thus, the above discussed studies have identified various technological factors, including ease of use, observability, richness of information, and uncertainty that influence a firm's cognitive beliefs regarding the adoption of green innovation.

The research of LI ET AL. (2022) examined complexity, compatibility, relative advantage, and reliability, as various multifaceted characteristics that are identified as significant technological factors influencing a firm's behavior toward innovation adoption. The complexity of innovation indicates the degree to which an organization perceives technology as challenging to comprehend and utilize. The hypothesis posits that an increase in technological complexity correlates with a decrease in the likelihood of innovation adoption. Besides, challenges in innovation diffusion and knowledge sharing contribute to the complexity of technology (ZHANG ET AL., 2020). Consequently, organizations are more inclined to adopt an innovation when knowledge sharing regarding that innovation is facilitated within the organization.

Efficient knowledge sharing within an organization enhances the adoption of innovations that improve financial performance and support effective environmental management (LIAN ET AL., 2022). Additionally, the authors indicated that an innovation necessitates extensive efforts for learning and diffusion, the complexity level rises, thereby reducing the likelihood of adopting that complex technology. However, WANG ET AL. (2024) identified several factors influencing firm behavior regarding the adoption of green innovation, including insufficient private incentives, the complexity of technology replacement processes, and inadequate information about green innovation. The study concluded that financial incentives, policy interventions, training, and information on the benefits of green innovation significantly decrease the reliance on polluting technologies.

Compatibility denotes the organization's assessment of how well technology aligns with its established values, experiences, and requirements (WANG ET AL., 2024). Besides, if a firm perceives that technology aligns with its existing knowledge, the organization is more likely to adopt the technical innovation. In a similar vein, when green innovations build upon a company's existing knowledge, the diffusion of these innovations is facilitated and streamlined. In this pertinent, the research of LISI ET AL. (2020) highlighted technological changes and environmental policy specifically in the organic chemical industry, finding that innovations that augment existing technology are diffused more rapidly and easily within organizations than technologies that do not align with the firm's existing knowledge and production processes.

However, innovations aligned with a firm's capabilities demonstrate more significant positive effects on the environment (SHAHZAD ET AL., 2022). Relative advantage denotes an

organization's assessment of the benefits of innovation in comparison to its costs. If a firm believes that the relative advantages of innovation surpass both the costs and the current technology, it is more likely to adopt the innovation. The relative advantage may be assessed in terms of price, quality, ease of use, lifespan, and the satisfaction a firm derives from utilizing the innovation. If the relative advantages of innovation are greater, companies are more inclined to adopt the innovation and pursue higher economic gains (WANG ET AL., 2024).

Organizations adopting green innovations may experience several benefits, including reduced consumption of energy and natural resources, decreased greenhouse gas emissions, improved environmental and financial performance, and enhanced responsiveness to social and environmental expectations (ZHANG ET AL., 2020). In this regard, WANG ET AL. (2024) highlighted green technology as the notable factor that influencing the adoption of green innovation in the pulp and paper industry, finding that financial benefits are significant technological characteristics impacting this adoption. The perceived net benefits drive the organization to adopt the technology and realize the associated advantages.

Tri-ability indicates that organizations are more inclined to adopt innovations that can be tested in advance, particularly when such innovations involve a significant level of uncertainty. Previous studies have indicated that various technological factors, such as relative advantages, complexity, and compatibility of innovations, influence the adoption of green innovations in the transportation sector in China (WANG ET AL., 2024). In their study, the authors found that Chinese logistic companies widely adopt green technologies, as they perceive significant benefits for both environmental sustainability and economic performance. Based on transportation industry, the research of ZHANG ET AL. (2020) revealing that human capital, customer pressure, and environmental uncertainty significantly influence the adoption of green technology and innovation, whereas organizational and governmental support show an insignificant relationship with this adoption.

The examination of WANG ET AL. (2024) found significant correlations between green innovation and the adoption of environment-focused technologies in the manufacturing sector, revealing a positive association between these variables. Similarly, the research of ZHANG ET AL. (2020) examined the determinants of green information technology adoption within organizations, identifying various economic, ethical, and regulatory factors influencing this

adoption. However, this technology can be adapted through green innovation. The authors additionally noted that a firm readily adopts new technology which is green based when it is easy to learn; otherwise, adoption is hindered; and in that case green innovation can support facing the challenge. Thus, the findings of the above discussed literature indicate that the adoption of green innovation is essential to mitigate the challenges related to the instilment of green technologies. Therefore, the abovementioned literature supports developing the hypothesis below.

H2. Green technology adaptation has a positive relationship with green innovation

3.3 Green innovation and circular economic performance

Since the start of the twenty-first century, the development and growth of environmental concerns that have significantly altered every facet of human existence; it has improved the processes for product and service conception, manufacturing, and delivery (ALI ET AL., 2024). On the other hand, the recent integration of innovative digital manufacturing technology and precision equipment into these processes has facilitated new avenues of innovation in production and delivery (KHAN ET AL., 2024). These novel technologies have enhanced quality and value, expedited development and market entry, and promoted sustainable manufacturing. Innovation for green manufacturing thoroughly acknowledges the environmental impact and resource efficiency in production. The primary characteristics of innovation to green technologies include systematic organization, eco-prevention emphasis, economic adherence, and improved efficiency (ABDALLAH ET AL., 2024). In the past decade, sustainable development has garnered significant attention in the industrial sector owing to heightened awareness and recognized advantages of green technologies for society (JOHL & TOHA, 2021).

Innovation, as the paramount catalyst for growth, accelerates a corporation toward excellence and ensures a competitive edge; it also improves environmental efficiency, so facilitating the accumulation of social capital essential for future advancements (SIEDSCHLAG ET AL., 2022). The authors additionally indicated that an increasing number of organizations have incorporated green innovation as a fundamental element of their strategy to alleviate the adverse effects of conventional growth models. The Chinese government incorporated green innovation for establishing a foundation for the promotion of a green technology bank to facilitate the adoption of green technologies (LIU & WANG, 2022).

Numerous countries have recently established state-level financial institutions to advance sustainable development and implement the plan for green industry, such as Japan and Canada (LIU & WANG, 2022). These institutions can utilize public-private partnerships (PPPs) to promote green infrastructure and technology innovation. Moreover, this environmental innovation facilitates organizations in producing environmentally sustainable products by reducing resource consumption and waste to achieve sustainable development (ABDALLAH ET AL., 2024). Researchers such as UL-DURAR ET AL. (2024) have identified green innovation as a crucial catalyst for sustainable development, asserting that environmentally friendly processes and products deliver comparable value to consumers while minimizing social and environmental repercussions. Moreover, UL-DURAR ET AL. (2024) further indicated that the principal advantages of green innovation can be capitalised if circular production system is implemented; and there are numerous stakeholders also supported for its adoption and implementation. While radical transformation is essential at the ecological, cultural, and social levels, organizations must fulfil their specific role in circular economy-based performance (BAG ET AL., 2022).

Nonetheless, the adoption of green innovation encounters considerable obstacles in attaining circular economy-based performance within manufacturing organizations due to several decision-making considerations. Due to escalating commodity prices and apprehensions about sustainable sourcing, organizations may choose for cutting-edge, eco-friendly technology to reduce waste and expenses, hence gaining a competitive edge (AI ET AL., 2024). However, there are no definitive criteria for the global categorization of the adoption of circular economy-based performance (SIEDSCHLAG ET AL., 2022). In addition to that SIEDSCHLAG ET AL. (2022) highlighted numerous apprehensions persist regarding the adoption of green and innovative technologies, including financial obstacles, environmental regulations, market demand, knowledge, and awareness. From a financial standpoint, acquiring essential precision equipment and skills may represent a significant share of organizational expenditures; thus, organizations must ensure the viability of such investments (UL-DURAR ET AL., 2024).

Green and environmental policies and activities are believed to enhance company success only when universally implemented, with endorsement and backing from all stakeholders. Studies indicate that insufficient consumer interaction and acknowledgment result in a depletion of investments and resources (VENCE & PEREIRA, 2019). In this pertinent, JOHL & TOHA (2021)

have determined that over reliance on coal energy is the principal contributor to harmful emissions; enhancing energy efficiency can mitigate this through green technical innovation and activities. Consequently, it is essential for organizations to assess the social, economic, and environmental dimensions of circular economy-based performance (LIU & WANG, 2022).

Because of climate change, developing and underdeveloped nations must pursue sustainable and green technical solutions, green innovation, and circular economic system (KHAN ET AL., 2024); specially some Southeast Asian and African countries are the least innovative countries, with a low rating both in Asia and globally. For example, the renowned industrial city of Lahore in Pakistan was designated as the most polluted city in the world due to inadequate air quality. To address these environmental issues and promote green innovation and circular production process, the current leadership of Pakistan has enacted rigorous environmental legislation to mitigate ecological degradation and has endeavoured to assist organizations in reducing their reliance on fossil fuels while harnessing renewable energy resources. The rigor of environmental plans, environmental taxation, and diminished hazardous emissions positively influences the green innovation more (ABDALLAH ET AL., 2024). Nonetheless, renewable energy resources are likewise finite. That is why the present study indicates that emerging nations like Mongolia may provide deeper insights on how green innovation and circular production policies might mitigate environmental degradation and promote eco-friendly products that reduce pollution and minimize industrial waste.

Following the theory on natural resource-based view, scholars acknowledged the significance of the adoption of green innovation and technology to maximum utilization of resources (ALI ET AL., 2024). These characteristics significantly influence the performance which is focusing on circular economy. While it may be contended that green innovation parallels all the new green technologies, the implementation of circular system and conditions of various technologies will differ markedly, leading to discrepancies in adoption factors based on the type of technologies (KHAN ET AL., 2024). Consequently, for a corporation to effectively implement a circular economy-based project, it must understand the factors that would enhance social acceptance among stakeholders. Therefore, it is essential to rigorously examine the implementation issues and adoption concerns by analysing these circular economy performance challenges. According to the support of above literature discussion, this study proposes the following hypothesis.

H3: Green innovation has a positive relationship with circular economy performance

3.4 Green Innovation as a Mediator

The linkages among circular economy, green innovation, and sustainable performance were emphasized in the research by RODRÍGUEZ-ESPÍNDOLA ET AL. (2022), which was backed by the theory of natural resource-based perspective (RBV). According to their research, RBV theory backs the idea that stakeholders' interactions with one another throughout green innovation processes would lead to a more circular economy that satisfies the environmental, economic, and social sustainability performance criteria. The idea that green technology adaptation is the main force behind green innovation practices was put out by KHAN ET AL. (2025), who also found that a circular economy leads to more green innovations. Likewise, ZAMEER ET AL. (2022) verified that green innovation mediates the creation of a circular economy, but they failed to consider the far-reaching effects of adapting green technology on green innovation. In a similar vein, the research conducted by RODRÍGUEZ-ESPÍNDOLA ET AL. (2022) shown that corporations and their key suppliers may increase green innovation by working together to create new environmentally friendly products.

Nevertheless, another study corroborated the results of RODRÍGUEZ-ESPÍNDOLA ET AL. (2022) showing that greening the suppliers would favorably affect green innovation. Furthermore, research out of Taiwan by LIU-WANG (2022) suggested a strong correlation between green product and process innovation and corporate environmental management strategies like green innovation. The connection between green innovation and the circular economy is not without merit. Many stakeholders, including suppliers, consumers, and the community, are becoming more concerned about environmental concerns and laws, which is why businesses are being pushed to collaborate closely with them throughout product development. According to KANAAN ET AL. (2023), businesses will reap the benefits of this partnership in the form of innovation, improved product design and production, and increased compliance with environmental rules. Manufacturers may benefit from green innovation concept's fresh ideas, methodologies, and technology while creating new goods, which can aid in the adoption of the circular economy. However, according to AWAN ET AL. (2023), green innovation is thought to provide continuously innovative solutions to gain a competitive edge and reduce environmental concerns in the sector at each level of the supply chain.

According to a literature study on circular economy carried out by RODRÍGUEZ-ESPÍNDOLA ET AL. (2022), an organization's environmental performance is impacted by how it applies circular economy strategies. It is important to incorporate a third variable, the mediating variable, to quantify the direct influence of circular economy adaptation on the organizational environmental performance. Adaptation of green technologies and the environmental performance of organizations are recognized to be mediated by green innovation (ZAMEER ET AL., 2022). Put another way, the environmental performance of an organization is not directly impacted by green technology adaptation; rather, it is influenced by green innovation, which is impacted by organizational environmental performance. The direct and indirect impacts are what these are called (RODRÍGUEZ-ESPÍNDOLA ET AL., 2022). The expenses of complying with environmental standards may be balanced off by encouraging innovation, which in turn boosts company performance (BONSU ET AL., 2024).

According to AL-KHATIB's (2022) research, environmental rules have an indirect effect on company performance and could nudge companies toward green innovation. People typically talk to this kind of indirect impact as the mediated effect. So, green innovation may be seen as a moderating variable; that is, the green innovation strategy acts as a go-between for environmental legislation and the organization's environmental performance. Considering the above discussion, the current research presupposed that green innovation may play a substantial mediating role between the adoption of green technology and the success of the circular economy. After that, our research went a step further by showing that green innovation mediates the direct connection between the adoption of green technology and the performance of the circular economy.

Despite the paucity of prior research in this area, the present study examines many facets of organizational performance with an emphasis on the circular economy and addresses the mediating function of green innovation. According to LIU-WANG's (2022) research on the topic, which is relevant to this discussion, environmental innovation strategies mediate the relationship between organizational business performance and relevant environmental pressure forces, such as government regulations, managerial environmental concerns, and the perceived importance of stakeholder pressures. The study was conducted in China's chemical industry and confirmed this finding.

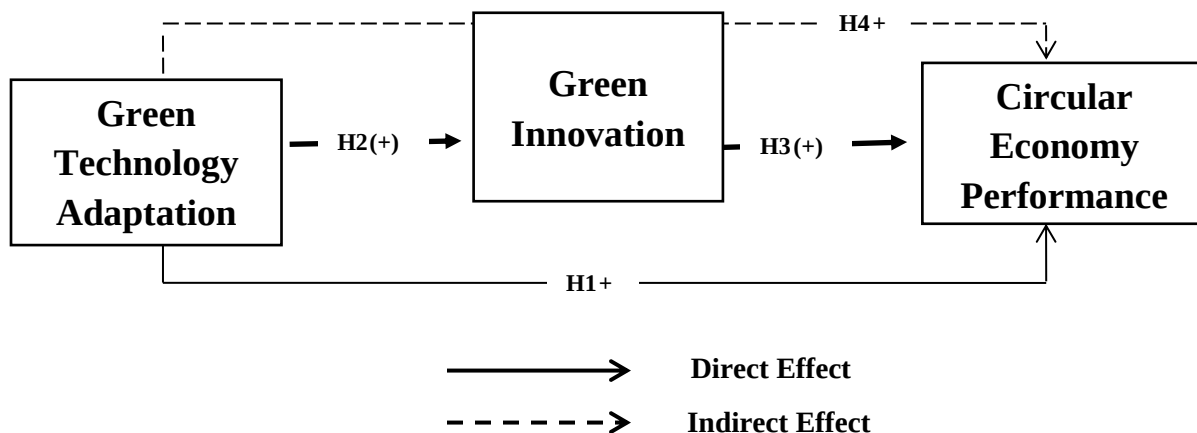
Furthermore, JUO-WANG (2022) investigated the relationship between corporate environmental ethics and competitive advantage in Taiwan's manufacturing business. The study found that green innovation performance mediated this impact. It was determined that, apart from green process innovation, green product innovation mediates the positive association between corporate environmental ethics and competitive advantage. What this means is that green product innovation in manufacturing has an indirect effect on competitive advantage while corporate environmental ethics have a direct effect. Plus, according to YOUSAF's (2021) suggested mediation model, green suppliers boost environmental performance and business advantage by fostering innovation in green products, processes, and managers. The importance of green innovation as a mediator between the adoption of green technology and the success of the circular economy is supported by this noteworthy discovery, which implies that greening the suppliers and green innovation are strongly associated with the competitive advantage and circular economic performance of organizations. Based on the above discussion, this research develops the following hypothesis.

H4: *Green innovation has a mediating effect between the relationships of green technology adaptation and circular economy performance*

3.5. Conceptual Model of this Research

Based on the above discussion, literature supports, to attain the present research objective, and to address the current research questions, this study proposes the following conceptual framework demonstrated in Figure 3 below.

Figure 3. Conceptual Model of this study



4. METHODOLOGY

4.1 Introduction

This chapter discusses the research methodologies and instruments used to investigate the correlation between the adoption of green technology, green innovation, and circular economy performance in the mining industry of Mongolia. This study examines how adopting green technology impacts the performance of the circular economy, with green innovation playing a mediating role. This chapter elucidates the research approach devised to examine the hypothesized correlation between the variables in accordance with the proposed framework. In addition, this chapter covers the various aspects of research methodology, including research design, population and sample selection, sampling frame, sampling technique, sample size determination, measurement and questionnaire design, and data analysis techniques.

4.2 Research Design

According to CRESWELL (2009), research design is a set of planned techniques for conducting research investigations that disseminate the findings derived from extensive postulations through various data collection and analysis methods. Based on the following considerations, the methodology has been designed for this study:

4.2.1 Research Nature

The objective of this study is to examine the performance of the circular economy as an organizational-level outcome in the mining industry in Mongolia. This research intends to investigate the relationship between uni-dimensional green technology adoption and the performance of a single-dimensional circular economy, considering the role of green innovation as a mediator. The present study adopted a quantitative research approach, using a structured questionnaire as the core research instrument. The research conducted was quantitative in nature, involving the collection of relevant data and the analysis of the relationship between variables, as outlined in a theoretical framework. In this pertinent, SALKIND (2006) proposed using a questionnaire as a survey approach to examine the relationship between various categories of constructs such as adaptation, organizational performance, company values, and individual perceptions in diverse contexts.

