

TOWARDS A CIRCU-LEAN CONSTRUCTION ECONOMY THROUGH STANDARDISATION

Nathan G. O. Johns¹, Saeed Talebi², & Mike Kagioglou³

ABSTRACT

As the perpetual advancement of the built environment engulfs the natural environment, sustainable development has been brought to the forefront of innovation within the construction industry. Strategies such as the Circular Economy (CE) and Lean Construction (LC) have been proven to support sustainable goals. However, their application within the construction industry has been hampered by the complexities of the industry's dynamics. Within both the CE and LC, standardisation has been incorporated to reduce complexity within the industry's pathology. Using a questionnaire to sample two case studies through an interpretivist perspective, this study seeks to define the foci of standardisation within the CE and LC and investigate the practice's presence, level of development, and driving force within building construction within the United Kingdom (UK). The findings of this study highlight the increased incorporation of standardisation within building construction in the UK, as well as its sheer driving force and the impact of a lack of standardisation. This study provides a novel contextualisation and conceptual framework for LC and CE standardisation in construction, and an empirical comparison of standardisation between UK house building and residential high-rise projects.

KEYWORDS

Lean Construction, standardisation, circular economy, construction industry.

INTRODUCTION

Construction is one of the world's most resource-intensive industries: it consumes roughly 50 % of all raw materials in the European Union and generates 20 – 35 % of global solid waste (European Commission, 2020). In the UK, the picture is starker—construction, demolition and excavation waste constituted 64 % (120.4 million tonnes) of all national waste in 2016 (UK Environmental Agency, 2021). To reduce the generation of waste in the construction industry, two core strategies have been promoted: the CE and LC (Benachio et al., 2021). The CE and LC are comprised of multiple practices to streamline the construction industry to reduce waste and increase the value of production (Alarcon, 1997; Benachio et al., 2021). However, due to the complexity of construction – involving multiple stakeholders, sectors, supply chains, and contributing industries – the implementation of the CE and LC has been impeded compared to other sectors, such as the automobile industry (Liker, 2004). A core enabling practice to reduce complexity within the pathology of the built environment is standardisation. By standardising materials, components, and designs, the built environment's composition is simplified and

¹ Lecturer/Dr, Engineering and the Built Environment, Sheffield Hallam University, Sheffield, United Kingdom, N.Johns@SHU.ac.uk, orcid.org/0009-0004-2377-3089

² Associate Professor, Engineering and the Built Environment, Birmingham City University, Birmingham, United Kingdom, Saeed.Talebi@BCU.ac.uk, orcid.org/0000-0001-6711-0931

³ Professor, Built Environment, De Montfort University, Leicester, United Kingdom, mike.kagioglou@dmu.ac.uk, orcid.org/0000-0003-3521-1484

categorised, which allows for the application of a wide range of advanced CE and LC practices (Alarcon, 1997; Benachio et al., 2021).

The lack of contextualisation and comparison between the foci of the CE and LC's approach to standardisation within the construction industry, with the aim of applying more advanced CE or LC practices, warrants investigation and comparison. Furthermore, within the UK construction industry, there is marginal empirical data on the application and impact of standardisation for CE or LC applications. Furthermore, there is a gap in knowledge surrounding the combination of LC and CE standardisation approaches and focuses. It is also unknown which disciplines within the construction industry favour the use of standardisation within practice. Finally, there is a gap in knowledge investigating the application of standardisation in high-rise structures compared to housebuilding. Similar studies have looked into the differences between practices of LC and the CE (Johns et al., 2023), as well as LC and building information modelling (Sacks et al., 2010). This study seeks to compile the standardisation foci of LC and the CE, investigate them within UK residential construction, and develop a combined circular-lean conceptual framework on the foci of standardisation.

STANDARDISATION TOWARDS LEAN CONSTRUCTION AND A CIRCULAR ECONOMY IN CONSTRUCTION

The finality of Earth's resources has caused ever-increasing market prices and environmental damage to obtain the raw resources needed for the construction industry (MacArthur et al., 2013). This has pushed the construction industry to pursue strategies to optimise material use to concurrently reduce the cost and environmental impact of construction activities. Two of the prominent strategies are being investigated to achieve economic and environmental targets: LC and the CE. The core philosophy of LC is to avoid wasted time, money, equipment, and materials (Alarcon et al., 1997). This is achieved by designing production flows and conversions to simplify and optimise the construction process by identifying areas for continuous improvement (Alarcon et al., 1997). The CE, on the other hand, is an economic structure that aims at reducing consumption and waste by transferring resource flows into a closed-loop circular system (MacArthur et al., 2013). The design and end-of-life stages are key in the CE, designing for maximum resource retention through the lifecycle, for the highest level of CE end-of-life material reduction and reintroduction into the economy (MacArthur et al., 2013). Kalemkerian et al. (2022) found multiple similarities between the approaches of green LC and the CE. For instance, the reductionist approach to material consumption stems from the design stage. One such practice that routinely appears in both bodies of knowledge is the standardisation of systems and components.

