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Exploring the Transport Infrastructure Sustainability Performance: An Investigation of the Transportation Projects in Saudi Arabia

Moahd Alghuson

Industrial Engineering Department, Faculty of Engineering, University of Tabuk, Tabuk 47512, Saudi Arabia; malghuson@ut.edu.sa

Abstract: In the Saudi Arabian construction projects, the transport infrastructure sustainability assessment has become a priority in recent years. The purpose of this research is to assess the sustainability performance of transport infrastructure projects in Saudi Arabia. It specifically seeks to assess the effects of these initiatives on the environment, society, and economy, while highlighting their advantages and disadvantages as well as potential areas for development. A key objective of this evaluation is to provide thoughtful analysis and suggestions for improving Saudi Arabia's transportation infrastructure development. The study was conducted using a Likert-scale questionnaire survey among 197 professionals in Saudi Arabia. The Cronbach's alpha test was conducted to assess the validity of the survey. Moreover, statistical analysis using SPSS software 25 was used along with the Spearman correlation test to evaluate the respondent behavior of the survey. The investigation serves as a foundation for devising strategies and policies to promote sustainable transportation practices in Saudi Arabia. The study's insights can guide effective planning and regulations that prioritize sustainability, environmental preservation, and public support. By focusing on these outcomes, transportation networks can be improved, environmental impacts reduced, construction methods enhanced, and safety ensured for workers and the public. A durable, effective, and environmentally conscious transportation infrastructure for Saudi Arabia's present and future generations could be achieved by embracing sustainable transportation infrastructure and giving priority to the determined results.

Keywords: transportation; construction management; sustainability factors; Saudi Arabia; questionnaire survey

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1. Introduction

Transportation is regarded as a crucial action area for achieving sustainable development. It plays an essential role in the economic sector by existing among the production patterns, at the geographic ladder, and in human movement [1]. The foundational elements of urbanization are the transportation system and infrastructure. Urban shape and locative structure are related to the idea of urban transportation [2]. Urbanization is planned in tandem with the advancement of the effectiveness and capacity of urban transportation networks. Urban transportation is currently receiving increased attention and is thought to be a crucial pillar supporting commuter mobility in cities experiencing population growth and area expansion [3]. However, due to various circumstances, including the volume and diversity of traffic and the diversity of origins and destinations, transportation in metropolitan areas is sophisticated and intricate. The current transportation system is widely acknowledged to be unsustainable almost everywhere [4].

According to statistics, the Kingdom of Saudi Arabia is one of the world's most urbanized nations, with eight out of every ten citizens residing in metropolitan areas [5]. Due to Saudi Arabia's rapid urbanization, industrialization population increase, climatic circumstances, and fuel abundance, motorized transportation is used too frequently [6].

Furthermore, Saudi Arabia's transportation industry consumes almost a quarter of the country's total energy, and future projections indicate that consumption will increase. As a result, numerous environmental and societal complications arise, such as rising levels of air and noise pollution, traffic congestion, and traffic accidents, which lead to negative impacts on the quality of urban life, ecology, human health, and productivity [7]. The UN General Assembly approved the 2030 Agenda for Sustainable Development in September 2015. The agenda, based on the idea of "leaving no one behind", aims to achieve sustainable development for all people. The agenda is centered on the 17 Sustainable Development Goals (SDGs), which are intended to compel all developed and developing nations to address the world's most pressing issues. Sustainability consideration in transportation design plans is a crucial factor in planning. The idea of sustainable development in the mobility industry serves as the foundation for the concept of sustainable transportation. It requires the capacity to supply the demand for mobility while reducing negative environmental effects and considering future generations' needs. The goal is to find a balance between providing for the planet's general well-being and maintaining natural resources and current transportation demands. We can ensure a more ecologically friendly and socially responsible approach to mobility by implementing sustainable transportation methods, leaving a good legacy for future generations [8].

