SOCIETY 5.0 FOR LEAN-DRIVEN SUSTAINABLE CONSTRUCTION: A CONCEPTUAL FRAMEWORK

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Abstract: Nowadays, the construction industry is significantly driven by the objective of achieving sustainable development. It creates a necessity to implement lean principles within the construction industry, as lean construction greatly contributes to sustainability. Despite lean construction's potential to achieve sustainable development, numerous barriers hinder its implementation. Consequently, the concept of Society 5.0 can be utilised as a transformative framework that integrates advanced technologies with a human-centric approach to overcome these issues. The aim of this research is to investigate how lean construction can be utilised along with society 5.0 to drive sustainable development in construction. To address this objective, a comprehensive literature review was conducted, and the content was analysed to align with the research objective. The findings of this research indicated that lean construction principles can be an effective application in any part of the construction process to prioritise sustainable outcomes. Moreover, the research revealed 95 barriers for lean integrated sustainable construction, categorised under political/government barriers, economic/financial barriers, technical barriers, social barriers, and other barriers. The research highlighted the necessity to integrate lean construction and Society 5.0 to overcome the barriers and drive sustainable development in construction. These research findings are paving the way towards conducting further research on the area of Society 5.0-enabled lean construction to drive sustainable development in construction.

Keywords: *Lean construction, Society 5.0, Barriers, Sustainable Development*

1. Introduction

Construction is the process of creating constructed facilities through transforming different resources, which strengthens panoramic economic growth through the creation of backward and forward linkages with other industries (Ma et al., 2024; Mahmood et al., 2024; Moavenzadeh, 1978). Despite its dominant role in economic growth and social improvement, the construction industry has significant unfavourable impacts, including not only environmental pollution, such as resource depletion (Chaudhary & Akhtar, 2024), biodiversity loss (Omopariola et al., 2024), and emissions contributing to climate change and air pollution (Mastromatteo & Amelio, 2024), but also human health concerns, such as indoor air quality issues (Luo et al., 2021), that compromise worker productivity and well-being, collectively highlighting the urgent need for Sustainable Construction (SC) practices (Maduka et al., 2016; Onubi et al., 2020).

Sustainable construction is imperative for addressing numerous global issues in the 21st century with the central focus of proper distribution of global resources (Cuesta et al., 2022; Yılmaz & Bakış, 2015). Interestingly, Bamgbade et al. (2017) highlighted that the construction industry has achieved gradual integration of sustainability practices. SC has rapidly been implemented globally in recent years as it facilitates optimum resource utilisation through energy and water conservation, pollution reduction, waste minimization, innovative design, and emphasising reuse and recycling practices (Lima et al., 2021). Nevertheless, sustainable development is a challenging task that requires significant effort. Singh (2016) emphasised that some of those challenges include the lack of investments, coordinated partnerships, continuous leadership, proper implementation, and indicators with effective data collection. This has highlighted the need to integrate sustainable development into construction practices more effectively, where Lean Construction (LC) can serve as a holistic approach to achieving this integration.

Initially, lean philosophy originated in the Toyota Production System (TPS) in the 1940s with the aim of increasing the production efficiency and reducing the costs by eliminating unnecessary wastes (Womack & Jones, 1997). Subsequently, Koskela (1994) introduced the first reference to apply lean principles in the construction industry as a solution to chronic issues of industry such as insufficient quality, low productivity, inadequate safety, and poor working conditions. Moreover, Akanbi et al. (2019a) stated that the concept of LC offers an innovative production philosophy by applying lean principles to construction and has the capability to revolutionise the construction industry by optimising project delivery and value for all stakeholders. Despite their potential to drive sustainable development, lean concepts face significant implementation challenges, necessitating solutions to minimise these barriers in the construction industry. Accordingly, Society 5.0 (S5.0) can be recognised as a promising framework to effectively mitigate barriers to lean-integrated sustainable development.

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In the 21st century, the construction industry is evolving a transformation towards sustainability through innovative approaches like S5.0, which is a human-centred, technology-driven concept ultimately aiming to improve human quality of life and environmental sustainability, which can be introduced as a foremost solution for prioritizing both project optimisation and societal well-being through the adoption of a smart society concept (Magni et al., 2024; Narvaez Rojas et al., 2021). Particularly in the context of S5.0, the adoption of Artificial Intelligence (AI) and Internet of Things (IoT) technologies not only improves construction processes but also enhances the ability to monitor and manage sustainability metrics in real-time, ensuring that projects adhere to environmental standards and SC practices (Arroyo et al., 2021). Concurrently, S5.0 plays a vital role in achieving lean-enabled SC through fostering collaboration among stakeholders, ensuring continuous improvement, and enabling innovative solutions that effectively address social, economic, and environmental challenges of lean-enabled SC (Schia et al., 2019; Sifa & Mbatta, 2023).

