Building a hierarchical framework of corporate sustainability transition challenges using the qualitative information approach

Tseng, M-L., Kurrahman, T., Hanita, A., Lim, M. & Negash, Y.

Original citation & hyperlink:
Tseng , M-L, Kurrahman, T, Hanita, A, Lim, M & Negash, Y 2021, 'Building a hierarchical framework of corporate sustainability transition challenges using the qualitative information approach', Industrial Management and Data Systems.
https://dx.doi.org/10.1108/IMDS-08-2020-0471

DOI 10.1108/IMDS-08-2020-0471
ISSN 0263-5577

Publisher: Emerald

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Purpose

This study aims to form a valid measure and hierarchical framework to achieve corporate sustainability transition.

Original Value

Corporate unsustainability practices have caused large amounts of energy consumption, resource depletion, and environmental impacts. There are challenges in transitioning to corporate sustainability that must be addressed. The most significant challenges that need to be solved to facilitate the transition to corporate sustainability are identified and arranged in a hierarchical model. Identifying the hierarchical relationships among the challenges develops a theoretical framework that extends the existing models to assist decision-makers.

Design

The fuzzy Delphi method is applied to validate and eliminate challenges in sustainability transition in qualitative information. Fuzzy interpretive structural modeling is to build a hierarchical framework under uncertainties.

Findings

This study finds that technology investment, data management, Eco-management, and socio-spatial embedding challenges are the highest hierarchical framework levels and affect corporate sustainability transition.

Practical Implications

A lack of awareness and knowledge, a lack of commitment, a lack of strategy, tolerance of unsustainable practices, a lack of stakeholder participation, and a fragmented market are perceived as the challenges that show the highest driving and dependence power. These challenges serve as a reference for government and construction firms to achieve corporate sustainability transition.

Keywords: corporate sustainability transition challenges; corporate sustainability; fuzzy interpretive structural modeling; fuzzy Delphi method

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1. Introduction

The improvement of Indonesia's economic growth and its high population has caused a rapid increase in the demand for new infrastructure and housing construction (Wibowo et al., 2018; BPS Statistics Indonesia, 2019). The acceleration of construction works has elevated energy consumption, resource depletion and environmental impacts (Chang et al., 2016; Pina and Burgos, 2017; Zhang et al., 2019). The implementation of sustainability is required for the construction industry and has led to exploring sustainable construction techniques, technologies, processes, and products (Lu and Zhang, 2016; Serafeim, 2020; Udomsap and Hallinger., 2020). The sustainable construction process needs to be explored from the traditional construction process perspective and a transition to corporate sustainability (Koho et al., 2015; Son et al., 2011; Darko et al., 2017). Corporate sustainability transition (CST) is essential to the shift from conventional to sustainable practices by incorporating the triple bottom lines (TBL) in economic, social and environmental areas into corporate activities (Bai et al., 2015; Lu and Zhang., 2016; Goh et al., 2020). CST guides the implementation of better practices in certain functions across industries (Deineko et al., 2019; Wannags and Gold, 2020). CST implies long-term, multi-perspective, and fundamental transformation processes that cause a shift toward sociotechnical changes; however, numerous challenges hinder CST realization (Markard et al., 2012; Fastenrath and Braun, 2018; Scordato et al., 2018; Wannags and Gold., 2020). Determining and understanding the challenges inhibiting CST in recent years is needed to move toward sustainable construction (Yang and Yang, 2015; Darko et al., 2018; Martek et al., 2019). Nevertheless, prior studies have not clearly addressed these CST challenges.

Technological expertise for operating and developing technologies and understanding these technological innovations' benefits had been major problems hindering CST (Darko et al., 2018). Improper CST has been reported in prior studies. Chan et al. (2017) argued that poor technological adoption provides a wide variety of TBL challenges that restrain the shift toward sustainability. Huang et al. (2018) argued that low technology investment discourages corporations from adopting and developing technologies and causes inefficiency in corporate operations, especially in waste diversion, limiting CST performance. Foong et al. (2017) identified that sociospatial embedding challenges caused the emergence of other economic, environmental, and technological challenges that hindered better CST performance. In addition, Martek et al. (2019) argued that lack of leadership as a social challenge brings separation, divergence, and even conflict in the formulation and adoption of sustainability practices. Pham et al. (2019) found that challenges in eco-management decrease the motivation to pursue sustainability practices and limiting the creation of plans and strategies for CST. Wu et al. (2017) found that externality challenges, the absence of economic convenience, and the uncertainty of returns and profit from sustainability practices create challenges in the sustainable transition process of social, environmental, and technological factors. Ghisellini et al. (2018) found that a lack of data management of environmental assessment and sustainability practices increases decision-makers' problems in adopting and developing sustainability practices and inhibiting CST. Nevertheless, the high initial cost of implementing sustainability practices discourages corporations from adopting sustainability practices and restricts CST (Kasai and Jabbour., 2014; Zhang et al., 2019). Prior studies have addressed CST challenges; however, a knowledge gap remains regarding these challenges. However, the absence of a holistic approach in prior studies makes them insufficient to capture the complete picture of CST challenges (Skellern et al., 2017; Chang et al., 2018; Wang et al., 2018). This study argues that social, economic, environmental, and technological challenges need to be holistically understood to improve CST.

CST challenges are a complex issue, and many challenges limit the transition process; however, prior studies have neglected to perform validation for industry measures and lack a systematic classification of the attributes under uncertainties (Yang and Yang, 2015; Chang et al., 2016). It is hard to determine the significant challenges based on judgments and perception in quantitative information. Linguistics vagueness is differences in interpretations and meanings (Bui et al., 2020; Chen et al., 2018).

This study applied the fuzzy Delphi Method (FDM) to confirm the construction industry's measures' reliability and validity and eliminate the experts' subjective preferences. The fuzzy interpretive structural modeling (FISM) was used to determine the improvement criteria and develop a comprehensive systematic framework of the complex problems faced by decision-makers. The FDM method evaluates the importance level of the challenges and eliminates unnecessary challenges based on experts' viewpoints (Kuo and Chen, 2008; Chen et al., 2018; Bui et al., 2020). The FISM method was conducted to arrange various attributes into an extensive systematic model to provide an adequate picture of CST challenges (Attri et al., 2013; Tseng et al., 2018; Wang et al., 2018). FISM identifies qualitative and interpretive solutions to complex problems. The objectives of this study are as follows:

- To construct a valid CST measure in qualitative information
- To build a theoretical and hierarchical model under uncertainties
- To guide the industry toward practical improvement

This study contributes to the literature as follows. (1) It constructs a valid and reliable set of CST challenges. (2) It provides practical recommendations with necessary implications to serve as a reference for government and construction firms and foster the shift toward sustainability and achieve CST. (3) Identifying the hierarchical relationships among the challenges develops a theoretical framework that extends the existing models and determines the major CST challenges to assist decision-makers. The rest of this study is organized as follows. Section 2 addresses the construction CST literature, proposed methods, and proposed measures. Section 3 explains the methodology of this study. Section 4 provides the results of this study. Section 5 discusses the study's conclusions and limitations and offers recommendations for future study.

2. Literature Review

This section includes a review of CST literature and discusses the proposed methods and measures in this study.

2.1. CST

CST is considered a strategy to achieve economic prosperity, environmental quality, and social equality (Koho et al., 2015; Chang et al., 2018). Corporations have started to engage with CST to find the solution by creating economic value toward reducing social and environmental issues associated with the organization's daily operation (Cancela et al., 2020). CST emerges because corporations realized the benefits; for instance, it increases competitiveness and reduces cost and risk (Dhanda and Shrotryia, 2020). Budsaratragoon and Jitmaneeroj (2019) argued that CST had become a key component of successful business strategies and operations in the industry.

CST encompasses corporate strategy changes from conventional to more sustainable, leading to the systematic adoption of better practices in entire corporate operations through sustainable social, economic, and environmental activities (Pham et al., 2019; Goh et al., 2020). Deineko et al. (2019) argued that CST involves values to reduce environmental impacts and a procedural shift toward long-term sustainability at a broader scope. Udomsap and Hallinger (2020) argued that CST generated sustainability practices that preserved natural resources and produced a healthy environment. Martek et al. (2019) highlighted that CST involves a long-term, multidisciplinary, and essential transformation approach that assists corporations in balancing profit maximization goals and sustainability demands. Mejia et al. (2018) argued that CST involves introducing alternative technologies and practices to reshape corporate activities to be more sustainable. Corporations must focus on how to solve the problems of uncertainty and ambiguity concerning sustainability. Skellern et al. (2017) argued that CST challenges should cover a broader picture incorporating social, political, economic, and environmental challenges and the lack of mature technological adoption. Huang et al. (2018) presented that the CST implementation remains weak due to social, economic, environmental and technological challenges. An understanding of CST challenges is still needed.

Social CST challenges involve the difficulties related to corporate stakeholders, such as perceptions, commitment and awareness, that inhibit CST. Foong et al. (2017) found that social challenges are the source of other CST challenges, such as economic, environmental, and technological challenges, because sustainability solutions depend on people's willingness to find those solutions.

Murphy et al. (2015) argued that CST challenges must be explained due to sociospatial embedding challenges that trigger other sustainability problems. Martek et al. (2019) argued that a lack of leadership, awareness, and knowledge of sustainability practices occurs due to sociopolitical challenges and limits CST. Chang et al. (2016) addressed regulations and legislation, including social challenges that inhibit corporate sustainability knowledge, promotion, and standards at the regional or local level. Jesus and Mendonca (2018) presented that institutional and regulatory challenges limit the reformation and creation of laws promoting sustainability, hindering CST. Pham et al. (2019) argued that poor eco-management in a corporation limits the formulation of plans and strategies toward sustainability, restricting CST performance. Serafeim (2020) claimed that public sentiment toward CST performance impacts sustainability activities' market pricing and inhibits CST. O'Niell and Gibbs (2020) argued that the government's poor commitment to adopt sustainability practices is a main social challenge that hinders CST. Pham et al. (2019) argued that poor stakeholder desire and involvement restrict firms' commitment to sustainability and limit CST performance. Hence, social challenges are perceived as a major threat to CST.

Economic CST challenges include the financial and economic problems that cause poor CST performance, and financial benefits are the main drivers of corporate attitudes toward sustainability. Wu et al. (2017) argued that externality challenges and uncertainty in returns and profit discourage corporations from adopting sustainable practices and increase social, environmental, and technological challenges. Firms' motivation to maximize their profit by decreasing their project costs affects their sustainability adoption decisions and is seen as a major challenge in achieving CST (Wang et al., 2018; Dhanda and Shrotryia, 2020). Kasai and Jabbour (2014) argued that the high initial cost of applying sustainability practices hinders the transition toward sustainability. Jesus and Mendonca (2018) found that economic and market liability limits the practical application of and investment in sustainability practices. Ghisellini et al. (2018) stated that CST had not been fully applied because of inadequate technology investment and discouragement of the adoption and development of technologies to support sustainability practices. Deineko et al. (2019) argued that economic challenges are also impacted by ineffective resource usage, limiting the shift toward sustainability. Economic challenges play an influential role in hindering CST and need to be considered.

Environmental CST challenges involve integrating sustainability innovation with environmental preservation practices, restricting the shift toward CST. Jin et al. (2017) argued that the high cost of waste diversion for reusing and recycling materials discourages corporations from engaging in sustainability practices and restricts the CST process. Ghisellini et al. (2018) argued that data management challenges led to a failure to track down and record sustainability practices, environmental assessments, and corporate waste diversion data, making it challenging to embrace and develop sustainability practices that are seen as environmental CST challenges. Schmid et al. (2020) stated that inadequate corporate methods for waste management to minimize waste and maximize reuse, refurbishment, downcycling, upcycling and remanufacturing practices elevate the difficulties in achieving CST. Pina and Burgos (2017) found that environmental sustainability challenges are triggered by poor environmental performance assessment plans, restricting the shift toward sustainability. Hence, environmental challenges need to be included in the assessment of CST challenges.

Technological CST challenges address the difficulties related to access to relevant, useful, and adequate hardware or technological adoption. Mejia et al. (2018) argued that CST is affected by TBL and introduces alternative technologies and practices into real-life settings to reshape social and material aspects to be more sustainable. Darko et al. (2018) presented that technological expertise's unavailability creates insufficient technological practices and brings problems that limit sustainability adoption. Zhang et al. (2019) addressed the technological challenges impacted by a lack of knowledge to use technologies appropriately, which hindered the shift toward sustainability. Chan et al. (2017) argued that corporations' lack of technological adoption caused various TBL challenges that inhibited CST. Wannags and Gold. (2020) stated that the existence of unexpected effects when adopting new technologies requires an organization's assessment to consider TBL. Technological challenges should be integrated into the assessment of CST challenges.