The current research is a cross-sectional study that involves the integration of data at a given moment in time and drawing conclusions through inspection at the same point in time (SEKARAN & BOUGIE, 2010). The present research included data and information on the perspectives of mining industry managers regarding the adoption of single-dimensional green technology, green innovation, and circular economic performance at the organizational level.

4.2.2 Data Sources

In this research, both primary and secondary sources of data were used. The main sources consist of thirty mining factories or enterprises, the perceptions of their managers, and all the data have been acquired with the use of a structured questionnaire, which was regarded to be primary data. In addition, secondary sources were used for the purpose of conducting the literature discussion for the present research. The term secondary data refers to information that has been gathered from personnel of selected organizations for objectives that are not related to this present research study specifically. There is a possibility that secondary data is accessible, which is completely suitable and completely sufficient for drawing conclusions, answering the issue, or finding a solution to the problem. In many circumstances, the collection of original data is not required. Secondary sources will be used in the process of doing empirical research to provide an explanation of the literature review, background literature for developing the hypotheses, a justification of the research gap, and a rationale for the hypothesized relationships among variables. Several journals, websites, organizational data sources, national data, books, periodicals, and newsletters were regarded as secondary sources for the purpose of providing information that was pertinent to the explanation of the literature and other material that was connected to it in the present research.

4.3 Population and Sample Design

4.3.1 Population and Sampling Frame

According to SEKARAN & BOUGIE (2010), the term 'population' is defined as the entire group of people, events, or things of interest that the researchers target to investigate. In any study, clarification of the population is necessary since it enables the researchers to avoid making mistakes while selecting the appropriate samples. In this regard, CAVANA ET AL. (2001) elucidated that if the researchers can get the appropriate sample, they would be able to demonstrate an assumption that would make it simpler to generalize to the full population. All the personnel who were working in management positions in mining organizations in Mongolia were regarded

to be part of the target population for this study. According to KARIM ET AL. (2023A), managers are groups of individuals who are responsible for carrying out their duties within their organization. These individuals are responsible for planning, making decisions, coordinating, motivating, and managing other activities that are pertinent to their work. Based on this study, it is assumed that managers possess the necessary qualifications, capabilities, and experience to comprehend and respond effectively to the research criteria given. In order to generalize the findings of the research, the present study looked at all types of managers and classified them into three distinct classes: upper-level managers, middle-level managers, and lower-level managers (operator managers). In addition, all three categories are taken into consideration in this research since it will provide the opportunity to assess the perspectives of all the different kinds of managers.

Furthermore, according to CUI ET AL. (2025), there are around 130 mining organizations that are now active in Mongolia, most of which are privately held. In order to determine the organization and its size, the present research divides the organization into three primary groups: big, medium, and small. These categories are used to identify the organization. For categorizing organizations, the number of workers working for the organization was taken into consideration. According to DAMIRAN ET AL. (2025), the mining organizations in Mongolia are classified as big when they have more than 500 workers, medium when they have more than 200 employees, and small when they have more than 100 employees. As a result of this conception, the current study takes into consideration the first ten (ten) organizations from each category for the purpose of data collection. This is due to the fact that these 30 (thirty) organizations contribute more than sixty percent to the gross domestic product of the mining industry in Mongolia (DAMIRAN ET AL., 2025). The names of these organizations are included in Appendix B for your convenience.

4.3.2 Sampling Design

The current study employed judgmental sampling. Judgmental sampling is a part of the purposive sampling of non-probability sampling design.

4.3.3 Sample Size

Various approaches have been proposed by researchers to determine the necessary sample size, including well-established formulas and references to past research. The current study emphasized both perspectives in establishing the necessary sample size. The formula utilized in the present investigation applies to the specified population. This formula is recommended for researchers

when a comprehensive list of the population is unavailable. The formula utilized in this study was selected due to the lack of information on demographics.

$$P = p(1 - p) \left(\frac{z}{E} \right)^2$$

Where:

- P is the sample size
- p is the proportion (0.5)
- z is the confidence interval according to the table and the value is 1.96 (0.05)
- E is the accepted error and the value is 0.05.

Therefore, based on the above formula the required sample size will be 384.

In addition, scholars have provided several suggestions for estimating sample size. For instance, SEKARAN & BOUGIE (2010) stated that, to estimate the minimum required sample size for multivariate analysis, the number of variables in the study should be at least ten times the number of variables. Hence, the minimum sample size for this research is 80 (8 multiplied by 10). (HOE, 2008) suggests that a sample size of 200 or more is adequate for data analysis. According to (HAIR ET AL., 2014), it is recommended that the minimum sample size for PLS-SEM should be at least ten times the number of structural paths in the model. In addition, HAIR ET AL. (2014) demonstrated that a sample size of 100 is adequate for data analysis using SEM-PLS. In another study based on a similar developing nation, KARIM ET AL. (2023B) utilized a sample size of 395 for data analysis and obtained favorable outcomes. Therefore, building on the existing literature, the present study identified 475 valid samples for efficient data processing.

4.3.4 Unit of Analysis

The unit of analysis in this study is comprised of managers at various levels (top-level, mid-level, and lower level) employed in the mining business. In this pertinent, SEKARAN & BOUGIE (2010) stated that individuals and groups possess distinct qualities that set them apart from each other. Furthermore, there exists a divergence in perceptions, attitudes, and behaviors exhibited by individuals belonging to distinct groups. Therefore, the type of information collected and the level at which it is combined for analysis are crucial factors in determining the unit of analysis for

decision-making. Thus, to assess how individual managers perceive the research objective, each individual operator was selected as the unit of analysis. Purposive sampling is a method that involves selecting individuals who possess the specific information needed for a study, either because they are the only ones who have it or because they meet specific criteria established by the researchers (SEKARAN & BOUGIE (2010)). In this regard, COOPER & SHINDLER (2011) stated that judgmental sampling is employed when a researcher selects a sample that meets specific criteria. The purpose of its utilization was to selectively gather data from a specified group. The selection of respondents in this study will be based on two factors. The questionnaire also specifies the inclusion requirements.

- i) Managers who have at least five years of experience in the mining organization and
- ii) Managers who have at least one year of job experience in their present working place.

4.4 Research Instruments

A well-structured questionnaire can be used in any study as a data-gathering technique. The questionnaire used in this research typically consists of four basic parts: Part I consists of five items designed to assess the adoption of green technology as a unidimensional independent variable. Similarly, part II focuses on the measurement of the mediating variable, i.e., green innovation, using five items, as well as a unidimensional construct. Additionally, part III assesses the measurement of unidimensional circular economic performance using six items. Lastly, Part IV includes items that pertain to the demographic factors of the respondents, with a total of 8 items.

The elements of the various variables were derived from pre-existing recognized, reliable, and valid scales. The measurement tools utilized in this study are summarized in the following Table 1.

Table 1 Measurement instrument of the research variables

Variables	Items	Sources
Green Technology Adaptation	5	AFUM ET AL., (2021) and XIA ET AL., (2022)
Green innovation	5	SHAHZAD ET AL., (2020) and SONG & YU (2018)

Circular Economy Performance	6	MARRUCCI ET AL., (2021)
Demographic Variables	8	Age, Gender, Religion, Marital Status, Education, Monthly Income, Current organizations experience, and Industry Experience.
Total	24	

4.4.1 Green Technology Adaptation

The adaptation of green technology is recognized as the process of changing, updating, and modifying the new application of environment-related science and technology in order to conserve the natural environment and resources for the purpose of reducing the negative impact that human activities have (AFUM ET AL., 2021). It is a technology adaptation process that aims to avoid producing waste (ALNOOR ET AL., 2024) and to make the most efficient use of resources. The measurement of green technology adaptation in this study included the use of five items derived from the scales developed from AFUM ET AL., (2021) and XIA ET AL., (2022).

The data from the respondents was collected using a five-point Likert scale, with options ranging from '1' for "strongly disagree" to '5' for "strongly agree".

Table 2: Developing Items Constructing Green Technology Adaptation

Item code	Items
GTA1	We have expertly utilized the tools and applications provided by green technology
GTA2	I have gained extensive knowledge of green technology in a short period of time
GTA3	I quickly adapted to the green technology implemented in my organization
GTA4	I have successfully administered all the resources offered by green technology
GTA5	I determine myself as a professional who regularly utilizes my organization's green technology

4.4.2 Green Innovation

Green innovation refers to the exploration, endorsement, and advancement of environmentally friendly goods, services, and processes that possess a certain level of originality. Moreover, green innovation involves novel concepts that strive to provide a product or service while avoiding harm to nature, upholding environmental standards, and adhering to ecological principles throughout its whole lifecycle, including design, manufacturing, use, and disposal (ASHRAF ET AL., 2024). The present research assessed organizational green innovation using a set of 5 questions that were derived from the established scale developed from SHAHZAD ET AL., (2020) and SONG & YU (2018).

The measurement tools, i.e., items pertaining to green innovation were conducted using a 5-point Likert scale, where '1' represents strong disagreement and '5' represents strong agreement.

Table 3: Items Constructing Green Innovation

Item code	Items
GI1	Our organization selects materials for manufacturing or design that generate less pollution.
GI2	Our organization minimizes the usage of materials in product development and design.
GI3	Our organization will meticulously evaluate if the product is easily recyclable, reusable, and biodegradable while developing or designing products.
GI4	The company's production processes efficiently minimize the release of harmful compounds or waste.
GI5	The company's production technique minimizes the use of raw material resources.

4.4.3 Circular Economy Performance

Circular economy performance refers to a specialized process within consumption and production systems that emphasizes recycling, repair, reuse, re-manufacturing, changes in consumption patterns, product sharing, new business systems, and modularization to achieve sustainable

performance in the textile industry (AMIN & OLÁH, 2024). The present research evaluated the success of the circular economy using a single outcome measure inside the organization. This result was analyzed at the organizational level. The assessment of circular economic performance was conducted using six items derived from the existing scale developed from MARRUCCI ET AL., (2021). A five-point Likert scale, ranging from '1' representing "strongly disagree" to '5' representing "strongly agree", was used to gather data from the respondents. The alpha value for all three dimensions was determined to be within the acceptable range recommended by HAIR ET AL. (2017), with a value of 0.70.

Nevertheless, the references for the measuring items that were used in the present investigation are shown in Table 4, and the items that are discussed in further depth are appended to the questionnaire as appendices.

Table 4: Items Constructing Circular Economy Performance

Item code	Items
CEP1	Our products are intended to be repaired, renovated, or remanufactured at the end of their life cycle.
CEP2	We use a manufacturing process that effectively eliminates leaks and reduces waste formation.
CEP3	We enhance the energy efficiency of our manufacturing processes.
CEP4	Our manufacturing process includes bi-products, end-of-life items, recycled materials, and reduced extra energy.
CEP5	We gather our raw materials or components from the sources that have reached the end of their useful life to recycle or recover resources.
CEP6	We minimize the excessive consumption of resources in our manufacturing process.

4.5 Pre-Test

The purpose of a pre-test is to uncover any complexities that may arise from the pre-examination process, such as word choices or biases that expose defects in the question's divine nature, consistency, and direction (COOPER & SHINDLER, 2011; ZIKMUND, 2003). Hence, pre-

examining is crucial to reduce the uncertainty associated with the questionnaire (PERNEGER ET AL., 2015; HOSAIN ET AL., 2024A). Using a significant number of respondents ensures that the questions in the questionnaire are fully understood by the respondents. Additionally, a pre-test helps to minimize any potential bias and aligns with the research environment (ZIKMUND, 2003).

According to HUNT ET AL. (1982), it is crucial to carefully choose respondents for pre-testing to enhance the accuracy and usability of the final data collection. This study used a convenience sample method to pick six managers from the mining industry, two specialists from the Mongolia Mining Association, and two academicians from two reputable public universities in Mongolia. The specified cohort of participants was chosen to evaluate the suitability, comprehensibility, and duration required to complete the questionnaire following the previous research conducted by QING ET AL., (2023).

To assess each item, a sample was provided with a series of queries to respond to the question. At first, participants were asked to analyze three aspects: 1) the precision of words and the significance of phrases, 2) the arrangement and order of questions, and 3) the accuracy of questions that measure the actual information related to the concepts being studied. In addition, the respondents have been observed while completing the questionnaire. During this stage, it takes the responders around 30 minutes to finish the tranquility task. At the end of this session, each participant was asked to share their comments and suggestions for all the elements of the constructions. During this stage, the respondent remarked that the questions were more lucid and comprehensible.

4.6 Pilot Study

The pilot study seeks to assess the clarity and dependability of the questionnaire, as well as examine the internal reliability of the measures. DE VAUS (1993) suggested conducting a pilot study as the initial stage to mitigate potential risks in a larger investigation. One of the primary justifications for doing a pilot study is to make predictions about the potential success of the main research project. Additionally, the pilot study allows for identifying any potential issues with the research protocol or the complexity of the planned methodologies (VAN TEIJLINGEN ET AL., 2001). The objective is to gather data from participants on the project to serve as a reference for comprehensive research (ZIKMUND, 2003).

Four organizations were selected from the list of options. The participants were chosen for the study based on their availability and willingly consented to participate. A total of 100 questionnaires were distributed evenly, and 40 of them were returned, resulting in a response rate of 40%. As indicated by prior research findings (for example, AL AMIN ET AL., 2024A), a sample size ranging from 10 to 40 is adequate for a pilot study. The reliability of all scales was assessed using SPSS (version 24). The internal dependability of the measurements is within the acceptable range of 0.793 to 0.857, as determined by NUNALLY (1978). The final analysis did not use these 40 samples obtained from the four organizations. The internal consistency reliability for each measure is summarized in the following Table 5.

Table 5: Cronbach's Alpha of Variables from Pilot study

SL No	Variables	Items	Cronbach's Alpha
1	Green Technology Adaptation	5	0.857
2	Green Innovation	5	0.793
3	Circular Economy Performance	6	0.851
	Total	40	

4.7 Data Collection Techniques

At the beginning of the research project, a formal request was sent to the mining organizations to solicit their participation in the study. A request letter, including research questionnaires, was sent to individual organizations at the beginning of the data-collecting procedure. In order to facilitate the administration of the structured questionnaire survey, the organizations were requested to provide their personnel authorization to contribute contributions. The letter of request includes a short summary of the study, the research objective for the questionnaire survey, and a rough data collection schedule plan for completion. A method known as drop-off and pick-up (DOPU) was used to administer the questionnaires. According to LANGLEY & KYPRI (2011), a DOPU technique enables respondents to fill out fields at their own convenience while also reducing the interviewer's potential for bias. Previously, AMIN & RUBEL (2020) conducted research that used this similar identical method for the purpose of data collection.

4.8 Data Analysis Techniques and Tools

Various statistical approaches and tools, including SPSS for data input descriptive analysis and structural equation modeling with Partial Least Square (PLS) for hypothesized relation, were employed in hypothesis testing. Structural equation modelling (SEM) aids in elucidating the connections among numerous variables (HAIR ET AL., 2014). SEM is essential for modelling applied multivariate analysis (REISINGER & MAVONDO, 2007).

Structural Equation Modelling (SEM) is a statistical methodology that enables the examination of relationships between independent variables (which can be continuous or discrete) and dependent variables (which can also be continuous or discrete). It is a collection of tools that facilitate this analysis (HAIR ET AL., 2017). It is a statistical method that combines elements of multiple regression and component analysis to concurrently estimate a set of interrelated dependent relationships. Multiple regression examines the relationship between variables, while factor analysis represents unmeasured ideas with numerous variables. This technique, known as multivariate analysis, is used to analyze complex data sets (HAIR ET AL., 2014). Furthermore, SEM focuses on examining hidden variables, specifically the examination of causal relationships between hidden variables (HOOPER ET AL., 2008). Structural equation modelling or route modelling is a statistical technique used to analyze the relationships between constructs and variables (HOOPER ET AL., 2008).

Structural Equation Modelling (SEM) is classified as a second-generation technique of multivariate analysis (CHIN, 2010). Previous methodologies, including analysis of variance, logistic regression, and multiple regressions, had certain limitations. These constraints included the assumption of a simplistic model structure and the requirement that all variables be observable and measured without any errors (HAENLEIN & KAPLAN, 2004). Furthermore, these preconceptions may be excessively limited when evaluating any intricate and authentic circumstances. In addition, while assessing the accuracy of variables, it is necessary to account for both random and systematic errors included in the observations (BAGOZZI ET AL., 1991). The mistakes in the 1st generation approaches are inadequate in accurately explaining the reality (HAENLEIN & KAPLAN, 2004).

4.9 Approaches of Structural Equation Modeling

The two methodologies commonly used to estimate the parameters of Structural Equation Modelling (SEM) are the covariance-based approach (CB-SEM) and the variance-based approach (VB-SEM). To reduce the disparity between the observed covariance and the expected covariance based on the theoretical model, CB-SEM employs the maximum likelihood (ML) method. The ML function can be utilized if the data distribution adheres to the normality assumption of CB-SEM. The reference is from the work done by URBACH & AHLEMANN (2010). Additionally, it is recommended to have a higher sample size of at least 200 to 800 cases for CB-SEM, as suggested by CHIN (2010).

The study utilized VB-SEM to estimate the model's parameters by analyzing loadings and path values. The objective was to minimize the discrepancy between the sample covariance and the covariance values predicted by the theoretical model. Thus, this procedure intends to reduce the covariance matrix of the observed measurements' overall suitability (URBACH & AHLEMANN, 2010). CV-SEM is designed to test a theory and is most appropriate for confirmatory research (GEFEN ET AL., 2000). PLS-SEM is a structural equation modelling (SEM) that is based on variance analysis. PLS-SEM is the primary method used when the study objectives involve predicting and explaining the variation of important target components using several explanatory constructs (HAIR ET AL., 2014). PLS-SEM prioritizes maximizing the amount of variation in the dependent variable that is accounted for by the independent variable rather than focusing on the covariance, which explains the link between items.