STANDARDISATION AND THE CIRCULAR ECONOMY

Dewagoda et al. (2024) stated that standardisation is a core practice of the CE to simplify construction designs into commonly used parts and materials to reduce inventory space on site and enable prefabrication and modularisation. Furthermore, they discuss the benefits of standardisation through the CE to enhance maintenance through replaceable parts and components to optimise the design, manufacturing, and assembly of structures for resource consistency and to minimise waste. In another study, Asante et al. (2022) found that the standardisation of designs was one of the key practices to enable the CE in the construction industry to extend lifecycles and increase the ability of companies to recover resources. Ultimately, the standardisation of designs in the construction industry focuses on the reduction of expenditure and waste through the application of the CE within the assembly and construction stages.

In addition to the integration of the CE in the design stage, Minunno et al. (2018) investigated the enabling factor that standardisation plays in the practical application of the CE

within prefabricated building components and modules. Standardisation provides a platform for the creation of adaptable components and modules that reduce waste and increase the reusability and recyclability of building elements for the CE. Moreover, Tokazhanov et al. (2022) discussed the benefits of standardisation to simplify components for the application of modularisation and to reap the benefits of prefabricated and repetitive work in the construction industry. In line with prefabrication and modular construction, Kohler et al. (2025) found that the routine application of standardisation in a supply chain increases the material yield of a project by streamlining information on material supplies and reducing errors, which ultimately reduces the cost and wasted time on a construction project. In addition, Barbhuiya and Das (2023) also found that standardisation of materials, components, and construction methodologies improves the collection of building information to optimise the circularity of buildings. However, Munaro and Tavares (2023) discussed the lack of standardised geometries for products within the construction industry as a barrier to the implementation of the CE. The lack of standardised geometries creates more waste due to the trimming and adjustments of products, as well as an increased number of product types. This shows that the standardisation of designs enables the standardisation of components, which can be developed into modular platforms for further application of the CE, reduction of cost, and material waste, and increase lifecycle value. Moreover, the standardisation of construction elements and materials simplifies information to identify further applications and increase the simplification of building designs.

STANDARDISATION AND LEAN CONSTRUCTION

Standardisation within LC resides within the fundamental principles of reducing variability and simplifying flows and conversions (Alarcon, 1997). Standardisation also links with the LC 5S group of management practices, which aim to sort, straighten, shine, standardise, and sustain processes (Babalola et al., 2019). Within LC, standardised tasks sort, organise, and clean processes for continuous improvement (Aziz et al., 2013). The use of standardisation in LC provides consistency within construction supply chains, contributing to the reduction in defects, inventory, over-processing, and improving quality (Bajjou and Chafi, 2018). Furthermore, Carvajal-Arango et al. (2019) stated that standardisation of the construction process is required to improve the sustainability performance of LC in practice, as it provides continuity for environmental assessment. In their study on prefabrication in China through lean, Li et al. (2024) discussed the standardisation of designs, production, materials, and components to increase the quality of buildings and structures. Additionally, Alvin and Fadhilah (2023) found that standardisation within the manufacturing and construction stages increases the time and material efficiency of the industry. In their study, they attributed standardisation to multiple strategies for sustainability, such as procurement, estimation, components, and regulations. Moreover, William et al. (2025) found that standardisation is a core element of achieving financial targets and reducing project expenditure. Overall, it can be seen that standardisation in LC simplifies the designs and processes of the construction industry to reveal opportunities for the continuous improvement of material use, process time, cost efficiency, and quality enhancement through the collection of information.

STANDARDISATION COMPARISON

Between the LC and CE standardisation strategies, there are many common foci (Table 1). The simplification of the construction design is a key element of both strategies to allow for the collection of information. Once implemented, the information collected on the standardised designs and processes allows for the reduction of material consumption/waste and a reduction in expenditure. Other than the aforementioned foci, common foci between the strategies are material and cost reduction. LC looks at material consumption as a form of waste, which in turn

increases the cost of a process. In comparison, the CE views material consumption as an additional strain on the environment, which leads to increased material waste and financial implications. Differences in the literature on standardisation in both strategies stem from the desired output. Within the CE, standardisation seeks to improve the reduction, reuse, and recycling of materials through multiple lifecycles. Compared with LC, which focuses on the enhancement of scheduling and the quality of the project. Overall, standardisation within both strategies aims to simplify and reduce materials/costs. However, the desired output differs based on the perceived value of the application; LC viewing value as time and quality through the reduction of waste in all of its forms/ the CE viewing value in terms of circularity through reduction, reuse, and recycling of materials. The combination of foci could create a more holistic approach to standardisation that forms a circulo-lean strategy for standardisation.