2.2. Proposed Method

Prior studies have analyzed and identified CST challenges using qualitative assessment (Foong et al., 2017; Ghisellini et al., 2018; Martek et al., 2019). In CST challenges, Chang et al. (2016) adopted a conventional content analysis of existing policy regarding sustainability practices to identify major policy challenges. Foong et al. (2017) carried out inductive and deductive approaches that involved interviews in understanding the professionals' perspectives and experience. Skellern et al. (2017) organized a systematic review and content analysis of existing conceptual approaches to identify the attributes and construct a conceptual framework that incorporates interdisciplinary concepts. Ghisellini et al. (2018) conducted a content analysis of other papers that focused mainly on CST barriers and factors to collect and construct the main challenges. Scordato et al. (2018) employed a policy mix approach with semistructured interviews and policy analysis to examine the interaction among instruments that expedite CST. Martek et al. (2019) directed in-depth focus group discussions with experts and used the Nvivo software package to code and analyze the results to determine the CST challenges. Chang et al. (2018) employed relative importance value and relative performance value analysis to determine the rank or hierarchical position of internal challenges influencing CST.

In a quantitative method to assess CST challenges, Chan et al. (2017) employed a multivariate statistical analysis with professionals' views regarding technological adoption for CST to investigate the relative importance of the proposed criteria. Darko et al. (2018) developed a nonprobability sampling technique and conducted a multivariate statistical analysis technique with the structural equation modeling method to analyze the significant CST challenges. However, CST challenges involve qualitative attributes and uncertainties because of linguistic preferences over the attributes (Ghisellini et al., 2018; Cui et al., 2019; Martek et al., 2019). The uncertainties cannot be captured effectively based on formal models and methods, making it difficult to gain insights into CST issues. This study proposes to conduct FDM and FISM based on experts' views to address the uncertainties and attributes formed with qualitative information. FDM is used to validate and eliminate the unnecessary criteria hindering CST based on knowledge, experience, and intuition of experts' from the construction industry in Indonesia (Chen et al., 2018). FDM provides a strong identification of CST challenges, allows experts to exchange opinions based on experience and knowledge, and covers experts' judgments in one investigation (Kuo and Chen, 2008; Bui et al., 2020). FISM was conducted to arrange various direct and indirect CST criteria into an extensive systematic model and identify the influence and direction of CST challenges (Tseng et al., 2018; Cui et al., 2018). FISM is used to identify qualitative and interpretive solutions to complex problems and organizes challenges into a hierarchical model to provide a realistic view of CST challenges (Attri et al., 2013; Tseng et al., 2018; Wang et al., 2018). Experts' points of view and judgments regarding CST challenges are used to examine the complicated relationship between CST attributes and construct them into a hierarchical structure (Tseng et al., 2018). A method combining FDM and FISM is to create a comprehensive theoretical and hierarchical model based on a valid CST set challenges.

2.3. Proposed Measures

CST is essential to shifting from traditional corporate practices to more sustainable practices by integrating TBL and technological perspectives into corporate activities (Markard et al., 2012; Lu and Zhang, 2016; Chang et al., 2016). In the construction industry, it is important to understand the challenges inhibiting CST and thereby overcome them. This study proposes a set of attributes representing four perspectives and 57 criteria (Appendix A), including social CST challenges (P1), economic CST challenges (P2), environmental CST challenges (P3), and technological CST challenges (P4). After the FDM assessment, 28 criteria are valid for Indonesia's construction industry, as indicated in Table 1 and discussed below.

Social sustainability challenges (P1) have an influential role in CST and lead to economic, environmental, and technological challenges, thereby increasing the difficulties construction firms faced in transition (Williams and Dair., 2007; Foong et al., 2017). Even technical solutions for sustainability depend on people's willingness to find those solutions. CST challenges such as economic, environmental, and technological challenges must be decoded as the outcome of social CST challenges

(Murphy et al., 2015; Fastenrath and Braun, 2018). The lack of vision (C1) from the government and construction industry regarding an ultimate target and deadline for CST practices is a challenge that inhibits CST (Koho et al., 2015; Ghisellini et al., 2018). Poor regulations (C2) inside the construction industry to monitoring and maintaining the implementation of sustainability practices and the lack of governmental support (C3) to encourage the application of corporate sustainability practices need to be solved to achieve CST (Bai et al., 2015, Ghisellini et al., 2018; Cui et al., 2019). Inadequate awareness from the Indonesian government toward sustainable development is a major issue that slows down CST within the construction industry.

Government actors' personal interests (C4) influence the government's decision-making and inhibit CST performance (O'Niell and Gibbs, 2020). The lack of awareness and knowledge (C5) from society and construction firms seen as sources of the other CST challenges (Koho et al., 2015; Martek et al., 2019). The bias regarding corporate objectives and the irregularity of practices and frameworks is a challenge in CST triggered by the lack of leadership (C6) (Litos and Evans, 2015, Budsaratragoon and Jitmaneeroj, 2019; Martek et al., 2019). A lack of community involvement (C7) or bottom-up initiatives from civil society to uphold and support sustainability practices is a challenge hindering the shift toward sustainability (Fastenrath and Braun, 2018). Moreover, the passive sustainability implementation caused by a lack of commitment (C8) is a challenge that restricts corporations' shift toward being more sustainable (Litos and Evans, 2015; Engert and Baumgartner., 2016). The difficulties in determining specific practices and balancing all operations in corporations due to a lack of strategy (C9) are seen as challenges that inhibit CST (Pham et al., 2019; Cancela et al., 2020). In addition, tolerance of unsustainable practices (C10) is considered a behavior that discourages corporations from setting sustainability agendas, and a lack of stakeholder participation (C11) may create disputes that limit the shift toward sustainability (Williams and Dair, 2007; Engert and Baumgartner, 2016; Pham et al., 2019).

In addition to social challenges, economic challenges (P2) limit construction firms' engagement in sustainability practices and hinder CST (Wu et al., 2017). Firms' motivation to maximize profit by decreasing their project costs is one of these challenges. Ghisellini et al. (2018) and Huang et al. (2018) found a lack of waste technology investment (C12) discourages corporations from adopting technologies, decreases the efficiency of resource use, and increases the emissions and waste that inhibit the shift toward CST. The high diversion costs (C13) trigger high prices of recycled products (C14) that caused uncontrolled natural resource use by corporations and restrained CST (Ghisellini et al., 2018; Huang et al., 2018). Besides, the low price of natural materials (C15) leads corporations to avoid using recycled materials (Ghisellini et al., 2018). A lack of incentives (C16) from stakeholders is seen as a factor that discourages corporations from moving toward sustainability, and it is known as a major economic challenge inhibiting CST (Ghisellini et al., 2018; Huang et al., 2018). Fragmented markets (C17) lead to a failure of sustainable products to enter various markets and be addressed to move toward sustainability (Cui et al., 2019; Martek et al., 2019). Firms' limitations in the practical application of sustainability often emerge because of the economic and market challenges and uncertainty in returns and profit (C18), which are considered a challenge limiting and discouraging CST investment (Jesus and Mendonca, 2018). In lieu of this, solving the problem of Indonesian construction industries' economic liability, which can be attained by the commitment from the corporations themselves and support from the government, is essential for better CST.

In construction, environmental challenges (P3) elevate difficulties in achieving CST and discourage corporations from adopting sustainability practices (Jin et al., 2017; Schmid et al., 2020). A lack of environmental assessment (C19) to obtain experts' and society's viewpoints about future projects was found to hinder CST (Pina and Burgos, 2017). Poor urban planning (C20) by the government that ignores the environmental goal of greater sustainability has led to short-lived buildings and inhibited the shift toward CST (Huang et al., 2018). Poor waste management facilities (C21) may be harmful to the public and environment and are considered a challenge for CST (Schmid et al., 2020). Ghisellini et al. (2018) revealed that lack of data (C22) related to CST practices limit the government's and corporations' ability to track down previous CST practices and the statistical amount of corporate material and waste challenge that negatively impacts decision making and restrains environmental CST. Additionally, the lack of a stable supply of construction waste materials (C23) to produce recycling products is a challenge for waste diversion and CST (Ghisellini et al., 2018). Hence, even if Indonesia has vast natural resources that construction firms can utilize, society and construction industries must not be contented and aware of environmental and sustainability performance.

Technological CST challenges (P4) potentially affect construction firms' corporate reputation and productivity and inhibit the shift toward CST (Chan et al., 2017; Darko et al., 2018). Insufficient reduction, reuse, and recycling applications (C24) limit corporate waste diversion efficiency, inhibiting CST (Huang et al., 2018). Darko et al. (2018) noted having an adequate research and development base for technological development can promote the adoption of technology that supports CST because the lack of local institutes and facilities for green building technology and research (C25) hinders the shift toward sustainability. The lack of professional knowledge and expertise (C26) to support corporate technological adoption and the risk and uncertainties involved in adopting new technologies (C27) discourages corporations from adopting new technologies and increases the difficulties in achieving CST (Darko et al., 2018). Also, the higher cost of technologies (C28), which limits certain corporations from adopting technologies, appears to be a major challenge in corporations' technological adoption (Darko et al., 2018). Therefore, solving those issues and achieving better technological performance able to enhance CST.

(Table 1 FDM - perspectives and criteria)

3. Methods

This section discusses the background of a CST case in Indonesia. The FDM and FISM methods are explained.

3.1. Industry Background

The development of Indonesia's economic growth and high population increase over the last decade have elevated the demand for new infrastructure and construction activities (Wibowo et al., 2018). The construction industry contributed USD 117 million – or 11.1% of the country's GDP – in 2018, making construction activities the third-largest contributor to the nation's economy (BPS Statistics Indonesia, 2019). The construction field is predicted to continuously grow over the forecast period (2020-2024). The market encompasses various sectors, such as commercial, industrial, residential, infrastructure, and energy and utility construction projects. However, construction is a major consumer of natural resources and producer of world carbon emissions and is a potential cause of environmental problems. Hence, the construction industry must implement CST to achieve more sustainable social, economic, environmental, and technological operations, which will lead to the adoption of better practices across the entire industry. However, the construction industry in Indonesia faces numerous challenges in achieving CSTs.

The lack of awareness of and commitment to upholding sustainability practices from construction firms due to Indonesia's huge availability of natural resources impedes the shift toward sustainability. Poor regulation from the government toward construction sustainability practices is a social challenge that limits the realization of CST. The lack of incentives and a fragmented market for sustainable construction discourages construction firms from adopting sustainability practices. Inadequate urban planning makes it impossible for the construction industry to use natural materials, which causes unsustainable construction operations efficiently. Landfilling activities from construction firms have caused a waste problem, even though some construction waste can be recycled. There is little involvement from construction firms in generating better construction waste diversion, reuse and recycling practices for building materials. Moreover, the lack of technological adoption by construction firms obstructs CST. Thus, it is necessary for the construction industry in Indonesia to overcome these CST challenges. This study can guide practitioners toward achieving CST by identifying the challenges that negatively affect CST performance. This study involved a group of 14 professionals with extensive experience in the construction industry in Indonesia.

3.2 Fuzzy Delphi Method

Ishikawa et al. (1993) introduced FDM to address the fuzziness of group decisions and improve the quality and efficiency of expert judgment processes. FDM is useful for validating the attributes and eliminating less important criteria based on experts' views (Chen et al., 2018). Presuming there are n experts and m attributes, expert a is requested to evaluate the significance value of attribute b as $j = (x_{ab}; y_{ab}; z_{ab})$, where $a = 1,2,3, \dots, n$; $b = 1,2,3, \dots, m$. The weight of attribute b is assessed as $j_b = (x_b; y_b; z_b)$, where $x_b = min(x_{ab})$, $y_b = (\prod_1^n y_{ab})^{1/n}$, and $z_b = max(z_{ab})$. The linguistic values are then computed using linguistic terms and triangular fuzzy numbers (TFNs), as shown in Table 2.

