Moving toward sustainability and circularity in hill road construction: A study of barriers, practices, and performance

Abstract

Purpose: This study explores the relationships among sustainability implementation barriers (resource, managerial, and regulatory barriers), sustainability practices (sustainable construction materials, sustainable construction design, modern construction methods, and environmental provisions and reporting), and sustainability performance (environmental, economic, and social) in hill road construction (HRC).

Design/methodology/approach: Primary data was collected from the 313 HRC practitioners with the help of a questionnaire, and research hypotheses were tested employing structural equation modeling.

Findings: The findings reveal a mixed effect of sustainability implementation barriers. Resource (managerial) barriers are negatively related to all practices except environmental provisions and reporting (sustainable construction materials), while regulatory barriers only negatively impact modern construction methods. On the other hand, all sustainability practices positively impact environmental performance, whereas economic (social) performance is positively influenced by all practices, except environmental provisions and reporting (modern construction methods), and positively affects economic performance.

Originality/value: In order to transform HRC toward sustainability, the barriers to sustainability implementation, sustainability practices, and performance need to be understood by practitioners; however, their relationships have not previously been empirically assessed in extant literature. Besides, past research appears to be predominantly focused on the environmental aspect, thereby neglecting economic and social aspects. This study is a modest attempt to bridge these research gaps.

Keywords: Construction industry, Waste management, Road infrastructure, Circular, Social performance

1. Introduction

Road infrastructure development fosters overall economic growth, enhances connectivity and accessibility, and reduces transportation costs (Gardoni and Murphy, 2020). However, hill road infrastructure development is complex and multidisciplinary, as hill road construction (HRC) differs from plain/ground road construction (RC) because it requires different planning and execution tactics (Hearn and Shakya, 2017). In this line, HRC is defined as the development of road networks in mountain regions. Thus, clearing forests, disposing construction spoil, rock blasting, and rerouting surface drainage systems for mountain road networks leads to landslides, floods, earthworks failures, and other geohazards (Bhandari, 2006; Hearn and Shakya, 2017). HRC is comparatively more responsible for adverse effects on ecological systems and human health than plain/ground road networks due to the discharge of atmospheric pollutants, forest loss, and energy consumption during a variety of processes (e.g., earthmoving, rock blasting, trucks transit on unpaved roads, crushing, material production, etc.) and the operation of diesel-powered equipment (Huang et al., 2013; McGuire, T.M., Morrall, 2000).

Recently, incorporating sustainability attributes in road design and construction processes considering all three aspects of sustainable development (i.e., environmental, economic, and social) has gained traction in research (Inti and Kumar, 2020). One of the first and most prevalent definitions considers sustainability as “development that meets the needs of the present without compromising the ability of future generations to meet their needs” (WCED, 1987). Starting from this definition, Pearce (1998) provides a dual definition of sustainability as “(1) development subject to a set of constraints which set resource harvest rates at levels not higher than managed natural regeneration rate, and (2) use of the environment as a waste sink on the basis that waste disposal rates should exceed rates of the managed or natural assimilative capacity of the ecosystem.” In line with an eco-business vision of the World Bank (1992), sustainability “means basing developmental and environmental policies on a comparison of costs and benefits and on careful economic analysis that will strengthen environmental protection and lead to rising and sustainable levels of welfare.” Similarly, Schmidheiny (1992) highlights that concept of sustainability “recognizes economic growth and environmental protection as are inextricably linked, and that the quality of present and future life rests on meeting basic human needs without destroying the environment upon which all life depends.” In recent years, additional definitions have been based on marketing and/or technological perspectives. As for the marketing perspective, Curtis and Walker (2001) declares that sustainability means balancing social, ethical, and environmental issues alongside economic factors within the product or service development process to ensure that the needs of both the business customer and society are met while protecting the ecosystem. As for the technological perspective, Vollenbroek (2002) highlights that sustainability relates to economic, ecological, and social developments. Possibilities to co-optimize these developments depend strongly on the availability of technologies, innovation strategies, and the institutional conditions set by government policies.

In this evolving scenario, researchers have stressed that adopting sustainability practices in RC can reduce up to 20% of greenhouse gas emissions (Lee and Madanat, 2017), 15% of agency costs, and 28% of user costs (Santos et al., 2017). Nevertheless, despite the existence of sustainable road implementation frameworks, their use is unclear and restricted (Ametepey et al., 2020). Moreover, in developing countries, many barriers (e.g., the lack of resources, workforce, adequate management, technology, etc.) restrict firms from attaining paramount sustainable RC performance (Pilger et al., 2020; Montoya-Alcaraz et al., 2020).

Theories and practices have been developed on sustainable RC. For instance, Giunta (2020) explored the environment al impacts of RC, and Karlsson et al. (2020) identified potential areas for reducing the same. Moretti et al. (2018) evaluated the impact of RC activities on human health. However, few researchers have proposed a sustainable road design model using a multi-objective optimization approach (Inti and Kumar, 2020). Wei et al. (2019) estimated and compared the environmental efficiency of the “Belt and Road” (B&R) and non-B&R initiative countries and further analyzed their environmental efficiency. Researchers additionally reviewed applying life cycle assessment (LCA) in RC (Balaguera et al., 2018). Furthermore, a case study was carried out to highlight the use of waste plastic materials for RC (Appiah et al., 2017). Sangiorgi et al. (2015) studied the performance of recycled waste materials. These studies have collectively made a noteworthy contribution to the development of state-of-art RC.

Nevertheless, the majority of the literature represents highway-based RC. No study represents sustainable HRC. Specifically, the literature lacks an investigation that underlines sustainability implementation barriers, sustainability practices, environmental performance, economic performance, and social performance, and their interrelationships with HRC. Findings of previous research have also claimed that in emerging economies, HRC tends to act as a catalyst for rapid and often unplanned and unregulated development in its corridor, and this can have unprecedented levels of impact (Hearn 2015). Therefore, this study aims to uncover the various barriers restricting the implementation of sustainable practices in HRC, sustainable HRC practices, and sustainable performance (environmental, economic, and social) and further test hypothesized relationships with regard to what extent sustainability implementation barriers restrict firms from implementing different types of sustainability practices and different sustainability practices impact sustainability performance.

With these premises, this study focuses on the HRC in India as RC is challenging due to rough terrain, inclement weather, budgetary constraints, and the lack of skilled workforce, among other factors (Inti and Kumar, 2020). India produces the third-highest carbon emissions, following China and the United States (International Energy Agency, 2016), and its emissions have risen by a 5.1% rate (PBL Netherlands Environmental Assessment International Energy Agency, 2016). Furthermore, the Indian Government continuously focuses on widening existing construction and developing new roads in hill areas (Quintero 2016). Thus, it can be inferred that there will be more emissions and waste if more unsustainable HRC exists. Besides, approximately 30% of the world's landslides occur in India, with the highest number of landslides (Ministry of Home Affairs 2011) due to human intervention (Zhang et al., 2012), and hill construction costs and delays in completing projects are significantly high in India (Kumar and Rao, 2014). Furthermore, constructing thousands of kilometers of roads around hills is causing heavy damage to the natural slopes and environment as a result of the ensuing quarrying and blasting (Inti and Kumar, 2020). Therefore, the sustainable management of hill roads is of utmost importance and will ensure paramount sustainable RC performance.

This article is structured in the following manner: Section 2 discusses the theoretical background and formulation of the hypotheses. Subsequently, the research methodology is elaborated in Section 3, followed by the data analysis and interpretation in Section 4. Finally, Section 5 reports the discussion and implications followed by the limitations of the study and future research avenues in Section 6.

2. Theoretical background and hypotheses development

2.1. Theoretical background

Previous research has emphasized that the rise of sustainability has offered new opportunities and represented a unique view of sustainable development (Inti and Kumar, 2020). After an initial period wherein an environmental outlook dominated the sustainability literature, the triple bottom line became the prevailing perspective. Policy makers, at a special United Nations summit held on 25 September 2015, defined the 2030 agenda for sustainable development and sustainable development goals (SDGs) and declared that "for sustainable development to be achieved, it is crucial to harmonize three core elements: economic growth, social inclusion, and environmental protection. These elements are interconnected, and all are crucial for the well-being of individuals and societies." Given this background, sustainability in the construction domain is becoming one of the most prevalent research topics in management literature, with several papers being published every year.

In pursuing sustainable development, HRC firms must integrate all aspects (i.e., environmental, economic, and social) into policies and actual practices (Suprayoga et al., 2020). Indeed, the shortage of supply of non-renewable materials, increasing costs of materials, and negative impact of non-renewable resources on the environment and society are encouraging scholars to explore relevant and sustainable solutions to overcome these concerns (Balubaid et al., 2015). Nevertheless, attaining a comprehensive level of sustainability is tedious due to scarce resources and sectoral fragmentation (Shashi et al., 2019). In addition, landslides, harsh climatic conditions, reduced working periods, non-availability of sustainable construction materials (Senouci et al., 2016; Hasan and Zhang, 2016; Davies and Davies, 2017), high initial costs, lack of knowledge, technological difficulties (Opoku et al., 2019), poor estimation, and unforeseen site conditions (Halwatura et al., 2013) are significant challenges which increase construction costs due to delays in execution. Likewise, political corruption is another factor that negatively impacts HRC (Lehne et al., 2018). Recently, researchers proposed a theoretical framework comprising sustainability issues to handle various construction-related challenges (Cruz et al., 2019). Zammataro (2010) reported that different performance measurements and comparative analyses of construction materials could improve sustainable performance. Likewise, optimizing mass-haul activities can confine the emission rate.