Table 1: Comparison of Standardisation foci from a LC and CE Perspective

Foci	Description	LC	CE
1. Simplification	Standardisation simplifies designs and systems to enable more advanced strategies, such as modularisation.	*	*
2. Information Collection	Standardised work allows for material and methodological information collection to reveal construction performances.	*	*
3. Time Reduction	Standardised systems and components create repetitive cycles, reducing the time for assembly.	*	
4. Material Reduction	The standardisation of materials and components allows for the reduction in consumption/waste compared to in-situ.	*	*
5. Cost Reduction	The reduction of materials, material waste, and time on construction projects reduces the expenditure of work.	*	*
6. Reuse & Recycling	Standardised designs and components allow for the analysis and collection of materials for reuse and recycling.		*
7. Quality Improvement	Standardisation enables continuous improvement that reduces defects and increases the quality of products.	*	

METHODOLOGY

This study utilises an interpretivist philosophy to understand and discern the experiences and opinions of professionals in the construction industry (Patton, 2014). A mixed-method approach was adopted, employing a non-generalisable questionnaire focused on two residential developers to examine the presence, development, driving force, and impacts of a lack of standardisation within the case studies (Saunders, 2019). Supply Chain One (SC1) develops high-rise residential buildings, whereas Supply Chain Two (SC2) develops houses. Both supply chains were integrated in their delivery of projects, providing consistency within each sample. Twenty-seven participants with six to thirty-five years of experience were identified for the study through a snowball sample within each supply chain. A snowball sample commenced with a purposefully selected participant in each supply chain with knowledge and links to each of the key divisions and directors within the supply chain (Saunders, 2019). A potential bias within the snowball sampling strategy is the rationale for referring the study to new participants. This form of bias was mitigated by the purposive selection of the primary recipient, who had a working knowledge of the division and directors to whom they could select the best participant based on their knowledge, experience, and merit.

A short questionnaire was used to collect qualitative and quantitative data. The instrument comprised open-ended questions exploring participants' understanding of LC, the CE, and the

perceived role of standardisation in enabling both strategies. A thematic analysis based on grounded theory was conducted on the qualitative data to assign responses to the defined themes within the literature to compare and contrast responses across participants (Patton, 2014). Responses were manually coded based on the identified themes (foci) within the literature review (Saunders, 2019). Additionally, a 4-point Likert scale was used for two questions to assess the extent to which participants viewed standardisation as a driver of, or a barrier to, the development of LC and CE practices. These items enabled a cross-comparison between disciplines and supply chains to understand the variance between groups. Measures of central tendency – the mean average - were applied to summarise responses, and descriptive statistics were used to visually represent the quantitative findings through a series of bar charts. A limitation of the quantitative dataset is the sample size, which precluded non-parametric significance and validity testing (Saunders, 2019).

FINDINGS AND DISCUSSION

Most participants demonstrated a general awareness of CE principles in day-to-day practice, although they were less familiar with its formal terminology or structured application within the construction industry. As participant 21 noted, “...some people explicitly recognise the process as a sustainable benefit..., where others would implicitly do it...”. A similar pattern was observed for LC: participants commonly described lean-related activities through operational practices such as value engineering or just-in-time delivery. Awareness of formal lean methodologies varied across roles, with higher levels identified among specific individuals. This suggests that CE and LC-aligned activities are present within routine practice but are not consistently identified or framed as CE or LC initiatives.

Another interesting finding was the lack of identification of the key foci among different participants (Table 2).

Table 2: Identified Foci of Participants in SC1 & SC2

SC1		Foci No.							SC2		Foci No.						
No.	Role	1	2	3	4	5	6	7	No.	Role	1	2	3	4	5	6	7
P1	Construction	*		*	*			*	P3	Construction		*	*	*			*
P2	Commercial	*		*	*		*	*	P4	Designer	*				*		
P5	Construction	*		*					P6	Waste Man.							
P7	Designer	*		*	*				P8	Construction							
P11	MEP Director	*		*					P9	Designer	*			*			
P12	Commercial	*		*	*	*			P10	Engineer	*				*		
P13	Commercial	*			*	*			P14	Commercial					*		
P15	Supplier	*		*	*				P18	Supplier							
P16	Demolition	*		*	*		*		P20	Supplier							
P17	Sustainability	*			*	*		*	P22	Sustainability				*		*	
P19	Commercial								P23	Logistics							
P21	Sustainability								P24	Sustainability		*		*	*		*
									P25	Procurement							
									P26	Logistics							
									P27	Designer	*		*				

Members of the same team and supply chain had largely different levels of knowledge in terms of how standardisation is applied within their projects and what the purpose of application is (i.e., the SC1 sustainability team). It can also be seen that SC1 had a broader knowledge of standardisation within their construction projects, whereas SC2 had fragmented indicators throughout the disciplines. The main disciplines with knowledge of standardisation within their

practice are construction managers, designers, and commercial managers. This suggests that standardisation activities have a larger impact on construction and commercial performance, which is heavily influenced by the design that dictates the operational and financial environments of construction projects.