Even though it has been identified through research that lean principles and society 5.0 are positively driving sustainable development in the construction industry, the impact of society 5.0 on lean-enabled SC has yet to be researched. Therefore, this paper is aimed at developing a conceptual framework to illustrate the impact of S5.0 on lean-enabled SC. This paper begins with a literature review on the issues in the construction industry and consequently discusses the barriers to implement lean principles to overcome those issues. It then explores the concept of Society 5.0 and its potential synergies with lean principles. Subsequently, the paper describes integration along with the aim of achieving sustainable development in construction. Finally, the developed conceptual framework incorporates the literature findings.

2. Research Methodology

This research aims to fill the knowledge gap by answering the research question, "How can the Society 5.0 drive lean-enabled sustainable construction?" Consequently, a comprehensive literature review was carried out by referring journals, conference proceedings, books, and electronic resources to investigate the issues in the construction industry, barriers to implementing lean principles, and the concept of Society 5.0 and its potential synergies with lean principles. Eventually, this paper was intended to develop a conceptual framework based on the literature review.

3. Literature Review

3.1 ISSUES IN THE CONSTRUCTION INDUSTRY

The construction industry of any country faces a multitude of complex challenges (Alaloul et al., 2018; Ofori, 2000). Abdul-Rahman et al. (2014) and Shahron et al. (2023) highlighted that construction projects face numerous financial issues, including payment issues (Che Haron & Arazmi, 2020), cash flow issues, financial resource issues, and market issues (Najjir et al., 2012). Accordingly, financial challenges such as difficulties in getting loans, rising interest rates, inflation in materials, labor, and transportation, currency fluctuations, and the absence of regular cash flow forecasting can hinder project development (Abdul-Rahman et al., 2014). Beyond financial and ethical concerns, Loganathan et al. (2017) and Silva et al. (2024) highlighted that other critical issues related to the construction industry include a lack of trust between stakeholders, shortage of skilled workers (Akomah et al., 2020), reluctance to adopt new work practices such as lean practices, adequate worker welfare, supply chain disruptions (A. Papadopoulos et al., 2016), a lack of client engagement and competence, design management inefficiencies and a lack of productivity benchmarks and standards (Muhammad et al., 2015). As a holistic solution, many researchers empirically proved both globally (Aziz & Hafez, 2013; Idrissi Gartoumi et al., 2024; Issa, 2013) and locally (Hettiaarachchige et al., 2022; Parameswaran et al., 2024) the possibility of implementing LC to minimise these prevailing issues in construction projects.

3.2 LEAN CONSTRUCTION

Koskela et al. (2002) stated that LC aimed at delivering a project with maximum value and minimum waste., which can be considered as a new production philosophy with the potential to overcome many industry issues (Akanbi et al., 2019b). According to Arbulu & Zabelle (2006), the conspicuous focus in lean project delivery is the achievement of maximum possible customer value, whereas other main attributes of this concept consist of defining value from a customer perspective, simultaneous product and process management, continuous supply chain improvement, and regular leadership. Moreover, many studies have evidently indicated the immense benefits that can be achieved through LC as indicated in Table 1.

Table 1 - Benefits of Lean Construction

Benefits of Lean Construction	References
Reduce the construction cost	[1],[2],[3],[4],[5],[6], [7],[8],[10]
Reduce the total project duration	[1],[5],[6],[8],[10],[11],[12],[15]
Increase the construction safety	[4], [6],[7],[8],[10],[12],[14],[15],[18]
Improve the quality of construction	[6],[7],[8],[9],[10],[12],[14],[15]
Increase project performance	[3],[7],[8],[9]
Enhanced customer satisfaction	[6],[7],[8],[9],[10],[13],[14],[15],[16],[17]
Improved adherence to sustainable development	[14],[17],[18]
Adapting to continuous improvement	[7],[10],[13],[14],[15]

