Understanding the Impact of Environmental Regulations on Green Technology Innovation Efficiency in the Construction Industry

Igamova Shaxinya Zikrilloyevna,
Associate professor ,PhD Bukhara State University

Abstract: Green Supply Chain Management (GSCM) has become an important approach in the construction industry to promote environmental sustainability throughout construction projects. However, even with its widespread use, the construction industry still causes many harmful environmental effects, such as high greenhouse gas emissions, resource depletion, excessive waste, and damage to natural habitats, all of which contribute to climate change. To combat these issues, a shift towards regenerative thinking is needed, which goes beyond reducing negative impacts and focuses on actively restoring ecosystems, replenishing resources, and repairing damaged habitats.This study builds on existing GSCM practices and highlights their limitations in achieving true sustainability. In response, it introduces a new framework called Regenerative Supply Chain Management (RSCM), which includes key regenerative principles: Focus on Place, Harmony with Place, and Co-evolution. This framework offers a more thorough approach and supports the transition toward regenerative practices. Ultimately, this framework provides valuable insights into advancing sustainable practices in construction and suggests practical steps for the industry. By adopting regenerative methods, the construction sector can help restore and renew the built environment, leading to a more resilient and sustainable future.

Keywords: Green technology innovation efficiency; Environmental regulations; Sustainable development; Network EBM model; Tobit regression analysis; Green supply chain management; Construction industry; Regenerative; Framework

Introduction.

Just like in other industries, Green Supply Chain Management (GSCM) is very important in construction. It involves a series of steps starting from the planning or design phase and continuing until the building's lifecycle ends. GSCM, which is part of the traditional supply chain, focuses on protecting the environment, providing economic benefits, and improving social aspects. The goal is to reduce or even eliminate the harmful environmental effects of the construction supply chain. This approach includes green design, manufacturing, purchasing, transportation, and reverse logistics, all integrated into the traditional supply chain networks. Several studies have explored the main goals of GSCM in construction, such as improving a

company’s competitive advantage, creating more value for stakeholders, and boosting the ecological, economic, and operational performance of the supply chain.

While Green Supply Chain Management (GSCM) offers many benefits in the construction industry, it typically focuses on reducing the environmental impact of buildings or achieving limited sustainability goals. However, factors such as population growth, the need for improved construction methods, ongoing resource use, environmental damage, and the growing effects of climate change emphasize the need for a more fundamental shift in how humans interact with the environment. Current tools and frameworks designed to help construction professionals move beyond traditional sustainability practices often fail to recognize the interconnectedness between human development and the wider environment. They also neglect key elements such as education, community involvement, and socio-economic diversity. As a result, there is an urgent need to embrace regenerative thinking, which focuses on actively engaging with the natural world and fostering a collaborative relationship with nature using adaptive, resilient, and restorative methods.

Regenerative thinking moves beyond sustainability by not only minimizing environmental harm but by improving the health and development of both social and ecological systems. This study addresses the limitations of current GSCM practices in the construction industry, which, despite aiming for green or sustainable outcomes, are not enough to actively restore and enhance our built environment over time. To solve this, the study proposes integrating regenerative principles into each phase of GSCM, creating a new framework called Regenerative Supply Chain Management (RSCM). Unlike GSCM, which focuses on achieving sustainability, RSCM aims for continuous improvement, restoring the built environment over time.

The study explores how GSCM can transition to a regenerative approach in construction. To guide this transition, two research questions were developed:

RQ1: What are the dominant GSCM practices in construction, and what are their performance limitations?

RQ2: How can regenerative principles be integrated into GSCM to foster a better relationship between humans and nature?

To answer these, the study first reviewed existing GSCM practices and their limitations. This led to two key findings: the main stages of GSCM used in construction and the challenges faced by these practices. Building on these findings, the study explored how regenerative principles could be incorporated into each phase of the construction supply chain. By doing this, a new RSCM framework was developed, emphasizing practices such as ecosystem restoration, resource replenishment, habitat regeneration, community co-evolution, and biodiversity enhancement. These practices

aim to create a positive environmental impact, unlike traditional GSCM practices, which merely mitigate harm.