In Saudi Arabia, infrastructure projects are frequently presented without taking into account the principles of sustainable development, which has led to project failures and abandoned facilities [9]. The project's sustainability performance can be impacted by how well sustainability criteria are implemented. In addition, sustainability variables make it easier for owners, engineers, and stakeholders to evaluate the development's progress toward sustainability by contrasting the actual performance with the desired performance [10]. Procedures need to be developed to handle the complexity of transportation infrastructures and the variety of trade-offs in these systems. An evaluation of sustainability appears to be necessary. This study addresses the acknowledged need for better environmental, economic, and social considerations concerning transportation infrastructure developments.

This research seeks to add to the body of knowledge on the sustainability of transportation infrastructure projects by offering a thorough analysis and suggesting a framework of relationships specifically for Saudi Arabia. The extensive survey and analysis carried out for this research add to the body of knowledge by offering information and insights on Saudi Arabia's transportation infrastructure's sustainability factors, which may not have been previously investigated or thoroughly studied.

2. Literature Review

2.1. Sustainability Factors of Transportation Infrastructure Project

Sustainability infrastructure assessment systems have recently been developed or are under development to measure the sustainability of infrastructure projects [11]. These systems are primarily used to monitor and assess the environmental, social, and economic sustainability facets of infrastructure efforts, ensuring that projects adhere to sustainable practices and make a positive contribution to the general well-being of people and the environment. The construction industry has implemented sustainability assessment systems to meet the need for sustainable development needs [12]. For Australian road infrastructure projects, Lim [13] identified 23 critical sustainability factors: air quality, water quality, noise and vibration, erosion and sediment control, flora and fauna, environmental and social impact assessment, life cycle cost, project risk, cultural heritage, inter-modality of transportation, the functional performance of the physical asset, community involvement, public governance, client liaison and collaboration with internal stakeholders, project governance, compliance with contract, and project specifications. The 10 areas that make up this group of 23 essential sustainability aspects are environmental, economic, social, engineering, community involvement, relationship management, project management, institutional sustainability, health and safety, resource use, and management. The New South Wales

Transport Division is responsible for implementing sustainable transportation infrastructure projects for the Australian government [14]. This division has developed a framework for transport projects to ensure that its transportation system is sustainable in the long run and that its environmental and sustainability performance is continuously improved. In the transportation division of New South Wales, environmental, social, and economic sustainability are the key concerns [15]. Throughout these spheres, sustainability is stressed as an important aspect of planning, developing, and delivering transport infrastructure [16]. Under the environmental category, sustainability factors include GHG emissions, water, pollution control, noise management, resource management, waste management, material consumption, and biodiversity [17]. Different criteria are included together under the sustainability evaluation framework. The social category includes factors such as stakeholder interactions, public support, and cultural preservation, all of which are essential in developing socially responsible infrastructure projects. However, INVEST is an assessment system that provides a list of sustainable factors and best practices to be incorporated into transportation projects [18]. It provides a thorough list of sustainable elements and best practices that should be incorporated into these projects. These recommendations can help transportation efforts adhere to sustainability ideals and have a good effect on the environment, society, and the economy [19]. INVEST was developed by the Federal Highway Administration (FHWA) of the United States and launched in 2012 [20]. The sustainability factors included in INVEST are intended to address sustainability throughout all stages of the project, namely: the planning stage, the development stage, and the operation and maintenance stage [21]. Among the sustainability factors included in INVEST are noise quality, ecology, biodiversity, visual impact, waste management, energy and carbon emissions, erosion and sediment control, flora and fauna, health and safety, life cycle cost, cultural heritage, public accessibility, and intermodal transport [22].

2.2. Sustainability Performance of Infrastructure Projects

One of the most important factors in accomplishing the objective of sustainable development is the sustainability performance over the life cycle of the construction project [23,24]. Litman [25] states that the sustainability criteria serve as a performance monitor and catalyst for building project performance. Previously, a group of people focused on either construction material recycling or construction technique optimization to achieve sustainability [26–31]. Therefore, the degree of sustainability performance of a construction project is greatly determined by the incorporation of sustainability aspects. Examples include problem-solving, client needs/objectives being met, and clear instructions [32–34].