On the other hand, merely implementing sustainability practices of focal construction firms, which is essential, is not adequate; overseeing contractors' performance has equal importance. The selection of the right contractors can foster a firm's overall performance. However, many factors impact contractors' selection, such as costs, resources, technology, expertise, and so on (Fernando and Guppy, 2006). Hasnain et al. (2018) used an analytical network process and proposed selection benchmarks for contractors. Besides, as compared to other firms, sustainable procurement practices among construction firms are very limited (Ruparathna and Hewage, 2015). Therefore, construction firms do not consider them in their procurement strategies (Islam et al., 2017). Recently, Metham et al. (2019) developed the "Green Road Incentive Procurement" to incentivize contractors to adopt and implement sustainable construction methods. Additionally, a sustainable procurement-based framework for the multi-stages of RC is being developed (Agbesi et al., 2018). Furthermore, Thompson and Sessions (2010) classified the benefits of recycling materials.

A few researchers claim that environmental management systems positively impact the environment, but their mere implementation may not guarantee paramount performance (Lam and Yu, 2011). This indicates the necessity of including other systems (e.g., innovation, training, benchmarking, performance evaluation, etc.). In the literature, evidence of employing linear programming about the associations among productivity, costs, and emissions during earthmoving operations also exists (Kaboli and Carmichael, 2014). Avetisyan et al. (2012) offered a decision model for selecting appropriate construction equipment. Kamali and Hewage (2017) proposed a model to choose suitable metrics for assessing life cycle sustainability in construction projects. According to Asmar et al. (2011), measuring accurate costs in RC projects has an immense role in assisting in the comparison of multiple projects. Still, inadequate project planning, implementation of shortcuts, and improper site investigations are a few factors that negatively impact the accuracy of the same (Akinradewo et al., 2020). Nikakhtar et al. (2015) stressed that implementing lean principles could confine the construction waste rate. Further, research divides construction-related surroundings into two groups: macro and micro (UKEssays, 2018). More specifically, the functionality of construction enterprises is influenced by the microenvironment elements (such as the workforce, collaborators, availability of resources, shareholders, etc.), which impacts their productivity. Additionally, the macro-environment is broader and is made up of external variables (such as natural and physical forces, political and legal issues, technology advancements, economic reasons, etc.) that affect all construction companies' activities (Huang et al., 2013; Hearn and Shakya, 2017; Inti and Tandon, 2021; Fitriani and Ajayi, 2022).

Furthermore, the literature also discusses and develops innovative technologies to transform RC more sustainably. Robinson et al. (2016) stated that technology-enabled processes rooted in the construction itself provide a unique extent of integration across the built environment, its planning, design, production, maintenance, and use. For instance, Kuenzel et al. (2016) clarified, using the decision theory, machine learning, and distributed artificial intelligence, a multi-agent system for asphalt RC can be designed and evaluated. Sjöö and Frishammar (2019) provided significant implications for developing and commercializing sustainable technologies. Further, considering the life cycle, the literature proposes a Building Information Modeling-based methodology for evaluating negative ecological impacts in RC through different phases (e.g., manufacturing, transportation, construction, maintenance, operational, recycling, and deconstruction) (Marzouk et al., 2017). Jang et al. (2015) designed a quantitative decision-making framework to support the application of environment-friendly technologies during RC. Mahamid (2011) underlined the risk matrix for factors causing time delays in RC, and Khair et al. (2018) proposed a vital framework to reduce such delays. Mahamid (2018) found a significant direct association between cost overrun and labor productivity in base works of RC. Zavadskas et al. (2010) presented a risk assessment model for construction projects.

Li and Chen (2012) argued that the road infrastructure development approach should consider social needs and the sustainability of economic development. Recently, researchers have analyzed the interactions among factors affecting social sustainability (Rostamnezhad et al., 2020). Likewise, Chasey and Agrawal (2012) examined diverse concerns in the RC life cycle that influence the execution of social sustainability. Siew et al. (2013) claimed that most construction firms exhibit low levels of environmental reporting. Suprayoga et al. (2020) emphasized the efficiency of resources (both materials and energy) used in RC and underlined the significance of the concerned road's resiliency. This implies that roads should be able to tackle the problems arising from climate and other natural disasters (Csete and Buzasi, 2016).

This study uses the resource-based theory (RBT) (Barney, 1991; Lee and Grewal, 2004) as its theoretical framework of reference. According to RBT, any resource of a firm facilitates its performance and competitive advantage when it is valuable, rare, imperfectly imitable, and exploitable by the firm (Barney, 1991; Lee and Grewal, 2004). A valuable resource improves a firm's bottom line or "generates something of value to the customer that competitors cannot achieve" (Erevelles et al., 2016, p. 898). A rare resource "is not abundant" (Erevelles et al., 2016, p. 898). Further, an imperfectly imitable resource means that "the resource cannot be easily copied" (Erevelles et al., 2016). Finally, an exploitable resource "enables a firm to take advantage of the resource in a way that others cannot" (Erevelles et al., 2016, p. 898). Past literature emphasized that sustainability, in general, can create a sustainable competitive advantage that is valuable, rare, difficult to imitate, and exploitable by organizations (Willard, 2009, 2012; Belz and Peattie, 2012; Ertz, 2021). Sustainable construction can be valuable, rare, imperfectly imitated, and exploitable, constituting a resource to create superior value for firms economically, environmentally, and socially.

2.2. Hypotheses development

2.2.1. Impact of sustainability implementation barriers on sustainable construction practices

According to Balasubramanian and Shukla (2017), the extent of the implementation of sustainable practices depends on several barriers. In this line, numerous barriers restrict the implementation of sustainable HRC practices, which are significantly higher in developing countries than in developed countries (Hussain et al., 2019). RBT stipulates that resources include physical capital, human capital, and organizational capital resources (Barney, 1991). Therefore, in this study, we consider three generic types of barriers: resources, managerial, and regulatory. Likewise, the literature reports four sustainability practices in HRC: sustainable construction materials, sustainable construction design, modern construction methods, environmental provision and reporting (Reutela and Pant, 2007; Alli et al., 2018). Ritzén and Sandström (2017) reported that implementing sustainability practices is a complicated multidimensional domain. However, innovative technologies and sustainable practices improve competitive capabilities, and HRC firms with efficient resource capabilities tend to adopt more sustainability practices (Bamgbade et al., 2019). Nevertheless, despite the number of benefits associated with implementing sustainable practices, construction firms are continuously struggling to implement those practices as they cost more than conventional practices, but only result in a slight improvement in construction processes (Hussain et al., 2019). The lack of design and construction teams, incentives, and training, and the investment risks among consultant and contractor firms are other reasons for stakeholders' reluctance (Opoku et al*.,* 2015). Sustainable construction's physical capital resources refer to the guidelines, procedures, software, systems, tools, and equipment to implement sustainable construction. Consequently, a lack of those resources might hinder the effective implementation of sustainable construction (Chang et al., 2016). Berardi (2013) recommended that a lack of stakeholders' relationships restricts them from resource sharing and makes sustainability implementation difficult.

H1: Resource barriers negatively impact the use of: (a) sustainable construction materials, (b) sustainable construction design, (c) modern construction methods, and (d) environmental provisions and reporting.

Human capital resources include insights from executives and managers to implement new methods and ways of approaching construction. Engineers, project managers, and other relevant professionals who are experienced in construction can infuse sustainable practices into their operations (Shokri-Ghasabeh and Chileshe, 2014; Nayak et al., 2017). In addition to human capital resources, a close construct refers to organizational capital resources, which refer to an organizational structure that enables a firm to transform its current practices into more sustainable practices. This means that sustainable HRC will become part of the firm's long-term business strategy and the mechanisms (i.e., processes, procedures, policies, corporate culture, and organizational structure/governance) to facilitate business alignment with such strategy (Hussain et al., 2017). A lack of human and organizational capital resources means sustainable construction practices will be significantly hindered (Fitrian and Ajayi, 2022). A lack of knowledge and awareness about sustainable methods makes firms reluctant to apply sustainable RC concepts (Zainul-Abidin, 2010). Besides, uninterested stakeholders often ignore regulatory sustainability, thereby resulting in its unsuccessful implementation (Berardi, 2013). Therefore, we posit that:

H2: Managerial barriers negatively impact the use of: (a) sustainable construction materials, (b) sustainable construction design, (c) modern construction methods, and (d) environmental provisions and reporting.