(Table 2. FDM vs. TFN for linguistic preferences)

The convex combination value D_b is generated using δ as follows:

$$u_b = z_b - \delta(z_b - y_b),\ v_b = x_b - \delta(y_b - yx_b),\ \text{where } b = 1,2,3, \dots, m \quad (1)$$

where δ ranges from 0 to 1 depending on whether experts' views are positive or negative. When $\delta = 0.5$, the fundamental perspectives are balanced among the expert group.

The accurate value of D_b is computed using

$$D_b = \int(u_b, v_b) = \delta[u_b + (1 - \delta)v_b] \quad (2)$$

Finally, the threshold $\partial = \sum_{a=1}^{n}(D_b/n)$ is calculated to select valid attributes (Bui et al, 2020).

If $D_b \geq \partial$, attribute b is accepted.

If $D_b \leq \partial$, attribute b must be eliminated.

3.3 Fuzzy Interpretive Structural Modeling

The FISM was first proposed as a systematic analysis tool to precisely determine the interrelationships among specific attributes through a hierarchical structural model design (Warfield, 1974). In FISM, digraph theory is used to systemize the attributes, and their direct linkages in uncertainty; systemic interrelationships are indicated using a binary connection between each pair of attributes (Wang et al., 2018). This study introduces TFN evaluation to address the linguistic information of expert judgments. The FISM approach is presented below.

Assume that the attitude set is composed of $E, e = 1, 2, \dots, n$ and that there are τ experts in the assessment group who are asked to use their linguistic preferences to evaluate the influence and importance level E_{ij}^{τ} between e_i and $e_j, i, j = 1,2, \cdots n$. The experts provided the evaluation tool using linguistic assessment and the TFNs, as indicated in Table 2. As a result, the structural self-interaction matrix evaluation is generated as follows:

$$E_{ij}^{\tau} = \begin{bmatrix} & e_1^{\tau} & e_2^{\tau} & \cdots & e_j^{\tau} \\ e_1^{\tau} & e_{11}^{\tau} & e_{12}^{\tau} & \cdots & e_{1j}^{\tau} \\ e_2^{\tau} & e_{21}^{\tau} & e_{22}^{\tau} & \cdots & e_{2j}^{\tau} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ e_i^{\tau} & e_{n1}^{\tau} & e_{n2}^{\tau} & \cdots & e_{nn}^{\tau} \end{bmatrix} \quad (3)$$

(Table 3. FISM vs. TFN for linguistic preferences)

The TFNs of each attribute in the matrix are then normalized using the following form:

$$\bar{a}_{ij}^{\tau} = \left(a_{ij}^{\tau} - min\, a_{ij}^{\tau}\right)/\varphi$$
$$\bar{b}_{ij}^{\tau} = \left(b_{ij}^{\tau} - min\, b_{ij}^{\tau}\right)/\varphi \quad (4)$$
$$\bar{c}_{ij}^{\tau} = \left(c_{ij}^{\tau} - min\, c_{ij}^{\tau}\right)/\varphi$$

where $\varphi = max\, c_{ij}^{\tau} - min\, a_{ij}^{\tau}$.

The left l_{ij}^{τ} and right r_{ij}^{τ} normalized values are assimilated as follows:

$$l_{ij}^{\tau} = \bar{b}_{ij}^{\tau}/\left(1 + \bar{b}_{ij}^{\tau} - \bar{a}_{ij}^{\tau}\right)$$
$$r_{ij}^{\tau} = \bar{c}_{ij}^{\tau}/\left(1 + \bar{c}_{ij}^{\tau} - \bar{m}_{ij}^{\tau}\right) \quad (5)$$

The normalized crisp value θ_{ij}^{τ} is computed as follows:

$$\theta_{ij}^{\tau} = \left[l_{ij}^{\tau}\left(1 - l_{ij}^{\tau}\right) + \left(r_{ij}^{\tau}\right)^2\right] / \left(1 + r_{ij}^{\tau} - l_{ij}^{\tau}\right) \tag{6}$$

The aggregated matrix M_{ij}^{τ} based on integrating the crisp values of all experts is as follows:

$$M_{ij}^{\tau} = \left[m_{ij}\right]_{n\times n} = \sum_{i,j=1}^{n}\left(\theta_{ij}^{\tau}\right)/\tau \tag{7}$$

Accordingly, experts are asked to confirm the probability by providing a positive number ranging from 0 to 1 (Govindan et al., 2012). The relationship probability between e_i and e_j is integrated into a P_{ij}^{τ} matrix as follows:

$$P_{ij}^{\tau} = \left[p_{ij}\right]_{n\times n} = \begin{bmatrix} & p_1^{\tau} & p_2^{\tau} & \cdots & p_j^{\tau} \\ p_1^{\tau} & p_{11}^{\tau} & p_{21}^{\tau} & \cdots & p_{n1}^{\tau} \\ p_2^{\tau} & p_{21}^{\tau} & p_{22}^{\tau} & \cdots & p_{n2}^{\tau} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ p_i^{\tau} & p_{n1}^{\tau} & p_{n2}^{\tau} & \cdots & p_{nn}^{\tau} \end{bmatrix}, 0 \le p_{ij} \le 1. \quad (8)$$

The expected matrix T is then conceived as follows:

$$T = \left[t_{ij}\right]_{n\times n} = \left[m_{ij}\right]_{n\times n} \times \left[p_{ij}\right]_{n\times n} \tag{9}$$

Based on the expected matrix T, the driving power α and dependence power β are obtained (Wang et al., 2018).

$$\alpha = \left[\sum_{i=1}^{n} t_{ij}\right]_{n\times 1} = \left[t_i^{\alpha}\right]_{n\times 1}$$
$$\beta = \left[\sum_{j=1}^{n} t_{ij}\right]_{1\times n} = \left[t_j^{\beta}\right]_{1\times n} \tag{10}$$

The driving power α and dependence power β are utilized as the vertical and horizontal axes to map the criteria into four quadrants: (1) the autonomy quadrant comprises weak driving power and weak dependence power criteria with fewer connections with other criteria; (2) the dependency quadrant comprises weak driving power and strong dependence power criteria, which have a strong dependence on other criteria; (3) the linkage quadrant comprises strong driving power and strong dependence power criteria that have strong effects on and are easily affected by other criteria; and (4) the driving quadrant comprises strong driving power but weak dependence power criteria, which significantly influence other criteria.

Threshold values α^t and β^t are computed to attain the binary matrixes, the binary reachability and the antecedent matrix, respectively. Particularly,

$$\alpha^t = \left[\sum_{i=1}^{n} t_{ij}\right]_{n\times 1}, if\ t_{ij} \ge \alpha^t, the\ reachability\ scale\ equals\ 1;\ otherwise, it\ equals\ 0 \tag{11}$$

$$\beta^t = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n}, if\ t_{ij} \ge \beta^t, the\ antecedent\ scale\ equals\ 1;\ otherwise, it\ equals\ 0 \tag{12}$$

The binary intersection set S is then presented as follows:

$$\alpha^t = 1, R = \{C_1, C_2, \cdots C_n\}; \beta^t = 1, A = \{C_1, C_2, \cdots C_n\} \tag{13}$$

$$S = R \cap A \tag{14}$$

Finally, the frequency F of the intersection set of each criterion is calculated using

$$F = \left[\sum_{j=1}^{n} s_{ij}\right]_{1\times n} = \left[s_j\right]_{1\times n} \tag{15}$$

If the F value is the lowest, the criteria make up the first level into a hierarchical model, and the second-lowest values make up the next level, and so on. The procedure leveling is repeated until all criteria are included, and the hierarchical structural model of the attributes is built.

3.4. Proposed Analytical Steps

1. A set of CST attributes is developed from the prior studies that follow a questionnaire for linguistic evaluation based on 14 expert participants from the construction industry in Indonesia: four members from the academic sector, three members from the related government, and seven members from private construction firms. The participants had an average of 8 years of experience in the construction industry. Face-to-face interviews were conducted to confirm the validity of the information and improve the data source's reliability; the expert participants were asked to confirm the validity of the attributes for CST and subsequently completed the questionnaires. The FDM is directed to identify the important attributes by applying Equations (1)-(2).

2. Subsequently, the FISM questionnaire is designed after the FMD results and used by the expert participants to complete additional assessments based on the validated attributes. The criteria contextual interrelationships are assessed based on experts' judgment, and the structural self-interaction matrixes (SSIM) is formed by applying Equation (3). Once the SSIM is completed, the crisp values are generated via Equation (4)-(7) to reduce fuzziness and obtain comparable and computable numbers.

3. The experts are asked to confirm the relationships probability among criteria by applying Equation (8), and the expected matrix T is then formed by Equation (9).

4. Form the dependence and driving power by applying Equation (10) after attaining the expected matrix. The dependence power indicated with the vertical axis and driving power with a horizontal axis.

5. Transform the qualitative opinion into binary codes that cover the individual reachability matrixes by applying Equations (11)-(12). This process transformed experts' individual reachability matrixes into an aggregated total expected matrix and used an average method to avoid the extreme value in judging the relationships.

6. The next step is to develop and partition the reachability matrix levels by determining the higher value criteria. The intersection set was derived using Equation (13)-(14). The FISM structural hierarchical model of the attributes is built based on the level partition by generating Equation (15).

4. Results

This section explains the results obtained from the analytical steps.

1. This study proposed 57 criteria from 4 CST perspectives for FDM evaluation. The CST criteria were evaluated based on experts' viewpoints using a fuzzy scale ranging from 1 (no importance) to 5 (very high importance). Then, the linguistic terms were converted into corresponding triangular fuzzy numbers, as shown in Table 2. Subsequently, FDM analysis was adopted by applying Equation (1)-(2) to obtain the experts' consensus on each criterion. The final decision with weights for each criterion is shown in Appendix A, with a threshold of 0.510. Ultimately, 28 criteria are accepted, and 29 are rejected; the accepted criteria that constitute the valid set of CST criteria are renamed and presented in Table 4.
   (Table 4. FDM list – criteria result)

2. Twenty-eight validated criteria as the result of FDM analysis were used to formulate the FISM questionnaires. This study consulted experts to answer questionnaires about the interaction and reachability level among criteria. The experts' judgments were transformed into the equivalent triangular fuzzy numbers shown in Table 3. The fuzzy scale from 1 (no influence) to 5 (very high influence) was used to analyze the interrelationship between criteria. The fuzzy structural self-interaction matrix is generated from Equation (3) and presented in Table 5. Subsequently, Table 6 shows the crisp values generated from Equation (4)-(7) to reduce fuzziness and obtain comparable and computable numbers.
   (**Table 5.** Fuzzy self-interaction assessment)
   (**Table 6.** Corresponding crisp values)

3. The experts' judgments were then aggregated by applying Equation (8)-(9), the total expected matrix was developed as presented in Table 7.
   (**Table 7.** Expected integrated matrix)

4. From Equation (10), the dependence (β) and driving (α) power are computed by summing the rows and columns of the total expected matrix. Figure 1 is drawn by plotting the β values on the y-axis and the α values on the graph's x-axis. Figure 1 shows the dependence and driving power graph that classifies the criteria into four quadrants of different power levels and values in the intersection matrix, thereby structuring the criteria into levels and groups. The results from the graph show that C5, C8, C9, C10, C11, and C17 belong to quadrant 1, or linkage criteria; C7, C12, C14 C19, C20, C21, C22, C24, and C25 are quadrant 2, or dependent criteria; C2, C13, C23, C26, C27, and C28 are grouped as quadrant 3, or autonomous criteria; and C1, C3, C4, C6, C15, C16, and C18 are grouped as quadrant 4, or independent criteria. The criteria are arranged into the 9 levels of the hierarchical framework and are classified into 12 aspects.
   (Figure 1. Causal diagram of the criteria)

5. Similarly, the expected matrix results are used to create the antecedent matrix generated from Equation (11) - (12), as shown in Table 8.
   (**Table 8.** Antecedent matrix)

6. The intersection matrix is then produced from Equation (13)-(14), shown in Table 9. Finally, Figure 2 presents the CST hierarchical framework is drawn by applying Equation (15). There are nine levels included in the FISIM hierarchical model: technology investment (A1), data management (A2), eco-management (A3), and sociospatial embedding challenges (A4); high initial costs (A5); the uncertainty of returns and profit (A6); a lack of leadership (A7); the unavailability of technological expertise (A8); and externality challenges (A9). These nine aspects are derived from the four perspectives.
   (**Table 9.** Intersection)
   (**Figure 2.** The CST hierarchical framework)

5. Implications

This section elaborates on the theoretical implications of the results. The managerial implications are also presented to provide practical guidelines for enhancing CST performance.