SIMPLIFICATION

Within SC1, the construction and design teams connected simplification with standardisation. For the construction director (P1) and construction manager (P5), standardisation was seen as a strategy that "... makes the production process a lot simpler". The design manager (P7) and construction manager (P5) for SC1 provided context on simplification and its impact, saying that standardisation reduces components to "... one set rather than having to do multiple different sizes" and that "If it's not standardised and it's not simple... we've got no chance of achieving the programme". This shows that the standardisation of the design provides simplicity within the construction process to improve the ability of the construction team to deliver the project to or even before the planned schedule. Within SC2, only the design manager (P27) found a correlation between standardisation and the simplification of the project, saying, "It simplifies the work because every time, they've got a very similar plan". This shows a similar finding to those in SC1; however, other disciplines on the construction teams did not identify the use of standardisation to simplify the construction process. This shows a disconnect between the implementation of simplification through standardisation and those constructing, managing, or costing the development.

In both supply chains, the suppliers, the sustainability, and commercial teams didn't make the connection, along with the other supply chain-specific disciplines, that simplification can have benefits in the delivery of a project, LC, or the CE. Simplification was a prominent focus that arose within the empirical findings. Dewagoda et al. (2024), Tokazhanov et al. (2022), Alarcon (1997), Babalola et al. (2019), and Aziz et al. (2013) identified simplification as a core focus of standardisation within LC and the CE. Based on the disciplines that identified simplification as a focus, the empirical studies indicate that the design and construction operations benefit the most from the simplification of the construction process.

INFORMATION COLLECTION

For information collection, both supply chains had few responses on the review of components and processes for standardisation and the potential benefits in practice. In SC1, a construction manager (P5) said that they "...[design] it in the factory because it makes more sense, having gone through trials and errors". This shows that the developer seeks innovation through standardisation and conducts research and development activities to understand the implications of the practice. In comparison, a construction manager (P3) in SC2 said that "... they standardise, and then they improve the efficiency". Based on the details provided in their response, the participant did not have specific knowledge on the level of information collected on the standardised house designs, the type or detail of the analysis, or the dynamics behind the application of standardisation within the designs. Both responses reflect the level of communication and collaboration seen in the responses of simplification, whereby the construction managers in SC1 have a higher level of integration within the standardisation process. Both supply chains showed no consideration in their responses for the information collected on the standardisation of the designs to increase the application of LC or the CE.

In both supply chains, it was identified by the construction managers as a measure of progress and waste generation. This aligns with Kohler et al. (2025), Barbhuiya and Das (2023), and Carvajal-Arango et al. (2019); however, all three suggest higher levels of analysis from the collection of information, such as environmental assessments or using building information

modelling. This suggests that standardisation does ease the process of collecting information, but at present, it is not used to its full potential.

TIME REDUCTION

For time reduction, SC2 had no explicit responses for using standardisation to improve project schedules. This could be due to the high level of standardisation of their work, creating a detachment from its effects on their projects. In comparison, SC1's construction team and designers showed strong links between the use of standardisation and the benefits to their construction schedules. The construction director (P1) stated that "[standardisation] makes the production process... a lot quicker". Furthermore, SC1's construction manager (P5) said, "If it's not standardised and it's not simple... we've got no chance of achieving the programme". This shows that standardisation has become a key practice within SC1 to quicken the construction process and achieve the set programme for their developments. The design manager (P7) further contextualised the level of development of their standardisation practices by pushing "...the more repetitive work, which brings the bigger benefit to... the programme". Decisions such as the choice of building frame system were chosen "...because of the speed at which we can install them [standardised columns]". The choices of SC1 show that the standardisation of their designs creates real improvements to their construction schedules, including the additional time required to alter and innovate the designs themselves. Although the effects of standardisation on the time required to construct a project are apparent in the sample, the overall LC approach was not known to the respondents and could be used to further improve the design and scheduling of both supply chains. The standardisation foci for the reduction of time (Alvin and Fadhilah, 2023) was heavily discussed in SC1 by the construction managers and designers as a core practice to meet the schedules on the projects. This suggests that standardisation is a key practice to meet the schedules of the modern construction industry.