Enhance collaboration among project participants	[7],[9],[10],[13],[15]
Enhance labour productivity	[6],[8],[10],[14],[15]
[1] (Salem et al., 2005), [2] (Zimina et al., 2012), [3] (Aziz & Hafez, 2013), [4] (Bajjou et al., 2017), [5] (J. Sarhan et al., 2018), [6] (Ahmed et al., 2020), [7] (Albalkhy & Sweis, 2021), [8] (Mossman, 2009), [9] (Šuman & Semič El-Masr, 2013), [10] (Babalola et al., 2019), [11] (Forbes & Ahmed, 2010), [12] (Bajjou & Chafi, 2018), [13] (Ogunbiyi et al., 2014), [14] (Marhani et al., 2012), [15] (J. G. Sarhan et al., 2017), [16] (Freire & Alarcón, 2002), [17] (Nahmens & Ikuma, 2012), [18] (Ikuma et al., 2011)	

Since the benefits of LC tremendously address a wide range of prevailing issues in the construction industry across all aspects, including but not limited to quality, cost, safety, and sustainability, it is inevitable that implementing LC is one of the outstanding solutions for most construction industry-related issues. However, it is essential to emphasise that the implementation of LC is not free of barriers.

3.3 BARRIERS FOR LEAN INTEGRATED SUSTAINABLE CONSTRUCTION

Demirkesen et al. (2019) emphasised that, given the construction industry's dynamic and fragmented nature, utilising numerous tools is essential for efficiency, with lean implementation proving effective despite being a relatively new approach. However, Forbes & Ahmed (2004) emphasised that despite the evident benefits of LC, numerous hindrances arise when amalgamating the lean principles into construction projects. Moreover, several studies identified the barriers to implement LC, focusing on specific regions such as Bangladesh (Ahmed & Sobuz, 2019), Jordan (Al Balkhy et al., 2021), the United Kingdom (Bashir et al., 2015), and China (Shang & Sui Pheng, 2014). Table 2 presents the barriers for lean integrated SC.

Table 2 – Barriers for Lean Integrated Sustainable Construction

No	Barriers	Reference
	Political /Government Barriers	
1	Stringent requirements and approvals	[3],[5],[9],[10]
2	Lack of knowledge in lean	[1],[12]
3	Lack of government support for research in lean	[1],[3],[8],[9],[12],[13],[14],[25],[27],[28],[29],[30],[31]
4	Stringent requirements and approvals during contracting	[13]
	Economical / Financial Barriers	
5	Inventory costs	[2][5]
6	Dimensional variation cost of lean tools	[2], [10]
7	Lack of incentives and poor wages	[1],[4],[12],[28]
8	Consulting costs in lean	[1]
9	Market conditions	[1],[2],[4],[6],[9]
10	Insufficient financial resources	[8],[12],[16],[17],[18],[22],[25]
11	Additional implementation cost	[1],[9],[12],[28]
12	Time and commercial pressure	[9],[25],[28],[31],[32]
13	High inflation rates	[1],[8],[27],[28],[31]
	Technical Barriers	
14	Complexity of lean philosophy and terms	[1], [2],[3],[8],[9]
15	Complexity in design	[1],[4],[9],[10]
16	Inefficiency in takt time planning	[11], [33]
17	Failure in operational excellence	[1],[8],[9],[23]
18	Lack of knowledge in Last Planner implementation	[4],[8]
19	Lack of performance measurement systems	[1],[8],[9],[12],[21],[22],[27],[28],[29]
20	Limited use of off-site construction	[13],[22]
21	Insufficient program planning	[22]
22	Lack of appropriate lean technology or tools	[16],[22]
23	Lack of technical capabilities and green initiatives	[12]
24	Insufficient standardization	[3],[18],[22],[30],[32]
25	Lack of technological adaptations	[3],[27],[29],[30]
	Social Barriers	
	Workforce Barriers	
26	Problems in teamwork and diverging aims in lean	[1],[2],[3],[4],[8],[9],[23],[25],[27],[28], [29],[30],[32]
27	Language problem for non-native speakers	[2],[10]
28	Shortage of manpower	[10]
29	Employees' resistance to lean	[2],[4]
30	Stress and pressure in deadlines	[1],[4],[7]
31	Lack of incentives and motivation	[13],[22]
32	Reluctance of project participants to share risk–reward	[13]
33	Avoid making decisions and taking responsibility	[22]
34	Less personal empowerment	[22]
35	High turnover of workforce	[13],[22]
36	Lack of clear definition of individual's responsibility	[3],[8],[28],[30],[32]
37	Lack of individuals performance measurement	[1],[9],[27]
38	Complexity of lean in eyes of workers	[13],[22]
	Cultural Barriers	
39	Resistance to change	[1],[2],[3],[5],[9],[10],[12],[16],[19],[21] [22],[23], [24],[25],[27],[28],[29],[31]
40	Diversity in adopting lean culture	[2],[5],[12]
41	Lack of long-term lean philosophy	[3],[12],[13]

