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# Modeling the critical barrier factors to hindering sustainable construction: sampling the Turkish construction industry

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Received 24 February 2024
Revised 18 May 2024
Accepted 22 June 2024

## Abstract

**Purpose** – Considering the construction industry’s vital role in economic development and social consequences, this study seeks to pinpoint critical barriers hindering Turkey’s sustainable construction (SC). Although several studies highlighted the barriers to SC worldwide, none identified the critical factors. By identifying and understanding these barriers, the research aims to comprehensively understand practices and formulate strategic recommendations to promote sustainable construction.

**Design/methodology/approach** – A systematic approach is adopted to achieve the research objectives. The study involves identifying potential barriers to SC with a systematic literature review. A questionnaire was organized and distributed via e-mail to architects, civil engineers, and contractors. The criticality of identified barriers was determined with normalized mean value analysis, and critical barrier factors (CBFs) to SC were isolated with exploratory factor analysis. Finally, the effect size of these factors was quantified through structural equation modeling.

**Findings** – This study identified 32 critical barriers hindering the SC in the Turkish construction industry among 49 barriers. Furthermore, this study revealed six CBFs to SC that are “inadequate supervision and control of SC,” “fear of transition to sustainable construction and disruptions in adoption,” “lack of educational opportunities,” “return on investment and financial bias,” “awareness and knowledge gap about SC,” and “lack of demand from stakeholders.” Among them, “awareness and knowledge gap about SC,” “fear of transition to SC,” “lack of educational opportunities,” “lack of demand from stakeholders,” and “inadequate supervision and control of SC” were determined as the very highly crucial CBFs hindering SC.

**Originality/value** – Although some studies have identified the barriers to SC qualitatively and quantitatively, studies have yet to provide insights into the critical barrier factors hindering SC. Therefore, this study comprehensively and quantitatively determines the relevant CBFs to SC using exploratory factor analysis and utilizes confirmatory factor analysis and structural equation modeling to present a structural model of how critical factors affect the SC.

**Keywords** Sustainability, Sustainable construction, Structural equation modeling, Quantitative analyses

**Paper type** Research paper

## 1. Introduction

Through its linkages with other industries, the construction industry stimulates significant economic growth and plays a vital role in economic development, with apparent outcomes (Durdyev and Ismail, 2012). Moreover, it correlates robustly with sustainable development across the “triple bottom line” of economic advancement, environmental influence, and social advancement. Hence, evaluating the construction industry entails considering its influence on socio-economic development and environmental and social consequences (Whang and Kim, 2015). On the other hand, along with these comprehensive effects of the sector, the environmental damage it causes is noteworthy (Dalirazar and Sabzi, 2023).

The negative impacts of the construction industry on the environment can be described by the fact that it produces 35–40% of $CO_2$ emissions (Ahmed *et al.*, 2023), consumes 40% of raw materials (Serpell *et al.*, 2013), generates 40% of solid waste and 40% of total energy production, and uses 16% of water resources (Dalirazar and Sabzi, 2023). Therefore, sustainability has gained increasing importance in recent years, and the demand for

Open House International

0168-2601
DOI 10.1108/OHI-02-2024-0065

sustainable buildings has increased accordingly (Ahmed *et al.*, 2023; Darko *et al.*, 2017). In this context, the construction industry needs to adopt practices and processes that produce sustainable construction.

According to Olubunmi *et al.* (2016), sustainable construction refers to reducing environmental impacts, enhancing the well-being of building occupants, delivering a financial return for developers and the local community, and integrating life cycle assessment into the planning and development process. Furthermore, a sustainable construction industry balances human needs by providing a safe, healthy, and physiologically comfortable building environment that ultimately increases user satisfaction and productivity (Durdyev *et al.*, 2018).

The report "*Sustainable Construction Industry in Developing Countries*" (Miranda and Marulanda, 2001) states that sustainable construction represents a comprehensive and unifying concept to re-establish equilibrium and synergy among the environment, economy, and society. Nevertheless, in the context of developing nations, the incorporation of even fundamental aspects of sustainability is at a nascent stage. For example, while developed countries prioritize efficient resource utilization and environmental impact reduction, developing countries encounter more significant challenges that hinder the adoption of sustainability (Cobbinah *et al.*, 2015).

Scholars worldwide have given this situation extensive attention (Holloway and Parrish, 2015), and they have examined the factors motivating a shift towards a more sustainable construction industry and the obstacles to implementing sustainable construction.

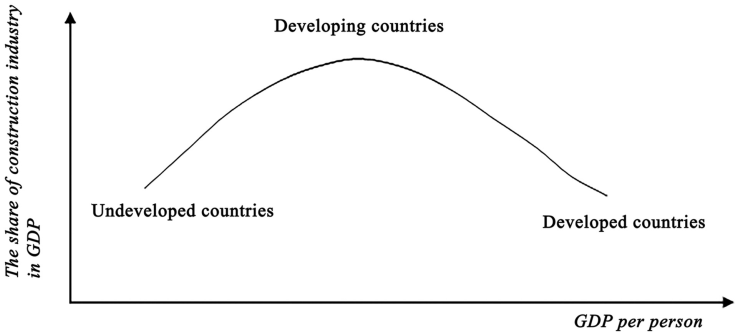
Previous studies in this domain indicate that the industry's condition regarding sustainability in developing countries is discouraging (Ali and Alkayed, 2019; Al-Otaibi *et al.*, 2022; Martek *et al.*, 2019; Xie *et al.*, 2022). Nonetheless, this approach is also in contrast to a comparable approach in developed nations, which predominantly emphasizes the economic facets of sustainability.

In this regard, when analyzing the studies conducted in this context, it is noteworthy that the majority of the studies focus mainly on developed countries such as the US (Darko *et al.*, 2017; Karji *et al.*, 2020), the UK (Darko *et al.*, 2018; Heffernan *et al.*, 2015; Osmani and O'Reilly, 2009; Williams and Dair, 2007), Italy (Hunter *et al.*, 2018), Ireland (Souaid *et al.*, 2022), Australia (Martek *et al.*, 2019), and Sweden (Persson and Grönkvist, 2015). However, the number of studies on this topic in developing countries is relatively low.

Therefore, it is of utmost importance for the construction industries of developing countries to pinpoint the critical barrier to sustainable construction (SC). In many developing countries, the construction industry plays a significant role in driving economic growth, as (Asante and Mills (2020) highlighted. This sector is known to substantially contribute to the gross domestic product (GDP), which measures national output and input. According to Sertyeşilişik (2017), construction industries in developing nations play a crucial role in supporting their economies, contributing approximately one-third to the development of physical infrastructure and representing about 15% of their GDPs.

The correlation between a country's economic development stages and the proportion of the construction sector within its GDP was explored by Bon (1992) and depicted as the "Bon curve" (Figure 1).

As depicted in Figure 1, low-income or underdeveloped countries typically exhibit relatively low volumes within the construction sector and GDP. In contrast, developing nations experience a surge in industrialization driven by infrastructure projects, factories, offices, and housing construction, thereby increasing the construction sector's contribution to GDP. Conversely, in high-income or developed countries, the construction sector's share in GDP tends to decline due to reduced housing demand stemming from low population growth rates and the completion of much infrastructure.



**Source(s):** Figure courtesy of Bon (1992)

**Figure 1.**
Bon curve

The construction industry is a pivotal sector for national growth within the Turkish economy, presenting substantial investment prospects and bolstering national income. In Turkey, the construction sector primarily focuses on developing critical infrastructure such as bridges, dams, airports, roads, highways, and power systems (Sertyesilişik, 2017). According to data from the Turkish Contractors Association (2016), the construction industry's contribution to the Turkish economy can reach up to 30%. Hence, the construction industry is a cornerstone of the Turkish economy (Gurcanli *et al.*, 2021).

When this situation of the Turkish construction sector within the national economy is evaluated, it can be safely stated that the construction sector is the locomotive sector for Turkey. Therefore, identifying the critical barrier factors hindering sustainable construction is crucial. While numerous studies have delved into the barriers to sustainable construction on a global scale (Ali and Alkayed, 2019; Darko *et al.*, 2017; Karji *et al.*, 2020; Xie *et al.*, 2022), all of which are important, there remains a notable gap in research what are the critical barrier factors hindering the sustainable construction, and which of these are the most influential critical factors specific to the construction industry in Turkey or other developing countries. Hence, formulating strategic plans or pathways for successfully adopting sustainable construction in its initial phase remains challenging. Anticipations suggest that the imperative for implementing sustainable construction, mandated by public authorities, will likely extend to both superstructure and infrastructure projects in Turkey soon.

Consequently, it becomes imperative for organizations yet to embrace sustainable construction to integrate it swiftly and efficiently into their practices. From this standpoint, comprehending the critical barrier factors impeding sustainable construction becomes crucial when devising strategic plans for its successful implementation and widespread adoption. In essence, a literature gap exists, and there is a need for more knowledge within this domain.

For the reasons mentioned above, the primary aim of this research is to illuminate the critical barrier factors that pose challenges, impede progress, and propel sustainable construction practices within the Turkish construction industry.

In this context, the present study has four main objectives: (1) To identify the potential barriers to SC in Turkey, (2) To determine the criticality of the barriers that have been identified, (3) To determine the critical barrier factors to SC (4) To unveil the effect size of determined factors to SC by modeling.