MATERIAL AND COST REDUCTION

Material and cost reduction were the most commonly identified foci of applying standardisation within both supply chains. In SC1, the design manager (P7) said that they can "...improve a process by standardising... that benefits the production and reduces waste". However, "It's because of the speed... rather than a benefit in terms of reduction of concrete". This shows that the reduction of materials and time is often led by the potential cost savings. This was confirmed by the construction (P1) and commercial directors (P12&13) who said, "...waste is never anything that really comes up in that discussion", "It's something you do because it saves money. Consumption is the primary focus. Waste does have an influence because less waste equals less cost", and "More waste costs more money, so not necessarily driven by... reducing waste". This shows that the leading decision makers of developments rarely discuss waste as a primary problem that is reduced by standardisation, more of a side effect, and reducing the initial material input is one of the main foci of standardisation. This was echoed by the sustainability team (P17), who confirmed that "reducing waste isn't necessarily the main reason behind it...". The supplier (P15) in SC1 had a different perspective: "Repetition and standardisation are routes for efficiency, and with it comes reducing waste". This shows that most disciplines in SC1 do not see the correlation between material waste and reducing material consumption. Furthermore, the lack of connection between standardisation and material reduction in construction among the wider disciplines shows a lack of knowledge of LC and the CE.

In SC2, the focus of standardisation was focused on cost reduction and material reduction through material waste mitigation. The designers (P4&9) said that "It keeps the waste produced on site down" and "...more towards reducing costs rather than waste". Additionally, they stated that "We have a range of standard house types... they're all costed, we know how economical they are". This shows an active review and evaluation of their standardised house types to

increase standardisation, reduce waste materials and increase profits. When discussed with the construction manager (P3), they said the application of standard designs and elements produces "... a lot less waste". The sustainability team provided mixed answers. P22 said, "There's a big drive recently for standardisation, and I think standardisation will reduce waste", whereas P24 said that "A standard design and a standard bill of quantities is commercially the best thing to do. Homes that are highly standardised... are cheaper to build". A lack of connection between commercial disciplines and material or cost reduction through standardisation shows that the reduction of both is prioritised within construction and sustainability teams. The findings show that SC2, like SC1, is largely focused on the commercial impact of standardisation and that waste reduction is an addition to the enhancement of profit. In both supply chains, a level of relation to the CE and LC is present within material and waste reduction; however, high levels of CE and LC practice implementation are not identifiable.

The findings show that the LC and CE focus for material waste reduction through standardisation, as proposed by Dewagoda et al. (2024), Minunno et al. (2018), Munaro and Tavares (2020), and Alvin and Fadhilah (2023), are present within the sample. Cost reduction was another prevalent focus within the empirical data collection. The findings on cost reduction align with similar studies by Kohler et al. (2025), Munaro and Tavares (2023), and William et al. (2025), showing alignment between the focuses of the CE and LC.

REUSE AND RECYCLING

Within both supply chains, there was a lack of knowledge on the CE and the benefits of standardisation when applying the CE for reuse and recycling. This shows that reuse and recycling are not a primary consideration within the samples, which focus more on the 'reduce' element of the CE. The demolition group, however, discussed the benefits of construction standardisation on the disassembly and reuse/recycling of buildings. They said that "If all units are standardised, there's no reason why the cladding panels can't be lifted off, stacked, and put onto another building. Then you've got steel frames. It was bolted together. So, it can be unbolted and reused". This highlights the benefits of standardisation further into the lifecycle and within the end-of-life stage. If higher strategies such as the CE are going to develop further within the construction industry, the reuse and recycling elements need to be simplified and standardised for repetitive and measurable performances. Additionally, the lack of awareness among other disciplines shows a lack of understanding of the benefits of standardisation for the reuse and recycling of materials in the CE. This aligns with studies conducted by Dewagoda et al. (2024), Asante et al. (2022), and Minunno et al. (2018) on enabling the reuse and recycling of materials in the construction industry. These findings suggest that the application of standardisation within the construction industry will enable the disassembly of future structures, improving the recovery of materials and components.

QUALITY IMPROVEMENT

For quality improvement, both supply chains scarcely considered quality as a focus. However, sustainability (P17&24) disciplines in each supply chain suggested quality was enabled through standardisation by saying "...quality control issues are sort of the main thinking [for standardisation]" and "...we will be delivering a better-quality home". This shows that the standardisation of designs and components can improve the quality of projects through consistency. A construction manager in SC1 also noted this when they said: "[standardisation] will enable them to deliver the scheme to a high quality". This shows that quality improvement is an end goal of standardisation; however, the definition of quality may be subjective to each discipline or client. Furthermore, no specific LC or CE process was noted to suggest the practices were implemented to achieve either strategy. The improvement of project quality (Bajjou and Chafi, 2018; Li et al., 2024) was identified by construction managers in SC1 and

SC2, suggesting that the use of prefabricated or standardised designs/components reduces the environmental and labour/skill impacts on in-situ works. This could be further compared to other qualities of a construction project, such as material consumption, reuse & recycling, and time reduction. This suggests that quality is an ultimate output of standardisation, as it could subjectively encompass all of the other foci based on the individual's perception of quality.

