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A preliminary list of lean and sustainability based supplier selection criteria in the construction industry

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Abstract
Construction companies' supply chains, their efficiency and effectiveness, and leanness and sustainability performance can influence competitiveness, cost and time effectiveness and sustainability performance of the construction companies. This paper aims to provide a preliminary list of lean and sustainability based supplier selection criteria to be considered in the supplier selection phase to support establishment of lean and sustainable construction supply chain. With this aim, following the literature review covering 16 standards, indices and certificates, the Delphi Method and Best-Worst Method (BWM) were applied. The literature review revealed 649 criteria which have been refined to eliminate the overlapped criteria. In total 222 criteria were remained and grouped under 4 main categories. Based on these 4 main categories of criteria, four main groups of four round Delphi Surveys were performed. Delphi survey outputs provided input to the BWM to further assess and organize the criteria for supplier selection. In BWM, all main groups' optimal weights and their related criteria optimal and global weights were calculated. The identified criteria list can be considered as an input to the decision-making about supplier selection so that lean and sustainable construction supply chain establishment can be supported. This research is expected to be useful for construction industry professionals and academics in the relevant field.

Keywords
Best-Worst method, Construction supply chain management, Delphi method, Project management, Supplier selection.

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1. Introduction

As construction industry (CI) has significant environmental footprint compared to other industries, complying with the Pareto principle, CI's enhanced sustainability performance can be effective in the fight against climate change, and in supporting sustainable development. Competitive business world has inspired the suppliers to outperform their competitors by adopting novel and effective approaches for higher productivity and revenue (Shukla et al., 2021). Significance of the supply chain (SC) development in this competitive environment is evident from studies in the literature (Narasimhan & Das, 2000) as the SC has become a factor that distinguishes performance and competitiveness of a firm (Vickery et al., 1999; Morgan & Monczka, 1996). Egan (1998) asserted that the vital part is played by the SC in bringing about innovation and maintaining incremental and sustained performance improvements. Latham (1994) and Egan (1998) suggested that supply chain management (SCM) techniques should be implemented by the CI. Firms can improve their performance by evaluating the SC performance and eliminating the ineffective processes in pre-construction and construction phases. Involvement of numerous entities in the SC in the CI leads to complexity of the SC structure.

CI is significant from the development and ecological point-of-views (Tatlici & Sertyesilisik, 2019). Researchers have emphasized that SCM must include the sustainability dimensions of social, economic and environmental performance since 2000s (Rajeev et al., 2017). Researchers and scholars consider SCM as helpful for enhancing global environmental sustainability and increasing business productivity at the same time (Acquaye et al., 2017). SC provides remarkable contribution to the formation of circular economy that ensures sustainable economic development. SCM calls for comprehensive information about relevant processes, entities and individuals, logistics, products and services, as well as breakdown of resources and traceability of resources at all phases of production from acquisition of raw materials to completion of fully-functional building or project (Tatlici & Sertyesilisik, 2019). CI requires a strategy that organizes SC processes to support the project planning and to improve SCM (Tatlici & Sertyesilisik, 2019). As sustainable SCs necessitate efficient suppliers, suppliers must be selected carefully as they serve as the basis of SC systems (Rezaei et al., 2016; Suhi et al., 2019).

Latham (1994) and Egan (1998) emphasized that there is a quality problem in the CI and low level of client satisfaction. Furthermore, CI is well-known due to its environmental footprint. These problems are related with SC. Latham (1994) and Egan (1998) emphasized importance of SCM in CI. Construction organizations show interest in working alongside qualified suppliers to ensure the projects' success, attaining organizational objectives and rapidly recovering from interruptions in SC (Mahmoudi et al., 2022). Integration of lean and sustainable approaches to SC process can support solution of CI's problems. The main research problem of this research is related with how to establish lean and sustainable construction supply chain (LSCSC). The main research question of this paper is: "What are the supplier selection criteria for the establishment of LSCSCM?"

Sustainable and lean approaches' integration into the construction process plays important role in minimization of the environmental footprint of the CI and SC. Lean construction (LC) refers to the construction processes that deliver maximum value with lowest possible waste and minimum possible harm to environment and society (Le & Nguyen, 2021). Construction companies have been using the LC approach effectively for 20 years to render better performance (Le and Nguyen, 2021). Intensified competition can motivate companies to comply with sustainable and lean construction management principles.

CI is seeking of the practice needs of implementation of lean and sustainable management knowledge for competitiveness. LSCSCM orientation is a literature and industry gap (Bon-

Gang Hwang & Wei Jian Ng, 2013; Martínez-Jurado & Moyano-Fuentes, 2014; Wai Peng Wong & Kuan Yew Wong, 2014) to get competitive advantage in industry. Most construction companies have made it a practice to consider SC during the formulation of differentiation strategy due to significance of SC in achieving competitiveness (Waters & Waters, 2007). Effectiveness of SC can be established by implementing lean management approach and sustainable practices simultaneously. For example, the choice of a contractor is a complementary part of construction projects as the suitable contractor needs to be chosen that the construction projects and structures meet the quality standards (Erdogan et al., 2017). Efficiency in and competence of the contractor employed determines the quality of the constructed structure or building (Zavadskas et al., 2015). Establishment of an efficient SC can support customer value and competitiveness of the firm (Rahman et al., 2015).

Previous studies (e.g., Sevkli et al., 2008; Patil & Adavi, 2012; Eshtehardian et al., 2013; Cengiz et al., 2017; Polat et al., 2017; Karabayir et al., 2020; Sabri et al., 2022) have mainly focused on and examined the supplier selection criteria. This current paper differs from the previous studies and contributes to the literature as it analyses sustainability and lean approaches' integration to the supplier selection process. Furthermore, this paper contributes to the literature as it employs the Delphi survey and BWM together in determination of the supplier selection criteria.

This paper aims to provide a preliminary list of lean and sustainability-based supplier selection criteria to be considered in the supplier selection phase to support establishment of LSCSC.

2. Literature review

Enhancing sustainability performance of its supply chains (SCs) can contribute to the sustainable production in CI and to reduce its environmental footprint. Organizations can enhance their performance through improved management of their SCs and establishment of long-standing associations with SC entities (Egan, 1998). Hence, organizations must keep their SC under control and manage the processes (Maestrini et al., 2017: 299). It is essential to ensure the timely involvement of the supplier (Vrijhoef, 2011). The supplier selection decision at the project start plays significant role in minimization of cost, wastes and time losses. Furthermore, lean and sustainable SC is possible through effective supplier selection as supplier selected for the project based on the working standards, efficiency and material/method choices can affect the construction process. For this reason, achievement of the construction supply chain management (CSCM) is directly related to the success of the decisions made. Effective management of the project and its success depends on LSCSCM criteria.

Researchers and experts held the view that sustainable SCs allow organizations and firms to be more productive and to have greater reputation among clients (Chin et al., 2015). SCM entails practices that cover all phases of production and hence, it has become an integral part of manufacturing (Ferreira et al., 2016). Furthermore, sustainable SCs can reduce adverse impacts of processes on the society and environment (Chin et al., 2015). Main activities of sustainable supply chain management (SSCM) include management and planning of SC processes, review of customer demands and employee requirements (Badri Ahmadi et al., 2017). SSCM efforts to ensure maximum profit and to control ecological and social impact of the SC processes (Badri Ahmadi et al., 2017). Specifically, organizations need to resort to SSCM including employees, suppliers and customers (Suhi et al., 2019).

LC practices and approaches gradually made their way to the SC and distribution in the decade of 1990 (Tortorella et al., 2018). Implementing lean practices in SCs leads to lower amounts of waste and consequently yields better performance (Takeda-Berger et al., 2018, Saudi et al., 2019; Tortorella et al., 2019). CI has benefitted from the implementation of lean practices (Enshassi et al., 2019). LC approach has facilitated CI in better management of SC by improving the integration and efficiency of the SC (Meng, 2019; Koskela et al., 2020). The workflow or plan of processes in the CSC is streamlined with the integration of lean practices into the SCM (Le & Nguyen, 2021). There is still a need for more research on the emerging trend of integrating LC practices into CSCM (Lee & Nguyen, 2021). The concept of lean SCM emerged when lean principles and practices were incorporated into the SC (Khorasani et al., 2020). This concept further improved SCs performance. Lean SCM enables construction companies to overcome many challenges by enhancing the awareness of relevant concepts, motivating the senior management to accept change and focus on social factors essential for effective SCM (Abu et al., 2019). Garcia-Buendia et al. (2021) indicated the possibility of better performance in case of implementing the lean approaches in SCM.