No	Barriers	Reference
42	Traditional culture and attitude of employees	[18],[20]
44	Lack of long-term relationships with suppliers	[1],[9],[13]
45	Cultural differences	[12]
46	Cooperation problems outside the construction department	[22]
47	Absence of organisational culture representing LC	[16],[22]
48	Fierce market competition environment	[22]
49	Human attitude issue in the organization	[3],[8],[9],[5],[25],[28],[29],[30],[32]
50	Unfriendly organizational culture	[1],[3],[27],[31]
	Managerial Barriers	
51	Misperception about lean practices	[2],[5],[9],[23]
52	Risk aversion in lean implementation	[1],[2],[3],[5],[9]
53	Lack of top management support	[1],[2],[3],[5],[6],[13],[15],[17],[21],[22][23]
54	Inefficiency in resource planning	[3],[10]
55	Centralized decision making	[13],[21]
56	Hierarchies in organizational structure	[13]
57	Lack of effective supervision and control	[22]
58	Lack of commitment(managerial)	[1],[3],[9],[16],[21],[25],[27],[28],[29], [30],[31],[32]
59	The dominance of the traditional management practice	[16],[18]
60	Slow decision-making process from executive	[1],[9],[25],[27],[29],[30],[31]
61	The hegemony of the traditional management practice	[1],[27],[28],[29],[31]
	Communication Barriers	
62	Stakeholder issues in communication	[1],[2],[3],[6],[8],[9],[16],[17],[18],[23],[25],[27],[28],[29]
63	Lack of organizational communication	[3],[6],[7],[8],[23]
64	Lack of information sharing and integrated change control	[6],[7],[9],[23],[24]
65	Lack of involvement and transparency among stakeholders	[13],[15],[22]
	Educational Barriers	
66	Lack of awareness and understanding of LC	[1],[3],[12],[13],[14],[15],[16],[17],[18],[19],[20],[25], [27],[28],[29] [30][31],[32]
67	Lack of competencies at managerial and employee levels	[13],[16],[18],[21],[22], [25]
68	Lack of lean consultants, education, and training	[1],[3],[13],[15],[22],[24],[25],[27],[28],[29],[30][31],[32]
69	Inadequate administration to generate a learning cycle	[13]
70	Lack of alliances between academy and organizations	[26]
71	Lack of knowledge on applying LC for safety improvement	[14]
72	Nonrecognition of lean construction advantages	[22]
73	Deficiency in advanced technical knowledge and skills	[1],[27],[31],[32]
	Other Barriers	
74	Low tender prices	[9],[28],[31]
75	Inadequate preplanning	[3],[28],[32]
76	Lack of understanding of customer needs and requirements	[3],[9],[12],[13],[21],[32]
77	Less involvement of contractors in design process	[1],[9],[27],[29],[32]
78	Lack of client and supplier involvement	[1],[3],[9],[27],[28]
79	Uncertainty in production process	[1],[27],[29]
80	Traditional design approach	[1],[3],[27],[28],[29],[30]
81	Unclear project definition and job specification	[1],[27],[29]
82	Inefficient resource management	[9], [27],[28],[29],[30]
83	End user preference	[27]
84	Uncertainty (delay and shortage) in supply chain process	[1],[8],[27],[29],[31]
85	Long implementation period of lean principles	[3],[27],[28]
86	Lack of customer satisfaction measurement system	[9],[28],[32]
87	Use of non-standard components	[9], [27],[29],[32]
88	Incomplete complicated design	[9]
89	Lack of agreed implementation methodology	[3], [9],[28],[32]
90	Ineffective waste management	[1],[30],[32]
91	Lack of planning for quality	[12],[13]
92	Slow and partially visible results of implementation	[13]
93	Inaccurate and incomplete drawings	[13]
94	Project subcontracting	[3],[8],[12],[22],[25]
95	Fragmented and cyclic nature of the construction projects	[13],[16],[25],[28],[32]