## 2. Background of the study and research gaps

Examining the literature unveils several studies that identify factors affecting sustainable construction. While prior studies worldwide yield similar results, each country's conditions require specific identification due to its unique socio-economic-political context. These concentrations may vary according to the characteristics of the countries (demographic statistics, level of economic development, etc.) and the level of implementation of SC.

In the USA, studies are concentrated on identifying barriers to sustainable construction (Karji *et al.*, 2020) and financing sustainable building (Yi *et al.*, 2014).

In Europe, the focus is on identifying barriers to near-zero energy housing (Souaid *et al.*, 2022), creating intelligent energy cities for sustainability through project implementation (Hunter *et al.*, 2018), identifying the factors hindering the transition to sustainability in the construction industry (Martek *et al.*, 2019), and promoting sustainable building practices and best practices (Pitt *et al.*, 2009).

Furthermore, in China, the focus is on sustainability practices, barriers, future trends (Xie *et al.*, 2022), and the promotion of low-carbon sustainability (Jiang *et al.*, 2014). In the United Arab Emirates, the focus is on awareness of renewable energy building technologies (Albattah and Attoye, 2021) and a framework for accelerating the sustainable building movement (Sabbagh *et al.*, 2019).

While the vast majority of studies in the existing literature have investigated the critical drivers, barriers, challenges, and facilitators to the adoption of sustainable construction (Dalirazar and Sabzi, 2023; Sabbagh *et al.*, 2019; Zulu *et al.*, 2023) and green building implementation (Ahmed *et al.*, 2023; Mollaoglu *et al.*, 2016; Simpeh *et al.*, 2023; Wadu Mesthrige and Kwong, 2018; Ziliya and Faisal, 2020), some researchers have tried to provide innovative approaches to this issue in the context of technology (Xie *et al.*, 2022).

Although the outcomes of existing research on sustainable construction are significant, they tend to be primarily focused on either qualitative or quantitative analyses, relying solely on methodologies. For example, case studies (Herazo and Lizarralde, 2016; Lu *et al.*, 2022; Sultan and Alaghbari, 2023), focus groups, and semi-structured interviews (Murtagh *et al.*, 2016; Souaid *et al.*, 2022) content analysis (Yi *et al.*, 2014), Delphi technique (Ali and Alkayed, 2019; Nasereddin and Price, 2021), cluster analysis (Chang *et al.*, 2017a) were conducted as qualitative analyses, whereas, exploratory factor analysis and structural equation modeling (Darko *et al.*, 2017; Watfa *et al.*, 2023), relative importance index (Al-Otaibi *et al.*, 2022), analytic hierarchy process (Tsz Wai *et al.*, 2023) and scientometric analysis (Ashour *et al.*, 2021; Hou *et al.*, 2022) were conducted as quantitative analyses.

Although previous qualitative review studies offer valuable insights, the literature still needs to be filled with critical barrier factors to SC. Knowing these factors is crucial when formulating a strategic plan for its effective SC.

Therefore, this study highlights the critical barrier factors to SC, focusing on the Turkish construction industry's unique context, which can be generalized to other developing countries. A comprehensive analysis of the literature via a systematic literature review was conducted to identify the potential barriers. Subsequently, a normalized mean value analysis was conducted to highlight critical barriers. Afterward, exploratory factor analyses were executed to pinpoint the contributing critical barrier factors. Finally, the factors obtained were modeled using structural equation modeling to unveil the impact size of each one on SC. Previous studies in this domain have yet to use these methods. The current study employed an online questionnaire, as did most previous studies. Unlike most previous studies, the survey questions were formulated by leveraging a systematic literature review, enhancing the reliability and objectivity of the criteria. Furthermore, the criticality of criteria has yet to be investigated in any previous studies.

## 3. Research methodology

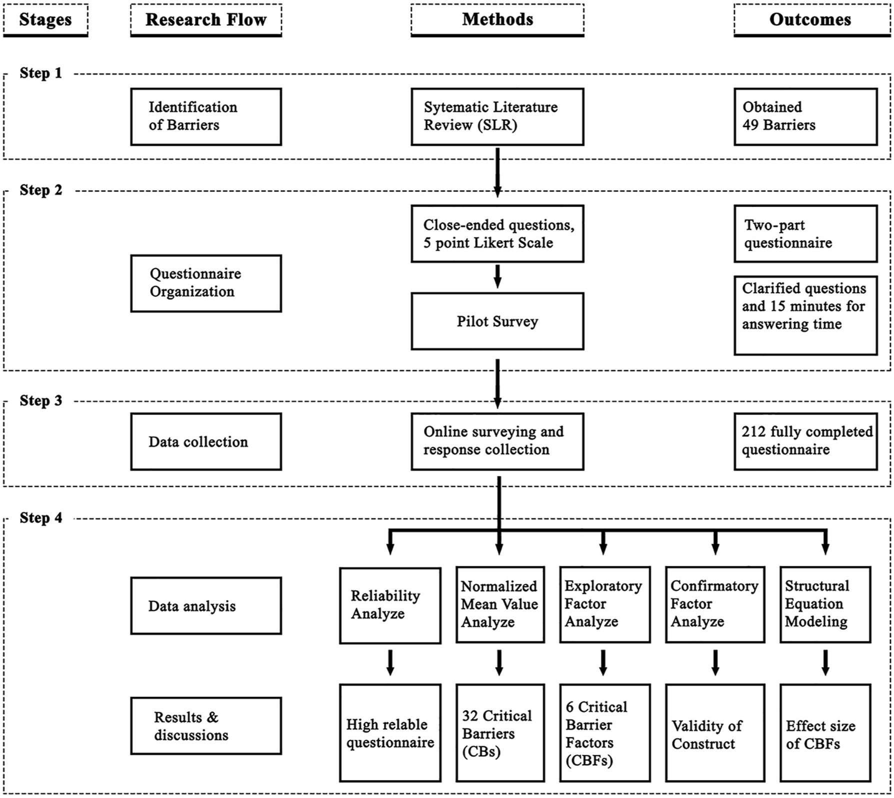
This research quantitatively identifies and models the critical barriers to SC in the Turkish construction industry. A multistage methodological framework was employed in this context, primarily focusing on assessing potential barriers in this domain. The extensive methodological approach of the current research is depicted in Figure 2.

The study commenced with a Systematic Literature Review (SLR) to identify the potential barriers (BRs) to SC. Subsequently, a questionnaire was developed and validated. Data gathering was initiated with an online survey administered to participants. An initial step in data analysis involved evaluating data reliability. A normalized mean value ranking was performed to identify critical barriers (CBs). Additionally, exploratory factor analysis was conducted to unveil underlying critical barrier factors (CBFs). Finally, the obtained factors were modeled with structural equation modeling (SEM) to unveil the impact size of each CBF on SC.

### *3.1 Identification of potential barriers to SC with SLR*

The present investigation begins by identifying potential barriers to SC. To gather data from the literature in a systematic, transparent, impartial, and reproducible manner, these criteria were derived through an SLR, widely acknowledged as an objective methodology by many researchers (Tranfield *et al.*, 2003; Denyer *et al.*, 2008).

As a robust methodological approach, SLR is employed to methodically assess, analyze, and comprehend all research associated with a specific topic, subject, or phenomenon in the



**Source(s):** Created by authors

**Figure 2.**
The framework of research methodology

field of science (Wolfswinkel *et al.*, 2013). In this context, the pertinent literature was thoroughly reviewed utilizing this approach.

In this study, a three-stage methodology was established to identify potential barriers to SC, encompassing the "planning," "execution," and "documentation" phases (Figure 3). The research question was formulated during the planning phase, and a review protocol was constructed. The research questions are as follows:

*RQ1.* What are the potential barriers to SC?

*RQ2.* What are the critical barriers to SC?

*RQ3.* What are the critical barrier factors hindering SC?

*RQ4.* What are the effect sizes of critical barrier factors to SC?

To explore this research domain, this study selected the Web of Science (WoS), which is recognized as the premier database for literature review (Yadav *et al.*, 2023). WoS was selected owing to its comprehensive coverage of critical publications and inherent analytical capabilities that generate reliable metrics (Yu *et al.*, 2020). Furthermore, WoS employs advanced citation-matching algorithms that surpass those of Scopus (Valderrama-Zurián *et al.*, 2015), enhancing its value as the primary data source for this investigation.

During the execution phase, primary studies were identified, systematically chosen, extracted, analyzed, and synthesized. In this phase, the search query used in WoS was: (ALL FIELDS) "*sustainability*" AND "*construction*" OR "*construction industry*" AND "*barrier*" OR "*challenges*." The time frame of the search was from 200 to 2023 (March), yielding 834 records. This time frame allows for a comprehensive examination of the evolution of sustainable construction practices over more than two decades. It covers a significant period during which sustainability issues gained increasing prominence in the construction industry globally. Beginning the review in 2000 provides a historical context for understanding the development and adoption of sustainable construction practices. It allows for tracing the trajectory of initiatives, policies, and challenges the construction industry faces in embracing sustainability principles. Extending the review up to 2023 ensures that the findings are relevant and up-to-date, capturing recent advancements, trends, and emerging challenges in sustainable construction. This allows for a more nuanced understanding of current barriers and potential pathways for improvement.