5.1. Theoretical Implications

This study extends the literature by providing theoretical contributions to CST theory. The integration of social, economic, environmental, and technological perspectives of CST allows this study to develop a holistic measure for better CST performance. Subsequently, a hierarchical framework that indicates the level of major CST challenges is formed to determine a strategic approach to achieving CST. The 28 criteria are arranged into nine levels and categorized into nine aspects representing areas that are perceived to be major threats to CST. This study finds that technology investment (A1), data management (A2), eco-management (A3), and sociospatial embedding (A4) challenges are the main aspects that affect CST performance.

This study's results show that technology investment challenges are the most influential aspect from an economic perspective, reaching the highest level of the hierarchical framework. From an economic viewpoint, technology investment refers to the purchase of a technological asset or interest, in which capital works to achieve corporate objectives. This aspect involves corporations' efforts to contribute and share capital for adopting and developing technologies that can generate profit and support CST performance. These challenges discourage corporations from adopting and developing technologies, decrease the efficiency of corporate operations, especially in terms of resource use, and increase waste and emission production, which restricts CST (Ghisellini et al., 2018; Huang et al., 2018). Technology investment challenges increase the pollution caused by corporate operations and limit material reuse and recovery, elevating the destructive dismantling process and hindering CST performance. Increasing technology investment to support the research, invention, distribution and development of technologies is necessary to achieve CST goals. Technology investment must be recognized as an activity that brings sufficient financial returns and positive impacts for both people and the environment. The government and corporations need to work together to promote the importance of technology investment to achieve better CST performance.

From an environmental perspective, management challenges are at a high level of the hierarchical framework and are confirmed as a major aspect influencing CST performance. This aspect refers to the poor management of data on previous sustainability practices and statistical data on corporate materials and waste, which negatively influences decision making and inhibits CST performance (Ghisellini et al., 2018). Data management provides insights and understanding regarding corporations' need for sustainability practices and is useful for governments and corporations to formulate plans and strategies to pursue CSTs. Poor data management that failed to account for previous sustainability practices elevates decision-makers' difficulties in adopting and developing sustainability practices. Therefore, enhancing data management capabilities is needed to provide adequate information for stakeholders to support better CST performance. Data management must not be underestimated and must be recognized as an important element that can bolster sustainability practices. Corporations must accurately calculate the material usage and amount of generated waste that they produce and record all of the practices to allow corporations to reflect and construct strategies to actualize better sustainability transitions.

Eco-management challenges, which cover criteria from all the perspectives in this study – social, economic, environmental, and technological – are another major aspect in the CST hierarchical framework. This aspect refers to the threat to various management and operational strategies to reduce unsustainability, especially in terms of environmental effects caused by human activities. Eco-management is essential for corporations and governments to review and maintain their sustainability practices and create policies to achieve better CST performance. A lack of eco-management capabilities reduces the motivation to adopt sustainability practices and discourages the formulation of plans and strategies for CST, limiting the widespread development of sustainability practices (Pham et al., 2019). Hence, improving eco-management is necessary for corporations and the government to motivate and support sustainability practices. To overcome these challenges, corporations need to implement sustainability measures for all operations and support stakeholders' decision-making. Enhancing knowledge and practical skills through various training types is required to deepen the understanding of sustainability and perform eco-management. The government also needs to set sustainability standards to encourage corporations to adopt eco-management and achieve better CST performance.

From a social perspective, sociospatial embedding appears in the CST hierarchical framework and can be considered the main aspect. This aspect deals with the context in which transition occurs. Sociospatial embedding includes the industry's condition and the effect of culture, politics, regulations, and institutions on corporations' ability to adopt sustainability practices (Foong et al., 2017; Martek et al., 2019). This challenge is perceived as the cause of other CST challenges, such as economic, environmental, and technological challenges because settling CST challenges depends on people's cultures and willingness to solve that problem. Therefore, sociospatial embedding challenges need to be solved to reduce the emergence of other challenges and support better CST performance. Raising awareness and knowledge to strengthen the community's and stakeholders' commitment to and involvement in upholding sustainability practices are necessary to overcome sociospatial embedding challenges.

In sum, CST hierarchical framework has been provided in this study. The key aspects consist of technology investment, data management, eco-management, and sociospatial embedding challenges. Thus, these aspects hinder CST performance, and it is necessary to overcome all of these challenges to achieve better CST performance. The investment in technological assets is essential to support the shift toward sustainability and bring sufficient financial returns. Data management provides insights and understanding related to the relevant needs for CST practices and is recognized as critical for governments and corporations to formulate strategies, plans and policies. Better eco-management by the corporations and governments can establish better policies supporting the CST and maintaining sustainability practices. Further, the dependency on people's awareness and willingness to solve the problems constructs sociospatial embedding challenges that act as sources of other CST challenges, such as economic, environmental, and technological challenges.

5.2 Managerial Implications

This study's results showed that criteria such as a lack of awareness and knowledge (C5), a lack of commitment (C8), a lack of strategy (C9), tolerance of unsustainable practices (C10), a lack of stakeholder participation (C11), and a fragmented market (C17) significantly interact with other criteria. Subsequently, these other criteria may be influenced or vice versa. For this reason, these latter criteria are recognized as major attributes that assist construction firms in Indonesia in improving CST performance.

The existence of huge natural resources supporting the Indonesian construction industry caused a lack of awareness and knowledge (C5) in the sustainability transition. This criterion needs to be addressed to overcome the sociospatial embedding challenge and attain better CST performance. This challenge refers to the lack of perception and understanding of sustainability practices. A lack of awareness and knowledge triggers other challenges because perception and understanding are the foundation of people's actions. In this way, awareness is important for corporations to be able to point out current problems hindering CST before formulating the actions to solve those problems. Firms' lack of awareness and knowledge causes lateness in responding to any problems and limits CST. Hence, this challenge hinders transformation and the practical adoption of sustainability and must be solved to achieve better CST performance. A deeper understanding of environmental issues and sustainability benefits and practices is needed within the Indonesian construction industry to overcome this challenge. Corporations need to understand and identify the root cause to completely solve this challenge and move toward better CST performance.

The Indonesian construction industry's nature that only concentrated on financial outcomes triggered a lack of commitment (C8) from the firm's stakeholders. Due to this reason, this criterion is another major challenge that needs to be recognized. This criterion refers to stakeholders' failure to consider sustainability measures to incorporate operational activities. In some cases, this challenge occurs not because there are difficulties in practical and operational activities but merely because sustainability plans and strategies do not exist within corporate agendas. However, the success of CST performance requires commitment from stakeholders. Sustainability practices and transitions are difficult to implement if there is no attention or serious commitment from stakeholders. A lack of commitment may decrease the efficiency and effectiveness of CST and is seen as a major social challenge to CST performance. A lack of commitment must be addressed to achieve CST. Better commitment from corporate stakeholders in the Indonesian construction industry is needed. It can be achieved by improving stakeholders' knowledge and understanding of environmental issues and the importance of sustainability practices. Including a sustainability measure in operational activities is also necessary to enhance stakeholders' commitment to sustainability practices.

To achieve better CST performance, corporations should be able to maintain the transition process. A lack of strategy (C9) is one of the challenges that should be overcome because it causes sociospatial embedding challenges and impacts adopting sustainability. A lack of strategy refers to developing and integrating details of sustainability practices, including the vision for and long-term planning of CST performance. This challenge occurs in the Indonesian construction industry because sustainability plans are hindered by materials, technologies, and professionals' unavailability. A lack of strategy negatively impacts CST performance and causes other problems, such as poor eco-management, a lack of stakeholder participation, poor coordination, and a lack of systematic urban planning. In contrast, a better CST strategy brings a better process, work, and sustainability implementation and optimizes practices applied in the transition process. Therefore, an adequate strategy is required in the construction industry to achieve better CST performance. Corporate vision, mission, and values need to be combined with sustainability measures to generate sustainable implementation and strategies. Corporations need to deepen the understanding of issues to formulate better strategies.

Inadequate policy to regulate the construction industry to shift toward sustainability from the Indonesian government instigated the tolerance for unsustainable practices (C10). This criterion is essential to minimize the eco-management challenge and is considered a central challenge of CST performance. Tolerance of unsustainable practices refers to the condition in which stakeholders and regulators permit unsustainable measures. In some instances, corporations and stakeholders are willing to adopt sustainability practices. Still, they have some obstacles to realizing it, and because the government allows unsustainable practices, corporations are discouraged from pursuing sustainability practices. One of the main reasons this challenge occurs is stakeholders' failure to create standards and regulations to control corporate sustainability operations. Tolerance of unsustainable practices is also caused by corporations' ignorance of environmental issues and sustainability measures. This challenge triggers poor decision-making that limits corporations from achieving sustainability transitions and increases severe environmental problems. Hence, the government and the construction industry need to be committed and cooperate in discontinuing the tolerance of unsustainable practices to support the move toward better CST performance. The government needs to play an essential role in establishing standards and controlling corporations' sustainability practices.

Moreover, the Indonesian construction industry's CST is also inhibited by a lack of stakeholder participation (C11). This criterion a significant to solve the eco-management challenge due to the requirements of actors' full participation and engagement in CST processes. A lack of stakeholder participation refers to the condition when stakeholders are not included or barely included in corporations' implementation of sustainability measures. Stakeholders have a strong influence on decision-making, which affects the adoption and development of sustainability practices. Stakeholders, including corporate management, government and society, need to support each other to achieve sustainability goals. The role of stakeholders as initiators for determining the direction of the CST process is essential. In addition, the CST process needs to interact with stakeholders in problem-solving and critical analysis to achieve CST. High participation from stakeholders in the transition process demonstrates corporations' ability to face and implement sustainability practices. Therefore, the Indonesian construction industry needs to prioritize the role of stakeholder participation to support CST. Understanding stakeholders' important role is required to achieve better CST performance.

The market fragmentation (C17) in Indonesia is recognized as a key challenge that needs to be solved to achieve CST. This criterion is recognized as critical for eco-management challenges and supporting the shift toward sustainability. A fragmented market refers to the marketplace situation in which no corporation can affect the industry's movement in a particular direction. This challenge is caused mainly by diverse energy costs, standards and requirements, competition between corporations in the Indonesian market, and uncertain returns on investment in sustainability practices, forcing corporations to produce unsustainable products. The massive need for residential buildings is also seen as a major obstacle in terms of market fragmentation. Besides, consumers' various socioeconomic statuses in the market are a challenge for the market and for CST. Thus, market fragmentation must be solved to support better CST performance and overcome this challenge. The construction industry needs to innovate more and optimize sustainability practices to produce high-quality, sustainable products that can compete in the marketplace.

(**Figure 2.** Causal diagram of the criteria)

6. Conclusion

CST has been analyzed and recognized as a major issue in recent years. Although various strategies to pursue better CST performance have been implemented, challenges that hinder corporations from adopting and developing CST remain. Hence, this study strives to analyze experts' judgments of these problems to reveal the major challenges in achieving CST. A set of 57 challenges categorized into four perspectives – social, economic, environmental, and technological – is proposed to construct valid theoretical and hierarchical models to provide adequate guidance for practical improvements toward CST performance. This study applied a combined FDM and FISM method. Fuzzy set theory was used to convert experts' judgments into quantitative data. FDM is applied to validate and eliminate the criteria that the experts considered to be less influential in inhibiting CST.

Subsequently, FISM is conducted to arrange various direct and indirect challenges into a hierarchical model and identify CST challenges' influence and direction to provide a realistic view of these challenges.

This study constructed a hierarchical CST framework that included nine aspects and 28 criteria. These nine aspects represent areas that are perceived as the main threats to CST include: technology investment, data management, eco-management, sociospatial embedding challenges, high initial costs, the uncertainty of returns and profit, a lack of leadership, the unavailability of technological expertise and externality challenges. The findings showed that technology investment, data management, eco-management, and sociospatial embedding challenges are at the highest level of the hierarchical framework and are considered major aspects that affect CST performance. Six of 28 criteria were analyzed and recognized as the criteria that show the highest dependence and driving powers, including a lack of awareness and knowledge, a lack of commitment, a lack of strategy, a tolerance of unsustainable practices, a lack of stakeholder participation, and a fragmented market. These attributes were found to be significant in hindering CST in the construction industry, and practitioners need to prioritize solving these challenges to achieve better CST performance.