[1] (Alenezi, 2020c), [2] (Ghandour, 2020), [3] (Alenezi, 2020b), [4] (Ogunnusi et al., 2020), [5] (Alenezi, 2020a), [6] (Osuizugbo, 2020), [7] (Gamil & Alhagar, 2020), [8] (Zamani et al., 2021), [9] ((S S King et al., 2021), [10] (Alsharef et al., 2021), [11] (Oey & Lim, 2021), [12] ((Kawmudi et al., 2020), [13] ((Vithana et al., 2020), [14] (Pathirana, 2020), [15] (Alenezi, 2020a), [16] (Osuizugbo, 2020), [17] (Gamil & Alhagar, 2020), [18] ((Zamani et al., 2021), [19] ((S S King et al., 2021), [20] (Alsharef et al., 2021), [21] (Oey & Lim, 2021), [22] ((Kawmudi et al., 2020), [23] ((Vithana et al., 2020), [24] (Pathirana, 2020), [25] (Alenezi, 2020a), [26] (Osuizugbo, 2020), [27] (Gamil & Alhagar, 2020), [28] ((Zamani et al., 2021), [29] ((S S King et al., 2021), [30] (Alsharef et al., 2021), [31] (Oey & Lim, 2021), [32] ((Kawmudi et al., 2020), [33] ((Vithana et al., 2020)

According to Table 2, the study identified 95 barriers for LC implementation, highlighting the key barriers including inadequate government support, lack of performance measurement systems, teamwork challenges, resistance to change, insufficient management commitment, communication gaps, limited awareness and training, financial constraints, and slow decision-making. Nevertheless, 48 out of 95 identified barriers fall within various categories of social barriers, emphasising the pioneering role that human, cultural, and organisational factors play in the implementation of LC. This finding is further corroborated by the statement in which Moradi & Sormunen (2023) asserted that "people are the main root cause of the barriers, enablers, and implications of LC adoption and implementation.". Therefore, there is a need to explore a suitable

approach to address these barriers that prioritise humans and society while simultaneously addressing other relevant obstacles.

3.4 THE CONCEPT OF SOCIETY 5.0: A PATHWAY TO THE FUTURE

Huang et al. (2022) stated that both society and industry are significantly interdependent on each other, where industry developments can drive social developments as shown in Figure 1 below.

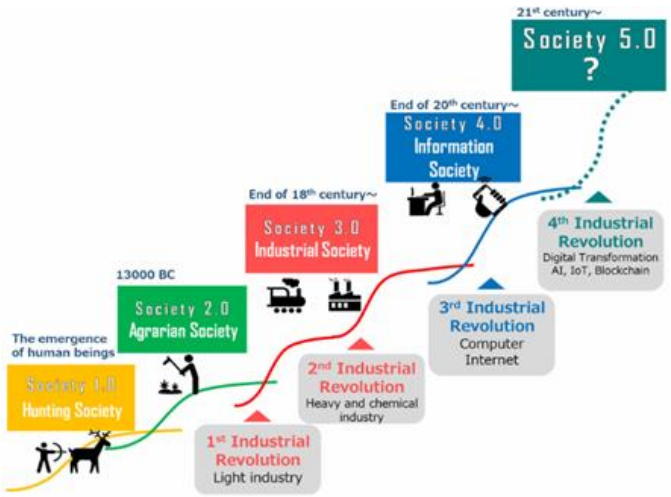

Figure 1, Chronological Development of Human Societies (Source:(Keidanren, 2020))

According to Figure 1, the industrial revolution transformed from industry 1.0, where steam-based machines were introduced, to industry 5.0, where sustainable, human-centric systems were implemented, society also evolved from society 1.0 to S5.0. Furthermore, various studies describe the concept of S5.0 from multiple perspectives. For example, Mourtzis et al. (2022) and Akman & Erdirençelebi (2024) described S5.0 as an approach designed to solve the current societal issues through the merging of cyberspace and physical space by utilising advanced information and communication technologies and aims for a super smart society that ultimately creates a high-quality and comfortable life for everyone in the society. Additionally, Deguchi et al. (2020) defined S5.0 as a highly intelligent society that was created by integrating cyberspace with physical space, and the concept relies on the generation, processing, and exchange of data and knowledge. Accordingly, Figure 2 below presents the main characteristics of S5.0.