Thus, the present study utilized PLS-SEM to analyze and interpret the data. The following Table 6 provides an overview of both CV-SEM and variance-based SEM, as well as their practicality.

Table 6: Comparison between PLS-SEM and CB-SEM

Criteria	PLS-SEM	CB-SEM (AMOS)
Objective	Prediction oriented	Parameter oriented
Approach	Variance-based	Covariance-based
Assumption	Predictor specification (nonparametric)	Typically, multivariate normal distribution and independent observation (Parametric).

Parameter estimation	Consistent as indicators and sample size increase (i.e., consistency at large)	Consistent
Latent variable scores	Explicitly estimated	Indeterminate
Epistemic relationship between LV and its measures	There are two ways to model this approach: formative and reflective	This technique always uses reflective indicators while using; on the other hand, the formative mode has its proponents.
Implications	Optimal for prediction accuracy	Optimal for parameter accuracy
Model complexity	Large complexity (e.g., 100 constructs and 1,000 indicators)	Small to moderate complexity (e.g., less than 100 indicators)
Sample size	Power analysis applied to the part of the model that contains the most predictors. A minimum of thirty to one hundred examples is suggested.	The ideal range for basic recommendations is two hundred to eight hundred, as determined by power analysis of certain models.
Type of optimization	Locally iterative	Globally iterative
Significant tests	Only by means of simulations; restricted validity	Available
Availability of global goodness of fit (GOF)	Are currently being developed and discussed	Established GOF metrics available

Source: CHIN (2010)

4.10 Evaluation of PLS Path Model Results

According to HAIR ET AL. (2017), the estimate and interpretation of the PLS path model are two-step processes that entail a distinct evaluation of the measurement model, which is also referred to as the outer model, and the structural model, which is referred to specifically as the inner model.

4.10.1 Measurement Model

When evaluating the measurement model, the primary focus is on determining the reliability and validity of the measurement items. When evaluating the reliability and validity of a measurement model, it is important to evaluate four criteria. These criteria include:

1. Composite reliability, which measures the overall reliability of the model.
2. Indicator reliability, which assesses the reliability of individual indicators.
3. Average variance extracted (AVE), which measures the amount of variation captured by the model.
4. The Fornell-Larcker criterion and/or cross-loading, which examine the discriminant validity of the model.

All these abovementioned criteria have been explained in the following Table 7.

Table 7: Explanation of the reliability and validity criteria

Criteria	Explanation
Composite Reliability	Composite reliability (CR) measures the accuracy of the observable factors explaining the latent variable (HAIR ET AL., 2014). Composite reliability serves the same purpose as Cronbach's alpha as an indicator of internal consistency (HAIR ET AL., 2014). Contrary to Cronbach's alpha, which ranks indicators by their reliability when evaluating models, composite reliability is more suited to PLS-SEM (HAIR ET AL., 2014). Researchers consider composite reliability values between 0.7 and 0.9 to be excellent, whereas values between 0.6 and 0.7 are considered adequate for exploratory investigations (NUNNALLY & BERNSTEIN, 1994).
Indicator Reliability/ Factor Loading	HAIR ET AL. (2014) suggested that the reliability of each indication must be considered when evaluating factor loading; specifically, the absolute standardized loading score for each indicator must be more than 0.7.

	Research by HAIR ET AL. (2017), as well as CHIN (2010), recommended that the indicator's reliability loading might be 0.5 and 0.6, respectively.
Convergent Validity	HAIR ET AL. (2014) suggested that convergent validity quantifies the extent to which many items measuring the same variable share a large percentage of variation. The average variance extracted, or AVE, must be met while assessing convergent validity. According to HENSELER ET AL. (2015), HAIR ET AL. (2014) and HENSELER ET AL. (2009), a value of at least 0.5 and above indicates sufficient convergent validity. A recommended value of 0.5 or higher for AVE, the mean-variance extracted for the items loading on a construct, indicates that, on average, more than half of the variances observed in the items were explained by their hypothesized factors, so it is considered sufficient (HAIR ET AL., 2017; HENSELER ET AL., 2009).
Discriminant Validity	Discriminant validity, or the extent to which items separating the constructs measure separate ideas, is the second condition worthy of attention for evaluating the validity of the PLS-SEM method (RAMAYAH ET AL., 2011). The Fornell-Larcker criteria suggested by FORNELL & LARCKER (1981) and cross-loading are two metrics proposed to evaluate discriminant validity (HENSELER ET AL., 2015; HENSELER ET AL., 2009). The square root of the AVE for a given construct should be greater than the correlational values of that construct with other constructs, according to the Fornell-Larcker criterion, which suggests comparing the correlations between constructs and the AVE for that construct (CHIN, 2010). In order to establish discriminant validity, the second criterion, which is based on cross-loading, requires that each indicator's loading be higher than the sum of its cross-loading (GÖTZ ET AL., 2009). In other words, discriminant validity was determined when the loading of an indicator concerning the associated latent concept was greater than the loading of all the other constructs.

4.10.2 Structural Model

Researchers must consider many criteria while assessing the structural model through Partial Least Squares software to determine the link between the latent variables proposed in the research model, like the approach used in the measurement model (DUARTE & RAPOSO, 2010). In this regard, CHIN (2010) indicated that once the in-corporateness of the measure has been developed, it is crucial to provide data that supports the theoretical model, namely the structural element or portion of the model.

However, All the determination of coefficient, bootstrapping, and predictive relevance have been explained in the following Table 8.

Table 8: Determination of coefficient, Bootstrapping, and Predictive Relevance

Criteria	Explanation
Determination of Coefficient (R^2)	According to HAIR ET AL. (2017), the degree of significance of the path coefficients and the coefficient of determination (i.e., R^2) are crucial assessment criteria for structural models because they provide clarity regarding the variance of dependent or endogenous latent variables. Since the goal of the PLS-SEM utilization method is to elucidate the endogenous latent variance, attaining a larger R^2 is crucial. Regarding this, R^2 values of 0.02-0.12 indicate weak; 0.13-0.25 indicate moderate; and 0.26 and above indicate considerable, which criteria have been proposed by CHIN (2010).
Bootstrapping Analysis	The present research has evaluated the structural model's path coefficients and performed a bootstrapping analysis to determine the path coefficients' statistical significance. According to CORDEIRO ET AL. (2010), bootstrap is a resampling approach that involves repeatedly random sampling and replacing the original sample to create a bootstrap sample and provide standard error for testing hypotheses. The bootstrap technique is a nonparametric method for evaluating the accuracy of the PLS estimates (CHIN, 2010). Through the utilization of bootstrapping approaches, each route coefficient's significance can be determined. A

	significant path that exhibits the hypothesized direction empirically supports the postulated causal link and vice versa (HAIR ET AL., 2017).
Predictive Relevance (Q^2)	The Stone-Geisser test of predictive relevance (Q^2) is a further PLS-SEM analysis. According to DUARTE & RAPOSO (2010), this type of test is regarded as an extra evaluation of model fit in the PLS analysis. A measure of how successfully the model and its parameter estimations reproduce observed values is shown by the Q^2 (CHIN, 2010). A model is considered predictively relevant when its Q^2 value is larger than zero (0), whereas models with a Q^2 value below zero can be considered as less predictively relevant (FORNELL & CHA, 1994). For assessing predictive relevance, cross-validated (CV) redundancy and communalities are the two forms of Q^2 statistics. The cv-communality evaluates the quality of the measurement model and examines the path model's ability to predict the manifest variables directly from their latent variable scores. Conversely, CV-redundancy, which is a measure of the structural model's quality, quantifies the model's capacity to predict the endogenous manifest variables indirectly via the use of latent variables that forecast the relevant block (TENENHAUS ET AL., 2005).

In summary, this chapter provides a comprehensive review of the study design, population, sample, and size of the sample, as well as the design of the questionnaire, the processes for data collecting, and the methodologies for data analysis that were used in this research. A discussion of the results of the analysis conducted to validate the hypotheses that were presented in the previous chapter will take place in the next chapter. PLS-SEM techniques are used in order to empirically examine the causal relationships among variables that were postulated in this research investigation. This approach is utilized in order to accomplish the research objectives of the present study.

5. FINDINGS OF THE ANALYSIS

5.1 Introduction

The current chapter reports the findings of the data analysis and hypothesis testing of the study. Data analysis starts with descriptive statistics, where the characteristics of the respondents were explained. Later, Harman single factor test was conducted to examine the common method variance (CMV). After assessing the acceptability of the data set based on the CMV, the research framework was examined using SMART-PLS 4 software. In this phase, both measurement and structural model were reported. In the measurement model both reliability and goodness of measure were assessed and in the structural model path coefficient, determination of R^2 and hypothesis testing were reported. Lastly, this chapter demonstrates the hypothesis results of the studied variables of the current research.

5.2 Response Rate

Table 9 clarifies the response rate of the current research. In total 500 questionnaires were disseminated from the different mining organizations. Among these 500 questionnaires 407 questionnaires were returned within two months duration, where 21 questionnaires were found incomplete and not acceptable. Therefore, the usable questionnaires were found 386 that were suitable for data analysis with a response rate of 77.2%. In this regard, HAIR ET AL. (2017) recommended that in case of PLS-SEM analysis, a minimum of 100 sample size is suitable for getting accepted outcome. In support to that previously, in the context of Mongolia, KIM ET AL. (2016) could attain 74.1% response rate for their research and found suitable outcome. Therefore, from the previous explanation 386 sample size for the current study is considered acceptable.

Table 9: Response Rate of this study

Questionnaire	Number	Percentage
Distributed Questionnaires	500	
Returned Questionnaires	407	81.4%
Usable Questionnaires	386	77.2%
Unusable Questionnaires	21	4.2%

5.3 Profile of Respondents

The current section talked about the demographic profile of the respondents. The demographic section covers the gender of the respondents, marital status, age of the respondents, educational qualification of the respondents, experience of the respondents in the present organization, and experience of the respondents in the industry. The following table provides detailed information of the respondent's demographic information of the current study.

Table 10: Descriptive Analysis of Respondents' Demographic Data

Demographic Data	Frequency (N= 275)	Percentage (%)
Gender		
Male	264	68.4
Female	122	31.6
Total	386	100%
Age		
16-25 years	56	14.5
26-35 years	88	22.8
36-45 years	132	34.2
46-55 years	91	23.6
56 years and above	19	4.9
Total	386	100%
Marital Status		
Single	71	18.4
Married	275	71.2
Divorced	32	8.3
Widowed	8	2.1
Total	386	100%
Educational Qualification		
Below Secondary	6	1.6
Secondary (SSC)	30	7.8
College diploma	78	20.2
Bachelor	216	56.0
Master	51	13.2
PhD	5	1.2
Others		
Total	386	100%
Total Experience in Current organization		
01 – 05	160	41.5
05 – 10	108	28.0
10 – 15	77	20.0
More than 15	41	10.5

Total	386	100%
Industry Experience		
01 – 05	62	16.1
05 – 10	78	20.2
10 – 15	131	33.9
More than 15	115	29.8
Total	386	100%

5.4 Prevention from data collection bias

PODSAKOFF ET AL. (2003) defined common method bias as any bias resulting from the measuring technique used. Common method variance may originate from many sources, including the context of a shared indicator, a common evaluator, a uniform measurement setting, or intrinsic attributes of the indicators themselves (PODSAKOFF ET AL., 2003). In this context, CARLSON & HERDMAN (2012) posited that the presence of CMV may result in an amplification of the correlations across variables and convergent validity. PODSAKOFF ET AL. (2003) subsequently recognized CMV as a substantial contributor to measurement inaccuracy, error, or issues. Nonetheless, CMV-related concerns might be resolved using either a procedural solution or a statistical methodology. Several procedural remedies are acknowledged in the discipline, including the use of distinct scale anchors for multiple dimensions, the implementation of proximal, methodological, or psychological separation, the collection of data on dependent and independent variables at different time intervals, counterbalancing survey items, and analogous strategies.

Numerous statistical techniques exist for assessing Common Method Bias (CMB), with the best recognized being Harman's single-factor test, the partial correlation approach, the management of measurable latent factors, the regulation of unmeasured latent variables, and the application of multiple method factors. To overcome the issues related to CMV, this research has included many procedural remedy strategies, including the use of proximal and methodological separation procedures as advised by Podsakoff et al. (2003). The poll included many factors, each with specific measurement requirements to ensure that the impression of one variable remained unaffected and unbiased by the others. Diverse scale kinds or anchors were used to assess the predictor and criteria variables. The endogenous variable, sustainable performance, will be evaluated on a seven-point Likert scale, with answer options spanning from '1' (strongly disagree) to '7' (strongly agree). The exogenous variable, green supply chain management, and the mediating variable, circular economy, will be assessed using a five-point Likert scale, ranging from 1

(strongly disagree) to 5 (strongly agree). In prior research, RAMAYAH ET AL. (2014) used two different scale formats to evaluate their independent and dependent variables and mitigate frequent technique biases.

The investigator of this study will use Harman's single-factor test, a commonly utilized statistical solution, to identify prevalent technique bias. PODSAKOFF ET AL. (2003) advised that researchers include all items under examination to do an un-rotated exploratory factor analysis, while adhering to a fixed factor count of one. If a single factor accounts for less than 50 percent of the variation, it may be inferred that common method bias is not present in the measurement approach or dataset.

In this study, the researcher addresses this potential biasness problem, Harman Single factor test was employed. Factor one accounted for only 34.29 percent of the variance, thus common method was not a persistent dilemma in this study. Since a single factor did not emerge and the first factor did not account for most of the variance, therefore this study concludes that the common method bias was not a major concern in this study.

The next section of this study reveals other related descriptive statistics and the analysis obtained by PLS method. The following Table 11 represents the results from Harman's Single factor test.

Table 11: Harman's Single factor test: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.486	34.289	34.289	5.486	34.289	34.289
2	2.933	18.334	52.623			
3	2.237	13.979	66.601			
4	1.025	6.403	73.005			
5	.650	4.066	77.070			
6	.597	3.733	80.803			
7	.488	3.052	83.855			
8	.434	2.712	86.567			
9	.415	2.594	89.162			

10	.327	2.045	91.207			
11	.311	1.943	93.150			
12	.298	1.862	95.012			
13	.265	1.657	96.669			
14	.231	1.446	98.115			
15	.166	1.035	99.150			
16	.136	.850	100.000			

Extraction Method: Principal Component Analysis.

Subsequently, KOCK (2015) proposed that Variance Inflation Factor (VIF) values obtained from an extensive collinearity test might indicate pathological collinearity and a potential intrusion of a model by common method bias. If all the VIF values derived from SEM analysis in the inner model are less than or equal to 3.3, it indicates that the model does not possess any common method bias (KOCK, 2015). Thus, based on the VIF values shown in Table 12, this study is not affected by common methos bias.

Table 12: VIF values

	CEP	GI	GTA
CEP			
GI	1.124		
GTA	1.124	1.000	

5.5 Goodness of Measurement Model

The introductory part of assessing the model is to explain the measurement model and the elements of the given model. Based on the reliability and validity of the constructing measurement items, the quality of measurement model was measured. Both theoretically and statistically the measurement items of all the variables in this study are reflective. Within the variables all of the items have been checked and obtained to be highly correlated with each other. The reflective measurement model must be highly inter-correlated with each other and theoretically be manifested by the variables suggested by DIAMANTOPOULOS & SIGUAW (2006). “Reflective

measurement model should be assessed to interpret their reliability and validity” (HAIR ET AL., 2014).

Therefore, considering the above issues, here, the measurement model was assessed by examining the internal consistency, reliability (composite reliability), indicator reliability (individual loading), (AVE) and discriminant validity, which have also been suggested by (HAIR ET AL., 2014).

5.6. Assessing Measurement Model

5.6.1 Convergent Validity

For measuring the same concept, multiple items are used to see if they are similar. The extent to this similarity is referred to as convergent validity (RAMAYAH ET AL., 2011). There are many ways to find the convergent validity (HAIR ET AL., 2014) among item measures like average variance extracted (AVE), composite reliability and factor loadings. The following Figure 4 shows the PLS generated model before conducting the CFA.