This study contributes to the CST literature by analyzing a valid hierarchical framework and the resulting major attributes that need to be addressed to improve CST performance. Solving the challenges mentioned in this study will assist practitioners and corporations in achieving CST. Technology investment, data management, eco-management, and sociospatial embedding challenges are at the highest level of the CST hierarchical framework and are, therefore, the most important aspects affecting CST performance. Guidelines for practitioners and corporations based on linkage criteria, including a lack of awareness and knowledge, a lack of commitment, a lack of strategy, tolerance of unsustainable practices, a lack of stakeholder participation, and a fragmented market, are provided to assist the decision-making process and achieve better CST performance.

Nevertheless, limitations exist in this study. The framework's comprehensiveness might be limited because the attributes proposed in this study were obtained from the literature and judged by fourteen experts. Future studies need to deepen and extend the related attributes proposed to improve the CST framework. Due to the specific experience, knowledge, and understanding of the industry, the limited number of expert respondents in this study may trigger bias in formulating the results. Hence, increasing the number of expert respondents in future studies is recommended to prevent this issue. In addition, this study focuses only on Indonesia's construction industry; thus, future studies should consider other countries to broaden the understanding of CST challenges.

Table 1
FDM - perspectives and criteria result

Perspectives	Criteria		Description	References
Social sustainability transition challenges	C1	Lack of vision	Lack of long-term vision and strategy in addressing the issues of sustainability.	Martek et al., (2019)
	C2	Poor regulations	Lack of mature and complete municipal regulation system to guide construction waste	Ghisellini et al., (2018)
	C3	Lack of governmental support	Lack of government support toward sustainability transition	
	C4	Involvement of personal interest	Government actors involvement of personal interest can influence the decision making of the government.	O'Neill et al., (2020)
	C5	Lack of awareness and knowledge	Poor awareness of sustainability concept among construction projects stake holders	
	C6	Lack of leadership	Lack of leadership was used to refer to lack of an entity to bring all valuable attempts and frameworks under one umbrella, and make them converge in terms of purpose and implementation.	Martek et al., (2019)
	C7	Lack of community involvement	Lack of societal driven bottom-up initiatives for construction sustainability transition.	Fastenrath and Braun., (2018)
	C8	Lack of commitment	Sustainability measure is not considered by stakeholders	
	C9	Lack of strategy	Sustainable measure is not available	Pham et al., (2019);
	C10	Tolerance to unsustainable practices	Unsustainable measure was allowed by the regulator or undertaker	Engert and Baumgartner.,(2016);
	C11	Lack of stakeholder participation	Stakeholder was not included, or was included too late, in the development process to implement sustainability measure	Williams and Dair., (2007)
Economic sustainability transition challenges	C12	Lack of waste technology investment	Lack of waste technology investment limiting the development of waste technology itself.	Ghisellini et al., (2018);
	C13	High diversion costs	High costs of separating, treating and recycling C&DW	Huang et al., (2018)

	C14	High prices of recycled products	High prices of recycled product lowering the demand from recycled product buyers.	
	C15	Low prices of natural materials	Low prices of natural materials drive people to stay with it.	
	C16	Lack of incentives	Lack of adequate subsidizing to discourage landfilling (low landfilling discharge fee, higher waste diversion costs than disposal in landfill).	
	C17	Fragmented market	A marketplace where there is no one company that can exert enough influence to move the industry in a particular direction.	Martek et al., (2019)
	C18	Uncertain return and profit	Uncertain return and profit are course by the market uncertainty.	Jesus and Menconca., (2018)
Environmental sustainability transition challenges	C19	Lack of environmental assessment	Lack of compulsory of the adoption of an environmental impact assessment for all construction projects.	
	C20	Poor urban planning	Lack of rational urban planning (short lifespans of buildings).	Ghisellini et al., (2018);
	C21	Poor waste management facilities	Developers must arrange waste management facilities, which must be designed, constructed and put into place along with the main project.	Pina and Burgos., (2017); Schmid et al., (2020)
	C22	Lack of data	Lack of data related to construction waste generation for policy decision making.	Huang et al., (2018);
	C23	Lack of stable supply of construction waste materials	Lack of stable supply of construction waste materials for manufacturing recycling products.	Chang et al., (2016)
Technological sustainability transition challenges	C24	Insufficient of reuse, reduce, and recycle application	Insufficient application of the reuse, reduce, and recycle approach in construction projects.	
	C25	Lack of local institutes and facilities for green buiding technology and research	Local institutes and facilities for green buiding technology and research is needed to support the development of technologies adoption.	Darko et al., (2018); Huang et al., (2018)
	C26	Lack of professional knowledge and	Professional knowledge and expertise in technologies are	

	expertise in technologies	needed to maximize technological adoption.
C27	Risks and uncertainties involved in adopting new technologies	Risks and uncertainties of the technological adoption discourage is a barrier of technologial adoption itself.
C28	Higher cost of technologies	Higher cost of technology discourage construction firms for technological adoption.

Table 2. FDM-Contrasting TFN for linguistic preferences

Linguistic terms	Meanings	Corresponding TFN
NI	No influence/importance	(0.0, 0.1, 0.3)
VL	Very low influence/importance	(0.1, 0.3, 0.5)
E	Equal influence/importance	(0.3, 0.5, 0.7)
HI	High influence/importance	(0.5, 0.7, 0.9)
VH	Very high influence/importance	(0.7, 0.9, 1.0)

Table 3.
FISM-Contrasting TFN for linguistic preferences

Linguistic terms	Meanings	Corresponding TFN
NI	No influence/importance	(0.0, 0.1, 0.3)
VL	Very low influence/importance	(0.1, 0.3, 0.5)
E	Equal influence/importance	(0.3, 0.5, 0.7)
HI	High influence/importance	(0.5, 0.7, 0.9)
VH	Very high influence/importance	(0.7, 0.9, 1.0)

Table 4.
FDM list – challenges' result

Criteria	Challenges	Weight (D_b)
C1	Lack of vision	0.637
C2	Poor regulations	0.789
C3	Lack of governmental support	0.630
C4	Involvement of personal interest	0.658
C5	Lack of awareness and knowledge	0.642
C6	Lack of leadership	0.675
C7	Lack of community involvement	0.671
C8	Lack of commitment	0.627
C9	Lack of strategy	0.639
C10	Tolerance to unsustainable practices	0.618
C11	Lack of stakeholder participation	0.683
C12	Lack of waste technology investment	0.683
C13	High diversion costs	0.665
C14	High prices of recycled products	0.658
C15	Low prices of natural materials	0.691
C16	Lack of incentives	0.627
C17	Fragmented market	0.691
C18	Uncertain return and profit	0.658
C19	Lack of environmental assessment	0.665
C20	Poor urban planning	0.707
C21	Poor waste management facilities	0.694
C22	Lack of data	0.639
C23	Lack of stable supply of construction waste materials	0.710
C24	Insufficient of reuse, reduce, and recycle application	0.655

C25	Lack of local institutes and facilities for green buiding technology and research	0.651
C26	Lack of professional knowledge and expertise in technologies	0.683
C27	Risks and uncertainties involved in adopting new technologies	0.702
C28	Higher cost of technologies	0.642
	Threshold (∂)	0.510

Table 5. Fuzzy self-interaction assessment

	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			...	C27			C28		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	...	a	b	c	a	b	c
C1	0.3	0.5	0.7	0.1	0.3	0.5	0.7	0.9	1.0	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.0	0.1	0.3	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	...	0.5	0.7	0.9	0.1	0.3	0.5
C2	0.7	0.9	1.0	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	0.5	0.7	0.9	0.7	0.9	1.0	0.1	0.3	0.5	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	...	0.3	0.5	0.7	0.3	0.5	0.7
C3	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.5	0.7	0.9	0.5	0.7	0.9	0.0	0.1	0.3	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	...	0.0	0.1	0.3	0.1	0.3	0.5
C4	0.7	0.9	1.0	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	0.0	0.1	0.3	0.5	0.7	0.9	0.7	0.9	1.0	0.7	0.9	1.0	...	0.0	0.1	0.3	0.0	0.1	0.3
C5	0.5	0.7	0.9	0.7	0.9	1.0	0.5	0.7	0.9	0.7	0.9	1.0	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	...	0.3	0.5	0.7	0.3	0.5	0.7
C6	0.7	0.9	1.0	0.3	0.5	0.7	0.0	0.1	0.3	0.7	0.9	1.0	0.7	0.9	1.0	0.3	0.5	0.7	0.1	0.3	0.5	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	...	0.3	0.5	0.7	0.5	0.7	0.9
C7	0.7	0.9	1.0	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	0.7	0.9	1.0	...	0.3	0.5	0.7	0.3	0.5	0.7
C8	0.5	0.7	0.9	0.3	0.5	0.7	0.7	0.9	1.0	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.5	0.7	0.9	...	0.5	0.7	0.9	0.5	0.7	0.9
C9	0.5	0.7	0.9	0.7	0.9	1.0	0.1	0.3	0.5	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	...	0.7	0.9	1.0	0.5	0.7	0.9
C10	0.7	0.9	1.0	0.5	0.7	0.9	0.7	0.9	1.0	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.7	0.9	1.0	0.3	0.5	0.7	...	0.5	0.7	0.9	0.3	0.5	0.7
C11	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.7	0.9	1.0	0.5	0.7	0.9	0.0	0.1	0.3	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	...	0.5	0.7	0.9	0.3	0.5	0.7
C12	0.5	0.7	0.9	0.1	0.3	0.5	0.5	0.7	0.9	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	0.3	0.5	0.7	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	...	0.5	0.7	0.9	0.3	0.5	0.7
C13	0.5	0.7	0.9	0.0	0.1	0.3	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.1	0.3	0.5	0.1	0.3	0.5	0.7	0.9	1.0	0.5	0.7	0.9	...	0.1	0.3	0.5	0.3	0.5	0.7
C14	0.5	0.7	0.9	0.1	0.3	0.5	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	0.7	0.9	1.0	0.1	0.3	0.5	0.3	0.5	0.7	0.7	0.9	1.0	0.7	0.9	1.0	...	0.1	0.3	0.5	0.7	0.9	1.0
C15	0.5	0.7	0.9	0.0	0.1	0.3	0.7	0.9	1.0	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	0.0	0.1	0.3	0.3	0.5	0.7	0.7	0.9	1.0	...	0.0	0.1	0.3	0.0	0.1	0.3
C16	0.3	0.5	0.7	0.1	0.3	0.5	0.5	0.7	0.9	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.1	0.3	0.5	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	...	0.1	0.3	0.5	0.0	0.1	0.3
C17	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	0.7	0.9	1.0	0.5	0.7	0.9	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	0.5	0.7	0.9	...	0.0	0.1	0.3	0.0	0.1	0.3
C18	0.7	0.9	1.0	0.1	0.3	0.5	0.0	0.1	0.3	0.7	0.9	1.0	0.7	0.9	1.0	0.3	0.5	0.7	0.1	0.3	0.5	0.0	0.1	0.3	0.7	0.9	1.0	0.7	0.9	1.0	...	0.5	0.7	0.9	0.3	0.5	0.7
C19	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	0.0	0.1	0.3	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	...	0.3	0.5	0.7	0.1	0.3	0.5
C20	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.1	0.3	0.5	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	...	0.5	0.7	0.9	0.1	0.3	0.5
C21	0.5	0.7	0.9	0.7	0.9	1.0	0.7	0.9	1.0	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	0.0	0.1	0.3	0.7	0.9	1.0	0.5	0.7	0.9	0.5	0.7	0.9	...	0.7	0.9	1.0	0.7	0.9	1.0
C22	0.7	0.9	1.0	0.3	0.5	0.7	0.1	0.3	0.5	0.3	0.5	0.7	0.7	0.9	1.0	0.5	0.7	0.9	0.1	0.3	0.5	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	...	0.0	0.1	0.3	0.3	0.5	0.7
C23	0.3	0.5	0.7	0.0	0.1	0.3	0.1	0.3	0.5	0.3	0.5	0.7	0.7	0.9	1.0	0.5	0.7	0.9	0.1	0.3	0.5	0.3	0.5	0.7	0.5	0.7	0.9	0.5	0.7	0.9	...	0.0	0.1	0.3	0.3	0.5	0.7
C24	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	0.0	0.1	0.3	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	...	0.3	0.5	0.7	0.7	0.9	1.0
C25	0.5	0.7	0.9	0.3	0.5	0.7	0.7	0.9	1.0	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	...	0.7	0.9	1.0	0.7	0.9	1.0
C26	0.5	0.7	0.9	0.0	0.1	0.3	0.7	0.9	1.0	0.3	0.5	0.7	0.5	0.7	0.9	0.7	0.9	1.0	0.1	0.3	0.5	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	...	0.7	0.9	1.0	0.0	0.1	0.3
C27	0.3	0.5	0.7	0.0	0.1	0.3	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9	0.7	0.9	1.0	0.3	0.5	0.7	...	0.3	0.5	0.7	0.0	0.1	0.3
C28	0.3	0.5	0.7	0.0	0.1	0.3	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.1	0.3	0.5	0.1	0.3	0.5	0.3	0.5	0.7	0.3	0.5	0.7	...	0.3	0.5	0.7	0.3	0.5	0.7