Literature review

To fully understand Green Supply Chain Management (GSCM) in the construction industry, Ming et al. (2019) describe GSCM as an innovative approach that involves addressing environmental concerns across all stages, from design and procurement to materials selection, project completion, handover, and even the end-of-life phase of the building. The goal is to improve a company’s competitiveness and long-term profitability. Da Rocha and Sattler further explain that GSCM aims to manage all supply chain activities to minimize environmental impacts in the final products, like buildings or infrastructure, working towards zero net harm to the environment.

Several GSCM practices specific to the construction industry have been identified in existing studies. For example, Hopkins emphasizes the importance of green design, which plays a critical role in the quality, time, and cost of construction projects. Green design includes practices like using recyclable materials, integrating solar energy, designing for minimal material and energy use, and selecting sustainable sites . Chowdhury et al. describe green design as the integration of environmental principles into traditional design methods to reduce negative environmental impacts. Zhang e note that green design varies by industry, focusing on minimizing a product’s environmental footprint over its entire lifecycle. Additionally, Rostamzadeh et al. mention that the green design stage often starts with an environmental impact assessment to better understand the building’s ecological effects.

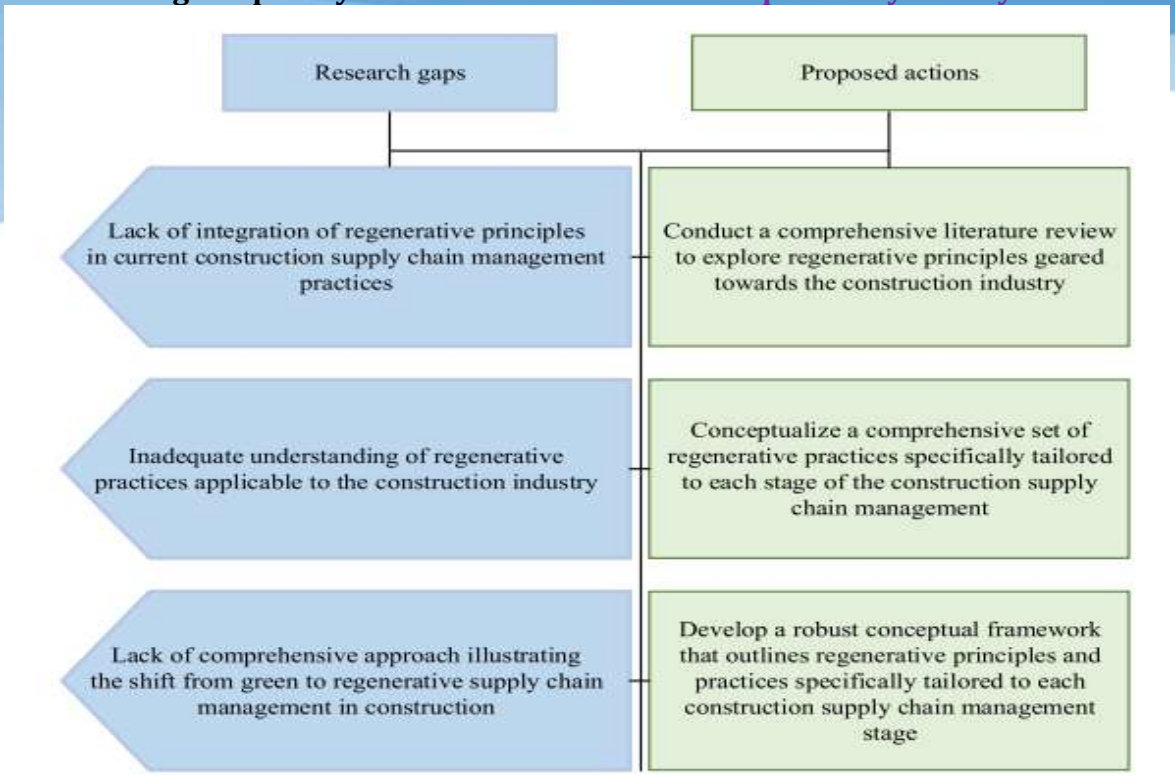

Figure 1. Research gaps and proposed actions investigated in the study

Green purchasing is another crucial element, involving the integration of environmental considerations into procurement processes. According to Rostamzadeh et al. and Wang et al. , green purchasing focuses on acquiring environmentally friendly materials and products that meet the necessary environmental standards. In construction, green purchasing should begin at the pre-qualification stage, where suppliers must have an Environmental Management System (EMS) and ISO 14001 certification (Balasubramanian and Shukla). Other practices include assessing suppliers’ environmental performance, purchasing non-toxic materials, and selecting suppliers based on their green initiatives (Ali et al., 2020; Bohari et al., 2024; Esfahbodi et al., 2016; Laosirihongthong et al., 2013).