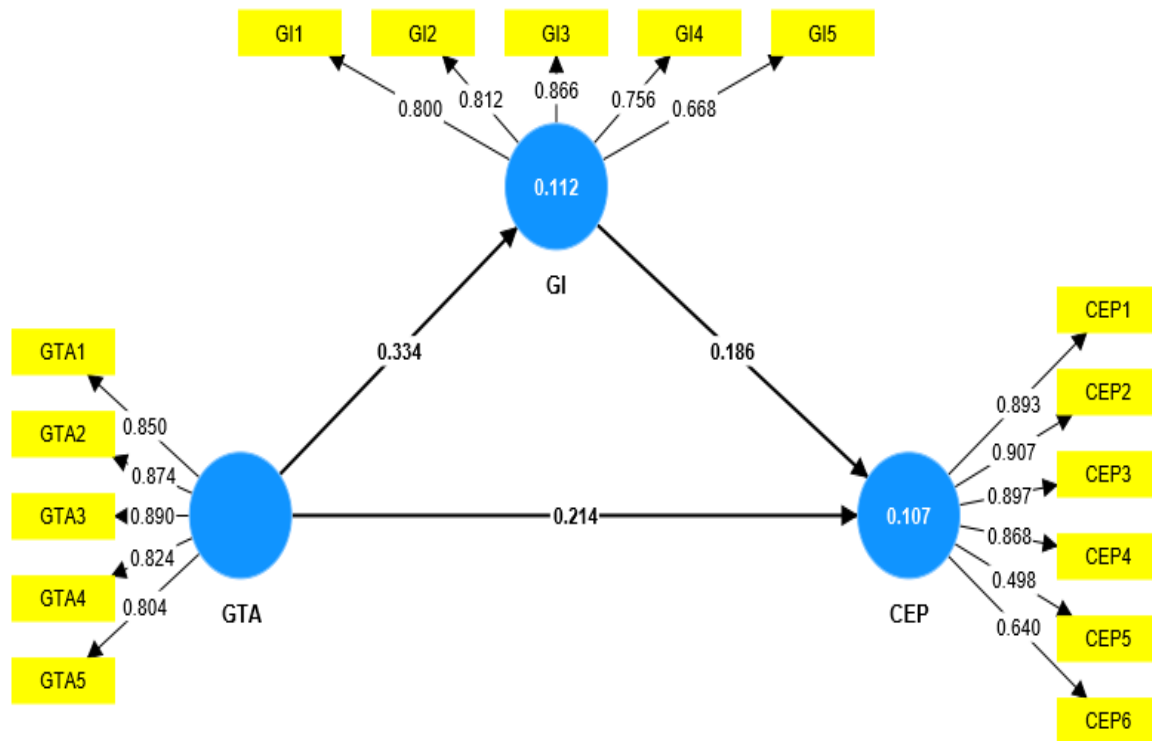


Figure 4: PLS generated model before conducting the CFA

Keeping this in view, a minimum cutoff point of 0.7 was applied for the loading scores according to the recommendation by HAIR ET AL. (2017). It was found to be significant based on the results found in Table 13. Three items that were deleted because of poor loading score i.e., below 0.7 such as GI5 (0.668), CEP5 (0.498), and CEP6 (0.640). Now, the AVE values of the variables are analyzed. In this case, AVE values must have above mentioned value of 0.5 or higher loading according to the recommendation by CHIN (2010). In Table 13, the AVE for every variable found in the study is available. The value of composite reliability (CR) was above 0.7 which is acceptable by the recommendation of HAIR ET AL. (2017). The range of 0.889 to 0.945 was found to be significant composite reliability. So, this study covers all the criteria required for convergent validity.

The following Table 13 represents the summary of the validity and reliability of the latent variables (constructs).

Table 13: Results of Measurement Model

Constructs	Measurement Items	Loading	AVE	CR	Cronbach's Alpha
Green Technology Adaptation	GTA1	0.852	0.721	0.928	0.903
	GTA2	0.875			
	GTA3	0.890			
	GTA4	0.823			
	GTA5	0.804			
Green Innovation	GI1	0.832	0.667	0.889	0.834
	GI2	0.830			
	GI3	0.840			
	GI4	0.763			
Circular Economy Performance	CEP1	0.899	0.810	0.945	0.922
	CEP2	0.913			
	CEP3	0.908			
	CEP4	0.879			

The following Figure 5 shows the PLS generated model after conducting the CFA (removing the poor loading values):

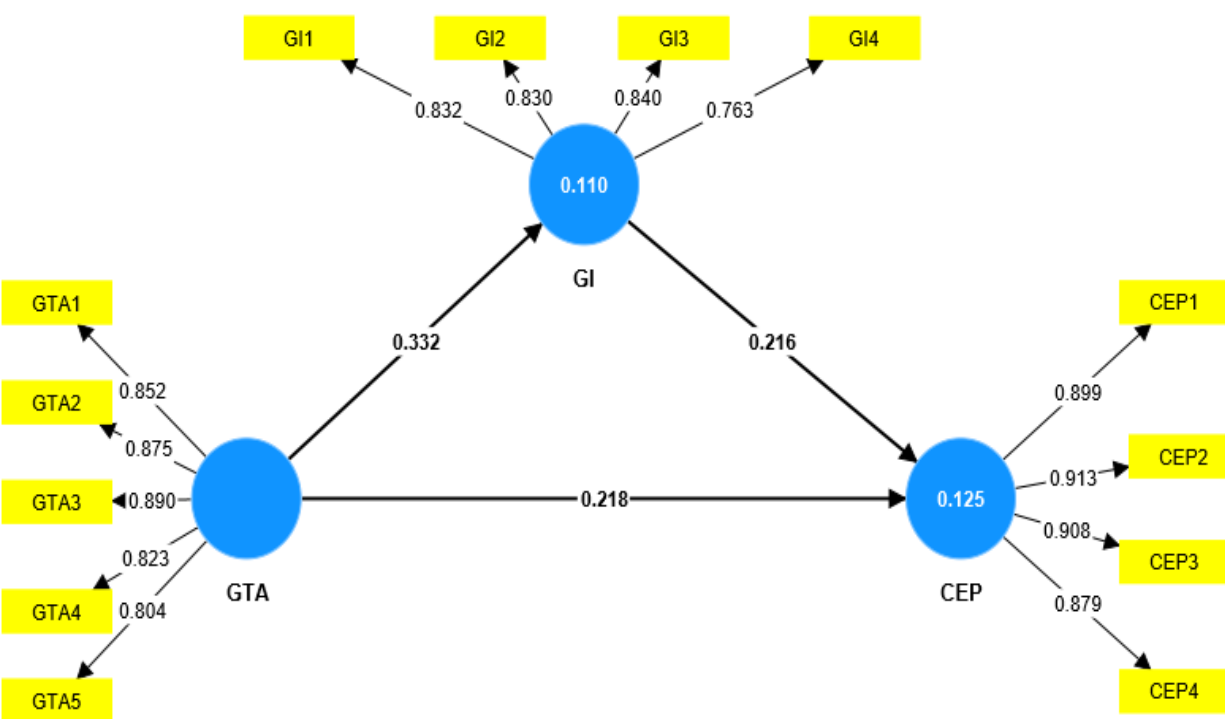


Figure 5: PLS generated model after conducting the CFA

Additionally, the range of 0.834 to 0.922 of the Cronbach's Alpha values was found to be acceptable for the reliability of the variable of this study recommended by CHIN (2010). The following Figure 6 shows the accepted level of Cronbach's Alpha values in this study.

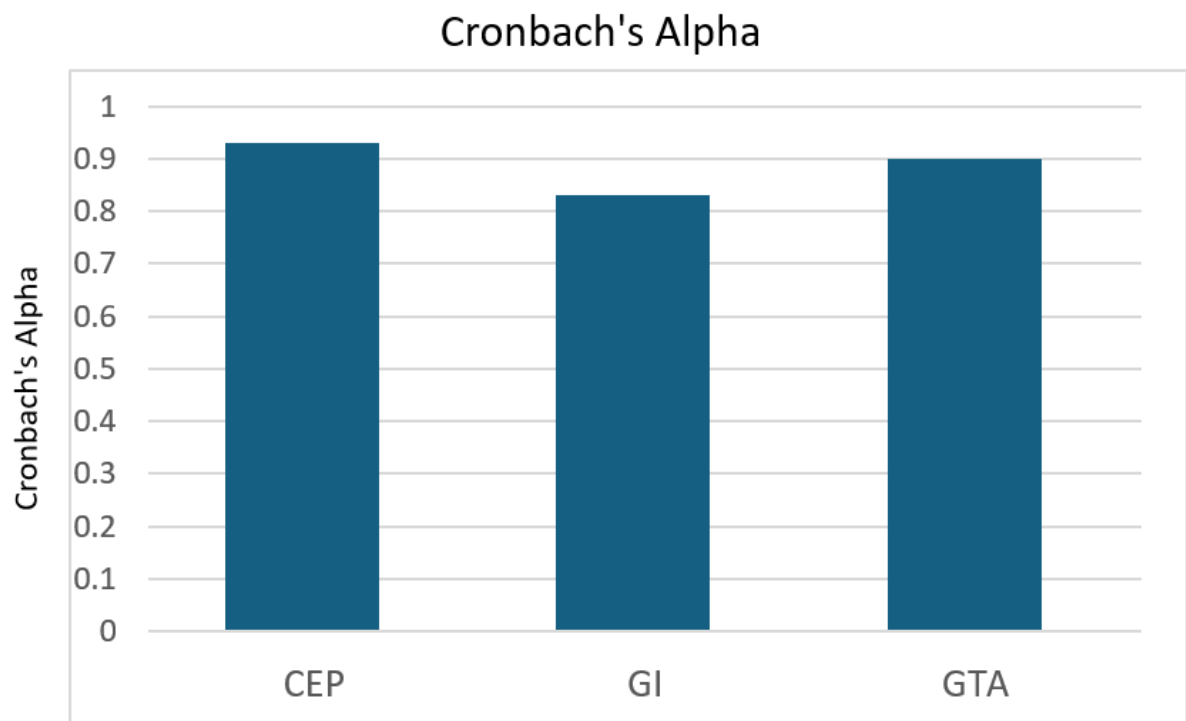


Figure 6: Cronbach's Alpha values of the variables

Moreover, Figure 7 below represents the composite reliability bar chart including the AVE values.

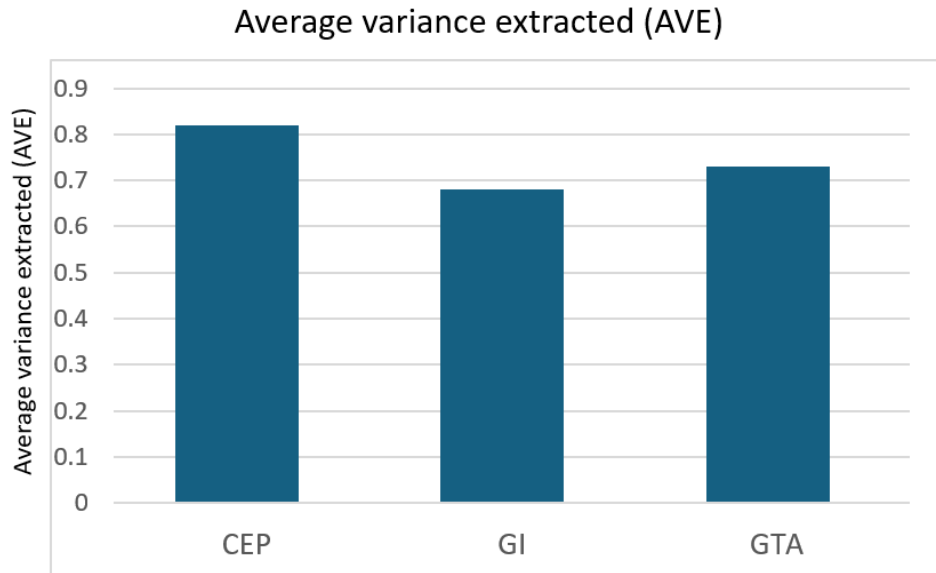


Figure 7: Composite reliability bar chart including the AVE values

5.6.2 Discriminant Validity

The discriminant validity is the extent to which a variable is truly distinct from other constructs (HAIR ET AL., 2014). According to RAMAYAH ET AL. (2011) discriminant validity of the measures was assessed by examining the correlations between the measures of potentially overlapping constructs. To address discriminant validity, the two methods that have put forward to determinant the constructs' discrimination validity is; the cross loading and Fornell-Larcker criterion.

Fornell-Larcker criterion was employed to ensure the discriminant validity of the model. In this criterion the square root of AVE is compared against the correlations of the other constructs (FORNELL & LARCKER, 1981). As shown in Table 14 the calculated value of AVE exceeds the inter-correlations of the diagonal constructs with the other off-diagonal constructs ensuring adequate discriminant validity.

Therefore, the results of the analysis of Table 14 below reveal that the measurement model of this study fulfills adequate discriminant validity.

Table 14: Fornell-Larcker Correlation Check

	CEP	GI	GTA
CEP	0.900		
GI	0.288	0.817	
GTA	0.289	0.332	0.849

***Note:** Diagonals (in bold) represent the squared root of the average variance extracted (AVE) while the other entries represent the correlations. GTA = Green Technology Adaptation, GI = Green Innovation, CEP = Circular Economy Performance.*

However, HENSELER ET AL. (2015) suggested that the Heterotrait-monotrait Ratio (HTMT) criterion shows better empirical results when assessing discriminant validity than the Fornell-Larcker criterion. Based on the recommendation of HENSELER ET AL. (2015), Table 15 below shows that all HTMT values of this study were below the threshold of 0.850, proving adequate discriminant validity.

Table 15: HTMT values of this study

	CEP	GI	GTA
CEP			
GI	0.322		
GTA	0.310	0.375	

***Note:** GTA = Green Technology Adaptation, GI = Green Innovation, CEP = Circular Economy Performance.*

Moreover, Figure 8 below represents the HTMT values of this study in a bar chart presentation.

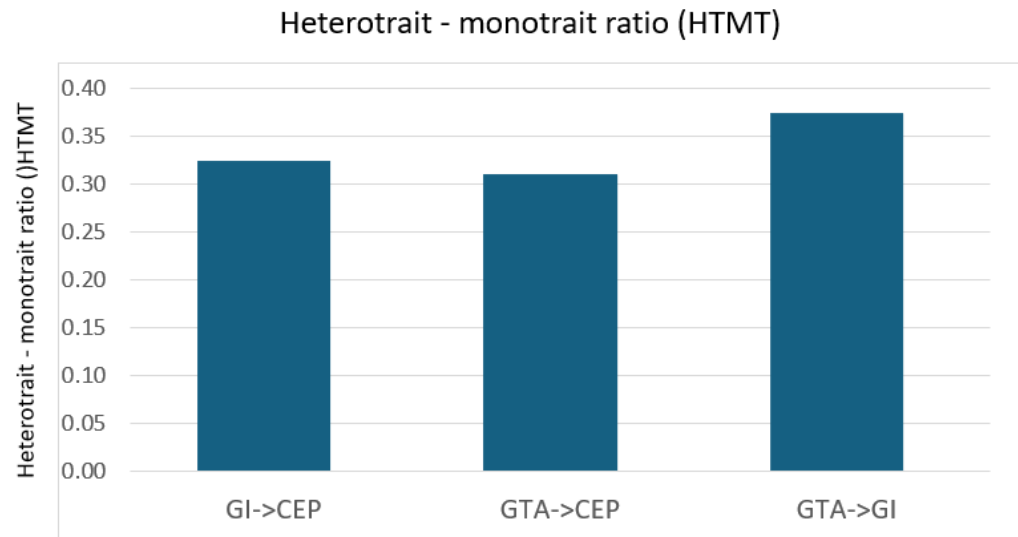


Figure 8: HTMT values of this study in a bar chart presentation

5.7 Assessing Structural Model

5.7.1 Direct Effect

A relationship between latent variables or constructs which are hypothesized in research models is represented through the structural model (DUARTE & RAPOSO, 2010). Main objective of PLS is prediction (HAIR ET AL., 2014). Through the variance that is explained (R^2) of the endogenous constructs and the importance of all path estimates, the principle of the theoretical model is understood (CHIN, 2010). After determining the path estimates, a bootstrap analysis was applied to find out the statistical significance of path coefficient. According to CHIN (2010), 500 re-samplings are recommended while using bootstrapping for estimating parameters. But according to HAYES (2009), at least 1000 re-sampling is recommended though 5000 re-sampling is alright for bootstrapping. In this study, 1000 re-samplings were applied for bootstrapping analysis to examine the significance of regression coefficients.

Here, there was one dependent variable i.e., circular economy performance having R^2 value 0.125 (moderate) and one mediating variable i.e., green innovation showing R^2 value 0.110 (weak). According to COHEN (1988), this value of R^2 can be taken as moderate because he recommended R^2 having range 0.02 – 0.12 as weak, 0.13 – 0.25 as moderate and 0.26 and above as substantial.

The value of R^2 for dependent variable i.e., circular economy performance having R^2 value 0.125. This suggested that green technology adaptation explains 12.5% of the circular economy performance. On the other hand, the value of R^2 for mediating variables, i.e., green innovation having R^2 value 0.110. This suggested that green technology adaptation explains 11% of the green innovation. The following Table 16 shows the R^2 and adjusted R^2 values of the dependent variables.

Table 16: R^2 and adjusted R^2 values

Variable	R^2 value	Adjusted R^2
CEP	0.125	0.121
GI	0.110	0.108

Additionally, Figure 9 shows the R^2 value bar chart and Figure 10 represents the adjusted R^2 value bar chart.

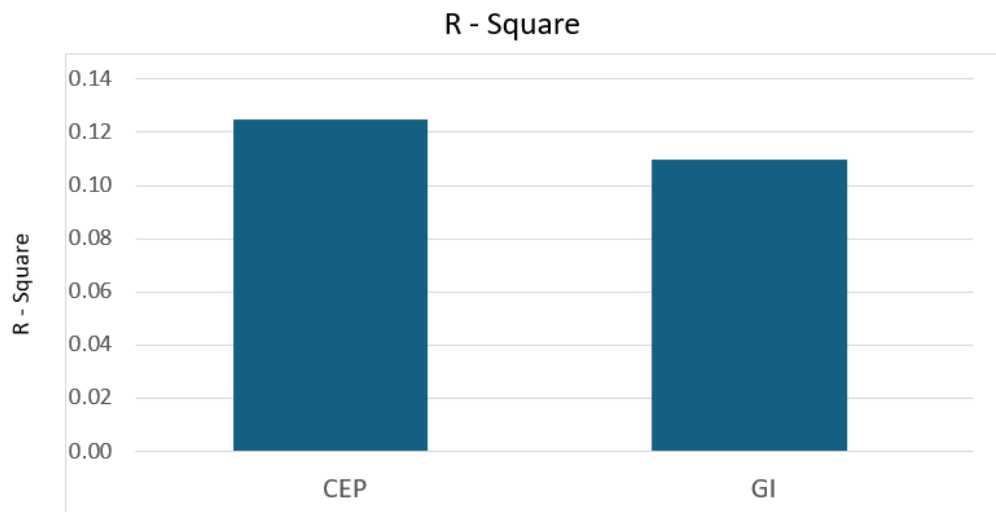


Figure 9: R^2 value bar chart

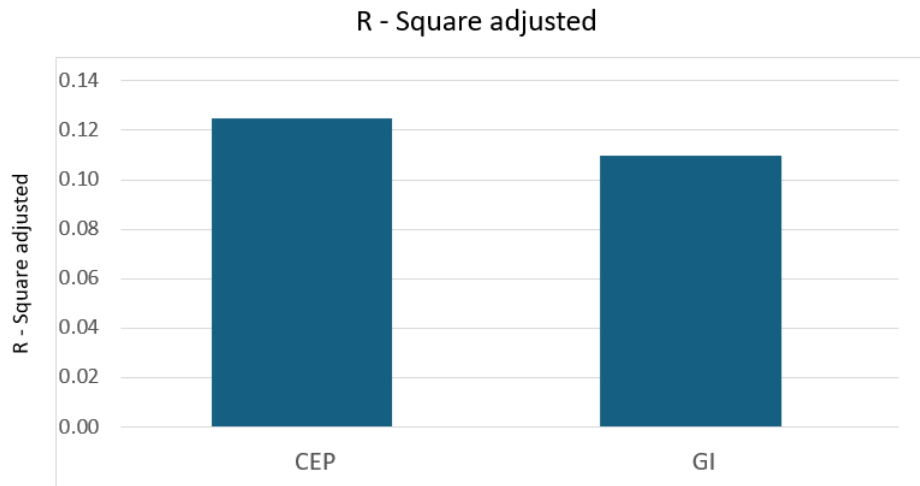


Figure 10: Adjusted R² value bar chart

Moreover, in this study, blindfolding technique was applied using omission distance 7 to assess the path model's predictive relevance. It was found that Stone-Geisser's Q² value (STONE, 1974; GEISSER, 1975) for both the endogenous constructs were above zero ($Q^2_{CEP} = 0.095$ and $Q^2_{GI} = 0.070$) in Table 17 below, indicating acceptable cross validated predictive relevance of the path model.