In addition to the micro-environmental factors derived from RBT (Barney, 1991; Lee and Grewal, 2004) and considered as barriers, macro-environmental regulatory factors play a crucial role in HRC since this is a heavily regulated industry. For example, materials, fire codes, or zoning need to conform to specific regulations (Shleifer, 2005). However, while regulation, control, and economic incentives might favor sustainable construction, past research has also shown that a large part of the regulation could also be detrimental to sustainability in construction (Pham and Kim, 2019). In fact, regulation is necessary when clients and providers are unlikely to conform to some rules due to additional costs, investments, or efforts needed on their behalf (Raynsford, 2000). For instance, additional costs required to conform to regulations will not be spent or invested in improving sustainable practices (Gan et al., 2015). In other words, those increased costs are the most significant barriers to green construction (Gan et al., 2015). Moreover, the impact is all the more detrimental when regulation is not aimed at increasing sustainability but at settling conflicts or regulating the status quo without encouraging organizations to implement more sustainable practices (Shi et al., 2012). Recently, Pham and Kim (2019) emphasized that fiscal and regulatory frameworks should be better utilized to achieve sustainable policy objectives, and incentives should be given to encourage the clients to adopt sustainable approaches in HRC. Hussain et al. (2019) highlighted that an unstable political environment, sustainability unawareness, and a lack of government policy top leadership support prevent the adoption and execution of green, lean, and the "Six Sigma" practices in the RC process. In such cases, regulation becomes a barrier, and we posit that:

H3: Regulatory barriers negatively impact the use of: (a) sustainable construction materials, (b) sustainable construction design, (c) modern construction methods, and (d) environmental provisions and reporting.

2.2. 2. Impact of sustainable construction practices on sustainable performance

Sustainability performance represents the conventional triple bottom line perspective (Elkington, 2013), including environmental, economic, and social performance. HRC construction results in environmental damage in terms of generating more noise, dust, and waste, and consuming a large quantity of energy resources throughout a project life cycle (Son et al., 2011). Thus, sustainable practices should be implemented from the time of project planning to its demolition phase (Pham and Kim, 2019). Researchers strongly advocated that implementing sustainability HRC practices can provide numerous benefits, such as reduced waste rate, enhanced human development, risk mitigation, and improved market access (Robinson et al., 2006). Furthermore, a sustainability strategy can facilitate HRC firms in fostering environmental competencies and building a better social image, resulting in enhanced performance (Adetunji et al., 2003). Empirical evidence also supports that firms that often execute sustainable HRC practices have better profitability and increased productivity through a higher level of employee satisfaction, mitigated environmental effects, and improved social image (Pham and Kim, 2019). Subsequently, sustainable construction designs help reduce travel lead time, save energy resources, reduce costs, and preserve local ecological biodiversity (Chang et al., 2016). Besides, unsustainable material choice, outdated construction methods, and ineffective designs negatively influence the environment (e.g., air, soil, and water quality) and society (Singh, 2007). Researchers have emphasized that using sustainable materials and modern methods under the lean and green philosophy can positively impact the environmental and economic outcomes of a firm (Shashi et al., 2019; Sangwa and Sangwan, 2022a).

Furthermore, it is worth mentioning that sustainable HRC practices are not only beneficial from environmental and financial viewpoints, but can also have a significant social impact on rural areas through safer and more secure constructions (Fatourehchi and Zarghami, 2020). Likewise, value management-based practices can provide satisfactory economic returns, accountability, and excellence in social and ecological performance (Pitt et al., 2009; Sangwa and Sangwan, 2022b). Therefore, we expect a positive impact of sustainable construction dimensions (i.e., sustainable construction material, sustainable construction design, modern construction methods) on sustainable performance, defined as both environmental and social performance (Dalal-Clayton, 1994):

H4: (a) Sustainable construction materials, (b) sustainable construction design, (c) modern construction methods, and (d) environmental provisions and reporting, positively impact environmental performance.

H5: (a) Sustainable construction materials, (b) sustainable construction design, (c) modern construction methods, and (d) environmental provisions and reporting positively impact social performance.

In keeping with the findings of Dalal-Clayton (1994), sustainability also has an economic dimension, meaning that sustainable construction should also be "economically viable by paying for itself with costs not exceeding income" (Shokouhyar et al., 2021). Yet, the ecological focus of sustainable construction brings inherent economic benefits. In fact, reducing carbon emissions due to reduced fuel consumption (Hughes et al., 2011) and reduced use of natural resources due to optimization of road width (Alamgir et al., 2017) will positively influence economic performance. Therefore, we further posit that there is a positive influence of different construction dimensions (i.e., sustainable construction material, sustainable construction design, modern construction methods, and environmental provisions and reporting) on sustainable performance in terms of economic performance as follows:

H6: (a) Sustainable construction materials, (b) sustainable construction design, (c) modern construction methods, and (d) environmental provisions and reporting positively impact economic performance.

2.2.3. Impact of environmental performance and social performance on economic performance

Although environmental performance should not be implemented solely for instrumental reasons and extrinsic motives such as profit, it should be mentioned that environmental performance often brings substantial benefits that result in strategic and tactic advantages, which may reverberate in enhanced economic performance (Shashi et al., 2019). For example, according to Martin and Schouten (2012), the contribution of environmental performance to economic performance occurs through heightened competitive advantage, which arises through several levers, including cost reduction, differentiation (through sustainability), innovation, development of human capital, and staying ahead of environmental regulation. Likewise, Willard (2009, 2012) posited that responsible advantage is crucially related to enhanced competitive advantage, translating into decreased costs and increased revenues. This occurs, more specifically, through reduced energy, waste, and water expenses, and reduced materials.

In a similar vein, Simão and Lisboa (2017) showed how green marketing and green branding bolsters multiple benefits, including "cost reduction (due to the lower resource consumption, such as water or energy), profit increase (from recycling and residuals reuse), production process enhancement (given the cleaner and more efficient technologies), corporate image upgrading, improvement of brand awareness and value as well as performance" (p. 183).

Consequently, it is fair to deduce that higher environmental performance leads to higher economic performance (Mallick et al., 2014). Environmentally and socially sound HRC can reduce the costs associated with maintenance and repair (Shi et al., 2012). Furthermore, the reduction, recycling, and reuse of construction materials assist in attaining a closed loop of material flow. The consequential reduction of construction and demolition waste ultimately leads to paramount economic performance (Schultmann and Sunke, 2007; Shi et al., 2012). Besides, Reutela and Pant (2007) stressed that sustainable HRC reduction helps reduce road accident rates and the associated loss of human lives, saving their costs for related settlements. Hysa et al. (2020) referred that HRC facilitates connecting rural and urban areas, thereby increasing job opportunities and a region's prosperity. A strong relationship between local residents and HRC firms might lower the rate of conflicts between them, resulting in lower conflict handling costs. Finally, social performance, like saving travel time, saving road users' costs, and reducing the number of road accidents that come inherently with sustainable construction (Zuo et al., 2012), will positively influence economic performance. Therefore, we posit the following:

H7: Environmental performance positively impacts economic performance.

H8: Social performance positively impacts economic performance.

Figure 1 shows the conceptual model under study.