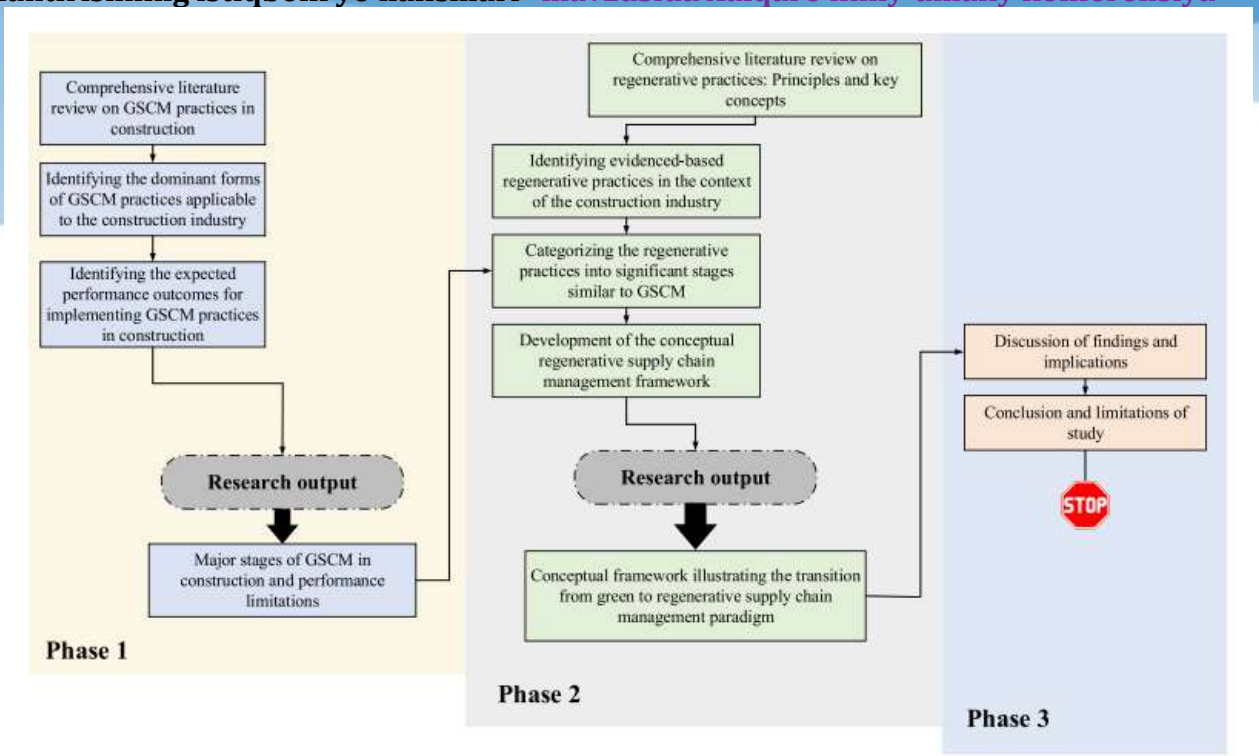

Figure 2. . Research framework

Green transportation in GSCM aims to reduce the environmental impact of transportation systems in construction projects. This stage complements other GSCM stages like green design and green purchasing (Kazancoglu et al., 2018). Green transportation practices in construction include using fuel-efficient vehicles, stacking vehicles for material transport, holding virtual meetings, and prioritizing shared or public transportation. Additionally, green construction is highlighted as an important stage in GSCM. According to Seth et al., green construction practices focus on managing energy use, water consumption, and toxicity at construction sites.. Lastly, it examines existing models used to measure innovation efficiency.

Recently, the definition of sustainability has been evolving, driven by the need for the regenerative concept (Mang and Reed, 2020). Several authors have attempted to define this concept. For instance, Jenkin and Zari (2009) describe the regenerative approach as a systemic process that restores damaged sites to a healthy state through human intervention and biophilic designs, which reconnect people with nature. Mang and Haggard (2016) define the regenerative concept as a framework of development strategies that enhance the co-evolutionary relationship between humans and ecosystems, promoting diversity, complexity, and creativity on the planet. Cole (2012a, 2012b) sees the regenerative concept as a fundamental shift in the way we think about construction, placing it within a broader context and understanding its larger role and impact.

From these various definitions, it’s clear that researchers agree sustainability alone is not enough to bring about the essential changes needed in our built

environment. The regenerative concept aims to create a mutually beneficial relationship between humans and ecosystems over time. It changes our understanding of the built environment by moving beyond a focus on buildings alone to include the interconnections between buildings, infrastructure, natural systems, and the larger context of communities, including culture, economy, and politics (Mang and Reed, 2012).

For the construction industry to embrace regenerative thinking, Craft et al. (2017) suggest that less emphasis should be placed on the individual elements of buildings, and more on the processes that focus on the co-evolution of the entire system. This approach advocates for humans to be seen as an integral part of the built environment. Regenerative thinking is not only redefining sustainability but also reshaping the role of the built environment (Mang and Reed, 2020). Today, many green and sustainability practices aim for net-zero or carbon-neutral outcomes, which fall under degenerating or zero-impact paradigms. Therefore, there is a need for a shift toward a more dynamic and holistic system of thinking—what is called the regenerative concept.

To illustrate the distinction between green, sustainability, and regenerative concepts, Figure 3 provides a comparison of each concept's position within the context of the built environment.