Table 17: Q² values

Variable	Q ² value
CEP	0.095
GI	0.070

Analysis showed that GTA to CEP ($\beta = 0.218$; $p < .05$; T value 4.048; P values 0.000) is positive and statistically significant. Therefore, H1 is strongly significant. Similarly, GTA to GI ($\beta = 0.332$; $p < .05$; T value 7.125; P values 0.000) is positive and statistically significant. Therefore, H2 is strongly significant. On the other hand, GI to CEP ($\beta = 0.216$; $p < .05$; T value 4.571; P values 0.000) is positive and statistically significant. Therefore, H3 is also strongly significant. Based on the above outputs, this study confirms that greater degree of green technology adaptation leads to higher degree of circular economy performance by the mining organizations in Mongolia. On the

other hand, favorable perception about green technology adaptation leads to higher degree of green innovation by the mining employees in Mongolia. Additionally, greater degree of green innovation leads to higher degree of circular economy performance by the mining organizations in Mongolia. Table 18 shows the results of direct hypotheses test.

Table 18: Results from Hypotheses Testing (Direct Effects)

Hypotheses	Paths	Std. Beta	Std. Error	T Statistics	P Values	2.5% LLCI	97.5% ULCI	VIF	Decision
H1	GTA → CEP	0.218	0.216	4.048	0.000	0.109	0.312	1.124	Significant
H2	GTA → GI	0.332	0.337	7.125	0.000	0.241	0.419	1.000	Significant
H3	GI → CEP	0.216	0.224	4.571	0.000	0.129	0.313	1.124	Significant

Notes: *GTA* = *Green Technology Adaptation*, *GI* = *Green Innovation*, *CEP* = *Circular Economy Performance*.; *VIF* = *Variance Inflation Factor*; *LLCI* = *Lower Limit Confidence Interval*; *ULCI* = *Upper Limit Confidence Interval*; *S* = *Supported*

Additionally, the following Figure 11 shows the PLS generated structural model with p values.

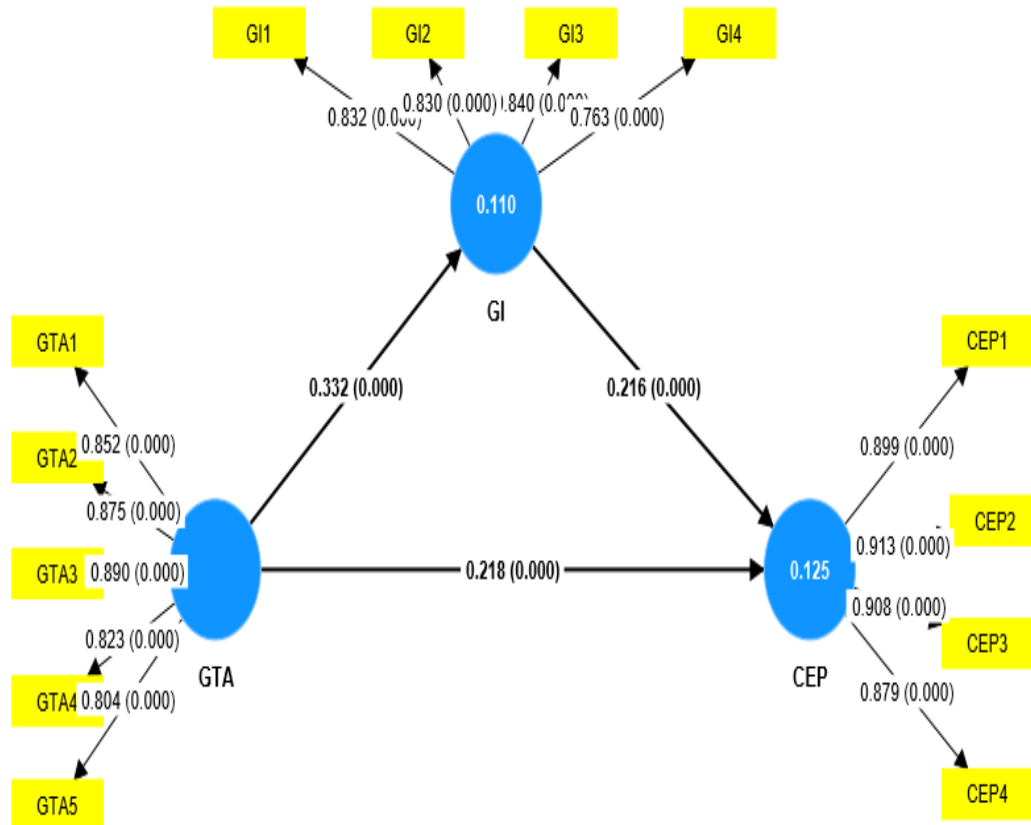


Figure 11: PLS generated structural model with p values

Moreover, the following Figure 12 shows the PLS generated structural model with t values.

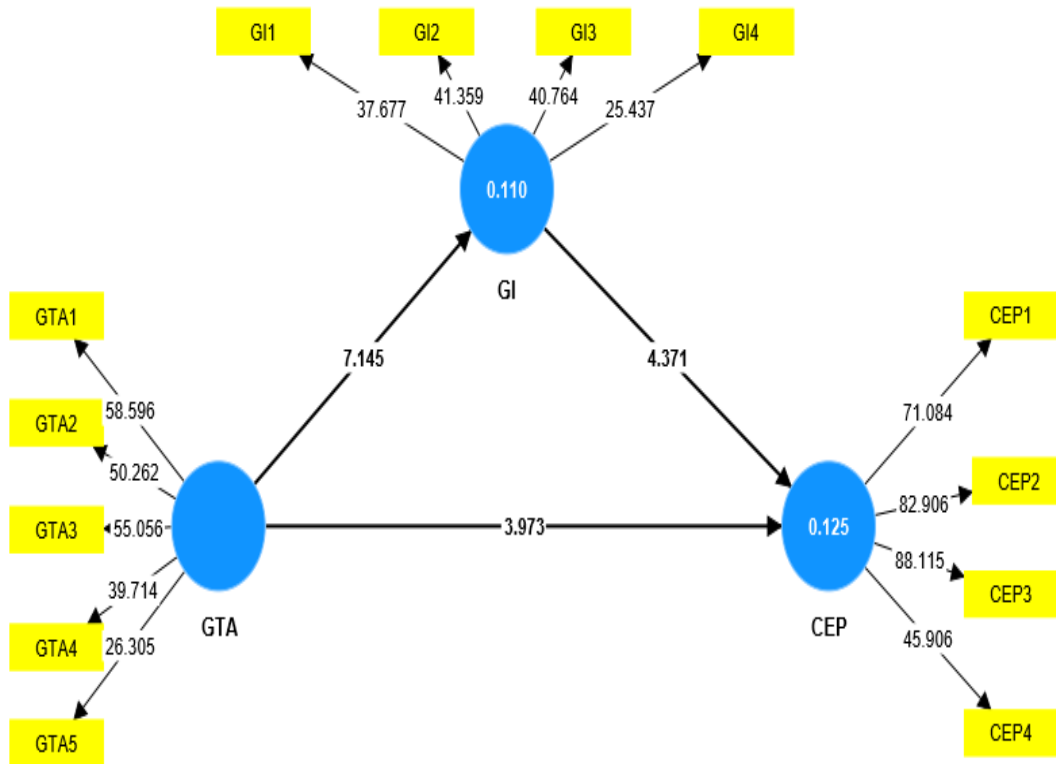


Figure 12: PLS generated structural model with t values

5.7.2 Indirect Effect

However, the analysis of this study further shows that the indirect relationships between GTA to GI to CEP ($\beta = 0.072$; $p < .05$; T value 3.346; P values 0.000) is positive and statistically significant. Therefore, H4 is strongly significant. This result represents that GI is partially mediating between GTA and CEP. Table 19 below shows the results from indirect hypothesis testing.

Table 19: Results from Hypotheses Testing (Indirect Effect)

Hypotheses	Paths	Std. Beta	Std. Error	T Statistics	P Values	2.5% LLCI	97.5% ULCI	Decision
H4	GTA → GI → CEP	0.072	0.076	3.346	0.001	0.037	0.120	Significant

Notes: GTA = Green Technology Adaptation, GI = Green Innovation, CEP = Circular Economy Performance.; VIF = Variance Inflation Factor; LLCI = Lower Limit Confidence Interval; ULCI = Upper Limit Confidence Interval; S = Supported

5.8 Summery of the Results

The results of the hypothesis are summarized in Table 20. A total of 4 hypotheses were tested and all were supported. The findings from all analysis were deliberated after the data presentation.

Table 20: Summary of Hypotheses Test Results

Hypothesis	Direct Path	Decision
H1	Green Technology Adaptation → Circular Economy Performance	Significant
H2	Green Technology Adaptation → Green Innovation	Significant
H3	Green Innovation → Circular Economy Performance	Significant
H4	Green Technology Adaptation → Green Innovation → Circular Economy Performance	Significant

In the quantitative part, profile of the respondents of the mining organizations in Mongolia was presented. Measurement model, the structural model, was assessed to test the hypotheses of this study. The results postulate empirical evidence supporting significant liner relationship between Green Technology Adaptation, Green Innovation, and Circular Economy Performance. All the four hypotheses were found significant out of four.

5.9 Discussion

RQ-1: Does green technology adaptation have a relationship with circular economic performance?

The first findings of this research indicate a positive relationship between the green technology adaptation and the performance of the circular economy. The first outcome of this investigation revealed a substantial positive correlation between the adoption of green technology and circular economic performance. Previous research likewise yielded a similar outcome. In the study on green technology adaptation conducted by Khan et al. (2023), the researchers elucidated that green technologies facilitate companies in optimizing resource use via creative solutions, including renewable energy systems, precision agriculture, and smart manufacturing. The use of energy-efficient technology reduces fossil fuel usage while improving production. The authors identified favorable correlations between the use of green technology and performance centered on the circular economy. Their research revealed that the progression of green technologies corresponds

with circular economic performance by reducing resource extraction and optimizing the utilization of inputs for extended periods.

Similar research conducted by Tanveer et al. (2022) showed that the use of green technology enhances operating efficiency and prolongs the lifespan of goods and materials, thereby minimizing waste. This optimization immediately enhances performance through the circular economy, fostering resource circularity and sustainability. A fundamental principle of circular economic performance is to reduce waste production. Green technologies enable this objective by offering novel approaches to reducing and managing waste. Advanced recycling methods, including chemical and mechanical recycling, allow the extraction of high-quality materials from intricate waste streams. Furthermore, biodegradable materials and eco-design principles guarantee that items may be reused, recycled, or organically degraded without causing environmental damage.

Nonetheless, SHAH & DAS (2024) reported an outcome comparable to that of the current study. The authors emphasized that the use of green technologies, including modular design and additive manufacturing, facilitates quicker disassembly and material recovery. These strategies reduce reliance on landfills, preserve natural resources, and promote sustainable production cycles, hence improve organizational performance grounded on a circular economy. Green technologies facilitate the effective recovery of value from end-of-life goods and industrial by-products. Technologies such as pyrolysis, anaerobic digestion, and sophisticated sorting systems guarantee the extraction of valuable materials and energy from waste streams. This improves performance aligned with the circular economy by converting trash into a resource and reducing dependence on new resources.

Conversely, ISLAM ET AL. (2023) contended that the implementation of low-carbon and resource-efficient technologies is essential for attaining the environmental objectives and efficacy of the circular economy. The authors said that linking economic development with environmental sustainability enables green technology to establish resilient industrial systems that harmonize ecological, economic, and social concerns. For instance, the adoption of electric vehicles (EVs) and their widespread use in transportation reduces emissions and enhances energy efficiency. Moreover, sustainable water management technologies, such as water recycling systems and desalination facilities powered by renewable energy, are essential for mitigating water shortages.

In supporting the present result, ALI ET AL. (2024) indicates that if the organization treats wastewater as any circular process, and returns it to the production cycle, these technologies support the circular economic performance by maximizing resource utility while minimizing waste. Beyond environmental benefits, green technology adaptation fosters significant social and economic advantages that align with circular economic performance goals. The development and deployment of green technologies create new job opportunities in renewable energy, sustainable agriculture, and green manufacturing sectors. This contributes to economic resilience while supporting social inclusion and equitable growth. For example, renewable energy projects in rural areas provide employment opportunities and access to affordable, clean energy, reducing energy poverty and promoting sustainable development. Moreover, the adoption of green technologies in urban settings, such as smart grids and energy-efficient buildings, enhances urban resilience and improves the quality of life for residents.

On the other hand, LIM ET AL., (2022) highlighted that the environmental costs of mining these materials often outweigh the benefits of the technologies they enable, especially when the production processes are not aligned with circular economic performance. The carbon footprint and ecological impact of extracting rare materials, coupled with the geopolitical complexities of their supply chains, present significant barriers to achieving resource circularity. Moreover, the rapid pace of green technology innovation exacerbates resource consumption. Each new generation of technology demands different materials, often rendering older systems obsolete and increasing the demand for virgin resources. This cycle contradicts the circular economic performance aim of reducing dependency on finite resources and extending the lifecycle of products and materials.

However, a critical component of circular economic performance is the ability to recycle and recover materials from products at the end of their lifecycle (TANVEER ET AL., 2022). However, many green technologies pose significant challenges in this area. For instance, wind turbine blades, composed of complex composites, are notoriously difficult to recycle, often ending up in landfills. Similarly, the recycling of lithium-ion batteries from EVs remains inefficient and costly, with current technologies unable to recover all valuable materials. Similarly, HAMADA ET AL., (2024) emphasized that the lack of standardized recycling methods and insufficient infrastructure exacerbate these issues. The inability to efficiently recycle green technologies not only leads to

resource wastage but also creates a new category of electronic and industrial waste, undermining the core tenets of circular economic performance.

On the contrary, ISA ET AL. (2021) explored the design of many green technologies that do not prioritize recyclability. For example, the integration of multiple materials in compact designs, while enhancing circular economic product performance, complicates the disassembly and recovery processes. This design flaw underscores the need for greater alignment between green technology innovation and circular economic performance. The high costs associated with adopting green technologies pose significant economic barriers, particularly for small and medium-sized enterprises and developing economies. Renewable energy systems, for example, require substantial upfront investments in infrastructure, including solar panels, wind turbines, and energy storage solutions. These costs often divert resources from other circular economic initiatives, such as developing robust recycling systems or promoting sustainable consumption patterns to attain the circular economic performance.

The findings of ROZHNOV ET AL. (2020) noted that the economic challenges of green technology adaptation are further compounded by the uncertainties associated with long-term returns on investment. Businesses and governments may hesitate to invest in these technologies without clear evidence of their economic viability, delaying the transition to a circular economy. Additionally, the economic benefits of green technologies are often unevenly distributed, favoring developed countries with greater financial and technological capacities. This disparity exacerbates global inequalities, limiting the ability of developing nations to participate in and benefit from circular economic initiatives and performance.

The empirical argument of IVANOVA & CHIPEVA (2021) indicated that rapid evolution of green technologies can lead to issues of obsolescence and technological lock-in. The authors found dissimilar results than the present findings. The researchers claimed that investments in specific technologies may become stranded as newer, more efficient solutions emerge, but it can create significant amounts of waste which ultimately give challenge to the environment. For instance, the replacement of older solar panels with newer, more efficient models generates electronic waste and increases demand for virgin materials to produce the upgraded technology. In this regard, IVANOVA & CHIPEVA (2021) argued that this cycle of obsolescence not only undermines circular economic goals but also creates a false sense of progress. By focusing on the constant

adoption of the latest technologies, industries may neglect simpler, more sustainable solutions and misuse the circular system such as repair, reuse, and refurbishment.