In acquiring these records, establishing well-defined inclusion and exclusion criteria is crucial for efficiently filtering the collected research publications and retaining only the

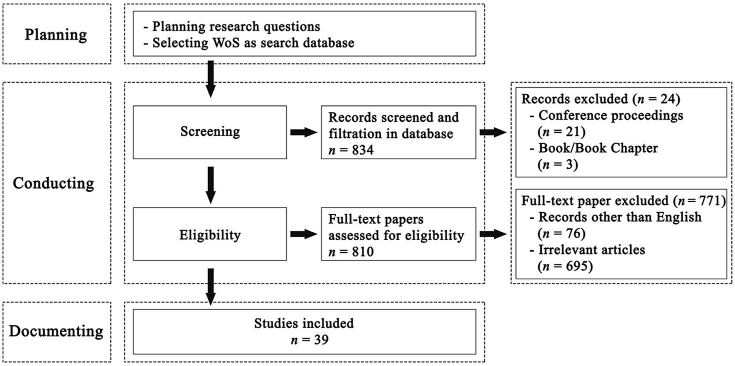


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**Figure 3.**
Phases of SLR

pertinent ones. Thus, specific inclusion and exclusion criteria were formulated to evaluate the literature. The inclusion criteria were: (1) research explicitly addressing SC barriers in construction projects and (2) studies published in peer-reviewed journals. Adopting a discerning approach concerning academic journals in the research domain is a strategic choice, considering that such articles typically maintain higher quality standards, as Shi *et al.* (2020) support. The exclusion criteria were: (1) research published in languages other than English and (2) studies lacking readily available full-text resources. After applying the inclusion and exclusion criteria, 39 articles were retained.

Through detailed analysis, 49 potential barriers to SC were identified and listed in Table 1.

### *3.2 Structuring the questionnaire*

The questionnaire comprised two main parts. The first part included the assessment of 49 BRs, detailed in Table 1. Participants rated the significance of these barriers to SC on a five-point Likert-type scale, with one indicating “very low” and five denoting “very high.” Furthermore, utilizing five-point Likert scales aids in evaluating the efficacy of current forecasting methodologies and devising optimal construction management strategies (Dadar *et al.*, 2019).

The second part collected personal and sociodemographic data, including occupation type, experience in the construction industry, education level, and the participant’s level of knowledge about SC.

### *3.3 Data collection*

The organized questionnaire was distributed to architects, engineers, and contractors in various roles, including project design and construction contracting within public institutions, construction companies, and building inspection institutions in the Turkish construction industry. A pilot study was undertaken to identify any statements in the questionnaire that were confusing or not fully understood, ensuring clarity. The pilot study also assessed the response time of the questionnaire. Fifteen participants participated in the pilot study, with five individuals from each profession, all with over five years of experience in the field. The final questionnaire was refined based on the comments and suggestions gathered during the pilot study.

The final questionnaire was e-mailed to 1,015 participants on 9 April 2023. Responses were accepted until 6 September 2023, and 215 were returned. Among the returned questionnaires, 212 valid surveys, representing a 20.88% response rate, were analyzed in this study.

Akintoye (2000) proposes an acceptable response rate for construction research falling between 20 and 30%, indicating that the achieved response rate was within acceptable bounds. Furthermore, the available scholarly works indicate that sample sizes ranging from 100 to 400 are deemed adequate for conducting structural equation modeling analysis, as Molwus *et al.* (2013) highlighted.

Random sampling techniques were used in this study. The random sampling technique, commonly employed in construction research, ensures the selection of a sample from the population with a non-zero probability, as highlighted by Gamil *et al.* (2020). This method effectively produces a sample that accurately represents the population while minimizing voluntary response bias. Hence, this approach was adopted for participant selection in this study. The calculation of the population sample size follows a methodology adapted from Gamil *et al.* (2020) (Equation 1). Specifically, based on insights from an SLR on barriers to SC, a questionnaire was formulated and distributed to architects, engineers, and contractors.

**Table 1.**
Potential barriers to SC

| Code of barriers | Definition of barrier | Source |
|---|---|---|
| BR1 | The fear of increased costs | [1–12] |
| BR2 | The belief that the duration of work will increase | [4], [10,11], [13] |
| BR3 | Lack of knowledge about the necessary materials | [4], [12], [14,15] |
| BR4 | Lack of necessary design knowledge | [4], [12], [15–18] |
| BR5 | Failure to procure the needed materials | [4], [6], [11,12], [14,15], [17,18] |
| BR6 | Insufficient variety of construction elements | [4], [6], [12], [15–18] |
| BR7 | Low number of expert engineers or architects on the subject | [4], [8], [10], [12], [15], [17] |
| BR8 | Contractor's reluctance to use sustainable building practices | [4], [10–12], [14,15] |
| BR9 | Owner's unwillingness to use sustainable building practices | [8], [10–16], [19] |
| BR10 | Failure of the project architect to transition from traditional building design to sustainable building design | [4], [10], [17], [20] |
| BR11 | Lack of knowledge about the ability to reduce consumption for all processes in the building lifecycle | [4], [15], [19], [21,22] |
| BR12 | Not knowing that it is eco-friendly | [5], [11], [15], [19], [22] |
| BR13 | Lack of awareness that quality will increase, and costs will decrease as a result of the transition | [4], [8], [10], [15] |
| BR14 | The thought that workflow will be disrupted | [10], [15], [22] |
| BR15 | Concern that productivity will be affected | [6], [15], [23,24] |
| BR16 | The belief that efficiency will decline | [6], [16], [24] |
| BR17 | The belief that the investment for the transition will not meet the expected economic impact (return on investment) | [4], [8], [14,15], [25,26] |
| BR18 | High initial investment costs for transition (material supply) | [8], [10], [14,15], [18], [26] |
| BR19 | Lack of financial resources for sustainable construction | [1–3] |
| BR20 | Failure to establish a quality-control system | [3], [5], [14], [27,28] |
| BR21 | The challenge of learning sustainable building practices | [5], [10], [15], [17] |
| BR22 | Lack of incentives to encourage these practices by institutions and organizations | [2], [8], [14], [23], [27] |
| BR23 | Lack of consultant support for the use of sustainable building practices | [8], [14,15], [27] |
| BR24 | Additional costs when the required consultant support is available | [2], [4], [10], [17], [27], [29] |
| BR25 | Perception that necessary consultancy support is a waste of time | [27,28], [30] |
| BR26 | Need for individual and group motivation to adopt sustainable building practices, from top management to the lowest level of the organization | [15], [29], [31] |
| BR27 | Lack of awareness and demand for sustainable building practices by employers or clients | [8], [10,11], [14–16], [18] |
| BR28 | Inadequate inclusion of sustainable building practices within the curricula of architecture and engineering departments at universities | [2], [4], [12], [16,17], [27], [32] |
| BR29 | Few or no faculty members familiar with sustainable building practices in universities | [4], [17], [27], [29] |
| BR30 | Lack of or insufficient efforts by professional associations related to the building sector to understand the differences between traditional building practices and sustainable building practices | [4], [10], [15], [29] |
| BR31 | Lack of industrial or academic training opportunities related to sustainable construction | [10], [12], [15], [17], [27], [29] |
| BR32 | Low or no use of sustainable building practices by the building contractor or owner | [10], [12], [29] |
| BR33 | The requirement for substantial organizational structure modifications to facilitate the integration of sustainable construction practices | [10], [15,16], [18], [28] |
| BR34 | Fear of abandoning the traditional project system | [4], [10], [14,15], [20] |

(*continued*)

| Code of barriers | Definition of barrier | Source |
|---|---|---|
| BR35 | Insufficient Turkish resources for sustainable building practices | [10], [27], [29], [33] |
| BR36 | Lack of time to learn and develop sustainable building practices due to the fast cycle, work overload, and strict deadlines in the construction industry | [10], [15], [17], [27] |
| BR37 | Failure to provide qualified labor in building production | [10], [15], [17], [34] |
| BR38 | Inability to establish a quality control system in material production and procurement | [3], [5], [14] |
| BR39 | Lack of production in accordance with technical drawings in sustainable building practices | [3,4], [12], [20] |
| BR40 | Improper storage of structural elements in production causes physical damage to structural elements | [12], [18], [28], [35–37] |
| BR41 | Failure to plan the storage process in accordance with work schedules, causing element damage and economic losses | [12], [18], [28], [35–37] |
| BR42 | Sustainable building practices require additional funds due to legal disputes, material upgrades, and other costs | [10], [17], [30], [38] |
| BR43 | Not being made compulsory by legal regulations | [2], [6], [11,12], [15–17] |
| BR44 | Lack of supervision by competent authorities | [8], [10], [15] |
| BR45 | Failure to ensure supervision by building audit firms | [6], [15], [28,39] |
| BR46 | Very low number of qualified personnel to supervise sustainable building practices | [10], [15,16] |
| BR47 | Failure to impose the necessary sanctions by official institutions in cases of deficiencies identified in the audit | [12], [17,18], [28], [39] |
| BR48 | Continuing the work without eliminating the deficiencies identified in the audit | [3], [4], [28] |
| BR49 | Cost and time losses incurred while eliminating the deficiencies identified in the audit | [2], [10], [38] |