The basis of competition in many industries is related with SC development (Narasimhan & Das, 2000). Problems in the SC need to be solved as fast and as effective as possible mainly due to the pressure on manufacturers and contractors to accomplish the work on time complying with quality requirements. Financial performance is exhibited by those organizations that have acquired coordination and responsiveness skills, which are elements of SCM abilities performance (Yu et al., 2018; Liao & Kuo, 2014). Competitive edge is generated in SC performance due to SCM abilities that generate tangible and intangible assets (Asamoah et al., 2021). Furthermore, they bring about SCM skills' development (Asamoah et al., 2021). Failure in SCM can damage company's reputation and risk company's survival. It is important for companies to look for innovative ways to manage the rising competition in the global market. At such point, adopting a performance improving system to SC at relatively early stages of projects could minimize the breakdown between suppliers while supporting smooth continuity of work. This could lead to LSCSCM collaboration between designers and contractors to the advantage of all parties to take a competitive advantage. As a result, the supplier selection decision at the beginning of the project plays significant role in minimization of loss and preventing potential problems. Moreover, LSCSC can be supported by cooperation with the most suitable supplier. Thus, suppliers can contribute to the improvement in communication by contractors.

The collaboration of the project and company features, human resources, and organizations have an impact on the SC and its process. SC's effectiveness depends on work motivation, adaptability, employee engagement, leadership, empowerment and shared norms (Othman & Ghani, 2008; Shub & Stonebraker, 2009). Effective SCs are typically found in organizations that offer employees continuous training (Smith-Doerflein et al., 2011). The human resource practices of an organization should be consistent with its SCM to support the SC members' involvement, encourage SC integration and ultimately, ensure that improved business outcomes are attained (Gómez-Cedeño et al., 2015). A vital part is played by human resource management (HRM) as it functions as a means of assigning relationships and responsibilities within the SC (Lengnick-Hall, 2013). There is a significant relationship between certain HRM practices (Menon, 2012). Gómez-Cedeño et al. (2015) were of the view that there were substantial direct effects of HRM on SCM outcomes and SCM implementation, and indirect effects on improving organizational performance and customer satisfaction. Alshurideh et al. (2022) emphasized the affirmative outcomes of integrating HRM and SCM in organizational sustainable SCs for managers, practitioners and academics.

Trio of environmental factors, material, and design is in interrelated interaction. This trio can facilitate SC, if these are brought together in a project. Based on the project, the decision of the material planned to be used in the design phase and its environmental impact, affect in a closed loop. Making a clear decision on the material to be used in the design phase can reduce the disruptions that may occur in the SC and construction process. In fact, the design team's contact with potential suppliers during the design phase can facilitate the SC flow in the future. An increasingly significant perception in SCM is collaboration as it has been identified by enterprises that working together offers benefits that are significantly greater than the risks (Kuo et al., 2021). When there is a smart SC, collaborative relationships between the stakeholders within the SC is enhanced (Kuo et al., 2021). SC network of the construction materials had and still has an environmental impact due to the requirements of industrialization and urbanization, particularly within the developing countries (Xu et al., 2020). Hence, it is vital to accurately evaluate construction materials SC network environmental protection efficiency so that targeted and correct optimization measures can be formulated and an economically and environment-friendly construction materials SC network can be ensured (Xu et al., 2020). Through these resource-efficient contributions, low-energy consumption direction can be created and ecological damage and environmental pollution can be decreased.

Performance and reporting can contribute to continuous monitoring of the SC and supplier performance. Strategy that can be used by companies as part of SSCM to cater to report on and enhance the degree of sustainable practices among suppliers as well as in their own operations is developing a sustainability report (Doorey, 2011). Researchers need to give increasing attention to the field of integrating SSCM with sustainability reporting (Wan et al., 2016). Strategy-making and long-term planning on the basis of sustainable development can be improved by sustainability accountability and reporting (Niehaus et al., 2018). Furthermore, there is effect of sustainability reporting on SSCM practices in leading companies as it causes the risks and operational efficiencies to be recognized and decreased, and supports the integration of sustainability issues within management procedures (Bunclark & Barcellos-Paula, 2021). The focus of earlier studies on construction SCs was on the way their construction projects performed, and not on their SCs, by measuring components like developer satisfaction and waste levels (Thunberg, 2016). Thunberg (2016) responded to this by proposing that CSC performance measurement should be carried out with respect to SC responsiveness, SC reliability and costs. A positive effect of SC agility, information technology and SC resilience is determined by Cherian and Arun (2022) on SC performance. It is necessary to improve the scientific rationality and operability of green construction SC performance evaluation (Liu et al., 2018).

3. Methods

This paper aims to identify the criteria to be considered in the supplier selection phase to support establishment of LSCSC. With this aim, three step research process has been performed (Figure 1).

Step 1: It is important to understand the role of environmental performance indicators (EPIs) in allowing experts to study environmental issues (e.g., pollution, climate, energy, biodiversity,