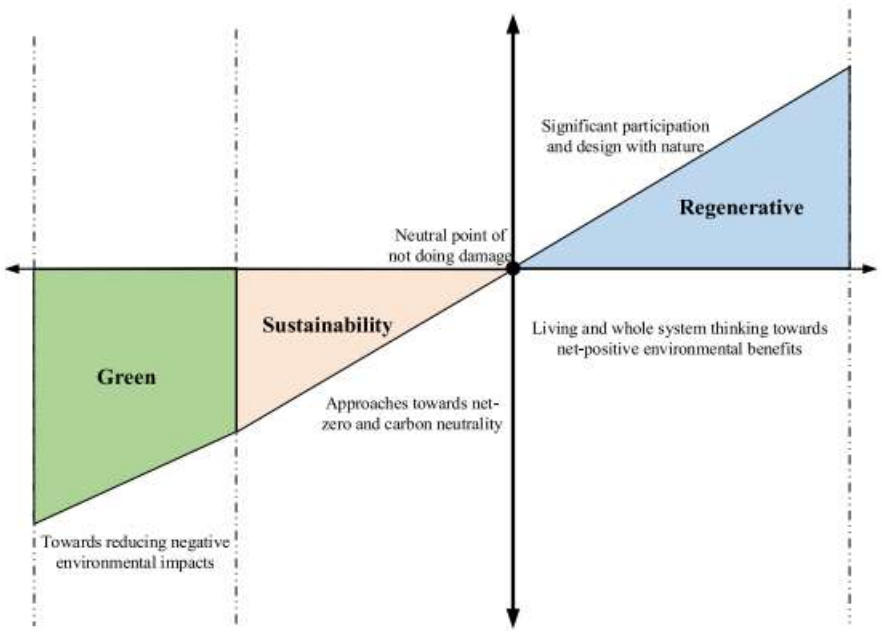

Figure 3. Positioning green, sustainability and regenerative concepts (Modified from (Reed, 2007)).

The first research output of this study outlined the concept of Green Supply Chain Management (GSCM) in construction, including its major stages and applicable practices. The following sections introduce evidence-based regenerative practices

derived from regenerative principles and integrate them into the key stages of the construction supply chain, mirroring the structure of GSCM. This integration contributes to the development of a novel framework, Regenerative Supply Chain Management (RSCM), which addresses the second research question.

Regenerative Design: Several regenerative design practices have been identified for incorporation during the design phase of construction supply chain management. Craft et al. (2017) proposed regenerative design practices that focus on the interaction between human and natural systems, resulting in net-positive benefits. These practices include creating a visually engaging entrance that connects natural elements with social spaces, such as walkways, and integrating planter boxes into building facades. This strengthens occupants’ connection to nature, improves their well-being, supports biodiversity, and enhances the building's adaptability to climate change. Bonyad et al. (2018) highlighted key practices for regenerative design, such as designing with nature, considering the local context of occupants, conducting integral assessments, and using passive solar designs. Other practices include incorporating public art, assessing sites as living systems, and creating inclusive public spaces (ILFI, 2019; Petrovski et al., 2021; Mang and Reed, 2020; Zari, 2010).

Regenerative Purchasing: During the purchasing stage, regenerative practices should address ecosystemic questions related to materials, such as their durability, energy consumption during production, social impact on the local community, and role in beautifying the built environment. Peretti and Druhmann (2019) suggest that specifying local materials helps support local employment and uses healthier materials, while sourcing from manufacturers that promote gender equality and ethical working conditions benefits the community and mitigates negative impacts. The JUST program by The International Living Future Institute (ILFI) guides purchasing decisions to ensure positive impacts through regenerative purchasing practices.

Regenerative Transportation: Conventional transportation systems, like buses and cars, contribute little to reducing carbon emissions and waste in construction. Tannous et al. (2020) proposed that housing construction workers near the site can minimize commutes and encourage alternative transportation methods like cycling and walking. If housing is not feasible, shared transport and multimodal transportation techniques can help reduce the carbon footprint. Additionally, using electric vehicles and cleaner fuels for transporting construction materials can further reduce environmental impacts, especially with regenerative braking systems in electric vehicles that turn braking energy into electricity (Gonzalez-Gil et al., 2013).

Regenerative Construction: To shift from a reductionist (green or sustainable) to a regenerative approach during construction, regenerative practices should be

incorporated into materials, technologies, and decision-making processes on site to improve workers' well-being and generate net-positive benefits. Research in other industries, such as self-healing materials and improved thermal storage (Guarino et al., 2015; Jaworski and Trzepiecinski, 2016), is now being integrated into the construction sector. Regenerative construction also includes using interpretive signage to educate visitors and occupants about the project, promoting the focus on place (Hughes et al., 2013; Carter, 2013; ILFI, 2019). Another practice is constructing water circulation systems and wetlands to collect stormwater, replenish underground water sources, and manage future climate uncertainties (Wallace et al., 2015).