**Note(s):** [1] Albattah and Attoye (2021), [2] Karji *et al.* (2020), [3] Ahmad *et al.* (2019), [4] Aghimien *et al.* (2018), [5] Chang *et al.* (2017b), [6] Darko *et al.* (2017), [7] Afacan and Demirkan (2016), [8] Gündes and Yildirim (2015), [9] Bharathi and Nicol (2013), [10] Olawumi and chan (2018), [11] Ziliya and Faisal (2020), [12] Ahmed *et al.* (2023), [13] Passa and Rompf (2007), [14] Souaid *et al.* (2022), [15] Horry *et al.* (2022), [16] Ali and Alkayed (2019), [17] Ashour *et al.* (2021), [18] Dalirazar and Sabzi (2023), [19] Benzar *et al.* (2020), [20] Vasconcelos *et al.* (2022), [21] Vives-Rego *et al.* (2015), [22] Owolana and Booth (2016), [23] Xie *et al.* (2022), [24] Sabbagh *et al.* (2019), [25] Eberhardt *et al.* (2019), [26] Berardi (2012), [27] Pompeii *et al.* (2019), [28] Tsz Wai *et al.* (2023), [29] Zakeri and Mahdiyar (2020), [30] Taherkhani *et al.* (2021), [31] Murtagh *et al.* (2016), [32] Celadyn (2020), [33] Tabatabaee *et al.* (2019), [34] Lehmann (2006), [35] Choi *et al.* (2019), [36] Wuni *et al.* (2022), [37] Hwang *et al.* (2018), [38] Chang *et al.* (2017b), [39] Al-Otaibi *et al.* (2022)
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**Table 1.**

$$SS = \frac{Z^2 \times P(1-P)}{C^2} \tag{1}$$

where:

SS = Sample Size;

Z = Z value (1.96 for 95 percent confidence level);

P = percentage picking a choice, expressed as a decimal (0.5 used for sample size needed); and

C = margin of error (9 percent), the maximum estimation error, which can be 9 or 8 percent.

$$SS = \frac{1.96^2 \times 0.5(1-0.5)}{0.09^2} = 118.57 \approx 119\ (\textit{as the minimum sample size})$$

The formula outlined by Enshassi and AlSwaity (2015) is utilized to evaluate the marginal error value. The maximum margin of error for a 95% confidence level is almost equal to 1.96 over the square root of $\approx \frac{1.96}{\sqrt{SS}} = \frac{1.96}{\sqrt{119}} = 0.18 > 0.09$. The margin is considered acceptable, with a minimum size requirement of 119. In the context of this study, a sample size of 212 can be considered adequate within this framework.

Of the 212 participants, 58.4% were architects, 34.9% were engineers, and 6.7% were contractors. Of these participants, 36.8% have 1–5 years, 35.4% have 6–15 years, 20.1% have 16–30 years, and 7.7% have 31–40 years of experience in the construction industry. Hence, a satisfactory level of experience was attained. Regarding educational level, 71.3% of participants had bachelor's degrees, 25.4% had master's degrees, and 3.3% had doctorates.

Finally, among the sample group, 84.1% of participants indicated adequate knowledge of SC, which was significant for the main subject of this study.

### *3.4 Analysis of data*

The questionnaire responses were analyzed using the Statistical Package for the Social Sciences (IBM SPSS) v.26.0 and LISREL (v.8.7). In particular, reliability analysis, normalized mean value analysis (NMV), and exploratory factor analysis (EFA) were performed with SPSS v.26.0. Confirmatory factor analysis (CFA) and structural equation modeling (SEM) were performed using LISREL.

In a survey utilizing a Likert scale, measuring reliability is essential to assess the internal consistency among the questions (Nunnally and Bernstein, 2007). Therefore, reliability analysis was first conducted to assess the internal consistency between questions. The reliability and validity of the responses were evaluated by calculating Cronbach's alpha (α) coefficient. Cronbach's alpha falls within a range of 0–1. According to commonly accepted standards, a Cronbach's alpha of 0.7 or higher signifies an acceptable level of reliability (Cronbach, 1951; Tavakol and Dennick, 2011).

Following the reliability test, an NMVs analysis was employed for each of the 49 barriers to identify the critical ones using Equation (2):

$$\textit{Normalized mean value} = \frac{(\textit{mean of barrier} - \textit{lowest ranked mean})}{(\textit{highest ranked mean} - \textit{lowest ranked mean})} \tag{2}$$

Any barrier with an NMV greater than 0.5 meets the critical barrier (CB). Many researchers have used this method of ranking analysis to classify critical (success) factors, such as Liao and Teo (2017), Xu *et al.* (2010), and Zhao *et al.* (2015), however, this method has not been used to evaluate the CBs for SC ever.

Discerning the underlying latent factor structure is crucial to fulfill one of the primary aims of this study. In this context, an EFA was applied to CBs to determine critical barrier factors (CBFs) that hinder the SC. To identify the CBFs, the data related to the CCs included in the survey were loaded into the SPSS software and then analyzed through EFA with the application of varimax rotation. In this study, principal component analysis was used as the factor extraction method, varimax rotation was used to identify significance (an eigenvalue of "1" was accepted as the cut-off), and the principal elements were recognized as CBFs, with a factor loading surpassing 0.4, as recommended by Nunnally and Bernstein (2007). The primary purpose of EFA is to reduce the number of variables while minimizing information loss and uncovering the structure of interrelationships among these variables (Hair *et al.*, 1992).

In the subsequent data analysis phase, CFA was conducted on the CBFs derived from EFA to construct validity, utilizing the LISREL software. Construct validity pertains to the effectiveness of quantifying a hypothesized factor (Lavrakas, 2008), and survey questions demonstrating higher construct validity are more adept at assessing the attributes they aim to uncover. Various fit indices were chosen to exhibit evidence of a robust fit between the model and the data, including the chi-square ($\chi^2$) test statistic, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA). In CFA, the path coefficients representing relationships among variables are regarded as effect sizes, with values below 0.1 indicating minor effects, approximately 0.3 indicating medium effects, and 0.5 or higher indicating significant effects (Lohmöller, 1989). In this investigation, associations with path coefficients of 0.5 or greater and *t*-values exceeding 2.58 were deemed statistically significant at a 99% confidence level.

Finally, SEM was built using LISREL 8.7 to highlight the effect size of each critical barrier factor hindering the SC quantitively. This analysis presents an occasion to verify the adequacy of the model regarding the connection between measurement paths and latent variables. While there are various perspectives on the sufficiency of path coefficients exceeding the 0.1 threshold, it is suggested to consider a path coefficient of 0.2 (Chin, 1998). In this study, path coefficients equal to or surpassing 0.5, along with a *t*-value exceeding 2.58, were deemed significant at a 99.0% confidence level (Jöreskog and Sörbom, 1993).

## 4. Results

### *4.1 Reliability analysis and validity of the questionnaire*

The dataset for the 49 barriers to SC in the Turkish construction industry exhibited a Cronbach's α coefficient of 0.955, surpassing the minimum threshold of 0.7. (Tavakol and Dennick, 2011) Moreover, it indicates that the responses have excellent internal consistency.

### *4.2 Determining and ordering critical barriers (normalized mean value analysis) to SC*

The means and standard deviations for all 49 barriers were calculated and displayed in Table 2.

The NMV revealed that 32 CBs out of the 49 BRs achieved NMVs exceeding 0.5. These were CBs and then used to determine the CBFs to SC.

The barrier with the highest mean value, BR18, with a mean of 4.14, received a rank of 1, while the barrier with the lowest mean value, BR21, with a mean of 3.01, was ranked 49 (Table 2).

### *4.3 Unveiling critical barrier factors to SC*

EFA reveals the structure between the sample group's variable characteristics and identifies a possible theoretical construct. This fundamental structure holds significance as one of the primary objectives of this study is to pinpoint the CBFs to SC. To fulfill this objective, EFA was conducted to uncover latent factors, employing the principal component method and utilizing Kaiser normalization with varimax rotation to 32 CBs.

Two CBs (BR14 and BR42) exhibited factor loading, so they were removed from the dataset, and EFA was repeated. Finally, 30 CBs were obtained and summarized in Table 3.

The Kaiser-Meyer-Olkin (KMO) value for assessing the sample's adequacy is 0.903, exceeding the 0.5 threshold, which suggests that the dataset is suitable for factor analysis, as per Pallant (2011). Six CBFs, each with an eigenvalue greater than 1, were subsequently extracted, collectively explaining 63.65% of the variance. Each factor is aptly labeled based on the inherent nature of the latent factors loaded onto that specific component.

The codes, labels, and interpretations for each of these CBFs are as follows:

| Barrier code | Mean | Standard deviation | Normalized mean | Rank |
|---|---|---|---|---|
| BR1 | 3.91 | 0.962 | 0.80* | 7 |
| BR2 | 3.50 | 0.971 | 0.43 | 38 |
| BR3 | 3.88 | 0.978 | 0.77* | 12 |
| BR4 | 3.63 | 1.067 | 0.55* | 28 |
| BR5 | 3.26 | 1.044 | 0.21 | 43 |
| BR6 | 3.11 | 0.99 | 0.07 | 47 |
| BR7 | 3.73 | 1.026 | 0.64* | 20 |
| BR8 | 4.11 | 1.009 | 0.98* | 2 |
| BR9 | 3.65 | 1.155 | 0.56* | 29 |
| BR10 | 3.44 | 1.041 | 0.37 | 39 |
| BR11 | 3.62 | 1.003 | 0.54* | 30 |
| BR12 | 3.18 | 1.194 | 0.14 | 45 |
| BR13 | 3.90 | 1.035 | 0.79* | 10 |
| BR14 | 3.82 | 0.957 | 0.72* | 17 |
| BR15 | 3.23 | 1.023 | 0.18 | 44 |
| BR16 | 3.10 | 1.047 | 0.06 | 48 |
| BR17 | 3.98 | 0.971 | 0.86* | 4 |
| BR18 | 4.13 | 0.986 | 1.00* | 1 |
| BR19 | 3.81 | 1.046 | 0.71* | 16 |
| BR20 | 3.72 | 1.033 | 0.63* | 24 |
| BR21 | 3.03 | 1.102 | 0.00 | 49 |
| BR22 | 3.94 | 1.024 | 0.83* | 6 |
| BR23 | 3.70 | 1.047 | 0.61* | 23 |
| BR24 | 3.89 | 0.95 | 0.78* | 9 |
| BR25 | 3.55 | 1.172 | 0.47 | 33 |
| BR26 | 3.53 | 1.074 | 0.45 | 34 |
| BR27 | 3.92 | 0.97 | 0.81* | 8 |
| BR28 | 3.67 | 1.109 | 0.58* | 25 |
| BR29 | 3.67 | 1.047 | 0.58* | 26 |
| BR30 | 3.72 | 0.957 | 0.63* | 21 |
| BR31 | 3.50 | 1.005 | 0.43 | 35 |
| BR32 | 4.05 | 0.894 | 0.93* | 3 |
| BR33 | 3.67 | 0.956 | 0.58* | 27 |
| BR34 | 3.53 | 1.131 | 0.45 | 36 |
| BR35 | 3.39 | 1.095 | 0.33 | 40 |
| BR36 | 3.88 | 1.094 | 0.77* | 41 |
| BR37 | 3.72 | 0.95 | 0.63* | 22 |
| BR38 | 3.55 | 1.004 | 0.47 | 32 |
| BR39 | 3.49 | 1.034 | 0.42 | 37 |
| BR40 | 3.19 | 1.043 | 0.15 | 46 |
| BR41 | 3.31 | 1.115 | 0.25 | 42 |
| BR42 | 3.80 | 0.997 | 0.70* | 18 |
| BR43 | 3.95 | 1.008 | 0.84* | 5 |
| BR44 | 3.82 | 1.068 | 0.72* | 14 |
| BR45 | 3.64 | 1.132 | 0.55* | 31 |
| BR46 | 3.88 | 1.089 | 0.77* | 11 |
| BR47 | 3.83 | 1.143 | 0.73* | 13 |
| BR48 | 3.76 | 1.096 | 0.66* | 19 |
| BR49 | 3.82 | 1.097 | 0.72* | 15 |

**Note(s):** * Refers to critical barriers (CBs)
**Source(s):** Created by authors

**Table 2.**
Identification and ordering CBs ($n = 212$)

| Factors | Code of CCs | Eigen value | EFA Loads of factors | % of variance | CFA Standardized coefficients |
|---|---|---|---|---|---|
| Factor 1 | BR47 | 11.32 | 0.841 | 16.02 | 0.84 |
| | BR44 | | 0.785 | | 0.81 |
| | BR48 | | 0.764 | | 0.80 |
| | BR45 | | 0.697 | | 0.70 |
| | BR43 | | 0.694 | | 0.73 |
| | BR46 | | 0.652 | | 0.74 |
| | BR49 | | 0.649 | | 0.66 |
| Factor 2 | BR24 | 2.22 | 0.741 | 13.87 | 0.68 |
| | BR23 | | 0.724 | | 0.70 |
| | BR37 | | 0.610 | | 0.61 |
| | BR22 | | 0.574 | | 0.70 |
| | BR20 | | 0.570 | | 0.60 |
| | BR27 | | 0.500 | | 0.73 |
| | BR33 | | 0.488 | | 0.62 |
| | BR19 | | 0.479 | | 0.66 |
| | BR36 | | 0.477 | | 0.63 |
| | BR11 | | 0.471 | | 0.62 |
| Factor 3 | BR29 | 1.72 | 0.833 | 10.92 | 0.73 |
| | BR28 | | 0.802 | | 0.69 |
| | BR30 | | 0.725 | | 0.72 |
| | BR32 | | 0.526 | | 0.70 |
| Factor 4 | BR4 | 1.43 | 0.823 | 8.02 | 0.82 |
| | BR3 | | 0.729 | | 0.82 |
| | BR7 | | 0.662 | | 0.66 |

(*continued*)

**Table 3.**
Results of EFA and CFA analyses

| Factors | Code of CCs | Eigen value | EFA Loads of factors | % of variance | CFA Standardized coefficients |
|---|---|---|---|---|---|
| Factor 5 | BR1 | 1.23 | 0.786 | 7.78 | 0.53 |
| | BR13 | | 0.549 | | 0.61 |
| | BR18 | | 0.513 | | 0.79 |
| Factor 6 | BR9 | 1.17 | 0.786 | 7.04 | 0.56 |
| | BR8 | | 0.768 | | 0.62 |
| | BR7 | | 0.498 | | 0.78 |
| Total explained variance | | 63.65 | | | $\chi^2$/df 1.942 |
| Kaiser–Meyer–Olkin (KMO) value | | 0.903 | | | RMSEA 0.047 |
| Barlett's test of sphericity | Approx. chi-square | 3496.66 | | | CFI 0.96 |
| | df | 435 | | | GFI 0.95 |
| | $p$ | 0.000 | | | AGFI 0.90 |

**Table 3.**

**Source(s):** Created by authors

*Factor 1:* Inadequate supervision and control of SC (ISC)

*Factor 2:* Fear of transition to sustainable construction and disruptions in adoption (FTSC),

*Factor 3:* Lack of educational opportunities (LEO),

*Factor 4:* Return on investment and financial bias (ROIFB),

*Factor 5:* Awareness and knowledge gap about SC (AKG),

*Factor 6:* Lack of demand from stakeholders (LDS).

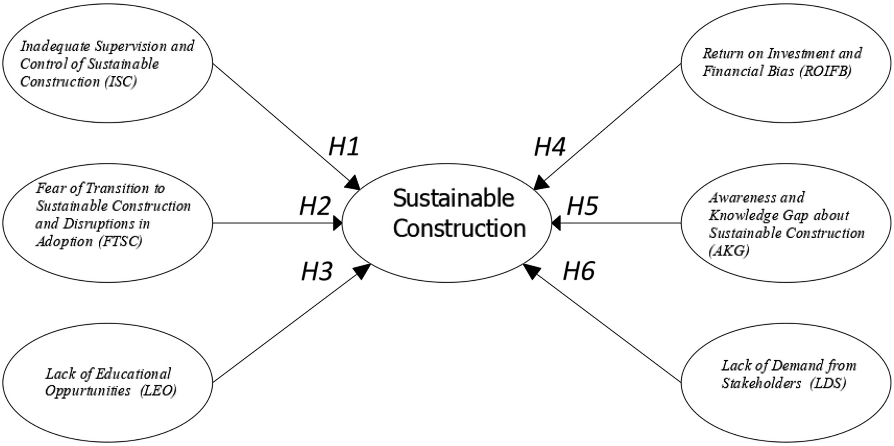
### *4.4 Confirmatory factor analysis (CFA)*

Table 3 displays the confirmatory factor analysis (CFA) outcomes, revealing that all the factor loadings surpass 0.5. Additionally, the model meets the stipulated goodness-of-fit (GOF) criteria, with a $\chi^2$/df ratio of 1.942, a Comparative Fit Index (CFI) of 0.96, a Root Mean Square Error of Approximation (RMSEA) of 0.047, and a Goodness-of-Fit Index (GFI) of 0.95. Taken together, these indices indicate a robust fit for the model. Considering this assessment of model fitness, it is noteworthy that the CFA model exhibits a firm fit and can be employed to evaluate the validity of the measurement scales.

### *4.5 Evaluation of measurement model*

A theoretical model was developed, where each pathway represents a conceptual connection between two constructs. Following this, six hypotheses were formulated, as illustrated in Figure 4.

In consideration of the six latent factors (ISC, FTSC, LEO, ROIFB, AKG, LDS) as CBFs to SC, a set of six hypotheses were formulated as below (paths in Figure 4):



**Source(s):** Created by authors

**Figure 4.** Hypothetical model of critical barrier factors to SC

*H1*. ISC has a direct effect on SC.

*H2*. FTSC has a direct effect on SC.

*H3*. LEO has a direct effect on SC.

*H4*. ROIFB has a direct effect on SC.

*H5*. AKG has a direct effect on SC.

*H6*. LDS has a direct effect on SC.

### *4.6 Reliability and validity test of model*

Two reliability measures, Cronbach's alpha (α) (CA) and composite reliability (CR), were employed to assess convergent validity and individual item reliability values within the measurement model (Hair *et al.*, 2017). In this study, all latent variables exhibited CR values exceeding the recommended threshold of 0.70, ranging from 0.79 to 0.90. Table 4 indicates that all CA values surpassed the suggested cut-off of 0.70, ranging from 0.796 to 0.902.