Table 6. Corresponding crisp values

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28
C1	0.000	0.185	0.765	0.286	0.000	0.000	0.000	0.378	0.533	0.000	0.533	0.378	0.378	0.185	0.222	0.576	0.576	0.765	0.000	0.000	0.378	0.576	0.378	0.000	0.378	0.765	0.576	0.185
C2	0.533	0.378	0.765	0.000	0.286	0.533	0.260	0.378	0.286	0.000	0.000	0.000	0.378	0.185	0.222	0.185	0.000	0.185	0.000	0.378	0.000	0.576	0.185	0.378	0.378	0.185	0.378	0.378
C3	0.286	0.378	0.378	0.000	0.286	0.286	0.000	0.576	0.000	0.286	0.286	0.378	0.185	0.185	0.222	0.000	0.185	0.378	0.378	0.378	0.000	0.000	0.000	0.378	0.185	0.378	0.000	0.185
C4	0.533	0.378	0.576	0.000	0.533	0.000	0.000	0.576	0.533	0.533	0.286	0.000	0.378	0.185	0.222	0.000	0.378	0.185	0.765	0.378	0.000	0.000	0.185	0.000	0.378	0.185	0.000	0.000
C5	0.286	0.765	0.576	0.533	0.000	0.533	0.538	0.576	0.000	0.000	0.286	0.185	0.000	0.185	0.639	0.378	0.576	0.576	0.185	0.378	0.000	0.378	0.576	0.000	0.576	0.378	0.378	0.378
C6	0.533	0.378	0.000	0.533	0.533	0.000	0.260	0.576	0.286	0.286	0.286	0.000	0.185	0.185	0.639	0.576	0.185	0.576	0.378	0.185	0.378	0.000	0.378	0.576	0.765	0.765	0.378	0.576
C7	0.533	0.378	0.378	0.000	0.533	0.286	0.538	0.576	0.000	0.533	0.000	0.378	0.378	0.185	0.444	0.576	0.576	0.576	0.000	0.185	0.765	0.185	0.000	0.378	0.000	0.378	0.378	0.378
C8	0.286	0.378	0.765	0.286	0.000	0.000	0.538	0.378	0.000	0.286	0.533	0.000	0.765	0.185	0.222	0.765	0.765	0.765	0.185	0.378	0.185	0.576	0.378	0.576	0.378	0.378	0.576	0.576
C9	0.286	0.765	0.185	0.286	0.000	0.286	0.538	0.378	0.000	0.000	0.533	0.378	0.000	0.185	0.639	0.765	0.765	0.576	0.576	0.000	0.378	0.765	0.378	0.378	0.765	0.765	0.765	0.576
C10	0.533	0.576	0.765	0.286	0.000	0.286	0.538	0.576	0.533	0.000	0.000	0.576	0.765	0.185	0.444	0.765	0.765	0.378	0.378	0.576	0.576	0.378	0.576	0.378	0.765	0.378	0.576	0.378
C11	0.286	0.576	0.576	0.286	0.533	0.286	0.000	0.576	0.000	0.286	0.000	0.000	0.378	0.378	0.222	0.765	0.378	0.576	0.378	0.765	0.765	0.765	0.185	0.765	0.576	0.000	0.576	0.378
C12	0.286	0.185	0.576	0.000	0.533	0.000	0.538	0.576	0.286	0.000	0.533	0.378	0.576	0.185	0.000	0.576	0.576	0.576	0.000	0.378	0.000	0.378	0.000	0.378	0.765	0.765	0.576	0.378
C13	0.286	0.000	0.576	0.286	0.286	0.286	0.260	0.185	0.533	0.286	0.533	0.765	0.378	0.000	0.000	0.378	0.000	0.378	0.378	0.378	0.576	0.000	0.185	0.378	0.000	0.185	0.185	0.378
C14	0.286	0.185	0.378	0.000	0.533	0.533	0.260	0.378	0.533	0.533	0.000	0.765	0.378	0.378	0.000	0.765	0.765	0.185	0.765	0.378	0.000	0.000	0.185	0.378	0.378	0.378	0.185	0.765
C15	0.286	0.000	0.765	0.286	0.000	0.286	0.538	0.000	0.000	0.533	0.286	0.185	0.378	0.576	0.222	0.000	0.765	0.000	0.000	0.378	0.378	0.185	0.185	0.185	0.185	0.378	0.000	0.000
C16	0.000	0.185	0.576	0.533	0.286	0.286	0.260	0.576	0.286	0.286	0.000	0.185	0.185	0.185	0.222	0.378	0.378	0.000	0.185	0.378	0.378	0.185	0.185	0.000	0.378	0.000	0.185	0.000
C17	0.286	0.378	0.378	0.533	0.533	0.286	0.538	0.765	0.000	0.286	0.533	0.378	0.576	0.765	0.000	0.576	0.378	0.765	0.576	0.378	0.378	0.185	0.765	0.378	0.000	0.765	0.000	0.000
C18	0.533	0.185	0.000	0.533	0.533	0.000	0.260	0.000	0.533	0.533	0.000	0.000	0.378	0.378	0.000	0.765	0.576	0.378	0.576	0.576	0.000	0.378	0.378	0.378	0.378	0.576	0.576	0.378
C19	0.000	0.765	0.378	0.000	0.000	0.533	0.000	0.378	0.000	0.533	0.286	0.378	0.000	0.185	0.639	0.576	0.378	0.378	0.378	0.765	0.378	0.576	0.185	0.765	0.000	0.576	0.378	0.185
C20	0.533	0.576	0.576	0.286	0.286	0.286	0.260	0.765	0.286	0.286	0.000	0.378	0.000	0.378	0.639	0.576	0.576	0.765	0.378	0.378	0.576	0.765	0.000	0.378	0.378	0.765	0.576	0.185
C21	0.286	0.765	0.765	0.000	0.000	0.533	0.000	0.765	0.286	0.286	0.000	0.576	0.576	0.185	0.222	0.576	0.185	0.765	0.378	0.765	0.378	0.576	0.185	0.378	0.765	0.000	0.765	0.765
C22	0.533	0.378	0.185	0.000	0.533	0.286	0.260	0.576	0.000	0.000	0.533	0.576	0.378	0.000	0.222	0.576	0.576	0.576	0.378	0.576	0.378	0.378	0.765	0.765	0.378	0.576	0.000	0.378
C23	0.000	0.000	0.185	0.000	0.533	0.286	0.260	0.378	0.286	0.286	0.533	0.185	0.378	0.185	0.000	0.765	0.378	0.576	0.576	0.185	0.378	0.378	0.378	0.378	0.185	0.000	0.000	0.378
C24	0.000	0.378	0.378	0.000	0.533	0.000	0.000	0.378	0.533	0.000	0.533	0.378	0.765	0.765	0.222	0.378	0.000	0.576	0.185	0.000	0.765	0.576	0.378	0.378	0.378	0.378	0.378	0.765
C25	0.286	0.378	0.765	0.000	0.286	0.000	0.538	0.576	0.286	0.000	0.533	0.000	0.378	0.378	0.639	0.378	0.378	0.378	0.000	0.185	0.378	0.378	0.000	0.185	0.378	0.765	0.765	0.765
C26	0.286	0.000	0.765	0.000	0.286	0.533	0.260	0.576	0.286	0.000	0.286	0.378	0.185	0.378	0.639	0.765	0.185	0.378	0.378	0.378	0.185	0.765	0.185	0.185	0.765	0.378	0.765	0.000
C27	0.000	0.000	0.576	0.286	0.286	0.286	0.538	0.576	0.533	0.000	0.533	0.000	0.576	0.185	0.222	0.576	0.185	0.378	0.378	0.185	0.000	0.765	0.000	0.000	0.576	0.378	0.378	0.000
C28	0.000	0.000	0.576	0.286	0.286	0.000	0.260	0.185	0.000	0.000	0.533	0.576	0.576	0.378	0.222	0.378	0.576	0.185	0.185	0.185	0.378	0.378	0.185	0.185	0.185	0.000	0.378	0.378