Regenerative End-of-Life (EoL) Management: The regenerative concept is starting to reshape EoL management practices by extending the useful life of construction materials and enabling their transformation into new products, reducing waste, and promoting reuse. Key regenerative practices in EoL management include careful dismantling, disassembly, and recovery to reduce landfill waste and conserve resources (Çimen, 2021). Tingley et al. (2017) proposed creating a database to track materials for reuse, overcoming barriers related to cost and data quality. The ILFI (2019) combined the three regenerative principles to develop a Materials Conservation Management Plan (MCMP) for adaptable reuse and deconstruction, optimizing material usage and encouraging the reuse of salvaged materials.

Conclusion.

This study emphasizes the critical need for a shift in the current green practices used throughout the construction supply chain management (SCM) phases. It calls for adopting regenerative thinking, which goes beyond merely minimizing environmental harm or achieving sustainability. Instead, regenerative practices focus on restoring damaged natural systems while promoting societal well-being. To achieve this goal, the study presents a novel Regenerative Supply Chain Management (RSCM) framework, based on three key regenerative principles: "Focus on place," "Harmony with place," and "Co-evolution."

A thorough review of existing literature was conducted to examine current GSCM practices in construction and their performance limitations. In response to these limitations, the study identifies 40 evidence-based regenerative practices, categorized into five stages aligned with the existing GSCM stages. These practices form the foundation of the RSCM framework, offering a more comprehensive and holistic approach to incorporating regenerative principles into construction.

The study's findings provide a stepping stone for future research, suggesting that future studies explore the practical application of RSCM under the lens of its core principles. The proposed framework represents a significant shift toward a regenerative

transformation in industries, aiming for a more harmonious relationship between human activities and the environment.

Limitations of the Study:

While this research provides valuable insights, there are some limitations:

Monitoring and Control Stage: The study incorporates regenerative practices into the major stages of construction SCM but does not specifically address the monitoring and control stage. Though this stage is less emphasized in the literature, it is crucial for ongoing project monitoring, quality control, and handling any deviations or issues during construction.

Conceptual Framework: The RSCM framework presented is primarily conceptual and has not been empirically tested. While it provides a theoretical foundation for integrating regenerative principles into SCM practices, additional research is needed to validate its effectiveness in real-world construction projects.

References.

1. Abdel-Basset M, Mohamed R, Sallam K, Elhoseny M (2020) A novel decision-making model for sustainable supply chain finance under uncertainty environment. J Clean Prod 269:122324

2. Abdolazimi O, Ma J, Shishebori D, Ardakani MA, Masaeli SE (2023) A Multi-Layer blood supply chain configuration and optimization under uncertainty in COVID-19 pandemic. Comput Ind Eng 182:109441

3. Adetunji I, Price ADF, and Fleming P (2008), Achieving sustainability in the construction supply chain. In Proceedings of the institution of civil engineers-engineering sustainability (Vol. 161, No. 3, pp. 161–172). Thomas Telford Ltd.

4. Ahmed SM, Azhar S, Ahmad I (2002) Supply chain management in construction: scope, benefits and barriers. Delhi Business Rev 3(1):1–6

5. Badi S, Murtagh N (2019) Green supply chain management in construction: a systematic literature review and future research agenda. J Clean Prod 223:312–322

6. Badri H, Bashiri M, Hejazi TH (2013) Integrated strategic and tactical planning in a supply chain network design with a heuristic solution method. Comput Oper Res 40(4):1143–1154

7. Balasubramanian S, and Shukla V (2017), Green supply chain management: an empirical investigation on the construction sector. Supply Chain Manag: An Int

8. Behera P, Mohanty RP, Prakash A (2015) Understanding construction supply chain management. Prod Plan Control 26(16):1332–1350

9. Bertsimas D, Sim M (2004) The price of robustness. Oper Res 52(1):35–53

10. Bolpagni M, Gavina R, Ribeiro D, and Arnal IP (2022), Shaping the future of construction professionals. Industry 4.0 for the Built Environ: Methodol, Technol Skills, 1–26.