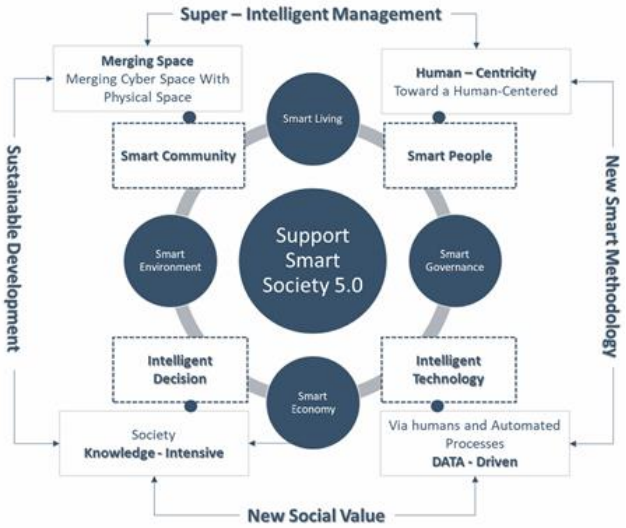

Figure 2, The concept of Society 5.0 *(Source:(Leng et al., 2022))*

As illustrated in Figure 2, Leng et al. (2022) featured S5.0 as a human-centred smart society aligned with a smart environment, smart living, a smart economy, and smart governance. Moreover, it aims to achieve a new social value characterised by a knowledge-intensive and data-driven society through sustainable development and super-intelligent management practices such as merging cyberspace with physical space. Similarly, Deguchi et al. (2020) characterised S5.0 by its merged cyberspace and physical space, its focus on being human-centric, its transformation to be knowledge-intensive, and its foundation as a data-driven society. The next section of this research presents a conceptual framework developed for the study.

4. Conceptual Framework

Green (2014) highlighted that a framework should be able to assist researchers in ensuring the coherence of their research projects and to help them maintain a clear focus on their research objectives aligning with a proper flow. Accordingly, by combining all the literature findings of the study, a conceptual framework was developed to represent the contribution of S5.0to drive lean-enabled SC in the construction industry. Figure 3 presents the developed conceptual framework for the study.

As presented in Figure 3, the research has identified 95 barriers for lean integrated SC, including political, economic, technical, social, and other barriers. According to the conceptual framework, S5.0 is characterised by smart living, a smart environment, a smart economy, and smart governance. Therefore, S5.0 has the potential to significantly overcome the barriers faced in lean-enabled SC by using advanced technologies and data-driven decision-making within a human-centric framework.

Political barriers, such as stringent regulatory requirements and lack of government support, can be mitigated through the integration of smart governance practices, enabling faster approvals and better alignment with SC goals. Economically, the use of digital technologies can reduce inventory costs, enhance financial planning, and optimise resource allocation, while mitigating the impact of high inflation and insufficient financial resources. From a technical perspective, S5.0 facilitates the adoption of innovative tools and technologies that address complexities in design, improve takt time planning, and enhance operational excellence. Furthermore, it provides a platform for improving knowledge-sharing, reducing inefficiencies in lean implementation, and promoting continuous learning and training, which are crucial for overcoming the technical and educational barriers in the construction industry. Socially, S5.0 improves collaboration among diverse teams, overcoming workforce resistance and cultural barriers by promoting a more inclusive, transparent, and adaptable work environment. By addressing managerial challenges, such as slow decision-making and risk aversion, S5.0 enhances organisational efficiency and responsiveness, ultimately driving the integration of lean practices in a sustainable and innovative manner. In summary, this conceptual framework emphasises the importance of adapting this novel society 5.0 approach with the integration of LC to drive sustainable development in the industry. However, there is a need to conduct a proper empirical investigation to identify the exact relationships between these barriers and society 5.0.

5. Conclusion

The construction industry is one of the most problematic industries all over the world and has created numerous global issues. Therefore, nowadays sustainable development plays a vital role in most of the construction projects, especially due to its enhanced project outcomes in par with social sustainability, economical sustainability, and environmental sustainability. When achieving sustainability within the construction industry, the concept of LC is widely utilised as it offers a variety of enhanced benefits to all the stakeholders in a construction project. However, implementing LC is not free from barriers. Accordingly, a comprehensive literature review was carried out and revealed 95 barriers for lean integrated SC, including political, economic, technical, social, and other barriers. Accordingly, 48 out of 95 identified barriers fall within various categories of social barriers, emphasising the necessity of addressing a human-centric approach within the construction industry.