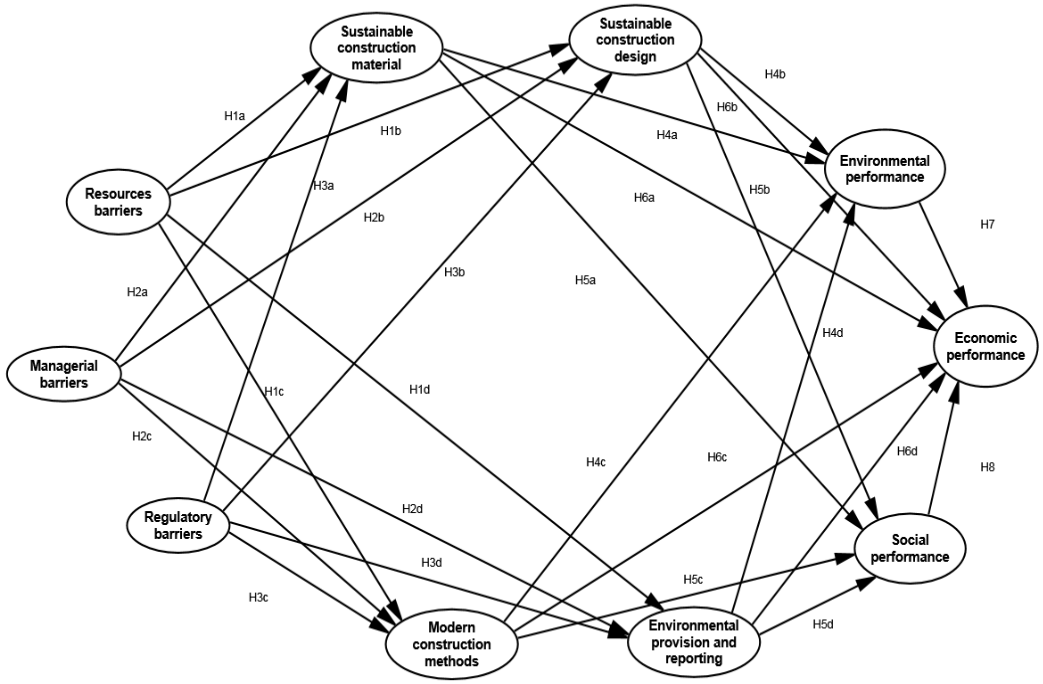

Figure 1: The proposed conceptual model

3. Research methodology

3.1. Procedure and participation

We conducted a field survey-based questionnaire to collect data and evaluate the proposed research hypotheses. A thorough literature review and in-depth discussions with HRC experts were carried out for the development of the survey questionnaire. The first draft of the survey questionnaire was initially forwarded to seven academics and eight HRC experts to ensure the clarity of all measurement items and for possible additions. The survey questionnaire was revised based on their valuable feedback, and a few other important measurement items were added to the questionnaire. Notably, minor changes were also made in the language of the questions to match the HRC context. Subsequently, the revised questionnaire was sent back to the same panel to validate the changes made in the questionnaire. Next, a pilot test was carried out involving 15 HRC practitioners. We asked them to illustrate any confusion and unclarity in the layout, measurement questions, and instructions, which consequently contributed in the form of minor improvements. Contact was made with critical practitioners using the snowball sampling approach. The investigation aim was demonstrated before forwarding the questionnaires to obtain their preliminary consent to participate in the survey (Yu et al., 2013). Informants were assured of maintaining the confidentiality of their responses. Only 539 hill road practitioners showed interest in the survey. Before beginning the survey, all participants were informed that the survey was entirely anonymous and voluntary and would be exclusively used for scientific purposes. Participation in the survey took place from the firms working in RC projects in Indian Himalayan ranges.

The questionnaire and a cover letter reporting the aim of the investigation were sent to interested practitioners involved in HRC through different channels, such as by email and post, or through personal visits, to optimize the response rate and lessen the possibilities of biases arising due to the consideration of a single survey data collection procedure (Dillman, 2000). Besides, according to past research, there are no significant differences in participants' responses across different survey modes (e.g., online, in-person) (Greenlaw and Brown-Welty, 2009). Further, two telephone and email-based reminders spaced by two weeks were sent to each non-respondent.

After discarding incomplete observations, a total of 313 usable questionnaires were included in the analysis, that is, a 58.07% response rate. In this regard, it should be noted that Dillman (2000) has reported that a survey response rate above 16% is acceptable. In the past literature, several researchers have suggested that the minimum survey response rate should be at least 16% (Dillman, 2000) or 20% in the empirical research in the operations management domain (O'Leary-Kelly and Vokurka, 1998; Shashi et al., 2019). Further, the researchers evaluated 1607 empirical articles from 17 sources and revealed 35.8% as the average response rate. Therefore, a 58.07% response rate can be deemed satisfactory for statistical inference. Furthermore, as Tripathy et al. (2016) indicated, the sample size representing the population in this study as the total usable responses are above 100.

Demographic information about the participants can be seen in Table 1, which summarizes respondents' characteristics, including occupation, professional role, appointment, qualification, education, and experience in HRC. The majority of respondents belong to the following categories: project owners (36%), consultant (11%), contractors (9%), advisor (3%), academicians/scientist/ researcher (10%), and others (31%). The majority of respondents were working as the following: project manager/EE/AEE or equivalent (30%), managing director/chief engineer or equivalent (10%), project director/SE or equivalent (20%), site engineer/junior engineer, or equivalent (15%), and others (25%). As for their educational backgrounds, they consisted of BE/BTech/AMIE (33%), ME/MTech (23%), diploma (17%), PhD (5%), and others (22%). Lastly, regarding work experience, the respondents have above 25 years (24%), up to 5 years (14%), 6-10 years (20%), 11-15 years (20%), and 16-30 years (22%).

Table 1: Characteristics of respondents

Title	Percentage
Professional Role	**%**
Project owners	36
Consultant/working on behalf of a consultant	11
Contractor/working on behalf of a contractor	9
Advisor/proof check consultant	3
Academicians/scientist/ researcher	10
Others	31
Respondent's Appointment	**%**
Managing director/chief engineer or equivalent	10
Project director/SE or equivalent	20
Project manager/EE/AEE or equivalent	30
Site engineer/Junior engineer or equivalent	15
Others	25

Educational Qualification	**%**
Diploma	17
BE/BTech/AMIE	33
ME/MTech	23
PhD	5
Others	22
Experience in hill road construction	**%**
Up to 5 years	14
6-10 years	20
11-15 years	20
16-25 years	22
Above 25 years	24

3.2. Non-response bias

In the literature, researchers have underlined that late returned survey responses show the opinion of non-respondents or can also be denoted as unwilling responses (Armstrong and Overton, 1977). Therefore, to measure the possible bias in received responses, we classified the responses into two groups: early and late. Subsequently, we relied on multiple methods. Initially, we determined the dissimilarities in the characteristics of early (187) versus late (126) responses by employing a t-test (Armstrong and Overton, 1977). The analysis did not confirm statistical dissimilates on any of the variables between the two groups. Subsequently, for further clarification, we carried out a small-scale survey by engaging non-respondents. Consequently, 31 responses were received in return. This response group was compared to the entire response group. The results again revealed no statistically proven dissimilates. Evidently, in this study, the bias mentioned above was not considered a problematic issue.

3.3. Common method bias

Richardson et al. (2009) defined common method bias (CMB) as "systematic error variance shared among measured variables caused by the function of the same method or source." It is often with a cross-sectional survey for data gathering (Guide and Ketokivi, 2015). It is mainly caused by adopting a single-method research design and social desirability associated with answering questions. Harman's single-factor test was initially approached to assess this issue, and all study variables were subject to exploratory factor analysis (EFA) (Podsakoff et al., 2003). CMB is supposed to exist either when: (1) an EFA extracts a single factor consisting of all the variables under study or (2) the first extracted factor demonstrates the majority of variance (above 50%) (Podsakoff and Organ, 1986; Doty and Glick, 1998). The EFA extracted eight unique factors cumulatively, explaining a 78% variance. However, the first extracted factor explained a 30% variance, which was not the majority. This galvanizes that CMB was not an issue (Podsakoff et al., 2003).

Subsequently, this was confirmed using the common latent factor approach (Podsakoff et al., 2012). A confirmatory factor analysis (CFA) was performed, and two models were developed: with and without single common factor models. The standardized regression weights of both models were compared to assess the related dissimilarities. The findings revealed no statistically proven regression weights' dissimilarities below 0.2, as Doluca et al. (2018) recommended. This provides confidence that CMB is not an issue in this investigation (Shashi et al., 2019).

3.4. Measures

The field survey consists of two sections. The first section of the questionnaire contains three scales measuring the constructs of the conceptual model. Resources, managerial, and regulatory barriers to the implementation of sustainability practices in HRC projects were measured with a 21-item scale adapted from various sources, namely Pitt et al. (2009), Serpell et al. (2013), Shokri-Ghasabeh and Chileshe (2014), Shang et al. (2021), and Fitrian and Ajayi (2022). The level of implementation of sustainability practices (i.e., sustainable construction materials, sustainable construction design, modern construction methods, environmental provision and reporting) was measured with a 24-item scale adapted from multiple sources such as Tan et al. (20211), Armstrong and Davis (2013), Huang et al., (2013), Hearn and Shakya (2018), McGuire and Morrall (2020), and Aranda et al. (2021). Finally, the sustainable performance of the organization was assessed with a three-dimensional scale comprising six items for the economic dimension adapted from Shi et al. (2012), Shen et al. (2007), Devkota et al. (2019), Pham and Kim (2019), and Inti and Tandon (2021), seven items for the environmental dimension from Shi et al. (2012), Pham and Kim (2019), and Inti and Tandon (2021), and eight items for the social dimension were adapted form Shen et al. (2011), Zuo et al. (2012), Sudmeier-Rieux et al. (2019), and Devkota et al. (2019). For all those constructs, the respondents were required to indicate their level of agreement with a total of 21 items on a 5-point scale ranging from "strongly disagree" (1) to "strongly agree" (5). In addition, the respondents were asked about their demographic characteristics in the second part of the survey.

4. Data analysis

4.1. Measurement model

Generally, a measurement model is first tested using an EFA, and then an investigation of the validity and reliability of the model constructs are carried out through a CFA, as well as related tests (Centobelli et al., 2021; Choudhary et al., 2022). In the literature, researchers have suggested the application of an EFA before a CFA even if the measurement items are adapted from established scales, as the prior expectations demonstrating initial theoretical constructs can be inaccurate (Jadhav et al., 2019).