Similarly, ROZHNOV ET AL. (2020) found adverse results than the current finding. The authors claimed that while green technologies aim to reduce environmental impacts, their deployment can lead to unintended trade-offs. For example, bioenergy production from agricultural waste competes with food production, potentially driving up food prices and contributing to food insecurity. Similarly, the large-scale installation of renewable energy infrastructure, such as wind farms and hydropower dams, can disrupt local ecosystems and biodiversity. The results of ROZHNOV ET AL. (2020) highlighted that these trade-offs underscore the need for a more integrated approach to green technology adaptation. Without careful planning and consideration of local ecological and social contexts, these technologies can inadvertently exacerbate environmental challenges. The adoption of green technologies often raises significant social and ethical concerns, particularly in the context of resource extraction. The mining of rare earth elements and critical minerals frequently occurs in developing countries with weak labor and environmental regulations. These practices can exploit vulnerable communities, perpetuate social injustices, and create significant environmental degradation.

On the other hand, KHAN ET AL. (2022) advocated that addressing these ethical concerns is essential for ensuring that green technologies contribute positively to circular economic goals. Without equitable and sustainable practices, the benefits of these technologies may be overshadowed by their social and environmental costs. A common criticism of green technology adaptation is the overemphasis on technological solutions at the expense of systemic changes. While technologies such as renewable energy systems and energy-efficient appliances are important, they cannot replace the need for broader behavioral and policy reforms. For instance, promoting sustainable consumption patterns and reducing overall material use are equally critical for achieving circular economic objectives.

However, SHAH & DAS (2024) explained that reliance on technological fixes can create a false sense of progress, diverting attention from more fundamental changes needed to transition to a circular economy. A balanced approach that integrates technological innovation with cultural, economic, and policy interventions is essential for addressing the root causes of environmental degradation. Scaling green technologies to meet global demands presents significant integration

challenges. Renewable energy systems, for example, require extensive upgrades to existing infrastructure, such as grid modernization and energy storage solutions. These upgrades often involve substantial material and energy inputs, reducing the net environmental benefits of these technologies. The result of SHAH & DAS (2024) highlighted that the fragmented nature of global supply chains further complicates the integration of green technologies into circular economic frameworks. The lack of coordination among stakeholders can lead to inefficiencies, redundancies, and resource wastage, undermining the potential benefits of these technologies.

Finally, the green technology adaptation, while pivotal for addressing environmental challenges, presents several obstacles that can also negatively impact circular economic performance. Resource-intensive development, limited recycling capabilities, technological obsolescence, high costs, and unintended environmental and social consequences highlight the complex relationship between green technologies and circular economic performance. To mitigate these challenges, a more holistic approach is needed. This includes designing green technologies with recyclability in mind, improving recycling infrastructure, addressing social and ethical concerns, and integrating technological innovation with systemic changes. By adopting a balanced and inclusive strategy, the adaptation of green technologies can align more effectively with the goals of the circular economy, fostering a sustainable and equitable future.

RQ2: Has green technology adaptation a relationship with green innovation?

The second result of this study revealed that green technology adaptation has a positive relation with green innovation. In another similar a digital technology-based study conducted by KHAN ET AL. (2022) indicated that green technology adaptation through digital infrastructure can improve traceability and transparency in supply chains. These technologies facilitate better resource tracking and efficient recycling processes, thereby ensuring maximum recovery and reuse of materials. In this regard, KHAN ET AL. (2022) indicated green technology adaptation accelerates innovation; and such innovations are critical for operationalizing circular performance in various sectors. The study of KHAN ET AL. (2022) also found similar results compared to the current research. They identified that green technology adaptation reduces the environmental footprint of economic activities, a critical aspect of green innovation. For instance, renewable energy technologies like solar and wind power replace fossil fuels, lowering greenhouse gas

emissions and combating climate change. Similarly, green chemistry innovations minimize the use of hazardous substances in industrial processes, reducing pollution and safeguarding ecosystems.

In another study, similar findings have been revealed by ÜLKÜ ET AL. (2022) where the authors claimed that green technology adaptation also promotes innovation and competitiveness by encouraging industries to explore new business models, such as product-as-a-service and sharing economies. Besides, these models reduce material consumption while meeting consumer demands, thereby contributing to circular economic performance. The successful integration of green technologies into frameworks for circular economic performance that requires robust policy support and multi-stakeholder collaboration. Governments play a pivotal role by enacting policies that incentivize green technology adoption, such as subsidies for renewable energy projects and tax benefits for eco-friendly businesses. International cooperation and knowledge-sharing platforms further accelerate the adoption of the best practices and innovative solutions. Public-private partnerships are also essential for driving investment in green technologies and scaling up their deployment. Collaborative initiatives between governments, industries, and research institutions can foster the development of cutting-edge technologies and ensure their accessibility to a broader range of stakeholders.

In a similar study with the present result by LIAN ET AL. (2022) advocated that the mining sector in Mongolia, a critical component of its economy, faces significant challenges in adopting sustainable practices. With growing environmental concerns and international pressure to reduce carbon footprints, the integration of green technology and innovation becomes imperative. This discussion explores the effects of green technology adaptation and green innovation on the circular economy performance of Mongolia's mining sector, synthesizing findings from various scholarly articles. In another similar study, LI ET AL. (2022) also found similar result with current findings where the authors emphasized the potential of green technologies in transforming Mongolia's mining sector. They argue that the adoption of renewable energy sources, such as solar and wind, can reduce the sector's reliance on fossil fuels, thereby decreasing greenhouse gas emissions and operational costs.

However, HAMADA ET AL. (2024) discussed the implementation of water recycling technologies in Mongolian mines. Their study demonstrates that these technologies help in conserving water resources, crucial in the arid regions where many Mongolian mines are located.

The authors also highlight the reduction in wastewater discharge as a significant benefit, contributing to environmental preservation. Similarly, LISI ET AL. (2020) also found supportive results like the present study. In their study, the authors analyzed the role of green innovation in enhancing green technology and attain circular economic performance of the mining sector. They found that innovations in mineral processing, such as the use of bioleaching, not only increase efficiency but also reduce the environmental impact by minimizing the use of toxic chemicals.

On the other hand, in another country's context SHAHZAD ET AL. (2022) provide evidence that green innovation, particularly in waste management, leads to the recovery and reuse of valuable minerals from mining waste. This approach aligns with the principles of the circular economy, reducing waste and creating new economic opportunities. Besides, ESPOSITO ET AL. (2024) explored the economic implications of adopting green technologies because of green innovation where the authors acknowledged the high initial investment costs, their study suggests that long-term savings and efficiency gains can offset these expenses, leading to overall economic benefits.

However, ZHANG ET AL. (2020) argued with present result because they found some challenges in green technologies. The authors pointed out some challenges related to green technology and innovation because of the lack of infrastructure and expertise, which hinder the widespread adoption of green technologies. Additionally, they argued that without substantial government support and international collaboration, the mining sector may struggle to fully integrate these innovations. Previously, WANG ET AL. (2024) emphasized the importance of robust policy frameworks in promoting green technology and innovation in the mining sector. They argue that regulatory incentives, such as tax breaks and subsidies, can encourage companies to invest in sustainable practices, thereby enhancing the circular economy performance.

In a China based study, ZHANG ET AL. (2020) highlighted that the national strategies can be outlined aiming at integrating green technologies with the help of green innovation. These strategies focus on aligning with international environmental standards and fostering public-private partnerships to facilitate the transition towards sustainability. Similarly, LI ET AL. (2022) highlighted the social benefits of green innovation in mining, such as job creation in new green technology sectors and improved community health due to reduced pollution. They additionally argued that the adoption of cleaner technologies can lead to better living conditions for communities near mining operations. In support of that LI ET AL. (2022) provided evidence of

the environmental benefits, including the restoration of degraded mining sites because of using eco-friendly rehabilitation techniques. They emphasize that these practices not only contribute to biodiversity conservation but also enhance the aesthetic and ecological value of the regions affected by mining.

WANG ET AL. (2024) also indicated the negative aspects and challenges related to green technology adaptation and green innovation because of the adverse finding of their study than the present research. WANG ET AL. (2024) highlighted that the unequal distribution of resources for green innovation can exacerbate economic inequalities. They suggested that without equitable access to funding and support, smaller enterprises may be left behind, undermining the inclusive growth goals of the circular economy. Similarly, BAAH ET AL. (2024) discussed the risk of technological lock-in, where early adoption of specific green innovations can limit industries' flexibility to adapt to newer technologies. This can slow the overall progress of the circular economy by perpetuating outdated technologies that may no longer align with current sustainability standards.

On the other hand, LIAN ET AL. (2022) serves as a case study showcasing the successful integration of green technologies in one of Mongolia's largest mining operations. The company has implemented renewable energy solutions and advanced waste management systems, significantly improving its circular economic performance. Conversely, LISI ET AL. (2020) argued that green innovation often requires substantial upfront investment in research and development, which can strain resources, particularly for small and medium-sized enterprises. They highlighted that the high cost of adopting green technologies can create economic disparities, where only well-resourced companies can afford to innovate, and potentially marginalize smaller players. However, ZHANG ET AL. (2020) highlights the use of electric vehicles in mining operations as part of their green innovation strategy. This initiative has led to a notable reduction in carbon emissions and fuel consumption, demonstrating the practical benefits of adopting green technologies in mining.

BAAH ET AL. (2024) further argued that even though the adaptation of green technologies and green innovation are the potential benefits for the company, the financial strain because of these high technological investments can limit the capacity of mining companies to invest in other crucial areas, potentially leading to reduced overall efficiency and performance within the circular

economy framework. Similarly, WANG ET AL. (2024) highlight the limitations of green technologies in harsh climatic conditions typical of Mongolia. They argued that the inefficiency of renewable energy sources like solar and wind in extreme weather can result in unreliable power supply, disrupting mining operations and impacting circular economy-based performance.

In another study, SHAHZAD ET AL. (2022) emphasized that the adoption of green technologies in the mining sector requires significant initial investments, which can impose an economic burden on companies, especially small and medium enterprises. These high costs can deter investments and slow down the transition to sustainable practices. However, the present study indicates that the adaptation of green technology and innovation in Mongolia's mining sector has shown promising results in enhancing circular economy performance. Despite challenges such as high costs and regulatory hurdles, the long-term benefits in terms of economic savings, environmental preservation, and social well-being are significant. Continued efforts in policy support, infrastructure development, and capacity building are essential to sustain this positive trajectory.

RQ3: Does green innovation have an association with circular economic performance?

The third result of this present study found that green innovation has a positive relation with circular economic performance. In support of the current result, previously ALI ET AL. (2024) emphasized the importance of green innovation (product, process and systems) and its impact on performance (circular economy performance). Similarly, KHAN ET AL. (2024) established a link and significant association between green innovation and environmental performance in a circular economic perspective. Besides, KHAN ET AL. (2024) demonstrated that green innovation is beneficial to generate a green economy that further expands circular economic performance globally. Thus, several studies have recommended that performance in relation to circular economy depends on green innovation quality and ecological sustainability. For example, the study of ABDALLAH ET AL. (2024) endorsed the significant affiliation between green innovation and performance in the circular economy that gives organizations a competitive advantage.

However, the success of green innovation can be traced back to the priorities set by business leaders; and it also boosts companies' efforts to participate in the circular economy (ABDALLAH ET AL., 2024)). In support of the result of the present study, ABDALLAH ET AL. (2024) stressed the connection between green and environmental efficiency in the circular economy. Another

similar study by JOHL & TOHA (2021) also found supportive results like the current study. The findings of JOHL & TOHA (2021) demonstrated that green workforce management upholds green innovation in product, process and environmental system innovation; and green innovation further enhances circular economy efficiency.

Additionally, JOHL & TOHA (2021) highlighted some existing literature that describes the significant affiliation between green workforce management and green innovation and company performance in an outline of the circular economy. Those studies emphasized the bridging value of green innovation between green workforce management and green performance affiliated with the circular economy. Those studies referred by JOHL & TOHA (2021) have demonstrated the positive relationship between green innovation, green workforce management, and environmental performance and the indirect link with circular economy performance. Similarly, SIEDSCHLAG ET AL. (2022) highlighted the relationship between strategic green innovation, green workforce management (hiring, training, development), firms, and leverage to accomplish the performance goal (i.e. circular economy).

On the other hand, the research of LIU & WANG (2022) established the mediator function of green innovation amid green workforce management and circular economy performance. The consequences disclosed that green innovation played a mediator role concerning green workforce management and circular economy performance. The result of LIU & WANG (2022) have shown a significant affiliation between green workforce management, as well as green innovation and the performance of an organization, in an outline of a circular economy. In their study, green innovation, a pivotal aspect of sustainable development, has emerged as a significant driver in enhancing the performance of the circular economy. The authors additionally explored how green innovation fosters resource efficiency, reduces waste, and promotes sustainable economic growth, thus positively impacting the circular economy. This discussion of the study of LIU & WANG (2022) synthesizes findings from multiple articles to provide a comprehensive overview of the positive impacts of green innovation on circular economic performance.

However, SIEDSCHLAG ET AL. (2022) argued that green innovation leads to improved resource efficiency by integrating sustainable practices into product design and production processes. They emphasize that eco-design principles, which prioritize the use of renewable materials and energy, contribute to a more efficient use of resources. Moreover, their study supported this view by

highlighting those green innovations, such as modular product designs, facilitating easier disassembly and recycling, thus reducing waste and extending product lifecycles. In support of the present result, UL-DURAR ET AL. (2024) provided evidence that green innovation in industrial processes, such as the adoption of closed-loop systems, significantly minimizes waste generation. Their analysis of case studies across different industries reveals that companies implementing green innovations achieve substantial reductions in raw material consumption and waste disposal costs.

The economic advantages of green innovation are well-explained by BAG ET AL., 2022), where the researchers found that environmental regulations can stimulate innovation, leading to cost savings and competitive advantages. The scholars additionally argued that green innovations not only reduce environmental compliance costs but also open new market opportunities for eco-friendly products. Moreover, the scholars underscored the environmental benefits of green innovation by demonstrating how circular business models, such as product-as-a-service, reduce the ecological footprint of consumption. Their findings suggest that there are green innovations in service delivery models, which prioritize access over ownership, lower resource use and emissions, contributing to environmental sustainability.

Nevertheless, AI ET AL., 2024) explored the shift from traditional ownership models to service-oriented business models, facilitated by green innovation. The researchers concluded that this shift enhances circular economic performance by reducing the need for new product production and promoting the reuse and recycling of existing products. Additionally, the scholars discussed the role of reverse logistics in supporting circular economic goals. They highlight those green innovations in logistics, such as advanced tracking systems and automated sorting technologies, improve the efficiency of material recovery processes, thereby enhancing the economic viability of recycling and remanufacturing operations. Besides, the researchers discussed the transformative potential of green innovation in driving systemic change towards a circular economy. They argued that technological advancements in areas such as renewable energy, digitalization, and biotechnology are enabling the development of new business models and industrial processes that align with circular principles.

Notably, SIEDSCHLAG ET AL. (2022) provided some case studies demonstrating how companies are leveraging green innovation to transition from linear to circular business models.

They highlight examples of firms that have successfully implemented product-service systems, where consumers access services rather than owning products, thus reducing material consumption and extending product lifecycles. Additionally, the scholars illustrated how digital technologies, driven by green innovation, transform traditional industries into more sustainable operations. They show that innovations like IoT and big data analytics optimize resource management, reduce waste, and improve the transparency of circular supply chains. The scholars further elaborated on the role of digital innovation in advancing circular economic performance. Their study indicates that the integration of digital tools in monitoring and optimizing resource flows results in more efficient and resilient circular systems, thus enhancing overall sustainability.

There are some authors who also found adverse results than the present findings; and despite some evident benefits, several challenges hinder the widespread adoption of green innovations. For example, BAAH ET AL. (2024) identified that there are high initial investment costs and technological uncertainties as significant barriers. They argued that overcoming these challenges requires supportive policy frameworks and financial incentives to encourage innovation. The scholars additionally highlighted the role of green innovation in influencing consumer behavior and promoting sustainable consumption patterns. They argued that innovations in product design, such as eco-labeling and life-cycle assessment, can raise consumer awareness and encourage more environmentally responsible purchasing decisions.

Similarly, ALI ET AL. (2024) discussed the importance of supportive policy frameworks in fostering green innovation and enhancing circular economic performance. They argue that governments play a crucial role in creating an enabling environment for green innovation through regulations, incentives, and public-private partnerships. The researchers further emphasized that the need for coherent policy measures to promote green innovation. The organization highlights the best practices from various countries that have successfully implemented policies to encourage research and development in green technologies, thereby driving the transition to a circular economy. Moreover, the scholars supported the present view by discussing the concept of product-service systems, which aim to shift consumer focus from ownership to access. She argues that such systems, enabled by green innovation, can lead to a reduction in material consumption and waste, fostering a culture of sustainability among consumers.

Conversely, KHAN ET AL. (2024) highlighted the opportunities presented by green innovation, suggesting that fostering collaboration between stakeholders can accelerate the development and diffusion of eco-friendly technologies. They advocate for policies that promote research and development in green innovation to sustain momentum towards a circular economy. Literature overwhelmingly supports the notion that green innovation has a positive impact on circular economic performance. By enhancing resource efficiency, reducing waste, and fostering economic and environmental benefits, green innovation emerges as a critical enabler of sustainable development.

As the global economy continues to face environmental challenges, the role of green innovation in driving the transition to a circular economy becomes increasingly vital. While green innovation is widely celebrated for its role in advancing circular economic performance, it is not without its challenges and potential negative impacts. Various authors have explored the unintended consequences of green innovation, revealing complexities that can hinder circular economic performance. The present study findings and discussions synthesized findings from multiple articles to provide a nuanced perspective on both the positive and negative impacts of green innovation on circular economic performance.

RQ4: Has green innovation a mediating effect on the relationship between green technology adaptation and circular economy performance?