STANDARDISATION AS A DRIVER

When reviewing the results of SC1 and SC2 for standardisation as a driver, it is clear to see that all of the participants viewed it as a driver (Figure 1). The mean average for both supply chains indicated that the overall choice was 'agree'. This suggests that, regardless of discipline, standardisation of systems and components provides a positive driving force. No disciplines disagreed that standardisation is a driver. The highest scores for standardisation as a driver were seen within the construction management, demolition, and logistical management groups. This suggests that the disciplines with the most interaction with materials and operations favour standardisation to improve their practice. Whereas disciplines with links to physical operations are less impacted by standardisation. Within the sample, there is some variance between supply chains within the construction management, commercial management, design, and sustainability groups. Within construction management and sustainability, SC2 found that there is a stronger driving force from standardisation. For commercial management and design, SC1 possessed stronger opinions on standardisation as a driver. This suggests that standardisation has a bigger impact on the construction and sustainability groups within SC2, which could originate in the repetitive work of house building and the use of standardised materials and components. Compared to SC1, the commercial managers and designers could favour standardisation due to a lack of repetition within their tailored high-rise buildings. Furthermore, based on the discussion of practices, standardisation can be interpreted as a precursor for more advanced practices within LC and the CE, such as modular construction in SC1. The results suggest that both SC1 and SC2 are focusing on standardisation to simplify and improve their practice for higher financial, operational, and material performances.

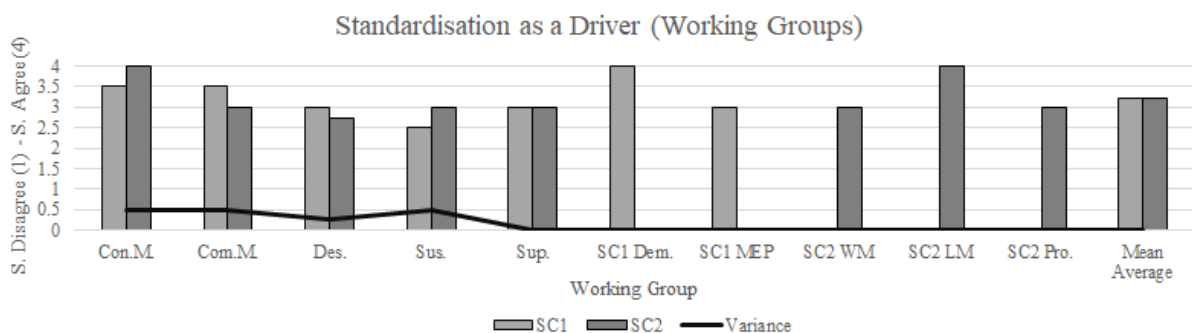


Figure 1: Standardisation as a Driver SC1 and SC2

A LACK OF STANDARDISATION AS A BARRIER

The results for a lack of standardisation as a barrier and more diversity within SC1 and SC2 (Figure 2). The mean average for both supply chains is 'agree', which shows that a lack of standardisation does pose a barrier to LC and the CE. However, the diversity of responses suggests a lack of standardisation could pose more of a barrier to specific disciplines compared to a holistic barrier across the supply chain. Disciplines that ranked a lack of standardisation as a significant barrier were demolition and waste management. The link between demolition and waste management suggests that a lack of standardisation has a higher impact on processes that produce waste and the management of waste through LC or the CE. Other disciplines, such as construction management, commercial management, sustainability, suppliers, and procurement,

also show that they are impacted by a lack of standardisation. This could suggest that the lack of standardisation has an impact on the core operations of building construction, which is complex and requires simplification. Disciplines that didn't identify a lack of standardisation as a barrier were SC1's design and MEP groups. This could originate from the scope of their projects, which are tailored 'one-off' high-rise developments. Ultimately, it can be construed that a lack of standardisation hampers the management of materials and waste, complicating it.