4.1.1. Exploratory factor analysis (EFA)

We employed an EFA to uncover the real rather than theory-based associations among scale items. In this line, attempts were made to underline a construct of a tight group of strongly associated scale items (Jadhav et al., 2019). We followed the guidelines proposed by Hair et al. (2010) for conducting the EFA. Three EFAs were carried out to examine the three constructs of sustainability barriers, sustainable construction practices, and sustainable performance, as these three represent diverse themes (Shashi et al., 2017). The following guidelines were used for the acceptance of the model: 1) Cronbach's Alpha values should be above 0.7; 2) Kaiser–Meyer–Olkin (KMO) values should be above 0.8; 3) extracted communalities should be above 0.6; 4) the Eigenvalues should be equal to or above 1; and 5) item loadings should be above 0.6 (Nunnally and Bernstein, 1994; West et al., 2012). Table 2 (sustainability barriers),

Table 3 (sustainable construction practices), and Table 4 (sustainable performance) report the EFA results. The analysis extracted three sustainability barriers dimensions: resource barriers, managerial barriers, and regulatory barriers, which together explain 69.39% of the overall variance (Table 2). A further analysis extracted the four dimensions of sustainable construction implementation: modern construction methods, sustainable construction materials, sustainable construction design, as well as environmental provisions and reporting, which altogether accounted for 71.42% of the overall variance (Table 3). Finally, an EFA extracted the three expected dimensions of sustainable performance: social performance, economic performance, and environmental performance, which collectively account for 71.45% of the overall variance (Table 4). All the extracted factors have an Eigenvalue above 1, item loadings above 0.6, and Cronbach's Alpha value above 0.7. Likewise, extracted communalities are above 0.6, and the KMOs for all dimensions are above 0.8, satisfying all the suggested thresholds.

Table 2: Sustainability barriers

Extracted Factors	**No. of items**	**Extracted Communalities**	**Factor Loadings**	**Eigen**	**Variance**	**α**	**KMO**
Resource barriers	9	0.796-0.613	0.830-0.709	10.15	29.47	0.947	
Managerial barriers	8	0.788-0.606	0.844-0.630	2.39	26.02	0.929	0.955
Regulatory barriers	4	0.718-0.668	0.828-0.748	2.02	13.90	0.853	

Note: α = Cronbach's Alpha.

Table 3: Sustainable construction practices

Extracted Factors	**No. of items**	**Extracted Communalities**	**Factor Loadings**	**Eigenvalues**	**Variance**	**α**	**KMO**
Modern construction methods	8	0.817-0.636	0.889-0.778	8.33	24.51	0.946	
Sustainable construction materials	5	0.833-0.710	0.897-0.817	3.43	16.34	0.928	0.913
Sustainable construction design	6	0.711-0.606	0.825-0.716	2.97	15.92	0.881	
Environmental provisions and reporting	5	0.734-0.679	0.843-0.787	2.41	14.66	0.892	

Note: α = Cronbach's Alpha.

Table 4: Sustainable performance

Extracted Factors	**No. of items**	**Extracted Communalities**	**Factor Loadings**	**Eigenvalues**	**Variance**	**α**	**KMO**
Social performance	8	0.727-0.604	0.833-0.714	9.51	26.18	0.933	
Economic performance	7	0.832-0.690	0.878-0.786	3.48	25.21	0.949	0.952

Environment performance	6	0.747-0.627	0.830-0.728	2.01	20.06	0.810	

Note: α = Cronbach's Alpha.

4.1.2. Measurement model's reliability and validity

To test the reliability, a three-step procedure was used. Initially, an EFA was applied to confirm the constructs' unidimensionality. The results in Tables 2, 3, and 4 reveal that all items had higher factor loadings on the construct they were supposed to load and had low cross-loadings on other factors, indicating unidimensionality. Subsequently, Cronbach's Alphas and corrected item-total correlation (CITC) were assessed. The Alpha values exceeded the threshold of 0.70 (Nunnally and Bernstein, 1994), and CICT values were above 0.3 (Kerlinger, 1986), indicating the reliability of the constructs (Hair et al., 2010). Additionally, the KMO measures are all higher than 0.5, and all Bartlett's tests of sphericity have *p* values smaller than 0.01.

Convergent validity was assessed employing a CFA, and all measurement items were linked to their relevant construct, while covariance was freely measured. According to past literature, three parameters ensure convergent validity: 1) items loading above 0.5; 2) Coefficient of Reliability (CR) above 0.7; and 3) Average Variance Extracted (AVE) for each construct, higher than the measurement error variance (Fornell and Larcker, 1981; Shashi et al., 2019).

Past literature claims that, for the measurement model, Chi-square/Df should be less than 3, GFI, IFI, TLI, and CFI should be above 0.8 (above 0.9 shows excellent fit), and RMSEA should be less than 0.05 (Cerchione et al., 2018). The CFA results indicate a satisfactory global fit of the measurement model (Chi-square/Df = 1.43, GFI = 0.835, IFI = 0.944, TLI = 0.941, CFI = 0.944 and RMSEA = 0.037), suggesting that the data aligns well with the measurement model (Hair et al., 2010). Additionally, the factor loadings are above 0.5 for all items, the CR values are above 0.7, and the AVE for each construct is higher than the measurement error variance, indicating that convergent validity is secured (see Table 6) (Centobelli et al., 2021).

The discriminant validity of the constructs was tested in order to evaluate to what extent one construct differs from others in the measurement model (Hulland, 1999). Researchers have recommended two statistical tests in this regard: the maximum shared variance (MSV) should be comparatively less than the AVE; and 2) the square root of each construct's AVE should be higher than all other inter-construct correlations (Hair et al., 2010). The results depicted in Table 6 demonstrate that MSV values are less than AVE values and that the square root of each construct's AVE is higher than any other inter-construct correlations involving that construct. The items within each construct are more firmly correlated than with items from other constructs satisfying the conditions of discriminant validity.

After confirming the validities mentioned above, we assessed the measurement model to identify the possible problems in the model as the majority of mainly considered global fit indices highly rely upon the power of the test, and the measurement model was checked for misspecifications (Saris et al., 2009). Accordingly, modification indices (MI), expected parameter changes (EPC), and the power of the MI test were taken into account (Van der Veld et al., 2009; Centobelli et al., 2021). The results highlighted the absence of misspecifications in the model, and thus, the measurement model remained unaltered with the fit index of the model mentioned above.

Table 5: Measurement model's results

Latent variable	Item	λ	Latent variable	Item	λ

Resource barriers	B5	0.81	Sustainable construction materials	P7	0.83
	B9	0.77		P8	0.86
	B11	0.79		P9	0.89
	B13	0.75		P10	0.83
	B16	0.81		P11	0.78
	B17	0.82	Sustainable construction design	P1	0.78
	B18	0.88		P2	0.67
	B19	0.83		P3	0.72
	B21	0.89		P4	0.76
Managerial barriers	B1	0.88		P5	0.68
	B2	0.81		P6	0.71
	B3	0.80	Modern construction methods	P13	0.80
	B4	0.83		P14	0.87
	B6	0.81		P15	0.84
	B7	0.78		P16	0.77
	B14	0.64		P17	0.82
	B15	0.79		P18	0.87
Regulatory barriers	B8	0.78		P19	0.88
	B10	0.76		P20	0.75
	B12	0.79	Environmental provision & reporting	P12	0.76
	B20	0.75		P21	0.77
Environmental performance	EN1	0.82		P22	0.83
	EN2	0.72		P23	0.81
	EN3	0.76		P24	0.78
	EN4	0.73	Social performance	SP1	0.81
	EN5	0.81		SP2	0.80
	EN6	0.80		SP3	0.83
Economic performance	EC1	0.83		SP4	0.68
	EC2	0.76		SP5	0.81
	EC3	0.88		SP6	0.82
	EC4	0.84		SP7	0.79
	EC5	0.85		SP8	0.80
	EC6	0.82			
	EC7	0.84			

Note: λ = Standardized Loadings.

Table 6: Validating the measurement of the CFA model

	CR	**AVE**	**MSV**	ECP	RB	MB	REGB	SCD	EPR	SCM	MCM	ENP	SP
ECP	0.949	0.728	0.371	**0.853**									
RB	0.947	0.667	0.392	-0.495	**0.817**								
MB	0.932	0.631	0.392	-0.534	0.626	**0.795**							
REGB	0.854	0.593	0.229	-0.342	0.479	0.445	**0.770**						
SCD	0.882	0.555	0.225	0.474	-0.422	-0.444	-0.336	**0.745**					
EPR	0.893	0.625	0.194	0.374	-0.288	-0.410	-0.208	0.371	**0.791**				
SCM	0.928	0.721	0.183	0.393	-0.428	-0.346	-0.316	0.286	0.271	**0.849**			
MCM	0.949	0.700	0.213	0.462	-0.349	-0.334	-0.304	0.362	0.279	0.299	**0.836**		
ENP	0.911	0.631	0.371	0.609	-0.343	-0.384	-0.313	0.368	0.441	0.365	0.426	**0.794**	

SP	0.933	0.635	0.180	0.424	-0.314	-0.417	-0.240	0.291	0.331	0.244	0.218	0.409	**0.797**

*Note***:** AVE = Average variance extracted; CR = Composite reliability; MSV = Maximum shared variance; ECP = Economic performance; RB = Resource barriers; MB = Managerial barriers; REGB = Regulatory barriers; SCD = Sustainable construction design; ERP = Environmental provisions and reporting; SCM = Sustainable construction materials; MCM = Modern construction methods; ENP = Environmental performance; SP = Social performance

4.2. Structural model testing

After confirming the constructs' reliability and validity, the structural model was evaluated. The structural model assesses the relationship between constructs and the model's predictive capabilities (Yadav et al., 2019). Accordingly, a structural equation modeling (SEM) approach with the Maximum Likelihood algorithm was used with the help of the AMOS Version 21 software in order to test the hypothesized model (Centobelli et al., 2021; Choudhary et al., 2022). Scholars recommended that there be at least 150 responses to consider the Maximum Likelihood method (Ding et al., 1995). Since the number of valid observations is above 300, the minimum condition of employing the method mentioned above is satisfied.