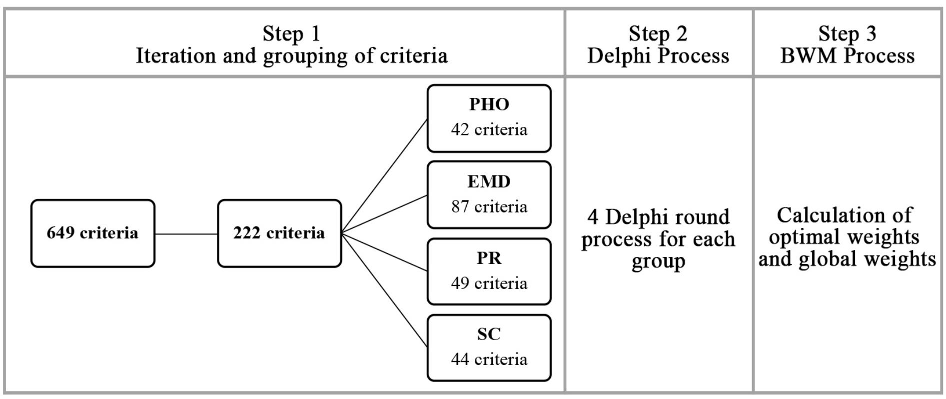

Figure 1. *Three main steps of the research.*

***Table 1.** Brief definition of standards, indices and certificates.*

Name	Definition
Global Report Initiative (GRI)	GRI stands for Global Reporting Initiative. It provides organizations with the opportunity of sustainability reporting (GRI, n.d.). The GRI entails 70 indicators for the sustainability measurement in terms of economy, society and environment (Joung et al., 2013). The GRI report allows comparing the sustainability performance delivered by an organization with the GRI standards. It also allows management of organization's sustainability performance. The GRI reporting intends to determine the decision-making at different organizational levels besides allowing the organization to manage decision-making (Courtnell, 2019).
Walmart Sustainability Product Index	Walmart has three key sustainability goals: to produce zero waste; 100% renewable energy will be provided; and selling products that sustain people and the environment. The index collects and analyzes information throughout a product's life cycle, such as procurement, production and shipping, sales, customer use and end of use.
Dow Jones Sustainability Indexes (DJSI)	DJSI is a benchmark used for assessment of the sustainability and financial performance of firms specifically the leading 10% firms listed in the Dow Jones Global Total Stock Market Index (SAM Sustainable Asset Management, 2012). The indices are very helpful for investing individuals and firms. The DJSI is mostly applied for assessing the organizational performance with respect to 12 economy-related criteria; however, the benchmark can also be used to assess the social dimensions of organizational performance (RobecoSAM, 2022).
2005 Environmental Sustainability Indicators (ESI)	The Yale Centre for Environmental Law and Policy formulated the ESI index with the objective to determine the ecological responsibility for different countries (SEDAC, 2022). The ESI entails 6 category of policy and 21 factors that are analyzed on the basis of 68 indicators of environmental sustainability (Environmental Performance Index, 2008).
Environment Performance Index (EPfI)	The EPfI was formulated by experts at Yale University to support the ESI. The EPfI evaluates the efficiency of the environmental policy of countries in terms of mitigating and preventing harm to environment and consequent effects on enhancing the ecosystem vitality, human health, and better resources management sustainability (Environmental Performance Index, 2008). There are about 19 indicators in the EPfI's that allow evaluation of the impact of various environmental issues (Tamanini, 2016).
International Organization for Standardization (ISO 14031)	Organizations are required to formulate their own set of indicators for self-assessment of their environmental performance under the ISO 14031 standard. The standard deals with manufacturing in three categories: 1) environmental condition, 2) operational performance, and 3) management performance (International Organization for Standardization, n.d.).
Environmental Pressure Indicators for European Union (EPrI)	EPrI entails indicators to measure the harmful practices of humans that are detrimental to environment. The number of indicators entailed in EPRI is 60 which covers almost 10 policy areas of climatic changes, air pollution, coastal and aquatic environments, damage to ozone layer, exhaustion of resources, issues of urban environment, waste, water pollution, exhaustion of water reservoirs and biodiversity loss (European Commission, 2001).
Japan National Institute of Science and Technology Policy (NISTEP)	The NISTEP report includes indicators that cover a particular organization's contributions through training, exported or imported patents and scientific publications, and technological progress based on staff skill level (NISTEP, n.d.).
European Environmental Agency Core Set of Indicators (EEA-CSI)	The EEA-CSI offers a number of reporting indicators. The EEA-CSI provides measurements that can be used to organize positive ecological effects in EU countries (Imzuwi, n.d.).
Corporate Social Responsibility (CSR)	CSR is described as the self-regulating model that is equally beneficial for an organization, the stakeholders and the public (IFC, 2022). CSR implementation enables organizations to be conscious of the ecological and social impact of their processes (Farrington et al., 2017).
Lean Reporting Criteria	The theory and practice of lean accounting and management reporting are relatively new and continue to develop. Recent research across 244 U.S. companies found that the implementation of lean accounting improves the performance of lean enterprises (Fullerton et. al, 2014). Lean management reporting involves 3 different levels of reporting; daily or hourly reporting of cell performance, weekly reporting of value stream box scores and monthly reporting of Value stream income statements (Pickering, 2017).
Agile Reporting Criteria	Hence, the agile approach can be deemed as an important technique that allows project managers and project teams to meet the evolving requirements of corporate world. Benefits of agile management are; Superior quality product, increased flexibility, improved project predictability, customer satisfaction, reduced risks, more relevant metrics, continuous improvement, better control, improved team morale.
IFC	The main focus of the Performance Standards is the clients. These standards allow risk identification as well as evaluation of impacts of risks. Consequently, the identified risks can be prevented and mitigated. Moreover, Performance Standards can be used to reduce the negative effects of risk through proper risk management strategies (IFC, 2022). Performance Standards direct the business towards sustainability through stakeholder involvement and communication of responsibilities of the client associated with a project. The IFC performance standards identify ecological and social risks. IFC standards makes it mandatory for the entities making direct investments to ensure minimum possible risk to environment and society through the implementation of Performance Standards for better exploitation of prospects (IFC, 2022). The IFC standards are followed by construction organizations for management of environmental and social risks. IFC offers guidance to the businesses to adjust their activities in adherence to the Sustainability Framework, relevant strategies, principles and initiatives provided by IFC performance standards. Consequently, the businesses are enabled to accomplish their developmental goals in a sustainable manner (IFC, 2022).
Sustainable Development Goals (SDG)	The United Nations General Assembly formulated the SDGs. It entails 17 global objectives or goals that serve as the "sketch or model that can be followed to obtain sustainability on the whole" (United Nations, 2017). It was proposed to fulfil the SDGs objectives by the year 2030. SDGs form a part of the UN Resolution namely the 2030 Agenda (United Nations, 2015).
Sustainable and Green Building Certification (Breeam, DGNB, Greenstar and Casbee)	"In the CI, triggering the SC with lean and sustainability can be obtained through the integration of the principles of sustainable and green building certifications into the SC" (Kupeli Tatlici & Sertyesilisik, 2022). The certificates related to the subject were searched in detail, a total of 45 were found. It has been determined that 4 certificate standards could provide maximum useful data for current study. These are: Breeam, DGNB, Greenstar and Casbee. BREEAM is the technique used worldwide for the evaluation of sustainability while preparing the master plan of construction projects including buildings and infrastructure (BRE Group, n.d.). The DGNB System is an effective method that evaluates the sustainability of construction project with respect to their environmental, socio-cultural and economic impacts such that all the impacts are given equal weightage (DGNB, n.d.). Another method named Green Star certification is found to be effective in confirming if the design and functioning of the public projects, infrastructure or building is sustainable enough ("Green Star," 2022). CASBEE is also employed to estimate the performance of building and the surrounding area in terms of its sustainability (JSBC, 2016).
Sustainable and Green Material Certification (EPD)	The International EPD System issues report about the product in light of its life-cycle assessment to highlight the impact of that product on global environment. The information communicated in EPD is clear, certified and comparable (EPD, n.d.).

erosion, environmental education and ecosystem services) and help them to assess efficiency of the methods that determine environmental impacts and exhaustion of natural resources (Ruez, 2019). The EPIs allow experts to determine the impact of various actions affecting the environment in either positive or negative ways with the different applications of EPIs for different situations (e.g., scales and topics) (Ruez, 2019). Considering the literature, internationally used standards, indices and certificates covering sustainability, lean and environmental factors that can contribute to this study have been researched (Table 1). The standards have been selected according to the prevalence and scope of their worldwide usage. Indices have been selected considering their contribution to the certifications for their inadequacies in accordance of lean and sustainability approaches. For instance, as Passos Neto et al. (2022) mentioned, the criteria from the Global Reporting Initiative

(GRI) were selected as it is a globally known and widespread organization. Furthermore, regarding to the certifications, 4 widely used certificates (i.e., Breeam, DGNB, Greenstar and Casbee) were examined. In this context, 16 standards, indices and certificates were examined in depth to determine the criteria for supplier selection to obtain LSCSCM (Table 1).

A total of 649 criteria were determined from 16 standards, indices and certificates that contribute to the aim of the study, which include sustainability and lean approaches. The identified 649 criteria have been refined for four times as overlapped criteria were combined and repetitive criteria were removed in each refining phase until further iteration could not be possible (Figure 1). As a result, 222 criteria were remained as input to the four group Delphi surveys (Figure 1). The identified 222 criteria were grouped into the four main categories [i.e., Project & Company features, Human Resources, Organizations (PHO), Environmental Factors, Material, Design (EMD), Performance, Reporting (PR) and SC] based on their contents (Figure 1). The first group, PHO, focuses on the current capacity of the supplier, the training of its employees, and the performance of its human resources when selecting a supplier. The EMD group evaluates the construction supply chain (CSC) process by prioritizing its environmental impact. Meanwhile, the technical characteristics of the materials to be used are important, and also take attention on choosing the environmentally friendly material at the design stage. The PR group takes into account the potential supplier's past performances when constructing the SC. Furthermore, it includes regular reporting by examining the performance of selected suppliers in the SC process. The SC group focuses on the process itself, with the start of the process.

Step 2: Four groups of Delphi surveys were applied simultaneously to identify the criteria to be used in the weight analysis in Best-Worst Method (BWM). Complying with Chan et al. (2001), Yeung et al. (2007), and Sourani and Sohail (2015), the Delphi method of this research consisted of four rounds. Delphi Rounds 1 and 3 of all four main groups of Delphi method were conducted through online research tool (veti.itu.edu.tr). Delphi Rounds 2 and 4 of all four main Delphi groups were conducted through e-mails sent to the participants of the four group. According to Chan et al. (2001), proper selection of experts for the panel is essential for effectiveness of the methods. Sample of each Delphi group was identified specially for each Delphi group based on their expertise and research areas. Identified lists of experts consist of academics and professionals in the relevant field. For PHO group 36 academics and 22 professionals, for EMD group 27 academics and 5 professionals, for PR group 32 academics and 28 professionals, and for SC group 44 academics and 23 professionals were invited to research. Some participants were included in more than one group. For all 4 main Delphi survey groups, in total 159 experts (105 academics and 54 professionals) were asked to take part in the Delphi surveys.

For the first round of the Delphi method, respondents in each group were inquired to choose minimum 5 maximum 10 criteria that are the most supporting criteria for achievement of LSCSCM from their related Group point of view. The consolidated findings from Round 1 were provided to respondents for Round 2 Delphi survey, and they were asked to evaluate their selections to determine if they wanted to change their initial choice. In the third round of the survey, participants assigned scores to the criteria using 5-point Likert scale ranging from 1 to 5 where 1 indicated 'the least important' and 5 indicated 'the most important'. Only the criteria with 50% or more of expert approval in round 2 were included in this round. The round 4 required the participants to review the scores they had assigned earlier to their group criteria considered the compiled results obtained from the previous round. E-mails were sent to remind all participants who had not yet completed their forms for each round. The data obtained from the Rounds 3 and 4 were transferred to the Statistical Packages for Social Sciences (SPSS) program and the reliability statistics (Cronbach's Alpha Coefficient), test of normality and correlation analysis were made for each group of criteria.