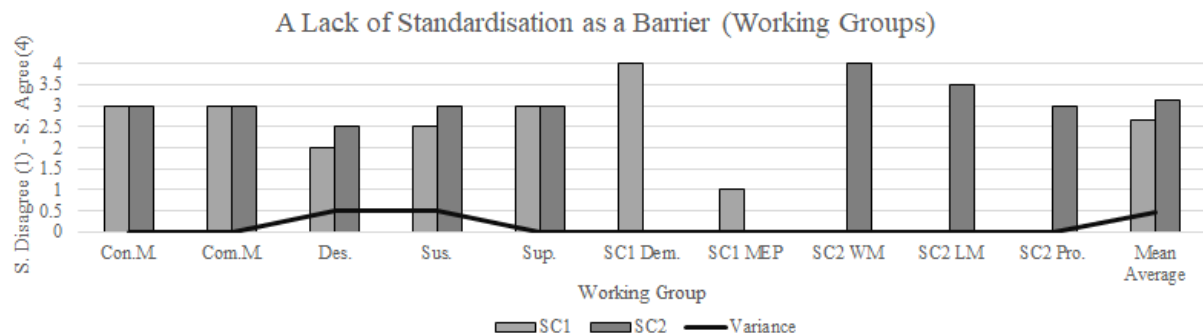


Figure 2: A Lack of Standardisation as a Barrier SC1 and SC2

SUMMARY

The overall perception of standardisation within SC1 and SC2 was positive. Participants showed a high level of application within their practice with key examples of standardised designs, materials, and components. This suggests that the development of standardisation as a practice within SC1 and SC2 is providing each respective supply chain with benefits to their practice. However, standardisation was not commonly linked to LC or the CE within the empirical studies, suggesting a lack of theoretical knowledge within the samples.

From the empirical studies and extant literature, clear relationships and processes could be seen between the foci of standardisation (Figure 3). Within the findings, simplification and information collection can be seen as the initial foci for application, followed by either reuse & recycling, cost, material, or time reduction, which leads to the improvement of the project's quality. Common foci could be considered circular and lean, whereas specific ones, such as reuse & recycling and time reduction, are more aligned with their own approach. If combined into one standardisation approach, a circu-lean strategy towards standardisation is developed.

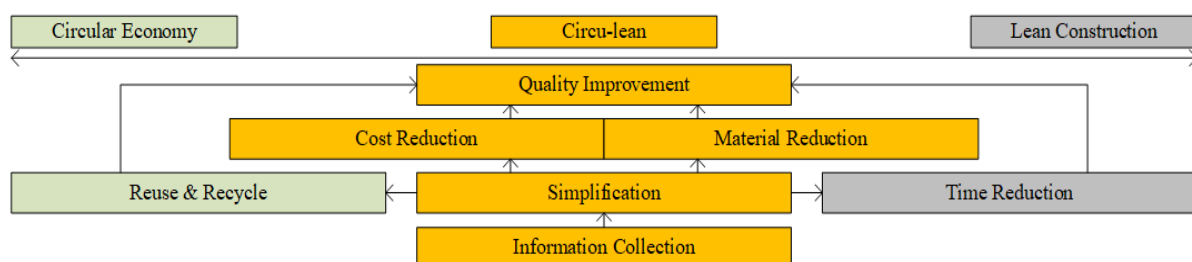


Figure 3: Conceptual Framework of Circu-Lean Standardisation

CONCLUSION

This study provides a novel conceptual framework combining LC and CE standardisation foci and their relationships to establish a new amalgamated circu-lean standardisation model. This advancement builds on studies such as Kalemkerian et al. (2022) by identifying specific practice-level insights into the mechanisms within the two strategies and their points of convergence to develop an empirically grounded hierarchy of standardisation foci. This contribution to theory can structure future theoretical and practical integrations of

standardisation within the construction industry. Moreover, this study has provided empirical insights into the application of standardisation within UK residential developments and the rationale behind practice, whether it is through a LC, CE, or unspecified strategic focus. Limitations of this study largely surround the use of case studies, their ability to be generalised, and the size of the sample within each supply chain. Future research could entail larger sample sizes, generalisable results across the construction industry, investigations into different construction sectors (i.e., infrastructure), and correlations with modular construction.