Consequently, the research findings highlight the ability of S5.0 concept to overcome most of the barriers for implementing lean integrated SC. The synergies incorporated within S5.0 approach mainly included smart living, smart environment, smart economy, and smart governance that prioritise this human-centric, super-intelligent society and the developed conceptual framework can be used as the basis for conducting further research.

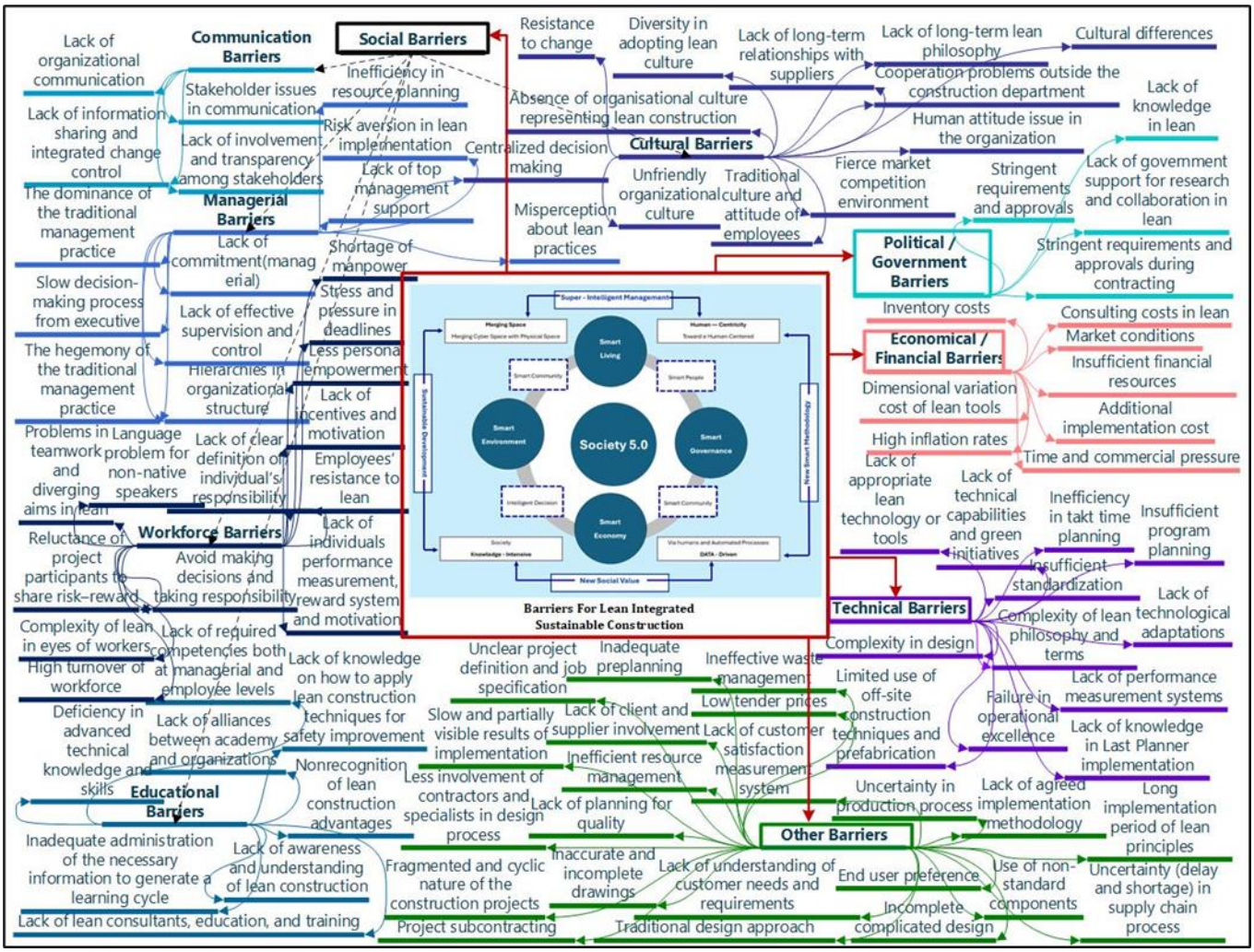

Figure 3, The conceptual framework for the lean enabled Society 5.

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