Step 3: Delphi survey outputs provided the input data for and the basis for the BWM to assess and organize the criteria for supplier–selection. Rezaei (2015) put forward a multi-criteria decision making (MCDM) method namely the BWM to employ structured approach for comparisons to deal with the complexity. Unlike other MCDM methods involving pairwise comparisons, the BWM involves comparison of each criterion individually with the best and the worst criteria (Labella et al., 2021). Literature indicates better performance of BWM compared to the analytic hierarchy process (AHP) (Rezaei, 2015; Malek & Desai, 2019; Gupta et al., 2020). Numerous research has been conducted on BWM due to its greater effectiveness in comparison to AHP approach (Liu et al., 2021). Moreover, BWM renders more consistent results than other MCDM methods (Ajrina et al., 2018). BWM also outperformed AHP in terms of statistical validation (Gupta et al., 2020; Moslem et al., 2020; Mostafaeipour et al., 2021). The main feature that makes BWM better than other methods is that this approach does not require many pairwise comparisons (Wankhede & Vinodh, 2021). Additionally, limited data requirement and lesser time-consumption are some of the pros of using BWM compared to traditional MCDM methods (Salimi & Rezaei, 2018). BWM has recently been used in the CI and has relatively limited resources in the literature (e.g., Norouzi & Namin, 2019; Scherz & Vafadarnikjoo, 2019; Mahmoudi et al., 2020; Celik & Gul, 2021; Ghasemi et al., 2021). The BWM method was employed in this current study as it allows the experts to effectively apply the concept of LSSC in SCM in the CI. The BWM method entails 5 steps for assigning optimal and global weight to decision criteria (Rezaei, 2015): The initial step includes identification of decision criteria (determined via Delphi results) $\{c_1; c_2; ...c_n\}$ (Rezaei, 2015). The second step involves identification of the best and the worst criterion (Rezaei, 2015). The third step involves best criterion comparison over the other by the weightage valued between 1 and 9 (where 1: equally important, 5: strongly more important, and 9: extremely more important) (Rezaei, 2015). The assigned number indicates the significance of the best criterion over the other. This results in Best-to-Other's vector, which is: $A_B = (a_{B1}; a_{B2}; ...; a_{Bn})$, where a_{Bj} denotes the preference of best criterion over other (Rezaei, 2015). The fourth step involves comparison of the worst criterion over the other by the weightage valued between 1 and 9 (Rezaei, 2015). Similar to step 3, the experts assign weightage valued between 1 and 9 to the criteria being compared against the worst one (Rezaei, 2015). The assigned number indicates the significance of the other criterion over the worst one (Rezaei, 2015). This results in Others-to-Worst vector, which is: $A_w = (a_{1w}, a_{2w}, ..., a_{nw})$, where ajw denotes the preference of criterion over worst criterion (Rezaei, 2015). The fifth and the last step involves determination of the optimal weights (w^*_1, w^*_2, ..., w^*_n) (Rezaei, 2015). To compute factors' optimal weights, the maximum absolute differences $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_w} - a_{jw}\right|$ for j should be minimized (Rezaei, 2015). This can be formulated as (Rezaei, 2015): Minmaxj $\left|\frac{w_B}{w_j}\right.$ $w_j \geq 0$ j, $\left|\left|\frac{w_j}{w_w} - a_{jw}\right|\right.$ subject to

$$\sum_{j=1}^{n} W_j = 1$$

$w_j \geq 0$, for all j (Rezaei, 2015).

This equation is converted into linear programming program to obtain the required solution as: Min ξ subject to

$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi$, for all j

$\left|\frac{w_j}{w_w} - a_{jw}\right| \leq \xi$, for all j

$$\sum_{j=1}^{n} W_j = 1$$

$w_j \geq 0$, for all j (Rezaei, 2015).

These steps were monitored for analyzing the optimal weights between criteria of the four main groups (i.e., PHO, EMD, PR and SC). BWM study

Table 2. *Summary of results of the 1st and 2nd rounds of the Delphi Surveys.*

	Round 1				Round 2			
	Number of participants		Number of criteria		Number of participants		Number of criteria	
	Total	Responded	Total	Selected	Total	Responded	Total	Selected
PHO	58	10	42	33	10	8	33	11
EMD	32	8	87	19	8	8	19	8
PR	60	14	49	23	14	9	23	8
SC	67	15	44	24	15	12	24	7

Table 3. *List of the groups selected criteria and their abbreviations selected from the 2nd round Delphi.*

Groups	Expansions of Criteria	Reference Index
PHO1	Prioritizing risks and opportunities in construction projects based on possible economic, social and environmental impacts	GRI 102
PHO2	Inspection of the social, cultural and environmental impacts of construction projects by an independent organization	GRI 102
PHO3	Working with waste management companies in construction projects	GRI 306
PHO4	Company's openness to collaborate with universities for research/ allocates funds for research / creates a qualified project team	NISTEP
PHO5	Organizing training for company employees	CSR
PHO6	Paying attention to complaints from employees	EPrI
PHO7	Having codes of conduct in the company	DJSI
PHO8	Integrating sustainability into the firm's brand strategy	DJSI
PHO9	Having resources to realize organizational structure and planning	DJSI
PHO10	Investing in human resources development	DJSI
PHO11	Monitoring the individual performance of human resources	DJSI
EMD1	Having a vision and mission focused on sustainable material selection	GRI 103
EMD2	Selection of material from recycled material	GRI 103/EPD
EMD3	Based on local and national standards in material selection	GRI 103
EMD4	Priority of supplier location and material handling system in material selection	GRI 103/204
EMD5	Priority of performance criteria in material selection	GRI 103
EMD6	Designing the project in a way that is suitable for that region and positively affects living conditions, taking into account the location of the project	GRI 203
EMD7	Using environmentally friendly and recyclable material	GRI 206/301
EMD8	Paying attention to whether it causes environmental problems in the long term in material selection	DJSI
PR1	Monitoring performance	Lean Reporting Criteria
PR2	Detailed examination of the social, economic and environmental impacts of construction materials in the report preparation process	GRI 101
PR3	Affecting performance of the organization from unclear corporate strategies, not being conveyed to managers and employees	Lean Reporting Criteria
PR4	Having sustainability reporting in construction projects	GRI 101
PR5	Covering the performance of the entire project with the sustainable reporting	GRI 101
PR6	Following and reporting the sustainable job descriptions of all stakeholders	GRI 101
PR7	Periodic preparation of sustainable reports	GRI 101
PR8	Reporting how much value the suppliers add	Agile Reporting Criteria
SC1	Priority of local suppliers in the production process	GRI 203
SC2	The importance of location in the selection of suppliers	GRI 308
SC3	Ordering the materials to be used as needed without storage	GRI 205/ Lean Reporting Criteria
SC4	Openness of suppliers to innovations that promote sustainability	Sustainable and Green Building Certification (Greenstar)
SC5	Paying attention to the shelf life of the products stored in the construction site	GRI 205
SC6	Monitoring the practices of stakeholders by applying sustainable and lean production specifications and guidelines in the supply chain	Walmart/DJSI
SC7	Taking environmental factors as the basis when selecting the supply chain suppliers	GRI 308

was created via the SurveyMonkey form. This form was created complying with the 5 stages of BWM in compliance with Rezaei (2015): comparison of all main groups (PHO, EMD, PR, SC) with each other, comparison of PHO sub-criteria (11 criteria), comparison of EMD criteria (8 criteria), comparison of PR criteria (8 criteria), and comparison of SC criteria (7 criteria). After data were gathered, the optimal weights were analyzed and calculated for all four main groups. Criteria optimal weights were found separately for all 4 main groups. Finally, all criteria global weights were calculated and overall performance ranking was obtained. Global weights calculated by multiplication of the criteria optimal weight and criteria's related group optimal weight.

As the Delphi process (Step 2) included reduction of the criteria set. Delphi participants consisted of experts from the CI and academics for the PHO, EMD, PR and SC groups. Furthermore, in BWM, it was aimed to create a new sample who could objectively evaluate the remaining criteria in Delphi as a whole process without being bound by the 4 groups. To identify the sample for BWM, academics that have research papers on SCM, and CSCM experts have been searched. As a result, the new participants consisted of 27 SC related academics and professionals. Lastly, the survey link was emailed to the sample.

4. Results

4.1. Data obtained through Delphi surveys

4.1.1. Results of the 1st and 2nd Rounds of the Delphi Surveys for the 4 main groups

In the first round, all data gathered form participants have been evaluated. The criteria which were rated at low level were eliminated. Consequently, the criteria with at least 20% of expert votes were kept for all 4 main groups (Table 2). As a result, 33 criteria out of 42 were remained for the PHO group, 19 criteria out of 87 were identified for the EMD Group, 23 criteria out of 49 were remained for the PR group, and 24 criteria out of 44 for identified for the SC group for the 2nd round of Delphi surveys. For the second round of Delphi, all remained criteria in each group listed in an Excel file including the rate of criteria. Similar to Chan et al. (2001) and Yeung et al. (2007), the criteria that ensured minimum 50% rate in the second round were chosen for the Delphi round three. Summary of the data gathered from the second round from all groups is provided in Table 2.