Figure 2 represents the structural model. The model reveals a good global fit to the data (CMIN/DF = 1.470, GFI = 0.822, IFI = 0.940, TLI = 0.936, CFI = 0.939, RMSEA = 0.039). Further, we tested the potency of standardized direct effect, standardized indirect effect, and standardized total effect taking standardized beta (β) into account, as suggested by Shashi et al. (2019) and Sakshi et al. (2020). The results of the test are reported in Table 7.

Hypotheses 1a-c, which posit that higher resource barriers decrease the use of sustainable construction material (H1a: β = -0.30, C.R. = -3.91, p = 0.000), the recourse to sustainable construction design (H1b: β = -0.20, C.R. = -2.57, p = 0.010), the use of modern construction methods (H1c: β = -0.18, C.R. = -2.31, p = 0.021), are all supported. However, the results further show that resource barriers do not hinder environmental provisions and reporting (H1d: β = -0.04, C.R. = -5.28, p = 0.597).

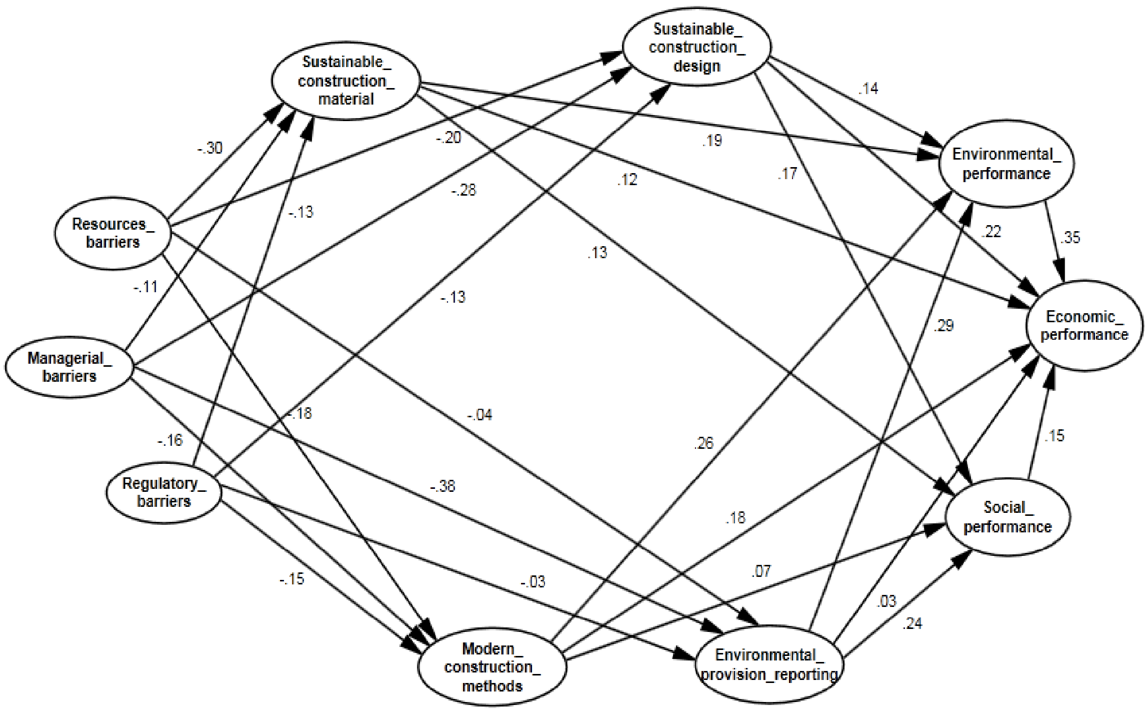

Figure 2: Structural model for HRC

Hypotheses 2b-d, postulate that higher managerial barriers dampen the recourse to sustainable construction design (H2b: β = -0.28, C.R. = -3.73, p = 0.000), the use of modern construction methods (H2c: total β = -0.16, C.R. = -2.18, p = 0.029), as well as environmental provisions and reporting (H2d: β = -0.38, C.R. = -4.79, p = 0.000), are all supported. However, the findings also suggest that higher managerial barriers do not limit the use of sustainable construction material (H2a: β = -0.11, C.R. = -1.46, p = 0.143), providing encouraging news but invalidating H2a.

Hypotheses 3a-b, which posit that higher regulatory barriers hinder the use of sustainable construction material, (H3a: β= -0.13, C.R. = -1.91, p = 0.056) and focus on sustainable construction design (H3b: β= -0.13, C.R. = -1.86, p = 0.062) are only marginally supported, as p value is lower than 0.100. Furthermore, the results support H3c (β= -0.15, C.R. = -2.21, p = 0.027), suggesting that regulatory barriers limit the use of modern construction methods. However, H3d, which inferred that higher regulatory barriers curb environmental provisions and reporting, was not supported (β= -0.03, C.R. = -0.47, p = 0.639).

Hypotheses 4a-d, which assert that environmental performance is positively influenced by the use of sustainable construction material (H4a: β= 0.19, C.R. = 3.36, p = 0.000), the recourse to sustainable construction design (H4b: β= 0.14, C.R. = 2.41, p = 0.016), the use of modern construction methods (H4c: β= 0.26, C.R. = 4.63, p = 0.000), as well as environmental provisions and reporting (H4d: β= 0.29, C.R. = 5.02, p = 0.000), are all supported.

In addition, social performance is positively influenced by the use of sustainable construction material (H5a: β= 0.13, C.R. = 2.10, p = 0.035), the recourse to sustainable construction design (H5b: β= 0.17, C.R. = 2.65, p = 0.008), as well as environmental provisions and reporting (H5d: β= 0.24, C.R. = 3.96, p = 0.000), but not by the use of modern construction methods (H5c: β= 0.07, C.R. = 1.21, p = 0.226). These results lend support to H5a-b and H5d but not to H5c.

Furthermore, economic performance is positively impacted by the use of sustainable construction materials (H6a: β= 0.21, C.R. = 2.46, p = 0.014), the recourse to sustainable construction design (H6b: β= 0.22, C.R. = 4.16, p = 0.000), and the use of modern construction methods (H6c: β= 0.18, C.R. = 3.50, p = 0.000), but not environmental provisions and reporting (H6d: β= 0.03, C.R. = 0.57, p = 0.571). These results collectively support H6a-c but not H6d.

Finally, the results provide strong support for accepting H7, stipulating that an enhanced environmental performance improves economic performance (β= 0.35, C.R. = 5.77, p = 0.000), and H8 which assumes that social performance improves economic performance (β= 0.15, C.R. = 3.02, p = 0.002).

Table 7: Hypotheses testing results

Note: *β* = Standardized path coefficients, C.R. = critical ratio, *p* = *p*-value.

Table 7: Hypotheses testing results

No.	Hypotheses	*β*	C.R.	*p*	Support
H1a	Resource barriers negatively impact the use of sustainable construction materials	-0.30	-3.91	0.000	Yes
H1b	Resource barriers negatively impact sustainable construction design	-0.20	-2.57	0.010	Yes
H1c	Resource barriers negatively impact the use of modern construction methods	-0.18	-2.31	0.021	Yes
H1d	Resource barriers negatively impact environmental provisions and reporting	-0.04	-0.528	0.597	No
H2a	Managerial barriers negatively impact the use of sustainable construction materials	-0.11	-1.463	0.143	No
H2b	Managerial barriers negatively impact sustainable construction design	-0.28	-3.73	0.000	Yes
H2c	Managerial barriers negatively impact the use of modern construction methods	-0.16	-2.18	0.029	Yes
H2d	Managerial barriers negatively impact environmental provisions and reporting	-0.38	-4.79	0.000	Yes
H3a	Regulatory barriers negatively impact the use of sustainable construction materials	-0.13	-1.91	0.056	No
H3b	Regulatory barriers negatively impact sustainable construction design	-0.13	-1.86	0.062	No
H3c	Regulatory barriers negatively impact the use of modern construction methods	-0.15	-2.21	0.027	Yes
H3d	Regulatory barriers negatively impact the environmental provisions and reporting	-0.03	-0.47	0.639	No
H4a	Sustainable construction material positively impacts environmental performance	0.19	3.36	0.000	Yes
H4b	Sustainable construction design positively impacts environmental performance	0.14	2.41	0.016	Yes
H4c	Modern construction methods positively impact environmental performance	0.26	4.63	0.000	Yes
H4d	Environmental provisions and reporting positively impact environmental performance	0.29	5.02	0.000	Yes
H5a	Sustainable construction material positively impacts social performance	0.13	2.10	0.035	Yes

H5b	Sustainable construction design positively impacts social performance	0.17	2.65	0.008	Yes
H5c	Modern construction methods positively impact social performance	0.07	1.21	0.226	No
H5d	Environmental provisions and reporting positively impact social performance	0.24	3.96	0.000	Yes
H6a	Sustainable construction materials positively impacts economic performance	0.12	2.46	0.014	Yes
H6b	Sustainable construction design positively impacts economic performance	0.22	4.16	0.000	Yes
H6c	Modern construction methods positively impact economic performance	0.18	3.50	0.000	Yes
H6d	Environmental provisions and reporting positively impact economic performance	0.03	0.57	0.571	No
H7	Environmental performance positively impacts economic performance	0.35	5.77	0.000	Yes
H8	Social performance positively impacts economic performance	0.15	3.02	0.002	Yes

Note: β = Standardized path coefficients, C.R. = critical ratio, p = p-value.