Table 7. Expected integrated matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	Dependence β
C1	7.033	4.568	6.268	6.970	7.211	6.992	3.277	6.319	7.004	6.956	7.176	4.158	4.659	3.641	5.925	6.192	5.829	5.308	4.759	4.174	4.105	5.429	4.534	4.465	4.927	5.296	5.018	4.401	5.450
C2	5.593	3.825	5.118	5.489	5.707	5.557	2.581	4.970	5.483	5.394	5.648	3.329	3.567	2.839	4.996	4.626	4.567	4.244	3.517	3.202	3.369	4.273	3.384	3.697	3.909	3.959	3.856	3.555	4.295
C3	5.044	3.516	4.609	4.977	5.134	5.041	2.350	4.382	4.967	4.895	5.137	2.883	3.415	2.646	4.450	4.201	4.314	3.936	3.257	2.888	3.008	3.769	3.114	3.370	3.629	3.548	3.685	3.420	3.914
C4	5.938	4.321	5.549	5.794	6.071	5.905	2.751	5.339	5.798	5.794	6.037	3.753	3.880	3.185	5.284	5.025	4.808	4.553	4.037	3.633	3.660	4.522	3.725	3.998	4.088	4.417	4.299	3.879	4.644
C5	8.051	5.086	7.220	7.918	8.072	7.925	3.765	7.066	7.959	7.805	8.214	4.676	5.250	4.045	6.488	6.825	6.593	6.005	5.114	4.524	4.552	5.952	4.936	4.785	5.468	5.824	5.651	5.111	6.103
C6	7.315	4.685	6.663	7.233	7.441	7.239	3.466	6.421	7.276	7.088	7.474	4.277	4.855	3.708	6.028	6.483	6.081	5.701	4.583	4.008	4.410	5.761	4.459	4.567	5.264	5.458	5.532	4.936	5.658
C7	7.729	5.309	7.044	7.531	7.880	7.595	3.726	6.820	7.567	7.560	7.801	4.721	5.181	4.169	6.545	6.707	6.382	6.157	4.997	4.507	4.893	5.808	4.779	5.250	5.373	5.404	5.574	5.156	6.006
C8	8.637	5.448	7.747	8.496	8.817	8.579	4.045	7.530	8.542	8.409	8.827	5.252	5.749	4.422	7.037	7.556	6.993	6.634	5.742	4.885	5.378	6.490	5.338	5.407	5.928	6.160	6.050	5.701	6.636
C9	8.455	5.477	7.629	8.333	8.622	8.404	3.991	7.498	8.290	8.250	8.639	5.320	5.540	4.368	6.979	7.405	6.945	6.514	5.641	4.927	5.249	6.451	5.259	5.395	5.741	6.339	5.965	5.462	6.539
C10	9.637	6.201	8.764	9.490	9.852	9.556	4.455	8.586	9.503	9.300	9.863	6.220	6.530	4.914	7.730	8.464	7.659	7.479	6.556	5.850	6.262	7.473	5.779	6.209	6.781	7.098	6.950	6.220	7.478
C11	8.972	5.946	8.090	8.841	9.173	8.912	4.150	7.870	8.823	8.780	9.126	5.837	6.042	4.550	7.360	7.933	7.207	7.061	6.228	5.518	6.006	6.957	5.449	5.884	6.322	6.718	6.644	6.032	7.015
C12	8.071	4.965	7.256	7.917	8.187	7.966	3.767	7.268	8.043	7.850	8.166	5.006	5.448	4.052	6.492	7.398	6.633	6.401	5.453	4.783	5.168	6.391	4.947	5.176	5.886	6.355	6.061	5.261	6.299
C13	6.521	4.356	5.911	6.518	6.645	6.452	2.926	5.729	6.412	6.365	6.606	4.554	4.333	3.128	5.158	5.745	5.093	5.164	4.455	4.009	4.250	4.909	3.740	4.488	4.658	4.648	4.978	4.559	5.082
C14	7.459	4.653	6.856	7.306	7.493	7.341	3.369	6.383	7.265	7.265	7.512	5.308	5.228	3.903	5.863	6.506	5.987	5.673	4.946	4.438	4.675	5.401	4.301	4.947	5.005	5.413	5.408	5.122	5.751
C15	5.891	3.771	5.409	5.727	5.992	5.836	2.762	4.946	5.753	5.743	5.894	3.916	4.077	3.376	4.764	4.959	4.832	4.403	4.169	3.448	3.646	4.042	3.509	3.845	3.864	4.067	3.947	3.991	4.521
C16	5.626	3.734	5.245	5.571	5.687	5.514	2.582	5.068	5.510	5.513	5.726	3.347	3.807	3.004	4.770	4.789	4.867	4.272	3.731	3.249	3.328	4.042	3.534	3.543	3.846	3.968	3.944	3.622	4.337
C17	8.072	5.194	7.238	7.870	8.153	7.947	3.599	7.111	7.866	7.786	8.089	5.168	5.335	4.084	6.344	7.334	6.593	6.249	5.706	5.037	5.008	6.016	4.970	5.249	5.395	5.921	5.891	5.138	6.227
C18	7.175	4.762	6.180	7.012	7.286	7.105	3.331	6.639	7.046	7.011	7.213	4.406	4.449	3.476	5.762	6.770	5.988	5.710	5.284	4.582	4.599	5.640	4.704	4.613	4.956	5.696	5.321	4.386	5.611
C19	8.629	5.953	7.957	8.540	8.824	8.579	3.931	7.902	8.525	8.431	8.760	5.295	5.715	4.331	7.327	7.593	6.717	6.658	5.604	5.326	5.471	7.144	5.060	5.834	6.476	6.580	6.710	5.413	6.760
C20	8.401	5.809	7.667	8.290	8.597	8.335	3.893	7.722	8.267	8.225	8.567	5.076	5.354	4.139	7.175	7.529	6.609	6.551	5.792	5.222	5.506	6.815	5.067	5.513	6.134	6.456	6.384	5.336	6.587
C21	8.597	5.856	7.898	8.558	8.787	8.563	3.951	7.721	8.493	8.385	8.825	5.646	5.729	4.088	7.086	7.648	6.767	6.859	5.731	5.358	5.800	7.096	4.995	5.820	6.341	6.526	6.647	5.787	6.770
C22	8.152	5.565	7.194	7.965	8.355	8.070	3.759	7.496	7.979	7.929	8.249	5.216	5.326	4.175	6.768	7.581	6.782	6.780	5.773	5.320	5.494	6.524	5.236	5.692	5.901	6.350	6.210	5.231	6.467
C23	6.298	4.351	5.421	6.159	6.376	6.226	2.843	5.675	6.108	6.063	6.366	3.895	3.947	3.167	5.067	5.820	5.396	5.209	4.576	3.935	3.947	4.627	4.214	4.155	4.205	4.711	4.615	4.161	4.912
C24	8.700	5.274	7.815	8.542	8.842	8.600	4.041	7.384	8.581	8.450	8.803	5.725	6.148	4.540	6.805	7.721	6.915	6.712	5.622	5.069	5.463	6.763	4.980	5.868	6.326	6.272	6.508	6.109	6.735
C25	7.591	4.797	6.937	7.463	7.692	7.483	3.622	6.638	7.506	7.449	7.766	4.568	5.145	3.877	6.221	6.555	6.210	5.809	4.875	4.442	4.622	5.833	4.478	4.798	5.368	5.560	5.601	5.033	5.855
C26	6.908	4.491	6.314	6.872	7.032	6.859	3.286	6.262	6.896	6.763	7.027	3.976	4.486	3.482	6.101	6.084	5.669	5.239	4.347	3.749	4.189	5.321	4.168	4.526	5.097	5.104	5.106	4.594	5.355
C27	6.831	4.444	6.252	6.828	6.983	6.794	3.255	6.278	6.861	6.702	6.979	4.126	4.467	3.243	5.854	6.218	5.493	5.301	4.520	3.812	4.453	5.354	4.128	4.578	5.036	5.123	5.002	4.629	5.341
C28	5.780	3.634	5.237	5.691	5.863	5.701	2.638	4.930	5.704	5.638	5.876	3.981	4.138	2.863	4.406	4.915	4.721	4.529	3.949	3.570	3.615	4.270	3.467	3.740	3.963	4.114	4.100	3.886	4.461
Driving α	7.397	4.857	6.696	7.282	7.528	7.324	3.433	6.570	7.287	7.207	7.513	4.630	4.922	3.765	6.100	6.521	6.023	5.754	4.963	4.409	4.647	5.681	4.509	4.836	5.210	5.467	5.416	4.862	

Table 8. Antecedent matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28
C1	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C2	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C3	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
C4	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C5	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C6	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	0	0	0	0	0
C7	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
C8	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C9	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C10	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
C11	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
C12	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	0	0	1	0	0
C13	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
C14	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C15	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C16	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C17	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
C18	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	0	0	1	0	0
C19	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0
C20	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0
C21	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0
C22	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	0	0	0	0	0
C23	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
C24	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0
C25	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C26	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
C27	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0
C28	1	0	1	1	1	1	0	1	1	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0

Table 9. Intersection matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	Frequencies	Levels
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C5	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	12	6
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	3
C7	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	13	7
C8	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	12	6
C9	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	12	6
C10	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	13	7
C11	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	13	7
C12	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	0	0	1	0	0	15	9
C13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C14	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C17	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	13	7
C18	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	3	4
C19	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	12	6
C20	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	13	7
C21	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	13	7
C22	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	0	0	0	0	0	14	8
C23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C24	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	13	7
C25	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	12	6
C26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
C27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

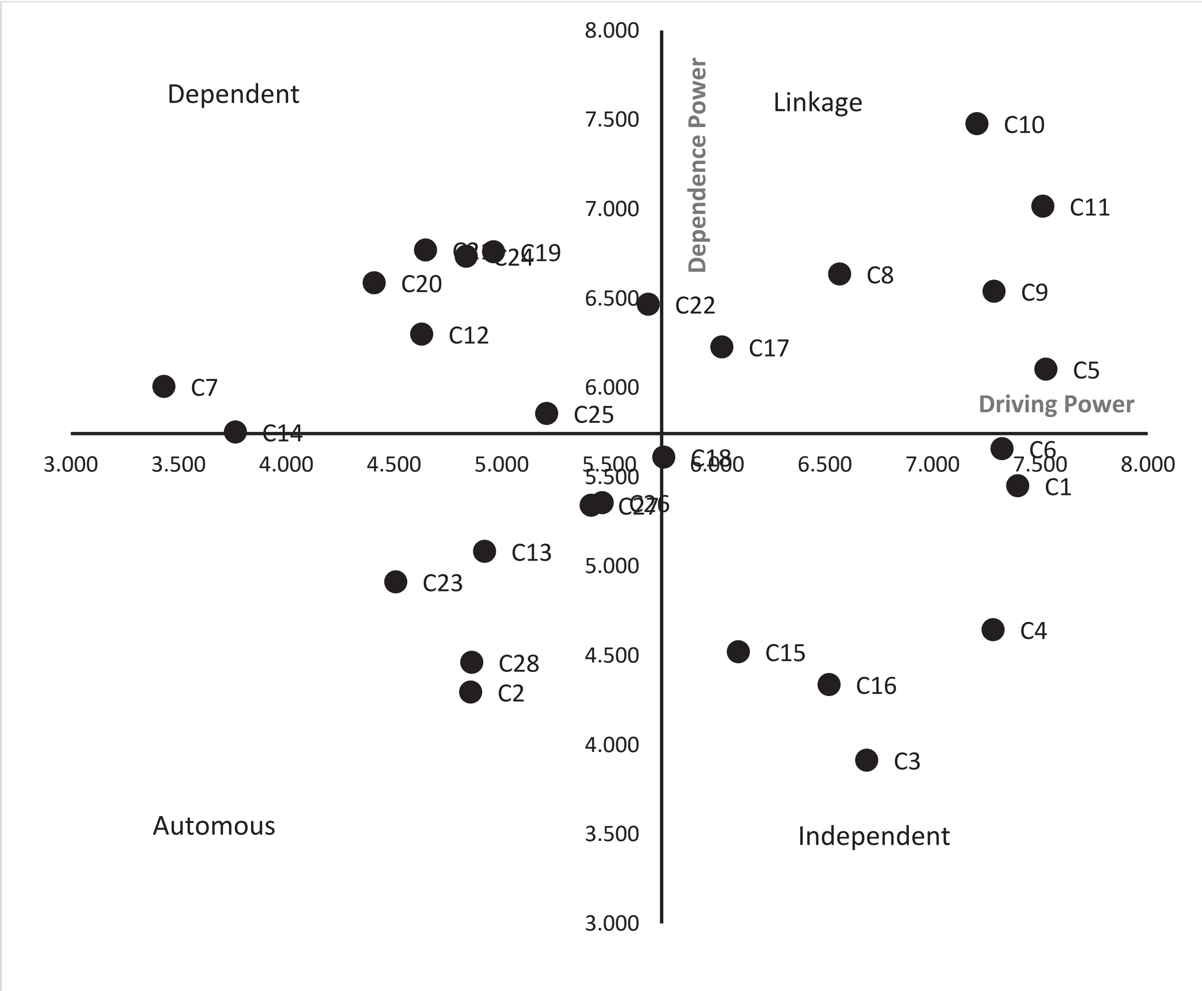

Figure 1.
Causal diagram of the criteria

Levels		CST hierarchical framework
1	Technology investment challenge	Lack of waste technology investment
2	Data management challenge	Lack of Data
3	Eco management challenges	Lack of community involvement Tolerance to unsustainable practices Lack of stakeholder participation Fragmented market Poor urban planning Poor waste management facilities Insufficient of reuse, reduce, and recycle application
4	Socio spatial embedding challenges	Lack of awareness and knowledge Lack of commitment Lack of strategy Lack of environmental assessment Lack of local institutes and facilities for green building technology and research