The list of the criteria selected from all four groups at the end of the 2nd round of Delphi surveys and criteria related references are provided in Table 3.

4.1.2. Results of the 3rd and 4th Rounds of the Delphi Surveys for the 4 main groups

Data obtained through the 3rd and 4th rounds of the Delphi Surveys for the 4 main groups were transferred to the SPSS computer software for computing analyzes to obtain correlation analysis. The following steps were monitored for analyzing the relationship between criteria of the four main groups (i.e., PHO, EMD, PR and SC). For the first step, the reliability test was computed for Rounds 3 and 4. At the second step, the normality test, skewness and kurtosis were performed for Rounds 3 and 4. Results of the normality test, skewness and kurtosis values have been provided in the Appendix A. At

Table 4. *The Alpha Cronbach Value results of Rounds 3 and 4.*

	Reliability Statistics		
	Cronbach's Alpha Round 3	Cronbach's Alpha Round 4	N of Items
PHO	.852	.862	11
EMD	.741	.641	8
PR	.602	.819	8
SC	.698	.780	7

Table 5. *Matrix of correlation between the PHO, EMD, PR and SC criteria.*

PHO Group Criteria

	PHO1	PHO2	PHO3	PHO4	PHO5	PHO6	PHO7	PHO8	PHO9	PHO10	PHO11
PHO1	1	.570	.114	**.853****	.342	.174	.234	.570	.522	.271	.000
PHO2		1	.429	.535	.429	.218	.683	.429	.218	**.882****	.535
PHO3			1	.000	.143	-.218	-.098	.429	.218	.339	.535
PHO4				1	.267	.000	.365	.535	.408	.254	.000
PHO5					1	.218	.293	**.714***	.655	.611	**.802***
PHO6						1	.149	.218	.333	.311	.000
PHO7							1	-.098	.149	**.788***	.365
PHO8								1	.655	.339	.535
PHO9									1	.311	.408
PHO10										1	**.762***
PHO11											1

EMD Group Criteria

	EMD1	EMD2	EMD3	EMD4	EMD5	EMD6	EMD7	EMD8
EMD1	1	-.141	.062	.258	.091	.645	-.062	**.868***
EMD2		1	-.439	.091	.710	-.091	.439	.038
EMD3			1	.240	-.113	-.240	-.731	.336
EMD4				1	.354	.167	.320	.420
EMD5					1	-.354	.113	.149
EMD6						1	.240	.560
EMD7							1	-.101
EMD8								1

PR Group Criteria

	PR1	PR2	PR3	PR4	PR5	PR6	PR7
PR1	1	.340	.273	-.262	.366	.339	-.069
PR2		1	.595	.355	**.710***	**.749***	.512
PR3			1	.308	.562	.471	.069
PR4				1	-.237	.570	**.693***
PR5					1	.320	.043
PR6						1	**.822****
PR7							1

SC Group Criteria

	SC1	SC2	SC3	SC4	SC5	SC6	SC7
SC1	1	**.899****	.564	.188	.033	-.231	.217
SC2		1	**.624***	.184	.320	-.068	.106
SC3			1	.294	**.597***	.108	-.102
SC4				1	.094	.108	-.102
SC5					1	.058	-.417
SC6						1	.376
SC7							1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

the third step, correlation analysis was made for the Round 4 results.

For the first step, all 4 main groups' reliability statistics were computed and evaluated (Table 4). For the PHO group the Cronbach's Alpha was calculated to be .852 in the 3rd round and 0.862 in the 4th round. For the EMD group, the Cronbach's Alpha was identified to be.741 for the 3rd round and 0.641 for the 4th round as one participant failed to respond in the 4th round. For the PR group, Cronbach's Alpha was calculated to be .602 for the 3rd round and 0.819 for the 4th round. For the SC group, Cronbach's Alpha was calculated as .698 for the 3rd round and 0.780 for the 4th round.

As the second step analysis for all groups criteria (i.e., PHO, EMD, PR and SC), the skewness and kurtosis values obtained through SPSS showed normal distribution according to Tabachnick standard range (± 1.5) for

Table 6. *Optimal weights of four groups for supporting establishment of LSCSCM.*

	PHO	EMD	PR	SC
	Weights	Weights	Weights	Weights
SCPP1	0,477273	0,204545	0,159091	0,159091
SCPP2	0,119048	0,601190	0,214286	0,065476
SCPP3	0,051282	0,128205	0,564103	0,256410
SCPP4	0,064815	0,157407	0,157407	0,620370
SCPP5	0,047377	0,602369	0,155668	0,194585
SCPP6	0,066038	0,141509	0,141509	0,650943
SCPP7	0,046632	0,590674	0,108808	0,253886
SCPP8	0,141631	0,568670	0,053648	0,236052
SCPP9	0,115979	0,162371	0,063144	0,658505
SCPP10	0,139785	0,139785	0,086022	0,634409
SCPP11	0,229358	0,137615	0,064220	0,568807
SCPP12	0,047619	0,333333	0,238095	0,380952
SCPP13	0,079365	0,507937	0,206349	0,206349
SCPP14	0,053333	0,126667	0,253333	0,566667
SCPP15	0,086957	0,521739	0,260870	0,130435
Average Weights	0,117766	0,328268	0,181770	0,372196

Table 7. *Global weights of all four groups' criteria that have impact on lean and sustainable SC.*

PHO	0,117766	4	PHO3	0,076483	9	0,009007	32
			PHO4	0,093743	4	0,011040	27
			PHO5	0,086062	6	0,010135	29
			PHO6	0,104368	3	0,012291	26
			PHO7	0,091617	5	0,010789	28
			PHO8	0,125880	1	0,014824	24
			PHO9	0,073514	11	0,008657	34
			PHO10	0,083730	8	0,009861	31
			PHO11	0,075671	10	0,008911	33
EMD	0,328268	2	EMD1	0,127432	5	0,041832	11
			EMD2	0,128255	3	0,042102	9
			EMD3	0,105910	8	0,034767	15
			EMD4	0,127970	4	0,042008	10
			EMD5	0,123907	6	0,040675	13
			EMD6	0,128283	2	0,042111	8
			EMD7	0,137098	1	0,045005	7
			EMD8	0,121144	7	0,039768	14
PR	0,18177	3	PR1	0,117317	6	0,021325	21
			PR2	0,127107	5	0,023104	20
			PR3	0,130234	4	0,023673	19
			PR4	0,106771	7	0,019408	22
			PR5	0,141497	1	0,025720	16
			PR6	0,140036	2	0,025454	17
			PR7	0,133770	3	0,024315	18
			PR8	0,103269	8	0,018771	23
SC	0,372196	1	SC1	0,135770	4	0,050533	4
			SC2	0,145890	3	0,054300	3
			SC3	0,110640	7	0,041180	12
			SC4	0,122110	6	0,045449	6
			SC5	0,125810	5	0,046826	5
			SC6	0,201153	1	0,074868	1
			SC7	0,158627	2	0,059040	2

all four main groups. In accordance with the normal distribution results of groups, the Pearson correlation test was performed as the third and the last step of the Delphi study to assess the relationship between normally distributed data.

In the Table 5, the Pearson correlation matrix of each group was analyzed in the SPSS program as a result of the 4-rounds of the 4 group Delphi surveys, and criteria directly related to each other were determined. The criteria having 1% significance level correlation for each group are indicated in black and bold character in the Table 5. The criteria having 5% significance level correlation for each group shown are indicated in red and bold character (Table 5). At the end of the Delphi Round 4 of each 4 main Delphi group, all remaining criteria were used as inputs to the BWM study to analyze their optimal and global weights and rank them according to their importance.

4.2. BWM results

The survey was conducted from practitioners' perspectives to identify the criteria level of importance. In total, 15 responses were obtained from 27 SC related academics and professionals. The results from SC professional participants (SCPP) were monitored for analyzing the optimal and global weights between criteria of the 4 main groups (i.e., PHO, EMD, PR and SC).

Optimal weight of the SC main group (0.372196) ranked higher followed by the EMD group (0.328268), the PR group (0.181770) and the PHO group (0.117766) (Table 6). The result depicts SC as the most effective performance group for achieving LSCSCM. It is found that the EMD group is the second important group whereas the PHO group has the least importance level.