The fourth result of this study found that green innovation has a mediating effect between green technology adaptation and circular economic performance. In support of the current result, previously, KHAN ET AL. (2025) indicated that while green innovation is essential for advancing the circular economy, it is crucial to acknowledge and address its potential of its intermediary or mediating role. Challenges such as resource allocation disparities, technological lock-in, rebound effects, and regulatory barriers highlight the need for a balanced approach. By understanding these complexities, stakeholders can develop strategies to mitigate negative impacts and enhance the positive contributions of green innovation to the circular economy. Similarly, RODRÍGUEZ-ESPÍNDOLA ET AL., (2022) identified policy and regulatory barriers as significant obstacles to the effective implementation of green innovation. They argued that inconsistent regulations and lack of supportive policies can stifle innovation and create uncertainty for businesses, hindering the progress of the circular economy.

ZAMEER ET AL. (2022) also pointed out that rigid regulatory frameworks can lead to compliance burdens, particularly for SMEs, making it challenging for them to invest in green innovation. This can slow down the transition to a circular economy and limit the potential benefits of green technologies. In this regard, BAAH ET AL. (2024) supported this view noting that the unequal distribution of resources for green innovation can exacerbate economic inequalities. They also cautioned that without equitable access to funding and support, green innovation could lead to a concentration of market power in the hands of a few large corporations, undermining the inclusive nature of the circular economy. Similarly, HAMADA ET AL. (2024) discussed the risk of technological lock-in, where early adoption of certain green innovations can limit the flexibility of industries to adapt to new, potentially more effective technologies. This can lead to a situation where outdated technologies persist, slowing down the overall progress of the circular economy.

Nevertheless, LIU & WANG (2022) found similar result as the present study on the concept of carbon lock-in, where investments in specific green technologies may inadvertently reinforce existing unsustainable practices. The scholars additionally argued that the path dependency created by early green innovations can result in long-term environmental inefficiencies and hinder the adoption of more advanced circular solutions. Similarly, KANAN ET AL. (2023) introduced the concept of rebound effects, where the efficiency gains from green innovation are offset by increased consumption. They also found that improvements in energy efficiency through green technologies can lead to lower energy costs, which may encourage higher energy usage, ultimately negating the environmental benefits. Besides, AWAN ET AL. (2023) provided case studies demonstrating that some green innovations, such as bio-based materials, can have unintended environmental trade-offs. They highlighted that the large-scale cultivation of bio-based materials can lead to deforestation, biodiversity loss, and competition with food production, which contradicts the principles of the circular economy.

In another research by HAMADA ET AL. (2024) where the authors found dissimilar results than the current findings; however, they discussed the social and behavioral challenges associated with green innovation. They also argued that consumer resistance to change and lack of awareness about the benefits of green products can limit their adoption, thereby reducing the overall impact of green innovation on the circular economy. Another dissimilar result was found by BATDELGER & ZAGDBAZAR (2022) where they explored the disconnect between consumer behavior and

sustainable consumption patterns. They suggested that green innovations often fail to consider the complexities of consumer behavior, resulting in low market penetration and limited environmental benefits. Similarly, HAMADA ET AL. (2024) elaborated on carbon lock-in, arguing that substantial investments in specific green technologies can reinforce existing unsustainable practices. This phenomenon can result in long-term environmental inefficiencies, reducing the adaptability of industries to embrace more advanced circular solutions.

Another dissimilar finding than the current research has been revealed by BONSU ET AL. (2024), where the scholars discussed the challenges in integrating green technologies into existing systems, noting that substantial infrastructure modifications are often required, which can be costly and time-consuming, delaying green solutions' implementation. Similarly, AL-KHATIB (2022) also found dissimilar results and they highlighted the limitations of niche innovations in scaling up, suggesting that systemic barriers, including market dynamics and institutional resistance, impede the broader adoption of green innovations, affecting their contribution to the circular economy. Besides, ZAMEER ET AL. (2022) addressed greenwashing, where companies exaggerate or misrepresent environmental benefits. This practice can erode trust and undermine genuine green innovations, diluting their positive impact on the circular economy.

LIU & WANG (2022) also revealed dissimilar findings than the present study, and they advocated empirical evidence of greenwashing's prevalence, showing that unsubstantiated environmental claims can lead to consumer confusion and skepticism, detracting from green innovation's efficacy in promoting sustainable consumption and production. This dissimilar finding has also been supported by JUO & WANG (2022) and they pointed out that the current technological advancements in water recycling are not sufficient to handle the scale of operations in Mongolian mines, leading to suboptimal use of water resources and limited impact on circular economy goals. Similarly, YOUSAF (2021) discussed the environmental trade-offs associated with green innovations. For example, the use of bio-based materials in mining operations may reduce dependency on traditional resources but can lead to biodiversity loss due to land use changes.

However, RODRÍGUEZ-ESPÍNDOLA ET AL., (2022) introduced the concept of rebound effects, where efficiency gains from green technologies lead to increased resource consumption, negating the environmental benefits. This effect is particularly evident in the mining sector, where increased efficiency often leads to expanded operations. Besides, KHAN ET AL. (2025) highlighted the

social disruptions caused by the rapid implementation of green technologies in mining communities. They argue that insufficient planning and community involvement can lead to social unrest and opposition, undermining the potential benefits of green innovations. Moreover, ZAMEER ET AL. (2022) emphasized that the displacement of communities due to the expansion of green mining operations can result in long-term social issues, such as loss of livelihoods and cultural heritage, negatively impacting the social aspects of the circular economy.

Another research conducted by HAMADA ET AL. (2024) also found dissimilar results than that present study; however, they discussed the regulatory and policy challenges that hinder the effective implementation of green technologies. Inconsistent regulations and lack of clear guidelines create uncertainties, which can discourage investments in green innovations and slow down progress towards CE objectives. Similarly, MARRUCCI ET AL. (2021) acknowledged the bureaucratic hurdles and the slow pace of regulatory reforms, which often fail to keep up with technological advancements, resulting in a mismatch between policy and practice in the mining sector. Besides, HAMADA ET AL. (2024) addressed the issue of greenwashing, where companies in the mining sector may exaggerate or misrepresent their environmental efforts. This practice can lead to a loss of credibility and trust, undermining genuine green initiatives and their impact on the circular economy.

Nevertheless, LIU & WANG (2022) provided empirical evidence that greenwashing is prevalent in the mining sector, leading to consumer and stakeholder skepticism about the true environmental benefits of green technologies and innovations. On the other hand, KANAN ET AL. (2023) highlighted the infrastructural challenges in integrating green technologies in the Mongolian mining sector. The lack of necessary infrastructure, such as reliable power grids and transportation networks, hampers the effective deployment and scaling of green innovations. Additionally, AWAN ET AL. (2023) discussed the limitations in local capacity and expertise in managing and maintaining advanced green technologies, leading to inefficiencies and reduced performance of these innovations within the circular economy framework.

The results of HAMADA ET AL. (2024) found a positive relationship between green technology adaptation and circular economy performance through the mediation of green innovation; however, the authors evident the circular economy performance based on various dimensions: resource efficiency, waste minimization, value recovery, environmental impact reduction, and

socio-economic benefits. By integrating these technologies, industries can transition toward sustainable practices that not only benefit the environment but also enhance economic resilience and competitiveness. Continued innovation, policy support, and collaborative efforts are essential to amplify the synergies between green technology and the circular economy, paving the way for a more sustainable and equitable future. Green technology adaptation is often heralded as a cornerstone of sustainable development, promising to mitigate environmental degradation and enhance resource efficiency.

However, the findings of MARRUCCI ET AL. (2021) highlighted the integration of green technologies into economic and industrial systems can also present challenges that undermine circular economic performance. This extended discussion explores the multifaceted negative relationship between green technology adaptation and circular economic performance, delving into resource inefficiencies, recycling limitations, economic barriers, and ethical concerns, supported by insights from various academic and industry sources. Green technologies, despite their benefits, often demand significant material inputs for their development and deployment. Renewable energy technologies like solar panels and wind turbines, as well as electric vehicle (EV) batteries, rely heavily on rare earth elements and critical minerals such as lithium, cobalt, and nickel. The extraction and processing of these materials can lead to substantial environmental damage, including habitat destruction, soil erosion, and water contamination.

6. IMPLICATIONS

6.1. *Theoretical Contributions*

This study enhances literature in several aspects. The present study's primary contribution is the proposal for testing of a conceptual model that elucidates the process by which a corporation might improve circular economic performance. This research aims to enhance existing literature by clearly examining the impact of green technology adaption and green innovation on circular economic performance in Mongolian mining enterprises. Numerous previous studies have shown that dynamic skills and resources, including green technology and staff innovation assistance, enhance performance results (ABDALLAH ET AL., 2024; MARRUCCI ET AL., 2021). This research aimed to augment the literature by demonstrating that the paradigm or theory of resource-based view significantly enhances circular economic performance. This research enhances the literature on green technology, innovation, and circular performance by integrating it with the resource-based theory perspective, demonstrating that the adaptation and innovation of green technology influence circular economic performance.

However, the existing conceptual model is intended to analyze through the lens of the resource-based view theory. This research extends the resource-based paradigm, positing that green technology and innovation are essential resources that create new assets and produce information, enabling businesses to get value from critical knowledge and resource sources. The current findings indicate that improving circular economic performance requires the integration of green technology with green innovation to align with the evolving achievement of organizational performance (ALNOOR ET AL., 2024). This study posits that improved circular economic performance necessitates a distinct array of internal organizational processes, green technology adaptation, and green innovation (ISA ET AL., 2021), thereby addressing the need for a deeper comprehension of the interplay among green technology adaptation, green innovation, and circular economic performance (AMIN & OLÁH, 2024).

Additionally, the current findings indicate that an organization's capacity to embrace green technology may be enhanced by insights derived from green innovation to achieve circular performance. Besides, the present study asserts that the adaptation to green technology may be achieved by deriving insights from green innovation, which are gathered inside an organization through a green management system. This research also indicates that there is increasing

acknowledgment of the significance of green technology adaptation and green innovation for optimal circular economic performance; however, limited focus has been placed on how these factors influence a firm's circular performance. The current research offers a restricted comprehension of methods to enhance circular performance. This research indicates that companies engaged in extreme green innovation may assimilate and internalize information for the adaptation of green technology.

Additionally, while numerous prior studies have investigated the effect of integrating green technology with the green innovation perspective on corporate circular performance (ABDALLAH ET AL., 2024; ALNOOR ET AL., 2024), this study claims that there exists a paucity of empirical research examining the impact of green technology adaptation on circular economic performance. For example, ISA ET AL. (2021) emphasized the need to elucidate the correlation between the adoption of green technology and circular economic performance. Similarly, KHAN ET AL. (2024) demonstrated that, from a capability's viewpoint, organizations possessing robust and current green technology may augment innovation. Our findings indicate that the integration of green technology via insights from green innovation is crucial for improved circular economic performance. The present results clarify the significance of green technology adaptation and its crucial role in enhancing circular economic performance. Moreover, the current analysis indicates that for optimal circular economic performance, all human, innovative, and technological resources inside the organization must possess sufficient expertise to navigate this system.

6.2. Managerial Implications

This research is intended to provide substantial managerial directions and insights to both the mining and other industry managers and organizational leaders about the administration of green technology for optimum circular economic performance. This study investigated the impact of green technology implementation and green innovation on enhancing circular economic performance. Managers and organizational leaders underscored the need for implementation of green technology and circular economic performance at the organizational level. There is growing recognition of the need for green technology adaptation; however, little attention has been given to its impact on circular economic performance.

Managers in the manufacturing industry may devise a range of viable green technology alterations to transform linear production processes into a closed-loop production system. The possession of powerful technical skills is crucial for improving performance by efficiently using technologies to reuse and recover materials from end-of-life items. A corporation focused on green innovation must prioritize the effective use of green technical advantages to improve circular economic performance. The results of the present research demonstrate that insights derived from predictive, perspective, and descriptive analytics expose shortcomings in circular economic performance.

This research shows the guidelines to the managers on how to implement green technology and achieve circular economic performance for their companies. There is a lack of managerial concerns on the benefits of green technology adaptation and green innovation to attain circular economic performance. The findings of this research provide substantial insights into improving circular economic performance using green technology and green innovation. Our results suggest that senior management might gain advantages by leveraging expertise in green innovation beyond simple adoption of green technology. An overreliance on integrating green technology may stimulate greater innovation, potentially influence businesses and achieve outstanding circular economic performance. A crucial lesson for managers is that circular economic performance requires an increasing dependence on the adaptation of green technology driven by green innovation.

Third, the adoption of green technology has attracted attention from academics and professionals in recent years, due to the increasing acknowledgment of technological dependence and the importance of business analytics competencies. Managers and organizational leaders need to use green technology to improve circular economic performance. However, the present research has been undertaken intending to highlight the importance of organizational green technology adaptation and green innovation in improving efficient circular economic performance to the policymakers of the industry. This study indicates that leading companies should adopt more green technology for better performance. Thus, optimum circular economic performance may be attained and sustained by the effective use of green technology adaptation.

Fourthly, this study results suggest that the use of green technology enhances alignment with circular economic performance goals by offering insights into green innovation, thereby assisting

firms in their shift towards more circular business practices. This research suggests to managers that a technology-driven circular economy relies on the firm's ability to effectively use green innovation insights to attain circular economic performance. Consequently, it is essential to discern optimum innovative insights to develop strategies that enable firms to enhance their circular economic performance. The ramifications for senior management suggest that the use of green technology and insights into innovation may increase the probability of attaining circular economic performance. Companies aiming to improve their production efficiency should include new insights to study and understand the many viewpoints on challenges related to circular economic performance.

Finally, this research reveals that, for maximum circular economic performance, all human, inventive, and technical resources within the firm must possess the competence to operate efficiently within this system. This study demonstrates that circular economic performance requires the use of green technology and innovation. The present research intended to highlight the importance of green technologies through the support of innovative insights, there has been less exploration of the effects of green technologies and innovation on circular economic performance. This research suggests that improved circular economic performance is more likely when green technologies are incorporated and developed in alignment with the firm's innovation perspectives. Effective green technologies are crucial; thus, firms with advanced ideas may enhance their knowledge, skills, and resources, thereby improving circular economic performance.

6.3 Limitations

This study makes substantial contributions to business and society, acknowledges its limits, and proposes avenues for further research. However, the present study's limitations are discussed below.

Firstly, the findings of this research pertain specifically to the mining sector and may not be applicable to other production environments. Moreover, the emphasis is on Mongolia's mining industry; however, this study may include other industries in Mongolia to ascertain their definitions of green technology, innovation, and circular performance, since both mining and other industries altogether contribute to the sustainability objectives of the Mongolian Government.

Second, alternating this research in a cross-cultural environment would facilitate the development of universally applicable metrics for green technology, innovation, and circular economy

performance inside labor-intensive other enterprises. Future study must gather data from many industries and locations to guide universal choices for emerging economies. Additionally, the efficacy of each variable has yet to be assessed. Future studies should use performance matrix analysis to assess the progress of circular economic performance. Consequently, next research may expand its focus by doing multigroup studies across other geographies.

Third, consistent with prior research, the current research recognizes its methodological and theoretical limitations, therefore presenting avenues for further investigation. This cross-sectional research gathers data at a singular moment in time. Evaluating green technology and innovation may need time to realize their optimal influence on performance enhancement. Future study may use a longitudinal methodology to investigate the temporal changes in organizational performance attributable to green technology and innovation, therefore enhancing comprehension.

Fourth, future study might use a mixed-method approach to better explore the relationship between green technology, innovation, and circular outcomes in companies, since there is a need for deeper understanding of respondents' perspectives when relying only on quantitative data derived from closed-ended questions.

Finally, the survey focused only on mining managers' opinions of circular economic performance. Subsequent research should include an additional tier of personnel in the study group. Future studies should focus on organizational initiatives aimed at reducing detrimental environmental behaviors among workers. Alongside organizational performance, future research should investigate the cultivation of environmentally sustainable behavior among workers, considering both actual and stated ideals.

In conclusion, although the limitations, the research offers a foundation for the proposed study paradigm and an empirical basis for future comparisons.

6.4 Conclusion

This research studied the influence of green technology adaptation on circular economy performance including the mediation of green innovation of mining businesses in Mongolia, a nation where companies actively use the mining business. Our results underscore the beneficial impact of adaptation of green technology and green innovation on circular economy insights and decision-making, resulting in improved circular economic performance. Green technology

adaptation and green innovation together are the more robust predictors of circular performance, whereas green technology adaptation is a more potent predictor of decision-making quality. Our research indicates that the mediating role of green innovation reveals a higher direct and indirect correlation between green technology adaptation and circular economic performance compared to other typical business models. Green technology adaptation and green innovation are entirely connected to enhance productivity, whereas green technology adaptation has a direct correlation with circular economic performance.

In summary, this research asserted that the significant and successful use of green technology adaptation in producing circular products may influence the link between green technology adaptation, green innovation, and circular economic performance. This study indicates that circular economic performance is often comprehensible because of the lens of organizational learning. This research enhances the existing knowledge on circular economic performance as a critical determinant of corporate entrepreneurship success. The present study's results elucidate how green technology adaptation and green innovation may augment circular economic performance. This research further substantiates the idea that a company's corporate investment success derives from its proper adaptation of green technology, applying green innovation, and attainment of circular economic performance.

7. NOVEL FINDINGS

The novel finding of this research is that green technology adaptation through green innovation boosts circular economic performance, i.e., efficiency, productivity, and creativity. Understanding how green technology adaptation affects circular economic performance is vital for Mongolia's mining industry's future. Theory emphasizes organizational and industrial adoption of green technology and green innovation, and the current study proves it through its empirical findings. The research examines perception-based circular performance, evaluating green technology adaptation and green innovation, whereas prior studies discussed basic literature only. This procedure reveals existing knowledge, discrepancies, and research needs for empirically examining Mongolia's mining sector.

The second novel finding of this study reveals that the adoption of green technology significantly enhances the performance of circular processes. This finding explains that the perception of the managers of the mining sector of Mongolia that an increase in green technology adaptation positively affects the productivity, efficiency, and overall circular-based performance of the company. Therefore, green technology adaptation significantly enhances the circular performance of Mongolia's mining industry.