5. Discussion, theoretical, managerial, and policy-making implications

5.1. Discussion

Previous studies have contributed to sustainable construction by documenting the impacts of sustainability practices using exploratory or conceptual approaches (e.g., Shen et al., 2007; Del Río Merino et al., 2010; Athapaththu and Karunasena, 2018; Chang et al., 2018; Yin, 2019). For example, Chang et al. (2018) emphasized that larger firms exhibit better performance (especially in quality management and customer service but less in community development) than smaller firms. Meanwhile, larger firms do not necessarily perceive sustainability as being more critical. Athapaththu and Karunasena (2018) proposed a framework for enhancing sustainable construction practices, but only for contracting organizations (i.e., C1 category construction contractors). Del Río Merino et al. (2010) promoted sustainability in construction at the end of its lifecycle through the reuse and recycling of construction and demolition waste (C&DW). By considering the whole construction project lifecycle, Shen et al. (2007) provided a comprehensive framework of sustainability performance checklist to pinpoint the primary factors affecting the sustainability of a construction project across its entire life cycle. Yin (2019) reviewed the sustainability of a specific project, namely the B&R initiative. Meanwhile, certain studies could not provide empirical validations for the association between sustainability practices and performance (e.g., Abidin and Iranmanesh, 2016, Chang et al., 2016, Yusof et al., 2016, Zhao et al., 2016). Consequently, evidence for the causal effect of sustainability practices on sustainability performance remains mixed, at best, and missing, at worst, due to the exploratory, conceptual, and/or highly specific nature of past research.

Second, a few scholars have attempted to explore the barriers to sustainable practices in construction, especially in emerging economies. For example, in developing countries, many barriers (e.g., lack of resources, manpower, adequate management, technology, etc.) restrict firms from attaining paramount sustainable RC performance (Pilger et al., 2020; Montoya-Alcaraz et al., 2020). However, despite the critical importance that the study of those barriers and their relationships with sustainable construction practices and performance can have for theory and practice, no such work has been executed in-depth to date.

Therefore, this study supports past conceptualizations suggesting that sustainability practices positively impact sustainable performance by examining such relationship with quantitative methods. More specifically, by uniquely drawing on RBT (Barney, 1991, Lee and Grewal, 2004), we posit that sustainability can create a sustainable competitive advantage that is valuable, rare, difficult to imitate, and exploitable by organizations (Willard, 2009, 2012; Belz and Peattie, 2012; Ertz, 2021). This advantage is then conducive to superior performance, environmentally, socially, and economically. Besides, the study posits that sustainability barriers will negatively impact sustainability practices and investigates the specific sector of HRC in an emerging economy. Therefore, the findings of this research fill the previously mentioned gaps in the literature by integrating sustainable construction barriers, sustainable construction practices, and sustainable performance into a holistic model underpinned by RBT (Barney, 1991; Lee and Grewal, 2004) to understand HRC better. This investigation is all the more valuable as the state-of-the-art impact of sustainable construction barriers on sustainable construction practices and its impact on sustainable performance in the context of HRC has been neglected, especially in developing countries. Besides, the study investigates barriers, practices, and performance from a multidimensional perspective, increasing, therefore, the probability of settling conflicting results in the past literature, such as the lack of impact of sustainable practices on sustainable development (e.g., Abidin and Iranmanesh, 2016, Chang et al., 2016, Yusof et al., 2016, Zhao et al., 2016), while providing a more fine-grained understanding of how barriers, practices, and performance are interrelated in SHR construction.

Consequently, the first noteworthy contribution of the study resides in classifying and empirically validating, through an EFA and CFA, the dimensions of sustainable construction barriers (i.e., resource barriers, managerial barriers, regulatory barriers), sustainable construction practices (i.e., sustainable construction material, modern construction methods, sustainable construction design, environmental provisions, and reporting), and sustainable construction performance (i.e., environmental performance, social performance, and economic performance) in HRC. Furthermore, SEM further established the strength of relationships between those multiple constructs.

With support found for 19 hypotheses (out of 26), the empirical results provide overall support for the conceptual framework, while leaving some room for explaining inconclusive results in extant research. More specifically, control over barriers can mitigate the uncertainties pertaining to the use of sustainable construction practices, which will reverberate onto triple bottom line performance. We anticipate that the study outcomes can enable HRC firms, particularly in emerging economies, to cope with sustainable construction barriers and implement sustainable construction practices to a fair extent that would foster sustainable growth (environmental, economic, and social).

5.2. Theoretical implications

This paper analyzed sustainability barriers, practices, and performance in an integrated model based on a self-reported survey from HRC professionals' survey data. Drawing on resource-based theory (RBT) (Barney, 1991; Lee and Grewal, 2004), the results support the interrelationships among sustainability barriers, practices, and performance.

Given these pieces of evidence, we highlight the following implications for research and policy-making regarding the relationships between barriers and practices. Firstly, in our study, we determined that resource barriers negatively impact sustainable construction materials, sustainable construction design, and modern construction methods. However, this impact is comparatively higher on sustainable construction materials than on the two other practices. Pitt et al. (2009) argued that the affordability of resources is the most significant barrier to sustainable construction. High sustainability implementation costs diminish economic competitiveness, and resource necessities create difficulties for firms to employ sustainability practices (Zhang et al., 2011; Shi et al., 2013; Chang et al., 2018). The availability of designers and contractors for sustainable construction can be essential in encouraging sustainability implementation. They can mitigate the adverse effect of the construction process on the environment and society while improving economic soundness (Tan et al., 2011). Hence, the study results suggest that the development and arrangement of resources would allow construction firms to use sustainable, local, recycled, and waste materials and use modern construction methods and technology to minimize the negative impacts on environmental and economic perspectives while constructing hill roads.

Secondly, the results clarified the role of managerial barriers in restricting sustainable construction design, modern construction methods, and environmental provisions and reporting. The lack of effect on sustainable construction material use may be explicable because, unlike design, methods, and reporting, the nature and quality of construction material are highly contingent upon other stakeholders' input, namely sellers. Yet, with increasingly more suppliers producing and marketing recycled aggregate (Kisku et al., 2017) or recycled/reused C&DW (Del Río Merino et al., 2010) as sustainable construction material, the use of such material grows on the market and increases in procurement shares despite unfavorable managerial policies toward sustainability. This increase in sustainable material might also result from stakeholders' pressure leading managers to use sustainable material, although they may not be particularly involved with sustainability (Pham and Kim, 2019). Interestingly, the negative impact of managerial barriers on environmental provisions and reporting was found to be higher than the impact on sustainable construction design and modern construction methods. This is one novel contribution that the lack of management commitment, sustainable management teams, awareness, and communication, and the non-enforcement of sustainable practices from the managerial point of view, primarily affect areas in which the firm has, in principle, a higher locus of control, such as provisions and reporting, and even then, only design and methods, both of which might be more akin to external stakeholder pressure (Pham and Kim, 2019), while the control over materials might even be less controllable due to the higher locus of control on the seller side.

Third, regulatory barriers also restrict sustainable construction implementation on hill roads (Munyasya and Chileshe, 2018). However, the results nuanced Munuaasya and Chileshe's (2018) findings in that regulatory barriers exert the weakest negative effect of all barriers. In fact, the lack of sustainable construction guidelines, green incentives, and government support hinders a firm's execution of sustainable construction methods. Therefore, regulatory pressure and the introduction of economic incentives might spur significant changes in the use of sustainable construction methods. However, in line with Yin et al. (2018), we further suggest that these efforts must be coupled with promoting awareness and adoption of sustainability practices so that they are also intrinsically motivated and not exclusively extrinsically "pushed on" SRC practitioners.

Fourth, as the relationship between sustainable HRC practice and performance is concerned, this study extends the literature by highlighting the positive impact of sustainable construction materials, sustainable design, modern construction methods, as well as environmental provisions and reporting on environmental performance. Nevertheless, in contrast to other sustainable construction practices, the impact of environmental provisions and reporting is the highest on environmental performance. Likewise, the study validated the positive impact of environmental provisions and reporting, sustainable construction design, and sustainable construction materials, respectively, on social performance. In contrast, the impact of modern construction methods is non-significant. Finally, the results contributed to the existing body of knowledge on sustainability by underlining the vital roles of sustainable construction materials, sustainable construction design, and modern construction methods in fostering economic performance. However, environmental provisions and reporting are non-significant for economic performance. These results suggest the following implications for research and policy-making: Sustainable construction materials and construction design are the only two sustainable HRC practices impacting the three sustainability dimensions. Thus, the positive impact of sustainable construction design on environmental and economic performance aligns with Cerchione et al.'s (2018) findings. In contrast, the positive impact of sustainable construction design on the three sustainability performance dimensions is in line with Le (2020). This can be explicable because sustainable construction material and design will reduce harmful emissions, waste rates, land use rates, and unnecessary cuttings, thus improving environmental performance and social performance (especially regarding land use, for the latter) while simultaneously boosting economic performance. On the other hand, modern construction methods mainly enhance environmental and economic (cost) performance but with limited benefits for social performance.