Following the groups optimal weights calculation, analyzes were made within the criteria of each group and their optimal weights were found. From the Table 7, in the SC group, SC6 (0.201153) was found to be the most effective criteria. SC7 (0.158627) occupies second position in the group. These criteria were followed by SC2 (0.145890), SC1 (0.135770), SC5 (0.125810), SC4 (0.122110), and SC3 (0.110640).

In the EMD group, EMD7 (0.137098) was found to be the most effective criteria. EMD6 (0.128283) was ranked second in the LSCSCM adaptation performance in CI. These criteria were followed by EMD2 (0.128255), EMD4 (0.127970), EMD1 (0.127432), EMD5 (0.123907), EMD8 (0.121144), and EMD3 (0.105910).

In the PR group, PR5 (0.141497) was found to be the most effective criteria followed by PR6 (0.140036), PR7 (0.133770), PR3 (0.130234), PR2 (0.127107), PR1 (0.117317), PR4 (0.106771) and PR8 (0.103269).

In the PHO group, 'Integrating sustainability into the firm's brand strategy (PHO8)' (0.125880) is found to be the most significant criterion in group followed by PHO2 (0.104568), PHO6 (0.104368), PHO4 (0.093743), PHO7 (0.091617), PHO5 (0.086062), PHO1 (0.084365), PHO10 (0.083730), PHO3 (0.076483), PH11 (0.075671), and PHO9 (0.073514).

The criteria are ranked and compared with global weight values to present a clear picture of significant criteria. SC6 (0.074868) criteria from SC group ranked first as global weight and the following second and third ranked criteria are SC7 (0.059040) and SC2 (0.054300) (Table 7). Furthermore, the global last ranked three criteria are from PHO group which also ranked last in group optimal weighting. These globally last ranked criteria from highest to lowest weight are as follows; PHO3 (0.009007), PHO11 (0.008911) and PHO9 (0.008657).

5. Discussion

According to the Delphi results, 11 out of 42 criteria for PHO, 8 out of 87 criteria for EMD, 8 out of 49 criteria for PR, and 7 out of 44 criteria for SC have been elected. Criteria obtained through Delphi surveys were used as input to the BWM. Global weights show that the decision makers in the BWM focus on the SC group criteria as a priority. Although the group rankings from the highest to the lowest are as SC, EMD, PR and PHO, the related criteria ranking order shows variety in order. Global weights ranking can be used for the supplier selection. SCPPs' top global weighted criteria in the descending order can be briefly explained and discussed as follows (Table 8):

SC6 (0.074868) can contribute to SC performance. It is vital to actively accomplish monitoring of the specifications and guidelines throughout the project life cycle. Controlling can make it easier to determine the variance and adopt the required precautions on time (Sertyesilisik, 2016).

SC7 (0.059040) conforms to the principles of leanness as well as sustainability. Hence, it is possible to identify supply related environmental and social risks early on (Koplin et al., 2007). Precautions need to be adopted to ensure that the operations are carried out smoothly (Sertyesilisik, 2016). The steps that are critical in choosing the strategy and ensuring objectives include identifying environmental factors, and assessing and prioritizing them (Alfaro-Saiz et al., 2020). These steps can help in identifying the efforts that should be made and hence, allocating resources that would be used within the SC. Each member of the SC should possess green knowledge and have the financial expertise to determine the SCM practices that are most appropriate for the organizations (Jing et al., 2019).

SC2 (0.054300) was found to be the third important criterion. Another factor that plays an essential part in the selection of supplier is geographical location because it has an impact on the lead time, logistics costs, and transportation (Wawasan Open University, 2012). There are certain organizations that need their suppliers to be situated within a given distance from their facilities. Furthermore, SC1 (0.050533) evolved to be a critical strategy for SC resilience. Prashara (2021) states that collaborating with local suppliers and service providers supports local communities with respect to generating trust, achieving market sustainability, and benefits at the societal level. Local presence is vital from the industrial point of view for fulfilling market requirements so that rapid, reliable, flexible, and more cost-efficient product and service delivery can be attained (Christopher, 2021). Suppliers can be protected from SC disruptions and external risk factors through localization as this strategic solution can decrease problems related to distance, variations in international currency, transportation costs, geopolitical risks, and worldwide market fluctuations (Andersson & Segerdahl, 2012). Furthermore, manufacture of building materials may provide important employment benefits to the local region (Rousseau, 2009). This can contribute to the social sustainability, and economic development of that region. Additionally, in recent times, there are a greater number of suppliers, retailers and SC members that are keen on using localization strategies in their specific areas to deal with SC risks and disruptions in the post-COVID-19 period (Sakthivel et al., 2021).

SC5 (0.046826) can help the products to keep a specified level of performance. The materials to be used in construction vary widely. As different storage conditions may be required for each material, it should be ensured that the necessary conditions are provided at site as well as in the manufacturer company so that materials do not get wasted.

SC4 can help suppliers to have more product information than their competitors. There is an inherent link between the sustainability concept and digital transformation, which increasingly becomes involved in all business domains, ranging from governance to operations (Bigliardi & Filippelli, 2022). Hermundsdottir and Aspelund (2021) asserted that consistent with the results of majority of the studies, firm competitiveness was affected positively from sustainability innovations. Furthermore, Yalabik and Fairchild (2011) stated that when there is competitive pressure from the market, environmental innovation is driven to a higher degree than regulations.

EMD7 (0.045005) can provide several advantages. For example, reducing CO2 emissions and global warming (Suhamad & Martana, 2020). From the sustainable development viewpoint, construction materials refer to the way resources are used effectively to fulfil the needs for and requirements of the current and future generations, while decreasing the damage caused to the environment (Rostami et al., 2015; Weißenberger et al., 2014).

EMD6 (0.042111) necessitates selection of appropriate suppliers. Taking precautions require improvement in the way technological and organizational solutions are developed for constructing urban environments with relatively few resources (Chebanova et al., 2019). Furthermore, the vital economic and technical indicators of buildings construction may be improved by ensuring the quality of construction objectives (Chebanova et al., 2019).

EMD2 (0.042102) can support achievement of sustainability. It is vital to use more recycled materials (Shooshtarian et al., 2020a). When recycled materials are used at any stage, the need to obtain new materials is decreased (Treloar et al., 2003). A reliable technique that is used for managing construction and demolition waste is waste recovery (Shooshtarian et al., 2020b). Using recycled materials in the CI can reduce the need for raw materials so that material depletion and other environmental issues can be reduced (Oyedele et al., 2014).

EMD4 (0.042008) can be a beneficial factor in the SC. When the supplier's location is close to the company, lower transport and delivery expenses can be incurred. Similarly, in case easily deformed product is supplied, a better option would be to source a supplier near the business so that the goods could be rapidly delivered (Factors Influencing Choice of Supplier, 2022).

6. Conclusion

This paper identified a preliminary list of lean and sustainability based supplier selection criteria to be considered in the supplier selection phase to support establishment of LSCSC. With this aim, following an in-depth literature review, four groups of four-stage Delphi surveys and the BWM have been applied. One of the most critical aspects of a successful construction project is the CSCM. Integration of lean and sustainable approaches to the construction SC can act as a key for the construction companies to get competitive advantage as it can support reduction in waste, elimination of waste of time, reduction in loss of money and lack of coordination and enhancement in effective use of resources and logistics. LSCSCM can support setting up an effective organization chart in the beginning of the construction project as it can support selection of suppliers.

SCPPs' top ten global weighted criteria in the descending order were determined as (Table 8): SC6; SC7; SC2; SC1; SC5; SC4; EMD7; EMD6; EMD2; and EMD4. Recommendations for application of these identified top ten global

Table 8. *Recommendations for application of top ten weighted criteria obtained from BWM results in CI.*