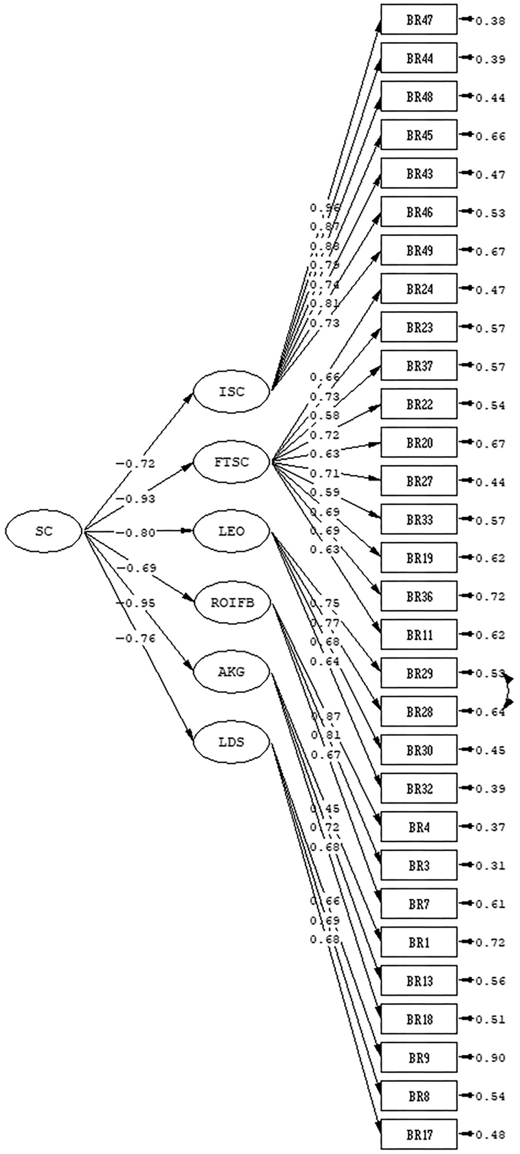
In addition to CA and CR, the Average Variance Extracted (AVE) test was utilized to assess internal consistency. The AVE values should ideally exceed 0.5 (Fornell and Larcker, 1981). In this study, all AVE values ranged from 0.50 to 0.66, surpassing the required AVE of >0.50, affirming the appropriateness of all constructs, as outlined in Table 4.

| Constructs/Latent variables | CR | CA | AVE |
|---|---|---|---|
| ISC | 0.90 | 0.902 | 0.57 |
| FTSC | 0.88 | 0.882 | 0.66 |
| LEO | 0.80 | 0.836 | 0.50 |
| ROIFB | 0.81 | 0.801 | 0.59 |
| ALK | 0.78 | 0.763 | 0.53 |
| LDS | 0.79 | 0.796 | 0.54 |

**Source(s):** Created by authors

**Table 4.** Reliability and validity test results

Concerning the theoretical model (Figure 4), a conclusive SEM was constructed (Figure 5), displaying the standardized path coefficients for each hypothesis. The evaluation of the model included assessments using goodness-of-fit (GOF) measures, *t*-value tests, and the examination of path coefficient values, considering both their magnitudes and statistical



Chi-Square = 821.12, df = 427, *P*-value = 0.00000, RMSEA = 0.047

**Source(s):** Created by authors

**Figure 5.**
Final SEM of CBFs to SC

significance. Tables 5 and 6 enumerate the parameters considered for validating the model.

The constructed SEM exhibits a high fitness level, as evident in Table 5. Consequently, based on the prescribed GOF measures, the model was deemed satisfactory. Table 6 details the hypothetical paths, $R^2$ values, and the assumed impacts.

Each hypothesis exceeds the critical one-tailed $t$-value of 2.58 at a significance level 0.01. The SEM analysis reveals that all hypotheses within the conceptual model received support, as highlighted in Table 6.

All results of hypotheses tests just rejected null hypotheses with a 99.0% level of confidence and $t$-values >2.58, as shown in Figure 5 and Table 6. Table 6 shows that AKG (0.95), FTSC (0.93), and LEO (0.80) have the most crucial negative impact on SC, followed by LDS (0.76), ISC (0.72), ROIFB (0.69), respectively.

## 5. Discussion

In this study, a methodology was formulated and validated to examine and assess the CBFs to SC. This section concentrates on the six latent factors identified through EFA and CFA, which were modeled using SEM due to their substantial influence on SC.

The SEM process successfully validated all six hypotheses. As illustrated in Figure 5 and outlined in Table 6, there are variations in the path coefficient values among the hypotheses. Path coefficients approaching one indicate a robust correlation, while values closer to zero suggest a weaker relationship, aligning with insights from Hair *et al.* (2017). Consequently, the significance and impact of CBFs are categorized into three groups: coefficients ranging between 1 and 0.71 are considered very highly crucial with a profound effect; those between 0.70 and 0.51 reflect a high impact, and values spanning 0.50 to 0.20 signify a moderate effect (Lohmöller, 1989). When Figure 5 and Table 6 are analyzed, it is noteworthy that five out of six factors can be regarded as very highly crucial barriers, whereas the remaining one has a high impact on SC. AKG, FTSC, LEO, LDS, and ISC with 0.95, 0.93, 0.80, 0.76, and 0.72 path

| Fit index | Suggested values | Structural equation results | Evaluation |
|---|---|---|---|
| $X^2$/df | $0 \leq X^2/\text{df} \leq 3$ | 1.92 | Good |
| GFI | $0.95 \leq$ GFI $\leq 1.00$ | 0.95 | Good |
| AGFI | $0.95 \leq$ AGFI $\leq 1.00$ | 0.94 | Good |
| RMSEA | $0 \leq$ RMSEA $\leq 0.05$ | 0.047 | Good |
| CFI | $0.95 \leq$ CFI $\leq 1.00$ | 0.96 | Good |
| NFI | $0.95 \leq$ NFI $\leq 1.00$ | 0.97 | Good |

**Source(s):** Created by authors

**Table 5.** Summary statistics of the model

| Hypothetical paths and expected influences | Path coefficient* | $t$-value (1-tail) | Interpretation | $R^2$ |
|---|---|---|---|---|
| H1: ISC → SC | −0.72 | 9.84 | Supported | 0.52 |
| H2: FTSC → SC | −0.93 | 10.25 | Supported | 0.87 |
| H3: LEO → SC | −0.80 | 8.91 | Supported | 0.64 |
| H4: ROIFB → SC | −0.69 | 8.75 | Supported | 0.48 |
| H5: ALK → SC | −0.95 | 6.42 | Supported | 0.90 |
| H6: LDS → SC | −0.76 | 6.74 | Supported | 0.58 |

**Note(s):** *All standardized path coefficient estimates are expected to be significant at $p < 0.01$
**Source(s):** Created by authors

**Table 6.** Standardized coefficient estimates ($p$-value) of the final structural equation model

coefficients are considered within the high-affecting critical barrier factors. These noteworthy factors are discussed below.

### *5.1 Regarding awareness and knowledge gap about SC (AKG)*

The awareness and knowledge gap about SC (AKG) is one of the CBFs that significantly impedes SC with a 0.95 path coefficient. Understanding AKG's profound impact on the industry's ability to embrace environmentally conscious practices is critical. In analyzing the global situation concerning the awareness and knowledge gap as a significant barrier to sustainable construction, it is evident that this issue extends beyond Turkey. Studies conducted in various developing countries such as Ghana, Cambodia, Indonesia, Nigeria, Chile, and Zambia have all highlighted similar challenges. These studies consistently point out that a lack of awareness and knowledge of sustainability significantly hinders the adoption of sustainable construction practices (Djokoto *et al.*, 2014; Ghansah *et al.*, 2022; Osuizugbo *et al.*, 2020). This research emphasizes that progress in this field is only possible with a solid understanding of sustainable construction principles, including their benefits and methodologies. The limited awareness within the construction sector hampers informed decision-making processes, while knowledge deficiencies hinder the adoption of innovative and sustainable methodologies. Consequently, the repercussions extended beyond economic considerations to encompass a significant environmental footprint and missed opportunities for long-term viability. Concrete efforts are necessary to overcome these challenges, including comprehensive education and training programs, effective knowledge dissemination strategies, policy interventions, and collaborative initiatives among industry stakeholders.

Various strategies can be implemented based on the findings of this research to address the AKG. One practical approach may be to develop educational strategies tailored to address specific knowledge gaps in sustainable construction practices. This can involve creating awareness campaigns targeting professionals and the public to enhance understanding and promote the benefits of sustainable construction (Akadiri *et al.*, 2012; Okoye, 2021). Additionally, implementing sustainable building frameworks that emphasize a balance between economic, social, and environmental considerations can help shift the mindset of construction practitioners towards sustainability (Siraj *et al.*, 2022). In addition, promoting the adoption of green building technologies through proper strategies is essential. Addressing barriers such as higher costs and lack of awareness requires well-devised promotion strategies to encourage wider adoption of green building technologies in construction projects (Biwer *et al.*, 2020). Moreover, fostering effective learning strategies and metacognitive knowledge among construction industry stakeholders can enhance the use of sustainable practices during self-study and project implementation.

### *5.2 Regarding fear of transition to sustainable construction and disruptions in adoption (FTSC)*

The second very highly effective CBF is FTSC, with a 0.93 path coefficient. The reluctance to adopt sustainable construction practices and the barriers hindering the industry-wide adoption of sustainable construction practices are significant challenges faced in Turkey and various other countries. Studies conducted in different regions have highlighted similar challenges related to the fear of transitioning to sustainable construction (Aghimien *et al.*, 2018; Ghansah *et al.*, 2022; Karji *et al.*, 2020). Significant barriers identified include the fear of higher investment costs, lack of local green certifications, absence of government policies or support, and financial incentives (Al-Otaibi *et al.*, 2022). The reasons for resistance may vary across stakeholders, but the underlying hidden reason may also be fear of change. Resistance to change, client preferences, and inadequate knowledge and understanding of sustainability concepts have also been recognized as significant challenges in adopting sustainable construction practices that may be placed under this CBF (Aghimien *et al.*, 2018).