REFERENCES

- Adhi, A. B., & Muslim, F. (2023). Development of stakeholder engagement strategies to improve sustainable construction implementation based on lean construction principles in Indonesia. *Sustainability*, 15(7), 6053. Available: <https://doi.org/10.3390/su15076053>
- Alarcón, L. (1997). Lean construction. CRC Press. Available: https://books.google.co.uk/books?hl=en&lr=&id=tUpZDwAAQBAJ&oi=fnd&pg=PP1&dq=lean+construction+luis+alarcon&ots=CJWvLvt0jZ&sig=g5AYTqLqhr-QaQrRYzuHwIZgM60&redir_esc=y#v=onepage&q=5s&f=false
- Asante, R., Faibil, D., Agyemang, M. and Khan, S. A. (2022). Life cycle stage practices and strategies for circular economy: assessment in the construction and demolition industry of an emerging economy. *Environmental Science and Pollution Research*, 29, 82110-82121. Available: <https://doi.org/10.1007/s11356-022-21470-w>
- Aziz, R. F., & Hafez, S. M. (2013). Applying lean thinking in construction and performance improvement. *Alexandria engineering journal*, 52(4), 679-695. Available: <https://doi.org/10.1016/j.aej.2013.04.008>
- Babalola, O., Ibem, E. O. & Ezema, I. C. (2019). Implementation of lean practices in the construction industry: A systematic review. *Building and environment*. Available: <https://doi.org/10.1016/j.buildenv.2018.10.051>
- Bajjou, M. S., & Chafi, A. (2018). The potential effectiveness of lean construction principles in reducing construction process waste: an input-output model. *Journal of Mechanical Engineering and Sciences*, 12(4), 4141-4160. Available: <https://doi.org/10.15282/jmes.12.4.2018.12.0358>
- Benachio, G. L. F., Freitas, M. D. C. D. & Tavares, S. F. (2021). Interactions between Lean Construction Principles and Circular Economy Practices for the Construction Industry. *Journal of Construction Engineering and Management*. Available: [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0002082](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002082)
- Carvajal-Arango, D., Bahamón-Jaramillo, S., Aristizábal-Monsalve, P., Vásquez-Hernández, A., & Botero, L. F. B. (2019). Relationships between lean and sustainable construction: Positive impacts of lean practices on sustainability during the construction phase. *Journal of Cleaner Production*, 234, 1322-1337. Available: <https://doi.org/10.1016/j.jclepro.2019.05.216>
- Dewagoda, K. G., Ng, S. T., Kumaraswamy, M. M., & Chen, J. (2024). Design for Circular Manufacturing and Assembly (DfCMA): Synergising Circularity and Modularity in the Building Construction Industry. *Sustainability*, 16(21), 9192. Available: <https://doi.org/10.3390/su16219192>
- European Commission. (2020). A new Circular Economy Action Plan for a cleaner and more competitive Europe. *EUR-Lex*. Available: https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1andformat=PDF
- Fernandes, J. and Ferrão, P. (2023). A New Framework for Circular Refurbishment of Buildings to Operationalise Circular Economy Policies. *Environments - MDPI*, 10. Available: <https://doi.org/10.3390/environments10030051>

- Johns, N. G. O., Talebi, S., Shelbourn, M., Roberts, C., & Kagioglou, M. (2023). The circular revolution: a review of the synergies between lean and the circular economy. In *Proceedings of the 31st annual conference of the International Group for Lean Construction*. Available: <https://iglcstorage.blob.core.windows.net/papers/attachment-330f588c-6a90-4181-b1f7-0d2d92caa212.pdf>
- Kalemkerian, F., Santos, J., Tanco, M., Garza-Reyes, J. A. & Viles, E. (2022). Analysing the alignment between the Green Lean and Circular strategies: towards a Circular Lean approach. *Journal of Manufacturing Technology Management*. Available: <https://doi.org/10.1108/JMTM-11-2021-0480>
- Liker, J. K. (2004). Toyota way: 14 management principles from the world's greatest manufacturer. *McGraw-Hill Education*. Available: <https://www.accessengineeringlibrary.com/content/book/9780071392310>
- Macarthur, E. (2013). Towards the circular economy. *Journal of Industrial Ecology*, 2, 23-44. Available: <https://ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an>
- Minunno, R., O'Grady, T., Morrison, G. M., Gruner, R. L., & Colling, M. (2018). Strategies for applying the circular economy to prefabricated buildings. *Buildings*, 8(9), 125. Available: <https://doi.org/10.3390/buildings8090125>
- Munaro, M. R., Tavares, S. F. and Bragança, L. (2020). Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the construction industry. *Journal of Cleaner Production*, 260, 121134. Available: <https://doi.org/10.1016/j.jclepro.2020.121134>
- Patton, M. Q. (2014). Qualitative research & evaluation methods: Integrating theory and practice. *Sage publications*. Available: https://books.google.co.uk/books?hl=en&lr=&id=ovAkBQAAQBAJ&oi=fnd&pg=PP1&dq=patton+2014&ots=ZS1Z2stIz2&sig=7DXW7TG4y9rfDkCmkEhBX6AYHGU&redir_esc=y#v=onepage&q=patton%202014&f=false
- Sacks, R., Koskela, L., Dave, B. A., & Owen, R. (2010). Interaction of lean and building information modeling in construction. *Journal of construction engineering and management*, 136(9), 968-980. Available: [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0000203](https://doi.org/10.1061/(ASCE)CO.1943-7862.0000203)
- Saunders, M. (2019). Research methods for business students. *Person Education Limited*. Available: <https://www.pearson.com/se/Nordics-Higher-Education/subject-catalogue/business-and-management/Research-methods-for-business-students-8e-saunders.html>
- Tokazhanov, G., Galiyev, O., Lukyanenko, A., Nauyryzbay, A., Ismagulov, R., Durdyev, S., Turkyilmaz, A. and Karaca, F. (2022). Circularity assessment tool development for construction projects in emerging economies. *Journal of Cleaner Production*, 362. Available: <https://doi.org/10.1016/j.jclepro.2022.132293>
- William, L., Jose, G., & Nelly, G. L. (2019). Enhancing Cost Reliability in Construction: The Synergistic Impact of Bim and Lean Principles. *Journal of Cleaner Production*. Available: <https://doi.org/10.24928/2025/0111>