Rating Order	Top ten global weighted criteria		Recommendations for application of criteria
	Criteria Code	**Global weight**	**Road Map for Implementation**
1	SC6	0.074868	While creating the supply chain, the lean and sustainable production capacity of the stakeholders should be considered. In case of poor performance in production (e.g., quality, and logistics), a warning or fine may be imposed according to the guidelines.
2	SC7	0.059040	When selecting the supply chain suppliers, the production process of potential suppliers should be examined. Factors such as the source of raw materials, the waste generated in production, and the carbon footprint left should be evaluated.
3	SC2	0.054300	The supplier can be selected according to the optimum distance to be determined according to the climatic conditions in the region where the project is built. Furthermore, the geographical conditions need to be considered for ease of transportation and the industrial production capacity conditions.
4	SC1	0.050533	For rapid, reliable, flexible, and more cost-efficient product and service delivery, it is vital to consider selection of the local suppliers.
5	SC5	0.046826	To avoid the disruption risks of stored materials at the construction site, it can be ensured that the materials are not kept for a long time. In this case, from the contractor's point of view, lean production approaches and techniques such as Just in Time should be taken as a basis. Furthermore, suppliers' ability to adopt to and to implement these approaches and techniques should be considered.
6	SC4	0.045449	In order for the project to gain competitive advantage, suppliers should be ready to adapt sustainability. This criterion can be included in the contract in order to monitor the practices in the SC process.
7	EMD7	0.045005	The supplier's materials must comply with the Sustainable and Green Material Certifications, and applied by adding related criterion to the contract.
8	EMD6	0.042111	Starting from the design stage, attention should be paid to the design of the project in accordance with the region and its living conditions. Likewise, it is important that the materials to be used are correctly determined at the design stage. (e.g., avoiding the selection of materials that will deform quickly in harsh weather conditions and difficult to logistics)
9	EMD2	0.042102	Depending on the product range of the supplier, it can be ensured that the products are partially or completely selected from recycled materials. This recycled material ratio can be determined through the meeting with each potential supplier before the supply chain is established.
10	EMD4	0.042008	Type of materials, the supplier location and the distance of logistics are important. The handling system details of delicate materials should be clarified. Qualifications of handling system requested by the contractor could be included in the contract.

weighted criteria in CI are described in Table 9. All criteria are important for supplier selection to enhance LSCSCM performance (Table 8). Considering these criteria and using them in supplier selection as input to the decision process can support CI professional's decision-making process. With this roadmap, the selection process can be able to progress faster and result-oriented and support achievement of lean and sustainable chain establishment considering cost, time, performance, environment, and quality aspects. In addition to supplier selection, monitoring the performance of SC5, EMD7, EMD2 and EMD4 criteria throughout the SC process can contribute to the LSCSCM. Furthermore, criteria can be included in the contract to ensure that SC members comply with LSCSCM requirements. Similarly, SC4, EMD7, EMD2 and EMD4 can be qualified as criteria to be included in the contract.

Regarding SC6, the budget and timing of the project targets can be kept through deterrent sanctions on the stakeholders. Furthermore, in addition to budget, quality and time factors, environmental effects should be taken into account while creating the SC for SC7. Application of lean approaches in the production process can ensure that the environmental footprint is minimized. According to the SC2, the suppliers should be selected by determining the optimum distance based on the ease of transportation of the project location. For example, it can be possible to minimize disruption in the materials supply and labor due to the adverse weather conditions. Thus, time and financial losses can be avoided/reduced. SC1 mentioned that local suppliers should be given priority to take quick action in possible design changes during the construction process. It can have a positive effect in terms of communication and ease of control of the production process. Moreover, regarding SC5, construction site is a complex area where material circulation is intense. Materials delivered too early may be damaged, causing time and financial loss. Material and quality performance can be increased through JIT application. For SC4 criterion, selecting suppliers open to innovative practices (e.g., sustainability and lean) can contribute to the project. In each process where the supplier takes conscious action, the workload of the construction manager may decrease. Looking at the project profile, it can gain competitive advantage in CI. Selecting materials that comply with the Sustainable and Green Material Certification as mentioned in EMD7 can contribute to the competitive advantage. Furthermore, for EMD6, experienced suppliers who have done business in the same environment as the project location should be selected for the construction process and material procurement to progress in harmony. Thus, solution-oriented and fast material selection, application and supply can be supported. For EMD2, selecting a supplier that can make applications with partially recyclable materials in the project can support sustainability and competitive advantage. Finally, supplier location is an important EMD4 criterion for reducing logistics' carbon footprint. Materials' transport system selection can further contribute to this. Suppliers with environment-friendly packaging and planned delivery can minimize waste, unnecessary cost increases and environmental impacts.

Difficulties were encountered in this research. For example, difficulties encountered in BWM study were mainly due to participants' unfamiliarity with the method. Furthermore, the main limitation of this research is its focus on the supplier selection phase.

Project managers and construction executives may use this research results as an initial step to assess, track, and improve their SCs performance. This study has the significance of pioneering use BWM in the CI. Furthermore, it used Delphi survey and BWM successively. This study can provide a new perspective to academics and practitioners for understanding of how to further support LSCSCM. The implications of this paper can be used for future research. Furthermore, future researches are recommended to focus on the effects of adapting Industry 5.0 to the SC for lean and sustainable benefits on suppliers.

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Appendices

Appendix A. Normality test, skewness and kurtosis results for Delphi Round 3 and 4.

Table A1. *Shapiro-Wilk test results for the Group PHO's Delphi Round 3.*

	Tests of Normality					
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PHO1	.443	8	.000	.601	8	.000
PHO2	.347	8	.005	.676	8	.001
PHO3	.300	8	.033	.798	8	.027
PHO4	.228	8	.200*	.835	8	.067
PHO5	.391	8	.001	.641	8	.000
PHO6	.513	8	.000	.418	8	.000
PHO7	.391	8	.001	.641	8	.000
PHO8	.228	8	.200*	.835	8	.067
PHO9	.250	8	.150	.849	8	.093
PHO10	.280	8	.065	.745	8	.007
PHO11	.280	8	.065	.745	8	.007

Table A2. *Shapiro-Wilk test results for the Group PHO's Delphi round 4.*

	Tests of Normality					
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PHO1	.301	8	.031	.782	8	.018
PHO2	.263	8	.109	.827	8	.056
PHO3	.263	8	.109	.827	8	.056
PHO4	.250	8	.150	.849	8	.093
PHO5	.263	8	.109	.827	8	.056
PHO6	.455	8	.000	.566	8	.000
PHO7	.391	8	.001	.641	8	.000
PHO8	.263	8	.109	.827	8	.056
PHO9	.455	8	.000	.566	8	.000
PHO10	.300	8	.033	.798	8	.027
PHO11	.250	8	.150	.849	8	.093

Table A3. *Skewness and kurtosis normality results comparison of the Group PHO's rounds 3 and 4.*

Criteria		Round 3		Round 4		Tabachnick (z value)
		Statistic	Std. Error	Statistic	Std. Error	
PHO1	Mean	4.63	.263	4.25	.313	
	Std. Deviation	.744		.886		
	Skewness	-1.951	.752	-.615	.752	normal
	Kurtosis	3.205	1.481	-1.481	1.481	
PHO2	Mean	4.38	.375	4.25	.250	
	Std. Deviation	1.061		.707		
	Skewness	-1.960	.752	-.404	.752	normal
	Kurtosis	3.937	1.481	-.229	1.481	
PHO3	Mean	4.38	.263	4.25	.250	
	Std. Deviation	.744		.707		
	Skewness	-.824	.752	-.404	.752	normal
	Kurtosis	-.152	1.481	-.229	1.481	
PHO4	Mean	4.13	.295	4.00	.267	
	Std. Deviation	.835		.756		
	Skewness	-.277	.752	.000	.752	normal
	Kurtosis	-1.392	1.481	-.700	1.481	
PHO5	Mean	4.63	.183	4.25	.250	
	Std. Deviation	.518		.707		
	Skewness	-.644	.752	-.404	.752	normal
	Kurtosis	-2.240	1.481	-.229	1.481	
PHO6	Mean	4.88	.125	4.75	.164	
	Std. Deviation	.354		.463		
	Skewness	-2.828	.752	-1.440	.752	normal
	Kurtosis	8.000	1.481	.000	1.481	
PHO7	Mean	4.63	.183	4.63	.183	
	Std. Deviation	.518		.518		
	Skewness	-.644	.752	-.644	.752	normal
	Kurtosis	-2.240	1.481	-2.240	1.481	Z value (-1.51)
PHO8	Mean	4.13	.295	4.25	.250	
	Std. Deviation	.835		.707		
	Skewness	-.277	.752	-.404	.752	normal
	Kurtosis	-1.392	1.481	-.229	1.481	
PHO9	Mean	4.00	.267	3.75	.164	
	Std. Deviation	.756		.463		
	Skewness	.000	.752	-1.440	.752	normal
	Kurtosis	-.700	1.481	.000	1.481	
PHO10	Mean	4.25	.366	4.38	.263	
	Std. Deviation	1.035		.744		
	Skewness	-1.675	.752	-.824	.752	normal
	Kurtosis	3.136	1.481	-.152	1.481	
PHO11	Mean	4.25	.366	4.00	.267	
	Std. Deviation	1.035		.756		
	Skewness	-1.675	.752	.000	.752	normal
	Kurtosis	3.136	1.481	-.700	1.481	