The construction industry's reluctance to adopt sustainable methods and innovation has been identified as an attitudinal barrier to sustainable construction (Maqbool *et al.*, 2023). The lack of understanding of potential benefits, insufficient cooperation among practitioners, research institutions, and environmental organizations, and the absence of a systematic approach to pursuing sustainability goals have also been highlighted as influential barriers to incorporating sustainability in construction projects (Fathalizadeh *et al.*, 2022).

A country's socio-economic conditions and the construction industry's overall practices are crucial in defining the foundations for developing strategic plans to advance sustainable construction practices (Serpell *et al.*, 2013). The transition toward adopting sustainable alternatives in the construction industry must include dimensions of changing human behavior to overcome barriers and drive sustainable construction practices (Marsh *et al.*, 2021).

Behavior change is only effective with the critical social momentum required to drive the sustainability agenda, and there is a fear of transition. Furthermore, the uncertainty and risks of innovation trigger prejudice against SC and resistance to change (Souaid *et al.*, 2022). Therefore, there is a need for awareness-raising movements in organizations and supervision for SC.

### *5.3 Regarding lack of educational opportunities (LEO)*

The lack of educational opportunities (LEO) is the third very highly effective CBF gendering SC with a 0.80 path coefficient. This factor has been identified in various countries as a significant barrier hindering the adoption of sustainable construction practices, including Ghana, Cambodia, Nigeria, and Indonesia (Aghimien *et al.*, 2018; Durdyev and Ismail, 2016; Fitriani and Ajayi, 2023). Studies have highlighted that the need for more education and training on sustainable construction technologies, policies, and practices contributes to the slow implementation of sustainability in the construction industry (Aghimien *et al.*, 2018; Durdyev *et al.*, 2018). This lack of education and awareness impedes sustainable practices' development and successful implementation, hindering progress towards sustainable construction (Aghimien *et al.*, 2018). Moreover, the need for more skilled workers due to inadequate education and training programs poses a significant challenge to the effective adoption of sustainable construction methods (Susanti *et al.*, 2019).

Furthermore, the collaboration between the construction industry and universities is crucial to adopting SC. The integration of sustainability in the educational curriculum needs to be improved, and there needs to be more collaboration between educational disciplines (Ashour *et al.*, 2021). Correspondingly, the need for sufficient courses in universities' architecture and engineering departments indicates insufficient educational opportunities related to SC. In this context, Ziliya and Faisal (2020) emphasized the inadequacy of sustainable construction practices in education and training. Furthermore, Darko *et al.* (2017) underlined the principal hindrance of insufficient knowledge on sustainability. Therefore, there is a need for a robust collaboration system between industry associations and educational institutions. Sectoral and academic training opportunities and a sufficient number of studies by professional chambers related to understanding the differences between traditional and sustainable practices will play an essential role in this issue.

Several strategies can be implemented to address the LEO hindering sustainable construction. The first is introducing certification programs for sustainability to enhance the knowledge and skills of students and professionals in the construction industry (Kioupi and Voulvoulis, 2019). Another is developing strategies to promote sustainable construction through education and training programs (Akindele *et al.*, 2023). Furthermore, embedding sustainable development within educational curricula ensures that future professionals are equipped with the necessary knowledge and skills for sustainable construction (Murray and Cotgrave, 2007).

### *5.4 Regarding the lack of demand from stakeholders (LDS)*

The lack of demand from stakeholders (LDS) poses a common and very highly effective challenge to advancing sustainable construction practices in the Turkish construction industry with a 0.76 path coefficient, which can be generalized to other developing countries. Studies conducted in Ghana, Sweden, and Saudi Arabia have highlighted similar barriers related to the lack of demand for sustainable construction (Dalirazar and Sabzi, 2023; Djokoto *et al.*, 2014). The reluctance of clients and stakeholders to prioritize sustainability in construction projects has been recognized as a critical barrier to the widespread adoption of sustainable practices (Dalirazar and Sabzi, 2023; Djokoto *et al.*, 2014; Sarhan *et al.*, 2018). Additionally, limited client involvement in specifying lean construction requirements and preferences has been identified as a challenge in implementing sustainable construction practices (Sarhan *et al.*, 2018). Moreover, research in developing countries like Indonesia has revealed that ineffective advertisement of green buildings, perceived cost implications, lack of expertise, financial incentives, and risk and uncertainties contribute to the low demand for sustainable construction among clients (Ghansah *et al.*, 2022). The study in Ghana specifically highlighted the need for informed decision-making among industry practitioners and stakeholders to stimulate demand for green buildings (Guribie *et al.*, 2022). Furthermore, studies in Nigeria and Tanzania have emphasized the importance of stakeholder, project management, and technological factors in influencing sustainable construction practices (Ali *et al.*, 2023; Maqbool *et al.*, 2023). The lack of demand and strategy, cost implications, and public awareness are significant barriers to sustainable transformation in the construction industry (Ali *et al.*, 2023).

Addressing this barrier requires targeted efforts to raise awareness, provide incentives, enhance stakeholder engagement, and promote the benefits of sustainable construction, which will drive demand for green buildings and projects.

### *5.5 Regarding inadequate supervision and control of SC (ISC)*

Inadequate supervision and control of sustainable construction (ISC) is a critical barrier factor affecting SC very highly in Turkey, with a 0.72 path coefficient. Studies conducted in developing countries like Ghana and Indonesia have highlighted inadequate supervision as a major challenge in sustainable construction practices (Aghimien *et al.*, 2018; Susanti *et al.*, 2019). The lack of adequate supervision and control mechanisms leads to better safety performance, adequate training of workers, and unsafe working environments, which significantly impact the construction industry (Aghimien *et al.*, 2018; Susanti *et al.*, 2019).

Moreover, research in countries like China and Sri Lanka has emphasized the importance of effective construction supervision training programs to address productivity and performance improvement in construction projects (Kesavan *et al.*, 2022). Inadequate supervision affects the quality and safety of construction projects and hinders productivity and performance, leading to inefficiencies in the industry (Kesavan *et al.*, 2022).

Furthermore, studies in Tanzania and Vietnam have identified poor supervision as a barrier to sustainable construction practices, particularly ensuring compliance with environmental requirements and waste management regulations (Kongela, 2023; Lockrey *et al.*, 2016).

Addressing this barrier requires the development of effective supervision mechanisms, training programs for supervisors, and regulatory frameworks to ensure compliance with sustainability standards and practices in the construction industry.

### *5.6 Regarding return on investment and financial bias (ROIFB)*

Return on investment and financial bias (ROIFB) is a CBF that affects SC highly in Turkey, with a 0.69 path coefficient. ROIFB has been identified as a critical barrier hindering SC practices in various countries, including Ghana, Indonesia, and Libya. Studies have highlighted that the fear of higher investment costs, lack of financial incentives, and perceived financial risks associated with sustainable construction projects contribute to the reluctance of investors and stakeholders to engage in sustainable initiatives (Cunha *et al.*, 2020; Khalil *et al.*, 2021). The financial implications and uncertainties surrounding sustainable construction projects often deter investors from committing resources to such endeavors, impacting the overall adoption of SC (Cunha *et al.*, 2020; Khalil *et al.*, 2021). Furthermore, research in developing countries like Nigeria and Tanzania has emphasized financial challenges as significant barriers to implementing SC. Factors such as increased initial investment costs for sustainable projects compared to traditional buildings, lack of financial incentives, and financial weaknesses have been identified as key obstacles to sustainable construction (Cunha *et al.*, 2020). These financial barriers hinder the progress of sustainable construction initiatives and limit the adoption of environmentally friendly practices in the construction industry (Cunha *et al.*, 2020). Integrating financial sustainability with environmental and social considerations is crucial for driving sustainable construction practices and promoting long-term value creation (Park *et al.*, 2020). Overcoming these barriers requires addressing financial uncertainties, providing incentives for sustainable investments, and integrating financial considerations with sustainability goals to promote adopting environmentally responsible construction practices.

## 6. Conclusion

This study employed a multistage methodological framework to identify the critical barrier factors (CBFs) to SC and highlight the effect of each one on SC. Initially, 49 BRs to SC were identified with the SLR method. Using 49 BRs, a questionnaire was organized, and data collection was performed. A total of 212 fully completed survey forms were statistically analyzed, and by conducting NMV analysis, 32 out of 49 BRs were determined as CBs. An exploratory factor analysis was conducted to examine the CBFs, and six CBFs were obtained. As modeling the CBFs hindering the SC was one of the main aims of this study, structural equation modeling (SEM) was conducted for these six CBFs. SEM revealed that awareness and knowledge gap about SC (AKG), fear of transition to sustainable construction and disruptions in adoption (FTSC), lack of educational opportunities (LEO), lack of demand from stakeholders (LDS), and inadequate supervision and control of SC (ISC) were the CBFs very highly affect the hindrance of SC with path coefficients 0.95, 0.93, 0.80, 0.76, and 0.72, respectively. Furthermore, return on investment and financial bias (ROIFB) was the CBF that highly affected the hindrance of SC with a 0.69 path coefficient.

This study is distinctive in its focus on identifying the CBFs that impede the progression of sustainable construction practices. By delineating these obstacles, the research offers invaluable insights for scholars, stakeholders, and policymakers involved in sustainable construction, aiding them in understanding and addressing the challenges hindering the widespread adoption of sustainable practices across construction projects.

Furthermore, this study stands out as one of the few endeavors to construct a comprehensive framework for quantifying the impact and magnitude of these CBFs on sustainable construction efforts. Such a model serves as a tool for policymakers and organizational leaders within the construction industry in Turkey and holds potential for application in similar contexts within other developing nations. This quantified framework is poised to facilitate the development of tailored strategies and frameworks to promote sustainable practices within the construction industry.