According to the third novel findings of this research, green innovation has a significant and favorable effect on circular performance. It may be inferred that the managers of the mining industry in Mongolia have the opinion that a rise in green innovation by the employees of the organization has a favorable impact on the organization's overall performance in terms of productivity, efficiency, and circularity. As a result, the mining sector in Mongolia can accelerate more green innovation to attain outstanding circular performance.

In terms of the environmental and economic aspects, the study investigated whether the integration of green technology adaptation and circular performance demonstrates a notable positive mediating impact of green innovation, indicating a significant interaction effect. This study reveals a novel finding that green innovation has partial mediation between green technology adaptation and circular performance. So, policymakers can incorporate innovation in the adaptation of green technologies to achieve extreme circular performance.

SUMMARY

Green technology and the circular economy are currently prominent in research about sustainability. The circular economy diverges from traditional systems and has the potential to enhance value by decelerating or halting resource cycles. The performance of the organizational circular economy enhances the reduction of input waste, promotes environmental preservation, and fosters stakeholder-centric systems. Circular economic performance necessitates distinct company models based on innovative technologies and operational strategies. Nonetheless, the use of green technology refers to how companies utilize their existing resources to create new products, industrial processes, and further resource development. There are some challenges related to educating, training, organizing, and coordinating that will hinder the implementation of green technology in businesses. The researchers contended that corporate knowledge assets, environmental technology, and industrial alliances influence the adoption of sophisticated wastewater treatment technologies, while community variables include public involvement and environmental regulations.

However, this study indicates that the senior management of organizations can be significantly influenced by the adoption of green technology. Market dynamics propel environmental awareness, green entrepreneurship, green technology, and green innovation in enterprises, encouraging to adopt the circular economy. Additionally, the use of green innovation concepts and applications has provided firms with a competitive advantage. This research investigates the firm's comprehension of productivity and resource optimization associated with green innovation. Green innovation has the potential to enhance sustainable management for environmental protection. Companies may use green innovation to enhance resource efficiency and mitigate environmental costs. Pioneers in emerging countries may establish elevated prices for environmentally sustainable products, enhance their brand visibility, advocate for their eco-friendly offerings, and maybe penetrate new markets. Green innovation enables companies to maintain competitiveness by offering sustainable and advantageous benefits. Nevertheless, the experts identified additional advantages for companies stemming from green innovation.

The Mongolian mining industry exemplifies a circular economy through its environmental stewardship and adaptation to local communities, using green technologies. Mining corporations significantly influence local green technology adoption policies. Rural inhabitants initially

perceived mining as detrimental to the ecosystem, pasturelands, and winter habitats, despite its advantages for the local economy. Nomadic and rural inhabitants previously against the corporations intruding onto their land and witnessing environmental degradation due to mining activities. Later, the nomadic herders, vulnerable to weather-related calamities that threaten their livestock, started to rely on mining. For ranchers who have lost their whole herd, mining represents their last resort. Numerous local inhabitants are employed in extensive mining operations.

Mining enterprises influence the municipal policy due to their contribution to local employment rates. The herders of Mongolia have resorted to *ninja mining*, or small-scale artisanal mining, for their survival. This job may provide compensation beyond the minimum wage in regulated environments. The mining boom and emerging cities have enhanced the service industry. Formerly nomadic people may get employment indirectly by catering to mining personnel. Numerous nomadic individuals migrate to mining towns and urban areas in pursuit of employment and improved livelihoods for their families. Certain rural inhabitants get aid because of insufficient public services. Research indicates that families engaged in mining incur higher healthcare expenses. Despite a decline in certain health metrics, people's access to healthcare and health expenditures have increased. Wealth from mining sites may provide superior education for nomadic children. Research indicates that the educational attainment of mining towns may rise despite a reduction in educational spending. Local regions may gain from new infrastructure initiatives such as road construction, while improved transportation connections advantage everyone.

The independent variable of this research is the adoption of green technology, which entails the incorporation of eco-friendly technologies into industrial and corporate operations to reduce resource consumption, waste, and environmental impact. The mediating variable was the green innovation, which enhances resource efficiency, minimizes waste, and facilitates material reuse to redefine economic activity. The objective of this research is to ascertain the impact of green technology on circular economic performance including the mediation of green innovation. Hypothetically this research assumed that the use of green technology enhances the circular economic performance. The first result of study revealed a significant positive connection between the use of green technology and circular economic performance.

The second result of this study revealed that the use of green technology enhances green innovation. The use of green technology fosters creativity, which is crucial for implementing circular performance across many sectors. The application of green technology reduces the environmental impact of economic operations, which is a fundamental aspect of green innovation. Alternative energy sources, such as solar and wind power, mitigate greenhouse gas emissions and combat climate change. Green innovation mitigates industrial pollution and safeguards ecosystems by reducing the use of hazardous materials. The third result proved that green innovation enhances circular economic performance. Green innovation fosters a green economy and enhances organizational circular economic performance. Consequently, a robust correlation between green innovation and circular economic performance, providing enterprises with a competitive advantage.

The fourth result indicates that green innovation mediates the relationship between green technology adoption and circular economic performance. Although green innovation is essential for advancing the circular economy, its intermediary or mediating role must be recognized. A comprehensive plan is required to manage the disparities in resource allocation, technological entrenchment, rebound effects, and regulatory obstacles. Comprehending these complexities enables stakeholders to develop strategies to mitigate adverse effects and enhance the contributions of green innovation to the circular economy.

The primary contribution of this study is the proposal to evaluate a conceptual model that elucidates how a corporation might enhance circular economic performance. This research elucidates the impact of green technology adoption and innovation on circular economic performance within Mongolian mining enterprises to enhance the existing literature. Dynamic capabilities and resource-based view concept, including green technology and employee creativity, enhance performance. This research aimed to enhance the literature by demonstrating that a resource-based viewpoint enhances circular economic performance. Incorporating the resource-based theoretical framework demonstrates that the adoption of green technology and innovation influences circular economic performance.

This study aims to provide managers and organizations with essential guidance on green technology management for achieving success in the circular economy. This research assessed the impact of green technology and innovation on enhancing circular economic performance.

Previously, scholars emphasized the need for green technology adoption for the development of the circular economy. The use of green technology is increasingly acknowledged, however its impact on circular economic performance remains largely unexplored. Manufacturing managers may initiate alterations to linear production processes by integrating green technology to establish a closed-loop system. Consequently, significant technical expertise is essential for enhancing performance via the effective reuse and recovery of resources from end-of-life products. A green innovation company must effectively use green technologies to enhance circular economic performance. The current study revealed that predictive, perspective, and descriptive analytics underscore cyclical economic performance challenges.

Finally, this research indicates that green technology and innovation enhance insights and decision-making within the circular economy, hence enhancing performance. The combination of green technology adaptation and innovation more accurately forecasts circular performance, whereas green technology adaptation alone more effectively predicts decision-making quality. Our research indicates that green innovation facilitates a more robust direct and indirect relationship between green technology adoption and circular economic success compared to other business strategies. The adoption of green technology directly influences circular economic performance, whereas green innovation enhances productivity.

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LIST OF ABBREVIATIONS

GTA	Green Technology Adaptation
GI	Green Innovation
CEP	Circular Economic Performance
GDP	Gross Domestic Product
GNP	Gross National Product
RBV	Resource-based View
RBVT	Resource-based View Theory
NRBV	Natural Resource-based View
NRBVT	Natural Resource-based View Theory
VAT	Value Added Tax
PLS	Partial Least Square
PLS-SEM	Partial Least Square: Structural Equation Modelling
CV-M	Covariance based method
CMB	Common method biasness
VIF	Variance Inflation Factor
CIF	Confirmatory Factor Analysis
EFA	Explanatory factor analysis
CR	Composite Reliability
CV	Convergent Validity
HTMT	Heterotrait-monotrait Ratio
SMEs	Small and Medium Enterprises
EV	Electric Vehicle
R&D	Research and Development

LIST OF TABLES

Table 1:	Measurement instrument of the research variables	61
Table 2:	Developing Items Constructing Green Technology Adaptation	62
Table 3:	Items Constructing Green Innovation	63
Table 4:	Items Constructing Circular Economy Performance	64
Table 5:	Cronbach's Alpha of Variables from Pilot study	66
Table 6:	Comparison between PLS-SEM and CB-SEM	69
Table 7:	Explanation of the reliability and validity criteria	71
Table 8:	Determination of coefficient, Bootstrapping, and Predictive Relevance	73
Table 9:	Response Rate of this study	75
Table 10:	Descriptive Analysis of Respondents' Demographic Data	76
Table 11:	Harman's Single factor test: Total Variance Explained	79
Table 12:	VIF values	80
Table 13:	Results of Measurement Model	82
Table 14:	Fornell-Larcker Correlation Check	86
Table 15:	HTMT values of this study	86
Table 16:	R ² and adjusted R ² values	88
Table 17:	Q ² values	89
Table 18:	Results from Hypotheses Testing (Direct Effects)	90
Table 19:	Results from Hypotheses Testing (Indirect Effect)	93
Table 20:	Summary of Hypotheses Test Results	93

LIST OF FIGURES

Figure 1:	Investment rate in various sectors in Mongolia	33
Figure 2:	Last five years per capita GDP of Mongolia	35
Figure 3:	Conceptual Model of this study	55
Figure 4:	PLS generated model before conducting the CFA	81
Figure 5:	PLS generated model after conducting the CFA	83
Figure 6:	Cronbach's Alpha values of the variables	84
Figure 7:	Composite reliability bar chart including the AVE values	85
Figure 8:	HTMT values of this study in a bar chart presentation	87
Figure 9:	R2 value bar chart	88
Figure 10:	Adjusted R2 value bar chart	80
Figure 11:	PLS generated structural model with p values	91
Figure 12:	PLS generated structural model with t values	92

LIST OF PUBLICATIONS



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Total IF of journals (publications related to the dissertation): 7,8

The Candidate's publication data submitted to the Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

27 October, 2025



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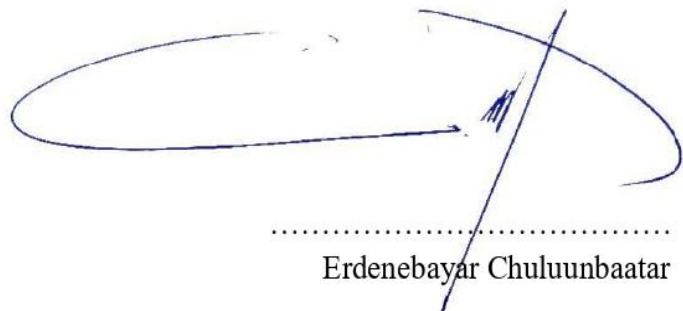
DECLARATION

I undersigned (name – Erdenebayar Chuluunbaatar, date of birth – 1982.02.28) declare under penalty of perjury and certify with my signature that the dissertation I submitted in order to obtain doctoral (PhD) degree is entirely my own work.

Furthermore, I declare the following

- I examined the Code of the Doctoral School of Management and Business Administration and I acknowledge the points laid down in the code as mandatory;
- I handled the technical literature sources used in my dissertation fairly and I conformed to the provisions and stipulations related to the dissertation;
- I indicated the original source of other authors' unpublished thoughts and data in the references section in a complete and correct way in consideration of the prevailing copyright protection rules;
- No dissertation which is fully or partly identical to the present dissertation was submitted to any other university or doctoral school for the purpose of obtaining a PhD degree.

Debreceen, 2025 October 26



.....
Erdenebayar Chuluunbaatar
Signature

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APPENDICES

Appendix-A: Research Survey Questionnaire

COVER LETTER FOR SURVEY QUESTIONNAIRE

CONFIDENTIAL

Dear Participant,

We are requesting your thoughtful assistance with some insights in order to complete this PhD study. Your participation in this research project would be highly appreciated. Through the intervention of green innovation, this study intends to ascertain the impact of green technology adaptation on the circular economy performance of organizations. So, the attached survey aims to gather data on green technology adaptation, green innovation, and circular economy performance by the mining organizations.

Taking part in this study is entirely dependent upon you. Except for your typical daily life activities, there will be no known difficulties involved with this research. Your answers will be kept secret and unidentified. All information gathered from this study will remain confidential and will be reported only in aggregate form. We are the only ones who will have access to the information you provide in this survey.

For considering the time and effort to fill out the survey, we are deeply thankful. Your insightful comments will certainly help with the progress and success of this study. Feel free to get in touch with either my academic supervisor or myself if you are curious about the results of the study later.

Sincerely yours,

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Inclusion Criteria for the Respondents

It is requested to distribute the questionnaire to those employees who fulfilled the following criteria:

- 1) Employees who are working in mining organization in Mongolia.
- 2) Permanent employees of the organization except on any kind of temporary, daily basis. or contractual employee.
- 3) Employees having more than three years of job experience in existing mining organization in Mongolia.

QUESTIONNAIRE

Part 1: Section A

This section is designed to measure your perceptions regarding the **green technology adaptation** of your organization. Please read each statement carefully and put (√) mark at the most appropriate option from your concept or opinion as a scale of 1 = strongly disagree to 5 = strongly agree.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Green Technology Adaptation						
1	We have expertly utilized the tools and applications provided by green technology	1	2	3	4	5
2	I have gained an extensive knowledge of the green technology in a short period of time	1	2	3	4	5
3	I quickly adapted to the green technology implemented in my organization	1	2	3	4	5
4	I have successfully administered all the resources offered by green technology	1	2	3	4	5
5	I determine myself as a professional who regularly utilizes my organization's green technology	1	2	3	4	5

Part 1: Section B

This section is designed to measure your perceptions regarding the **green innovation** system in your organization. Please read each statement carefully and put (√) mark at the most appropriate option from your concept or opinion as a scale of 1 = strongly disagree to 5 = strongly agree.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Green Innovation

- | | | | | | | |
|----|--|---|---|---|---|---|
| 1 | Our organization selects materials for manufacturing or design that generate less pollution. | 1 | 2 | 3 | 4 | 5 |
| 2 | Our organization minimizes the usage of materials in product development and design. | 1 | 2 | 3 | 4 | 5 |
| 3 | Our organization will meticulously evaluate if the product is easily recyclable, reusable, and biodegradable while developing or designing products. | 1 | 2 | 3 | 4 | 5 |
| 4 | The company's production processes efficiently minimize the release of harmful compounds or waste. | 1 | 2 | 3 | 4 | 5 |
| 5. | The company's production technique minimizes the use of raw material resources. | 1 | 2 | 3 | 4 | 5 |
-

This section is designed to measure your perceptions regarding the **circular economy performance** of your organization. Please read each statement carefully and put (√) mark at the most appropriate option from your concept or opinion as a scale of 1 = strongly disagree to 5 = strongly agree.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Circular Economy Performance						
1	Our products are intended to be repaired, renovated, or remanufactured at the end of their life cycle.	1	2	3	4	5
2	We use a manufacturing process that effectively eliminates leaks and reduces waste formation.	1	2	3	4	5
3	We enhance the energy efficiency of our manufacturing processes.	1	2	3	4	5
4	Our manufacturing process includes bi-products, end-of-life items, recycled materials, and reduced extra energy.	1	2	3	4	5
5	We gather our raw materials or components from the sources that have reached the end of their useful life to recycle or recover resources.	1	2	3	4	5
6	We minimize the excessive consumption of resources in our manufacturing process.	1	2	3	4	5

Part II

Background (demographic) information of the participants [Please tick (✓) the appropriate box]

1	Gender	1.	Male	2.	Female	3.	
2	Age	1.	16-25 years	2.	26-35 years	3.	36-45 years
		4.	46-55 years	5.	56 years and above		
3	Religion	1.	Muslim	2.	Hindu	3.	Christian
		4.	Buddhist	5.	Others		
4	Marital status	1.	Single	2.	Married	3.	Divorced
		4.	Widowed				
5	Education	1.	Below Secondary	2.	Secondary (SSC)	3.	HSC/Certificate/ College diploma
		4.	Bachelor degree	5.	Master degree	6.	PhD
		7.	Others				
6	Monthly Income	1.	Below 15,000	2.	15,000 – 25,000		
		3.	25,000 – 35,000	4.	35,000 and above		
7	Total Experience	1.	01 – 05 Years	2.	05 – 10 years		
		3.	10 – 15 Years	4.	More than 15 years		
8	Total Experience in Current Organization	1.	01 – 05 Years	2.	05 – 10 years		
		3.	10 – 15 Years	4.	More than 15 years		

Thank you for your participation and valuable time.

Appendix-B

Top 30 Mining organizations in Mongolia

1. Aranjin Resources
2. Erdenes Mongol
3. Erdenes-TavanTolgoi JSC
4. Erdenet Mining Corporation
5. Euro Khan LLC
6. Gan Tumur Industries LLC.
7. Geosan LLC
8. Gobi Coal and Energy Ltd.
9. Gobi Shoo LLC FLUORSPAR Mining And Processing Private Entity
10. Hahn Electrical Mongolia
11. Ikh Gobi Energy LLC
12. Just Group LLC
13. Khan Altai Resource LLC
14. Logantek - Always Pushing the Geoscience Envelope!
15. MERA Group
16. MONGOL BRIDGE BUSINESS GROUP
17. Master mining service
18. Mekhlopat LLC
19. Mining National Operator (MNO) LLC
20. Mongolian Metals Corporation
21. Mongolian National Mining Association/Монголын Уул Уурхайн Үндэсний
Ассоциаци
22. Naran Mandal
23. Oyu Tolgoi LLC / Оюу толгой ХХК

- 24. POLARIS ENGINEERING CONSULTING LLC
- 25. QSC LLC
- 26. Steppe Gold Ltd
- 27. Transwest Mongolia LLC
- 28. Trigteq
- 29. Xanadu Mines Ltd
- 30. Young Mining Professionals Mongolia