Table A4. *Shapiro-Wilk test results for the Group EMD's Delphi round 3.*

	Tests of Normality					
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EMD1	.371	8	.002	.724	8	.004
EMD2	.281	8	.062	.809	8	.036
EMD3	.281	8	.062	.809	8	.036
EMD4	.263	8	.109	.827	8	.056
EMD5	.301	8	.031	.782	8	.018
EMD6	.301	8	.031	.782	8	.018
EMD7	.347	8	.005	.676	8	.001
EMD8	.327	8	.012	.810	8	.037

Table A5. *Shapiro-Wilk test results for the EMD's Delphi round 4.*

	Tests of Normality					
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EMD1	.435	7	.000	.600	7	.000
EMD2	.296	7	.063	.840	7	.099
EMD3	.338	7	.015	.769	7	.020
EMD4	.504	7	.000	.453	7	.000
EMD5	.360	7	.007	.664	7	.001
EMD6	.504	7	.000	.453	7	.000
EMD7	.338	7	.015	.769	7	.020
EMD8	.258	7	.174	.818	7	.062

Table A6. *Skewness and kurtosis normality results comparison of the Group EMD's Delphi rounds 3 and 4.*

Criteria		Round 3		Round 4		Tabachnick (z value)
		Statistic	Std. Error	Statistic	Std. Error	
EMD1	Mean	4.50	.267	4.43	.369	
	Std. Deviation	.756		.976		
	Skewness	-1.323	.752	-1.230	.794	normal
	Kurtosis	.875	1.481	-.840	1.587	
EMD2	Mean	4.13	.398	3.86	.261	
	Std. Deviation	1.126		.690		
	Skewness	-1.113	.752	.174	.794	normal
	Kurtosis	.291	1.481	.336	1.587	
EMD3	Mean	4.13	.398	3.57	.297	
	Std. Deviation	1.126		.787		
	Skewness	-1.113	.752	1.115	.794	normal
	Kurtosis	.291	1.481	.273	1.587	
EMD4	Mean	4.25	.250	4.14	.143	
	Std. Deviation	.707		.378		
	Skewness	-.404	.752	2.646	.794	Not normal
	Kurtosis	-.229	1.481	7.000	1.587	
EMD5	Mean	4.25	.313	4.57	.202	
	Std. Deviation	.886		.535		
	Skewness	-.615	.752	-.374	.794	normal Z value (-1.76)
	Kurtosis	-1.481	1.481	-2.800	1.587	
EMD6	Mean	4.25	.313	4.71	.286	
	Std. Deviation	.886		.756		
	Skewness	-.615	.752	-2.646	.794	Not normal
	Kurtosis	-1.481	1.481	7.000	1.587	
EMD7	Mean	4.38	.375	4.43	.297	
	Std. Deviation	1.061		.787		
	Skewness	-1.960	.752	-1.115	.794	normal Z value (-1.51)
	Kurtosis	3.937	1.481	.273	1.587	
EMD8	Mean	4.13	.227	4.14	.340	
	Std. Deviation	.641		.900		
	Skewness	-.068	.752	-.353	.794	normal Z value (-1.14)
	Kurtosis	.741	1.481	-1.817	1.587	

Table A7. *Shapiro-Wilk test results for the Group PR's Delphi Round 3.*

	Tests of Normality					
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PR1	.245	9	.127	.825	9	.039
PR2	.259	9	.083	.844	9	.065
PR3	.298	9	.020	.752	9	.006
PR4	.414	9	.000	.617	9	.000
PR5	.223	9	.200*	.838	9	.055
PR6	.272	9	.054	.805	9	.024
PR7	.278	9	.044	.833	9	.049
PR8	.389	9	.000	.728	9	.003

Table A8. *Shapiro-Wilk test results for the Group PR's Delphi Round 4.*

	Tests of Normality					
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PR1	.298	9	.020	.752	9	.006
PR2	.271	9	.056	.816	9	.031
PR3	.351	9	.002	.781	9	.012
PR4	.351	9	.002	.781	9	.012
PR5	.223	9	.200*	.838	9	.055
PR6	.245	9	.127	.825	9	.039
PR7	.269	9	.059	.808	9	.025
PR8	.351	9	.002	.781	9	.012

Table A9. *Skewness and kurtosis normality results comparison of the Group PR's Delphi Rounds 3 and 4.*

Criteria		Round 3		Round 4		Tabachnick (z value)
		Statistic	Std. Error	Statistic	Std. Error	
PR1	Mean	4.11	.351	4.22	.324	
	Std. Deviation	1.054		.972		
	Skewness	-1.094	.717	.000	.752	normal
	Kurtosis	.611	1.400	-2.800	1.481	Z value (-1.89)
PR2	Mean	4.00	.373	3.78	.434	
	Std. Deviation	1.118		1.302		
	Skewness	-.690	.717	-.354	.717	normal
	Kurtosis	-.800	1.400	-1.806	1.400	Z value (-1.29)
PR3	Mean	4.22	.324	2.22	.401	
	Std. Deviation	.972		1.202		
	Skewness	-1.600	.717	-.68	.752	normal
	Kurtosis	3.194	1.400	.741	1.481	
PR4	Mean	4.33	.167	4.11	.200	
	Std. Deviation	.500		.601		
	Skewness	.857	.717	.018	.717	normal
	Kurtosis	-1.714	1.400	1.126	1.400	
PR5	Mean	4.11	.261	3.89	.261	
	Std. Deviation	.782		.782		
	Skewness	-.216	.717	.216	.717	normal
	Kurtosis	-1.041	1.400	-1.041	1.400	
PR6	Mean	4.33	.236	4.11	.351	
	Std. Deviation	.707		1.054		
	Skewness	-.606	.717	-1.094	.717	normal
	Kurtosis	-.286	1.400	.611	1.400	
PR7	Mean	4.00	.236	4.22	.278	
	Std. Deviation	.707		.833		
	Skewness	.000	.717	-.501	.717	normal
	Kurtosis	-.286	1.400	-1.275	1.400	
PR8	Mean	4.00	.289	4.11	.200	
	Std. Deviation	.866		.601		
	Skewness	-1.485	.717	.018	.717	normal
	Kurtosis	4.000	1.400	1.126	1.400	

Table A10. *Shapiro-Wilk test results for the Group SC's Delphi round 3.*

	Tests of Normality					
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df.	Sig.	Statistic	df	Sig.
SC1	.261	12	.023	.845	12	.032
SC2	.237	12	.061	.891	12	.123
SC3	.316	12	.002	.802	12	.010
SC4	.296	12	.005	.818	12	.015
SC5	.302	12	.003	.835	12	.024
SC6	.309	12	.002	.768	12	.004
SC7	.300	12	.004	.809	12	.012

Table A11. *Shapiro-Wilk test results for the Group SC's Delphi Round 4.*

	Tests of Normality					
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SC1	.166	12	.200*	.876	12	.078
SC2	.245	12	.044	.895	12	.137
SC3	.323	12	.001	.780	12	.006
SC4	.323	12	.001	.780	12	.006
SC5	.358	12	.000	.813	12	.013
SC6	.354	12	.000	.732	12	.002
SC7	.258	12	.026	.818	12	.015

Table A12. *Skewness and kurtosis normality results comparison of the Group SC's Delphi Rounds 3 and 4.*

Criteria		Round 3		Round 4		Tabachnick (z value)
		Statistic	Std. Error	Statistic	Std. Error	
SC1	Mean	3.75	.305	3.50	.337	
	Std. Deviation	1.055		1.168		
	Skewness	.035	.637	.000	.637	normal
	Kurtosis	-1.399	1.232	-1.428	1.232	
SC2	Mean	3.83	.271	3.58	.288	
	Std. Deviation	.937		.996		
	Skewness	-.412	.637	-.274	.637	normal
	Kurtosis	-.298	1.232	-.654	1.232	
SC3	Mean	3.33	.310	3.25	.179	
	Std. Deviation	1.073		.622		
	Skewness	-.275	.637	-.170	.637	normal
	Kurtosis	-1.472	1.232	-.091	1.232	
SC4	Mean	4.08	.260	4.25	.179	
	Std. Deviation	.900		.622		
	Skewness	-1.082	.637	-.170	.637	normal
	Kurtosis	1.492	1.232	-.091	1.232	
SC5	Mean	3.50	.417	3.42	.336	
	Std. Deviation	1.446		1.165		
	Skewness	-.866	.637	-1.003	.637	normal
	Kurtosis	-.474	1.232	.190	1.232	
SC6	Mean	4.42	.193	4.50	.195	
	Std. Deviation	.669		.674		
	Skewness	-.735	.637	-1.068	.637	normal
	Kurtosis	-.190	1.232	.352	1.232	
SC7	Mean	4.08	.193	4.17	.207	
	Std. Deviation	.669		.718		
	Skewness	-.086	.637	-.262	.637	normal
	Kurtosis	-.190	1.232	-.685	1.232	

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