### 6.1 Conceptual and empirical implications

The proposed model underscores the imperative of overcoming CBFs hindering the widespread adoption of SC, particularly within the architectural, engineering, and construction (AEC) industries of developing countries. This study aims to bridge the gap between theoretical understanding and practical implementation in the field by delineating the criteria for measuring achievement in sustainable construction. Notably, this research fills a crucial void in the literature by examining the CBFs impeding sustainable construction within the Turkish AEC industry, drawing insights from construction professionals actively engaged in sustainable practices.

(1) This study identifies and quantifies the influential factors that hinder SC through a rigorous process involving SLR and SEM. The conceptual framework developed herein expands upon existing models by incorporating additional components, such as the influence of critical barriers on sustainable construction implementation, thereby enriching our theoretical understanding of the subject.

(2) While previous studies on sustainable construction have predominantly focused on developed countries, this research extends its scope to include the unique challenges faced by the Turkish construction industry and, by extension, other developing nations. The empirical findings of this study provide valuable insights into the factors inhibiting the widespread adoption of sustainable practices, laying a solid foundation for future efforts to enhance the resilience and sustainability of local construction projects.

(3) Of particular significance is the development of a robust prediction tool (SEM) to assess the impact of critical barriers on the AEC industry, offering a novel perspective on the challenges hindering sustainable construction implementation. This study contributes empirically to sustainable construction discourse, shedding light on the intricate dynamics at play and paving the way for targeted interventions to address these barriers effectively.

(4) In light of the prevailing low level of sustainable construction adoption in developing countries, the findings of this empirical study underscore the urgent need for concerted action to overcome critical barriers and promote sustainability within the AEC industry in developing countries. This research catalyzes policy reform and organizational change by demonstrating the significant and negative impact of addressing these CBFs, urging stakeholders to embrace sustainable construction practices to benefit society and the environment.

### 6.2 Practical implications

Construction practitioners, policymakers, and scholars may use the following practical implications to understand and minimize the impact of CBFs hindering the SC.

Accordingly, *"Awareness and knowledge gap about SC (AKG)"* is the most critical factor for SC and, therefore, is worthy of attention. To minimize the adverse effects of this factor, the following few practical suggestions can be offered for policymakers, practitioners, and scholars:

(1) To increase awareness and knowledge about SC, governments play a crucial role in establishing construction policies that incentivize construction firms to adopt sustainable practices. Therefore, policymakers may develop and enforce building codes and regulations that incentivize sustainable construction practices, such as energy efficiency standards. Additionally, implementing green procurement policies for public projects to create market demand for sustainable construction practices

may minimize the adverse effect of AKG. Furthermore, governments in developing countries may provide financial incentives such as tax credits, grants, and subsidies for sustainable construction projects to encourage adoption among developers and contractors.

(2) Practitioners may invest in continuous education and training programs for construction professionals to enhance their understanding of sustainable construction practices. In addition, they may foster a culture of knowledge sharing within the organization by encouraging employees to share best practices and lessons learned from sustainable construction projects.

(3) Scholars may encourage interdisciplinary research collaborations between engineering, architecture, environmental science, and other relevant fields to address complex sustainability challenges in construction. Moreover, they may conduct case studies and empirical research to document best practices and lessons learned from successful sustainable construction projects. Finally, they may conduct longitudinal studies to assess sustainable construction practices' long-term environmental, social, and economic impacts, providing valuable insights for future decision-making.

The second most effective CBF is *"Fear of transition to sustainable construction and disruptions in adoption (FTSC),"* which hinders the SC.

1. Policymakers may develop supportive policy frameworks that provide clarity, consistency, and long-term incentives for sustainable construction adoption, reducing uncertainty and fear among stakeholders. In addition, policymakers may launch public awareness campaigns to educate consumers and businesses about the benefits of sustainable construction, fostering demand and reducing resistance to change.
2. Practitioners may initiate pilot projects to demonstrate the feasibility and benefits of sustainable construction techniques, allowing practitioners to gain hands-on experience and confidence in adoption. Moreover, they may develop risk management strategies to anticipate and mitigate potential disruptions associated with the transition to sustainable construction, such as supply chain disruptions or regulatory changes.
3. Scholars may evaluate emerging technologies and innovations for their potential to facilitate the transition to sustainable construction and provide guidance on their adoption and implementation. They may also conduct longitudinal studies to monitor the progress and impacts of sustainable construction initiatives over time, identifying factors contributing to successful adoption and addressing barriers as they arise.

The third CBF to SC is *"Lack of educational opportunities (LEO)."* We can propose the following practical recommendations to reduce the adverse impact of this aspect.

1. Policymakers should advocate for integrating sustainable construction principles and practices into formal education curricula at primary, secondary, and tertiary levels. In addition, policymakers may support the development of vocational training programs focused on sustainable construction skills, targeting tradespeople and workers in the construction industry. Allocating workforce development grants to support individuals seeking training and certification in sustainable construction practices may be another implication for policymakers. Finally, policymakers may facilitate collaboration between academia and industry to ensure that educational programs align with the needs and realities of the construction sector.

(2) Practitioners may establish internal training programs within construction firms to educate employees about sustainable construction techniques, materials, and technologies. Furthermore, they may pair experienced practitioners with junior staff members to provide mentorship and guidance on integrating sustainable practices into their work. Finally, they may collaborate with educational institutions, industry associations, and non-profit organizations to facilitate access to educational resources and training programs on sustainable construction.

(3) Researchers may research practical pedagogical approaches and educational interventions for teaching sustainable construction concepts and practices. They may develop curriculum materials, textbooks, and online resources tailored to different educational levels and audiences to enhance their understanding of sustainable construction.

The fourth most effective CBF impeding the SC is *"Lack of demand from stakeholders (LDS)."* To minimize the adverse effect of this *CBF,* the following practical suggestions can be offered:

(1) Policymakers may adopt and enforce green building standards and certification programs to set minimum requirements for sustainable construction practices. Incorporating sustainability criteria into public procurement policies to create demand for sustainable construction materials and services may be another implication.

(2) For practitioners, educating clients and stakeholders about the benefits of sustainable construction, including cost savings, energy efficiency, and environmental impact reduction, would be beneficial. They may emphasize sustainable construction practices' long-term value and return on investment, highlighting the potential for increased property value and marketability.

(3) Scholars would conduct cost-benefit analyses to quantify the economic, environmental, and social benefits of sustainable construction compared to conventional practices. They would collaborate with industry partners to translate research findings into practical solutions and promote adopting sustainable construction practices.

*"Inadequate supervision and control of SC (ISC)"* is another highly effective CBF hindering the SC. To reduce the adverse impact of this aspect, the mentioned practical recommendations may be proposed:

(1) Policymakers may allocate resources for regular inspections and enforcement activities to ensure adherence to sustainability requirements at construction sites. Moreover, policymakers may establish certification and accreditation programs for construction supervisors and managers to verify their competence in overseeing sustainable construction projects.

(2) Practitioners may implement robust quality assurance processes to ensure the meeting of sustainable construction specifications and standards throughout the project lifecycle. In addition, they may establish mechanisms for regular monitoring and reporting of sustainability performance metrics, such as energy consumption and waste generation.

(3) Researchers may use technology solutions such as building information modeling (BIM), remote sensing, and real-time monitoring systems to improve supervision and control of sustainable construction activities. They may develop metrics and indicators to assess the effectiveness of supervision and control mechanisms in ensuring compliance with sustainability requirements and achieving desired outcomes.

"*Return on investment and financial bias (ROIFB)*" is the last CBF hindering the SC. The following practical implications can be offered to minimize the adverse effects:

1. Policymakers would provide financial incentives such as tax credits, grants, subsidies, and low-interest loans for sustainable construction projects to offset initial investment costs and encourage adoption. Moreover, promoting green building certification programs such as LEED, BREEAM, and Green Star to signal the environmental and financial performance of sustainable construction projects to investors and stakeholders may be beneficial.
2. Practitioners may conduct a lifecycle cost analysis to compare the total costs of conventional construction versus sustainable construction over the entire building lifespan, considering energy efficiency, maintenance, and operational costs. Practitioners may also explore innovative financing mechanisms, such as green bonds, energy performance contracts, and incentives-based financing, to overcome upfront cost barriers and incentivize investment in sustainable construction.
3. Researchers may conduct longitudinal studies to assess the long-term financial performance and return on investment of sustainable construction projects, capturing lifecycle costs and benefits over time. In addition, they may develop financial models and decision-support tools to help stakeholders evaluate the financial viability and risk-return profiles of sustainable construction projects under different scenarios and assumptions.

### *6.3 Limitations and future research*

Despite the substantial endeavors undertaken in this research to make a substantial contribution to identifying critical barrier factors to SC, a few things could be improved. These limitations can be addressed in future research.

First, before organizing the questionnaire, SLR was conducted searching on WoS. Future studies may use a combination of two or more databases (such as SCOPUS, Google Scholar, etc.) to search for potential barriers to SC.

Second, the questionnaires were administered to the main occupational groups known in the construction industry, such as architects, engineers, and contractors. These professions were chosen because they are the main actors in the construction industry worldwide. However, for a more in-depth analysis, the perspective can be widened to include sub-contracting and super-contracting occupations and other related professions. Although Turkey is a valid example for developing countries, it may be helpful to make comparisons and generalizations. Therefore, comparing the same scale with a similar country would also extend the scope of this research.

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