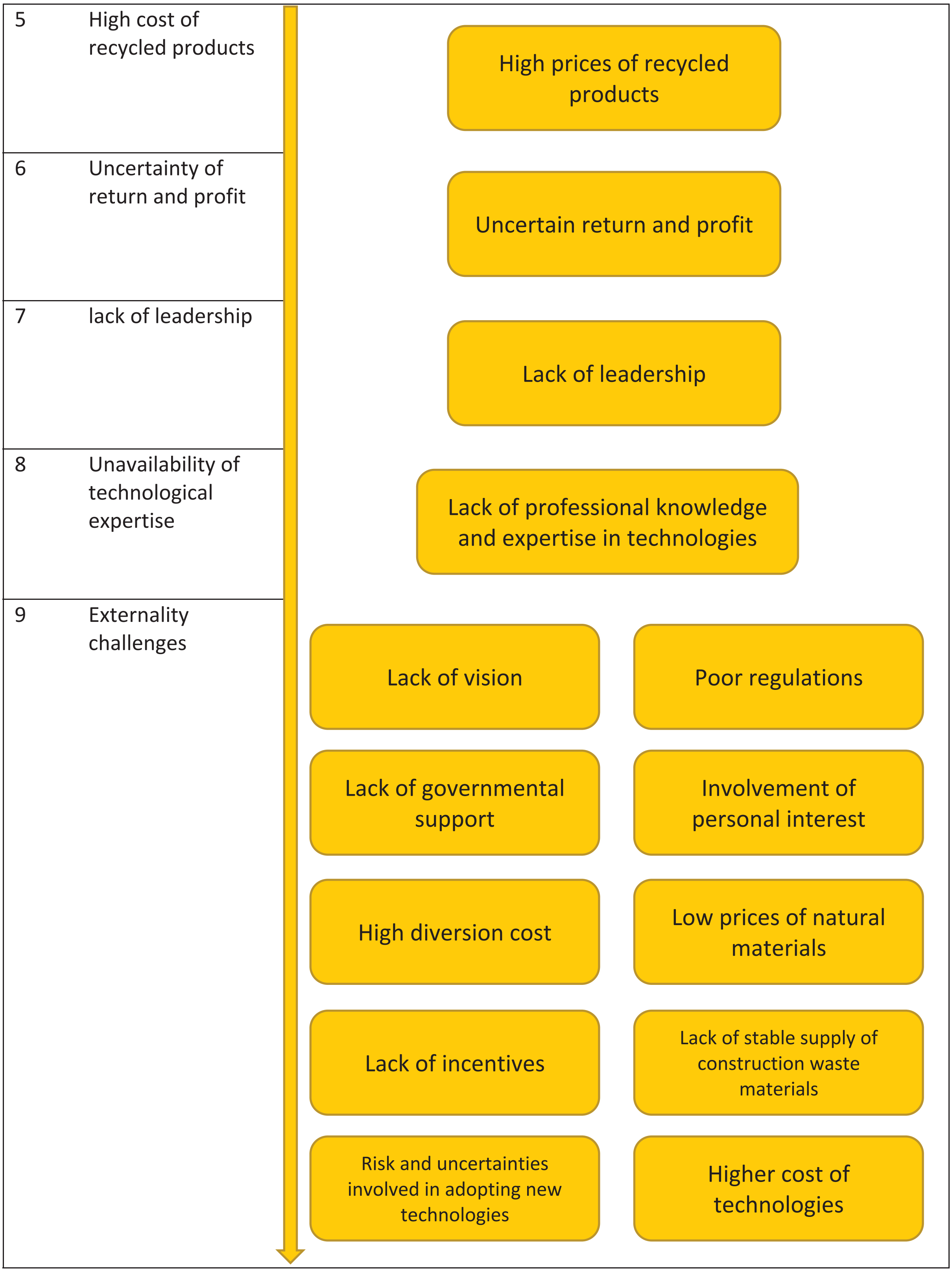

Figure 2.
The CST hierarchical framework

Appendix A.
The initial set of proposed challenges

Perspective	Criteria	Descriptions	References

Social sustainability transition challenges	O1	Lack of vision	Lack of long-term vision and strategy in addressing the issues of sustainability.	Martek et al., (2019)
	O2	Lack of audit	A failure to gather sufficient, competent evidence, lack of due care and lack of professional skepticism.	
	O3	Poor regulations	Lack of mature and complete municipal regulation system to guide construction waste	Ghisellini et al., (2019)
	O4	Lack of governmental support	Lack of government support toward sustainability transition	
	O5	Lack of standardization	Lack of policies that require designers or contractors to use a sustainable materials and methods in projects	
	O6	Poor coordination	Lack of effective coordination and efficient arrangement of activities by municipal governmental departments	
	O7	Government project plans approval	Government must not approve project plans which are not in accordance with the compulsory energy standards.	Chang et al., (2016)
	O8	Lack of safety measure	Government need to examine whether safety measures are planned by builders for the construction.	
	O9	Poor impact assessment	Developers need to prepare an environmental impact assessment document for the proposed project.	
	O10	Poor evaluation	If the project has the potential to produce huge negative impacts on the environment and the public, the developers must arrange hearings or other forms of meetings to acquire expert and public opinions about the proposed project.	
	O11	uneffective construction waste removal	Builders must effectively remove the construction waste they generate.	
	O12	safety accountability system	Safety accountability systems and safety education systems should be established, and safety management personnel should regularly conduct	

		safety checks and make safety inspection records.	
O13	safety education system		
O14	safety management personnel		
O15	Involvement of personal interest	Government actors involvement of personal interest can influence the decision making of the government.	O'Neill and Gibbs., (2020)
O16	Lack of awareness and knowledge	Poor awareness of sustainability concept among construction projects stake holders	Martek et al., 2019
O17	User behaviour	User behavior refers to the way users interact with a particular product.	
O18	Complacency	Complacency means a feeling of contentment or self-satisfaction, often combined with a lack of awareness of pending trouble or controversy.	
O19	Sustainability silos	Sustainability silos was the terms used by participants for describing the disjointed nature of attention to the various sustainability dimensions.	
O20	Lack of leadership	Lack of leadership was used to refer to lack of an entity to bring all valuable attempts and frameworks under one umbrella, and make them converge in terms of purpose and implementation.	
O21	Vested interest	A personal reason for involvement in an undertaking or situation, especially an expectation of financial or other gain.	
O22	Lack of community involvement	Lack of societal driven bottom-up initiatives for construction sustainability transition.	Fastenrath and Braun., (2018)
O23	Communication breakdown between	Communication breakdown is defined as a failure to exchange information,	Kasai and Jabbour., (2014)

		members of institution	resulting in a lack of communication.	
	O24	Lack of commitment	Sustainability measure was not considered by stakeholders	Williams and Dair., (2007);
	O25	Unbalanced sustainability practices	One sustainability measure was for gone in order to achieve another (traded)	Engert and Baumgartner.,(2016);
	O26	Lack of implementation	Sustainable measure was restricted, or not allowed, by regulators	Pham et al., (2019)
	O27	Lack of strategy	Sustainable measure was not available	
	O28	Tolerance to unsustainable practices	Unsustainable measure was allowed by the regulator or statutory undertaker (so no impetus for a sustainable alternative to be used)	
	O29	Lack of stakeholder participation	Stakeholder was not included, or was included too late, in the development process to implement sustainability measure	
Economic sustainability transition challenges	O30	Lack of waste technology investment	Lack of waste technology investment limiting the development of waste technology itself.	Ghisellini et al., (2018)
	O31	High diversion costs	High costs of separating, treating and recycling C&DW	
	O32	High prices of recycled products	High prices of recycled product lowering the demand from recycled product buyers.	
	O33	Low prices of natural materials	Low prices of natural materials drive people to stay with it.	
	O34	Lack of incentives	Lack of adequate subsidizing to discourage landfilling (low landfilling discharge fee, higher waste diversion costs than disposal in landfill).	
	O35	Ineffective green marketing	Green marketing refers to the process of promoting products or services based on their environmental benefits. Such a product or service may be environmentally friendly in itself or produced in an environmentally friendly way.	Martek et al., (2019)
	O36	Fragmented market	A marketplace where there is no one company that can exert enough influence to	

			move the industry in a particular direction.	
	O37	Uncertain return and profit	Uncertain return and profit are course by the market uncertainty.	Jesus and Mendonca., (2018)
	O38	High startup capital investment	The high startup investment for constructing a green building has been viewed, in a way, as a hindrance for installing sustainable constructions.	Kasai and Jabbour., (2014)
Environmental sustainability transition challenge	O39	Free waste dumping	Lack of application of existing regulations against illegal dumping.	Ghisellini et al., (2018)
	O40	Lack of environmental assessment	Lack of compulsory of the adoption of an environmental impact assessment for all construction projects.	Pina and Burgos., (2017)
	O41	Lack of systematic planning	Lack of systematic planning of waste recycling facilities.	
	O42	Lack of recovery targets	Lack of waste recovery targets in urban construction waste management regulations.	
	O43	Poor urban planning	Lack of rational urban planning (short lifespans of buildings).	
	O44	Poor waste management facilities	Developers must arrange solid waste management facilities, which must be designed, constructed and put into place along with the main project.	Chang et al., (2016); Schmid et al., (2020)
	O45	Lack of data	Lack of data related to construction waste generation for policy decision making.	Ghisellini et al., (2018); Huang et al., (2018);
	O46	Lack of environmental awareness	Lack of environmental awareness among architects, designers, and engineers.	Kasai and Jabbour., (2014)
	O47	Lack of stable supply of construction waste materials	Lack of stable supply of construction waste materials for manufacturing recycling products.	Ghisellini et al., (2018) Chang et al., (2016)
	O48	Lack of demand for recycled products	Lack of demand for recycled products caused market uncertaity and discourage recycling activity.	

Technological sustainability transition challenge	O49	Insufficient technology usage	Inadequate use of sustainable technologies in construction projects.	Darko et al., (2018); Huang et al., (2018)
	O50	Insufficient of reuse, reduce, and recycle application	Insufficient application of the reuse, reduce, and recycle approach in construction projects.	
	O51	Lack of local institutes and facilities for green buiding technology and research	Local institutes and facilities for green buiding technology and research is needed to support the development of technologies adoption.	
	O52	Unavailability of technologies suppliers	Unavailability of technologies suppiers limiting the development of technologies adoption.	
	O53	Lack of professional knowledge and expertise in technologies	Professional knowledge and expertise in technologies are needed to maximize technological adoption.	
	O54	Lack of awareness of technologies and their benefits	Lack of awareness of technologies and their benefits discorage construction firm to do technological adoption	
	O55	Unavailability of technologies in the local market	Unavailability of technologies in the local market limiting the technological adoption of the construction firms.	
	O56	Risks and uncertainties involved in adopting new technologies	Risks and uncertainties of the technological adoption discourage is a barrier of technological adoption itself.	
	O57	Higher cost of technologies	Higher cost of technology discourages construction firms for technological adoption.	

Appendix B.

The initial set of proposed challenges

Perspectives	Criteria		Weight	Decision
Social sustainability transition challenges Economic sustainability transition challenges	O1	Lack of vision	0.637	Accepted
	O2	Lack of audit	0.504	Rejected
	O3	Poor regulations	0.789	Accepted
	O4	Lack of governmental support	0.630	Accepted
	O5	Lack of standardization	0.333	Rejected
	O6	Poor coordination	0.456	Rejected
	O7	Government project plans approval	0.333	Rejected
	O8	Lack of safety measure	0.333	Rejected
	O9	Poor impact assessment	0.333	Rejected
	O10	Poor evaluation	0.504	Rejected
	O11	uneffective construction waste removal	0.333	Rejected
	O12	safety accountability system	0.333	Rejected
	O13	safety education system	0.333	Rejected
	O14	safety management personnel	0.333	Rejected
	O15	Involvement of personal interest	0.658	Accepted
	O16	Lack of awareness and knowledge	0.642	Accepted
	O17	User behaviour	0.333	Rejected
	O18	Complacency	0.470	Rejected
	O19	Sustainability silos	0.333	Rejected
	O20	Lack of leadership	0.675	Accepted
	O21	Vested interest	0.333	Rejected
	O22	Lack of community involvement	0.671	Accepted
	O23	Communication breakdown between members of institution	0.333	Rejected
	O24	Lack of commitment	0.627	Accepted
	O25	Unbalanced sustainability practices	0.333	Rejected
	O26	Lack of implementation	0.448	Rejected
	O27	Lack of strategy	0.639	Accepted
	O28	Tolerance to unsustainable practices	0.618	Accepted
	O29	Lack of stakeholder participation	0.683	Accepted
Economic sustainability transition challenges Environmental sustainability transition challenges	O30	Lack of waste technology investment	0.683	Accepted
	O31	High diversion costs	0.665	Accepted
	O32	High prices of recycled products	0.658	Accepted
	O33	Low prices of natural materials	0.691	Accepted
	O34	Lack of incentives	0.627	Accepted
	O35	Ineffective green marketing	0.333	Rejected
	O36	Fragmented market	0.691	Accepted
	O37	Uncertain return and profit	0.658	Accepted
	O38	High startup capital investment	0.333	Rejected
Environmental sustainability transition challenges	O39	Free waste dumping	0.333	Rejected
	O40	Lack of environmental assessment	0.665	Accepted
	O41	Lack of systematic planning	0.333	Rejected
	O42	Lack of recovery targets	0.333	Rejected
	O43	Poor urban planning	0.694	Accepted
	O44	Poor waste management facilities	0.707	Accepted
	O45	Lack of data	0.639	Accepted
	O46	Lack of environmental awareness	0.333	Rejected
	O47	Lack of stable supply of construction waste materials	0.710	Accepted
	O48	Lack of demand for recycled products	0.333	Rejected

Technological sustainability transition challenges	O49	Insufficient technology usage	0.333	Rejected
	O50	Insufficient of reuse, reduce, and recycle application	0.655	Accepted
	O51	Lack of local institutes and facilities for green buiding technology and research	0.651	Accepted
	O52	Unavailability of technologies suppliers	0.333	Rejected
	O53	Lack of professional knowledge and expertise in technologies	0.683	Accepted
	O54	Lack of awareness of technologies and their benefits	0.333	Rejected
	O55	Unavailability of technologies in the local market	0.333	Rejected
	O56	Risks and uncertainties involved in adopting new technologies	0.702	Accepted
	O57	Higher cost of technologies	0.642	Accepted

Note: the threshold value is 0.510