Fifth, related to the previous point, past studies failed to empirically examine the social dimension of sustainable performance in construction in general and in SHR construction in particular. Interestingly, the quantitative study results suggest that, as for environmental performance, social performance seems primarily impacted by environmental provisions and reporting. These findings are not very surprising when comparing such results with other literature streams. In fact, provisions and reporting, in particular, institutionalize sustainability among firms (Contrafatto, 2014), while such managerially-driven practices contribute to the construction and dissemination of meaning within the organization (Bebbington and Gray, 2000). The question of purpose goes beyond mere profit (economic performance) and touches, in fact, higher-order considerations, including environmental and social issues, which may explain the relationship between provisions/reporting on environmental performance and social performance. Subsequently, the study confirmed the positive impact of environmental performance on economic performance, which confirms past results from Shashi et al. (2019). Yet, a significant advancement in the literature is validating the positive impact of social performance on economic performance. These results echo Oliver et al. (2016) as well as Forteza et al.'s (2017) findings establishing that construction firms' profitability increases. However, accident rates increase until a tipping point from which more accidents reduce economic performance. Our study does not emphasize that quadratic relationship (inverted U-shape) and rakes are larger than road deaths/incidents by also including a reduction in travel time, transportation costs, and so on. Nevertheless, the findings converge with Oliver et al. (2016) and Forteza et al.'s (2017) conclusions about the positive impact of general social performance on economic performance. It is also worth mentioning that increased per capita income/ living standards may increase business opportunities due to higher worker purchasing power and reduced project completion time through higher worker motivation. In sum, the findings suggest that economic benefit might be achieved indirectly through enhanced environmental and social performance.

This research is therefore crucial since it complements the extant literature in several ways. First, it combines sustainability barriers, practices, and performance into a holistic framework and explores their causal relationships. Second, it overcomes the limited generalizability of past exploratory, conceptual, or highly specific approaches to the subject matter by using quantitative empirical methods in SEM. Third, the study examines the dimensionality of the focal constructs and empirically establishes those dimensionalities using exploratory and CFA. This study provides a more fine-grained and nuanced understanding of the interrelationships between sustainable barriers, practices, and performance. Furthermore, it focuses on the specific area of HRC, which differs from other construction projects in sustainability due to greater geographical complexity. Finally, the investigation takes the case of an emerging economy where construction projects, especially in the HRC sector, are booming worldwide and need proper guidance to implement sustainably.

5.3. Managerial and policy-making implications

This research further provides implications for managerial action and policy-making on sustainable HRC in general and in developing countries in particular. Both resource and managerial barriers are major constraints in exercising sustainable practices. Practitioners need to design unique related strategies to overcome them. Strategic partnerships among partners are highly important, and HRC managers should share their idle and under-utilized resources with their stakeholders to meet sustainability implementation-related requirements. Managerial level barriers are core concerns. Organizations need to pay special attention to frequently reinforcing sustainability practices, developing sustainability teams, and developing deep knowledge about different kinds of sustainability practices from internal and external sources. Managers need to understand the outcomes of promoting sustainable construction. Likewise, different parties involved in construction projects have different motives. Clear and regular communication between parties is of utmost importance. Understanding the lack of effective strategies and reasons for the non-enforcement of sustainable practices is more than necessary.

For policy makers, significant regulatory efforts in terms of sustainable construction guidelines, green incentives, provision for sustainable practices in contract agreements, and government support for implementing sustainable actions can significantly transition toward sustainability in HRC. Besides, the focus should be on the procurement and use of sustainable materials and sustainable construction design while constructing hill roads. It will not merely reduce the environmental impact but significantly reduce the variety of costs involved in construction and benefit society, which will ultimately improve goodwill and regional prosperity. Sustainable procurement can enable firms to improve their sustainability image and reputation with the community, as Lee (2020) suggested. The use of modern construction methods (e.g., sustainable cut and fill, modern equipment/technology, crash barriers/ parapet walls) will tackle the problems related to unnecessary cutting, emission, high waste, dumping, and so on. Likewise, firms need to pay special attention to improving their environmental and economic performance by successfully implementing sustainable construction practices to improve social performance further. Managers must simultaneously harness all the sustainability dimensions to achieve economic sustainability, match the steadily growing stakeholders' expectations for social sustainability, and confine the environmental burden of HRC projects.

Finally, regular, sustainable performance evaluation and measurement are of utmost importance. If there is a performance measurement, there will be a chance for improvement. Besides, focal construction firms must also guide their partnering firms about the different sustainable practices and frequently improve their sustainable performance. There is a need for adequate standardization of sustainability evaluation methods in terms of partners' selection criteria, the effectiveness of each sustainability practice, performance benchmarking, sustainability reporting, and so on. Both the construction authorities and construction firms should organize sustainability awareness programs on their ends.

6. Limitations and future research avenues

This research is not without limitations which may stimulate future research efforts. First, the results represent both large and small HRC projects within the Himalayan regions of India. Subsequently, other developing or even developed countries may have different HRC barriers, practices, and regulations. Therefore, study results may vary in other countries. Furthermore, this study only investigated the impact of barriers on implementing sustainable construction practices. Thus, future research can also integrate the impact of different challenges in the model. Further, researchers may also investigate the implementation of resilient construction practices in HRC.

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Appendix A

Please indicate your level of agreement regarding the following measures that act as barriers to the implementation of sustainability practices in hill road construction projects on a five-point scale ranging from 1 to 5 (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree).

Item	Measure
B1	Lack of awareness about sustainability
B2	Lack of professional knowledge about sustainable construction methods
B3	Lack of strategy to promote sustainable construction
B4	Lack of sustainable management teams
B5	High investment in sustainable construction
B6	Non-enforcement of sustainable practices
B7	Lack of top management commitment to implement sustainable practices
B8	Lack of sustainable construction standards/ guidelines
B9	Lack of funds
B10	No provision of sustainable practices in the contract agreements
B11	Lack of training for the stakeholders
B12	Lack of government support to implement sustainable practices
B13	Lack of database and information
B14	Rigidity in human behavior/ change resistance
B15	Lack of communication between various stakeholders
B16	Lack of designers and contractors for sustainable construction
B17	Non-availability of sustainable materials
B18	Uncertainty in the performances of sustainable materials

B19	High cost of sustainable materials
B20	Lack of incentives
B21	Absence of sustainability evaluation system

Please indicate your level of agreement with implementing the following sustainability practices during hill road construction on a five-point scale ranging from 1 to 5 (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree).

Item	Measure
P1	Optimization of road alignment (gradient)
P2	Optimization of roadway width
P3	Optimization of turning radius of curves/zigs
P4	Edge-to-edge carpeting/full-width blacktopping
P5	Modified design of structures
P6	Modified design of pavements
P7	Procurement of sustainable materials
P8	Use of excavated materials
P9	Use of cement-treated layers in pavement
P10	Use of plastics/geo-textiles/chemicals, etc.
P11	Use of local/marginal materials
P12	Training on sustainability
P13	Implementation of sustainable cut and fill method
P14	Minimization of blasting
P15	Soil stabilization
P16	Use of modern equipment/technology
P17	Construction of lined drain throughout
P18	Construction of retaining/edge wall throughout
P19	Use of crash barriers/ parapet walls
P20	Use of signboards and road marking
P21	Provision of sustainable practices in contracts
P22	Legal framework and enforcement
P23	Sustainable measurement and reporting
P24	Sustainability implementation guidelines

Please indicate your level of agreement with the following performance measures with regard to environmental performance during hill roads construction on a five-point scale ranging from 1 to 5 (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree).

Item	Measure
EN1	Reduction in earthwork quantities
EN2	Reduction in construction waste
EN3	Reduction in use of materials

EN4	Reuse of materials
EN5	Reduction in carbon emission
EN6	Reduction in landslides

Please indicate your level of agreement with the following performance measures with regard to economic performance during hill roads construction on a five-point scale ranging from 1 to 5 (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree).

Item	**Measure**
EC1	Reduction in land acquisition cost
EC2	Reduction in construction cost
EC3	Reduction in maintenance cost
EC4	Reduction in vehicle operating cost
EC5	Travel time-saving cost
EC6	Reduction in road accidents' cost
EC7	Reduction in environmental accidents cost

Please indicate your level of agreement with the following performance measures with regard to social performance during hill roads construction on a five-point scale ranging from 1 to 5 (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree).

Item	**Measure**
SP1	Decrease in number of road accidents
SP2	Decrease in number of deaths in road accidents
SP3	Reduction in travel time
SP4	Reduction in transportation cost
SP5	Reduction in completion period of roads/timely completion
SP6	Increase in scope of business ventures
SP7	Increase in land value
SP8	Increase in per capita income/ living standard