11. Chen CL, Yuan TW, Lee WC (2007) Multi-criteria fuzzy optimization for locating warehouses and distribution centers in a supply chain network. J Chin Inst Chem Eng, 38(5–6):393–407

12. Chen Z, Ming X, Zhou T, Chang Y (2020) Sustainable supplier selection for smart supply chain considering internal and external uncertainty: an integrated rough-fuzzy approach. Appl Soft Comput 87:106004

13. Chen JH, and Ma SH (2008), A dynamic reputation incentive model in construction supply chain. In 2008 International conference on management science and engineering 15th annual conference proceedings (pp. 385–392). IEEE.

14. Cheng JC, Law KH, Bjornsson H, Jones A, Sriram R (2010) A service oriented framework for construction supply chain integration. Autom Constr 19(2):245–260

15. Chibeles-Martins N, Pinto-Varela T, Barbosa-Póvoa AP, Novais AQ (2016) A multi-objective meta-heuristic approach for the design and planning of green supply chains-MBSA. Expert Syst Appl 47:71–84

16. Dantzig GB (1955) Linear programming under uncertainty. Manage Sci 1(3–4):197–206

17. El-Sayed M, Afia N, El-Kharbotly A (2010) A stochastic model for forward–reverse logistics network design under risk. Comput Ind Eng 58(3):423–431

18. Eriksson PE (2010), Improving construction supply chain collaboration and performance: a lean construction pilot project. Supply Chain Manag: An Int J.

19. Fahimnia B, Davarzani H, Eshragh A (2018) Planning of complex supply chains: A performance comparison of three meta-heuristic algorithms. Comput Oper Res 89:241–252

20. Fathollahi-Fard AM, Hajiaghaei-Keshteli M, and Tavakkoli-Moghaddam R (2020), Red deer algorithm (RDA): a new nature-inspired meta-heuristic. Soft Comput, 1–29.

21. Fattahi M, Mahootchi M, Govindan K, Husseini SMM (2015) Dynamic supply chain network design with capacity planning and multi-period pricing. Transp Res Part E: Logist Transp Rev 81:169–202

22. Ghahremani-Nahr J, Kian R, Sabet E (2019) A robust fuzzy mathematical programming model for the closed-loop supply chain network design and a whale optimization solution algorithm. Expert Syst Appl 116:454–471

23. Gholizadeh H, Fazlollahtabar H (2020) Robust optimization and modified genetic algorithm for a closed loop green supply chain under uncertainty: case study in melting industry. Comput Ind Eng 147:106653

24. Gholizadeh H, Fazlollahtabar H, Khalilzadeh M (2020) A robust fuzzy stochastic programming for sustainable procurement and logistics under hybrid uncertainty using big data. J Clean Prod 258:120640

25. Gholizadeh H, Jahani H, Abareshi A, Goh M (2021) Sustainable closed-loop supply chain for dairy industry with robust and heuristic optimization. Comput Ind Eng 157:107324

26. 16.Gao, Y., Tsai, S.-B., Xue, X., Ren, T., Du, X., Chen, Q., and Wang, J. (2023). An Empirical Study on Green Innovation Efficiency in the Green Institutional Environment. Sustainability, 10(3), 13. https://doi.org/10.3390/su

27. Игамова, Ш. З. (2023). ОСОБЕННОСТИ БУХАРСКИЙ ОБЛАСТИ С ПОЗИЦИЙ ИННОВАЦИОННОГО РАЗВИТИЯ ЭКОНОМИКИ. *Gospodarka i Innowacje.*, *42*, 170-174.

28. Igamova, S. (2021). PROCESS ANALYSIS OF ESTABLISHMENT WITH EQUIPMENT. *ЦЕНТР НАУЧНЫХ ПУБЛИКАЦИЙ (buxdu. uz)*, *7*(7).

29. Irizarry J, Karan EP, Jalaei F (2013) Integrating BIM and GIS to improve the visual monitoring of construction supply chain management. Autom Constr 31:241–254