Time, quality, and money have traditionally been established as the fundamental standards for evaluating the success of building projects [35]. In their research findings, Amiril, Nawawi, Takim and Latif [22] show that the application of sustainability principles has resulted in improved decision-making, decreased waste, efficient project delivery, avoided delays, and decreased constructability-related issues (rework, claim, etc.). Similar results were found by Alotaibi, Edum-Fotwe and Price [9], whose research indicates that the performance of road projects resulting from the application of sustainability factors is to reduce pollution and environmental impacts, public acceptance, fit for purpose and quality, minimize maintenance and operation costs, mitigate risks, on-time completion, protect cultural heritage, safe construction, and other factors. In addition, Amiril et al. [36] have identified the benefits of implementing sustainability factors through the performance of their projects, including safe construction, noise and vibration minimization, air quality, dust suppression, prevention of land contamination and degradation, protection of water quality, reduction of construction material footprint, minimization of carbon footprints and energy use, minimization of water usage, and maximization of energy efficiency.

For practical reasons, sustainable development is still considered a challenging issue that defies categorization [37–39]. According to Leal Filho et al. [40], it is commonly acknowledged that operationalizing sustainability—that is, knowing how to put it into practice—represents the true problem. According to Tafazzoli [41], infrastructure sustainability includes more effects than are typically studied, including the technical or structural quality of roads, project management, resource management, system effectiveness, resilience, and useful operational life of the assets, as well as governance and institutional aspects. In their research, Pham et al. [42] stated that sustainable construction is characterized as a building process that adheres to sustainable development's fundamental principles. The goals of environmental responsibility, social responsibility, and economic profitability should all be met by these processes.

2.3. Existing Research Gap and Research Opportunities

There have been relatively few studies carried out in Saudi Arabia, despite this topic being the focus of numerous studies in a few other countries. This study stands out by offering a broader perspective, as previous research has primarily focused on smaller-scale or regional analyses, leaving a notable absence of nationwide investigations. This study advances knowledge about environmentally friendly transportation techniques in Saudi Arabia, where the economy is quickly expanding. It presents a thorough framework that goes beyond conventional measurements and takes into account several aspects of sustainability, such as the influence on the environment, social equality, and economic viability. This shows the practical difficulties and prospects for development while offering insightful information about the sustainability performance of Saudi Arabia's transportation infrastructure. The survey is based on the framework of these indicators, which are grounded in the environmental, social, and economic aspects. Real-world data about transport systems and policies, infrastructure, urban development, and environmental degradation caused by transportation are utilized in the study. Ultimately, this paper highlights recommendations to achieve sustainable transportation in Saudi Arabia.

3. Methodology

3.1. Questionnaire Design

This study used a questionnaire approach to examine the sustainability performance of transportation projects in Saudi Arabia. This study's questionnaire design adopts a structured methodology that includes closed-ended questions. The questionnaire starts with an introduction that describes the study's goals, ensures anonymity, and gives directions on how to fill it out.

Additionally, a section is included to collect background data on the respondents, such as their experience, organization, and their part in the transportation project. Questions on technological, social, environmental, and economic performance are included. Microsoft Excel 2019 and the statistical program SPSS 25 were used to evaluate the data that were gathered. The use of these tools made data processing, manipulation, and statistical analysis efficient. A flowchart was made to show the sequential stages taken from the start of the research project to its completion in order to maintain clarity and transparency throughout the research process as shown in Figure 1.

Based on past research, the authors of this study decided to develop the questionnaire using a Likert scale [43–45]. As they are simple and quick to complete, Likert-scale-based questionnaires are popular for surveys [46]. Additionally, because they are based on participants' own experiences, the replies from Likert scales offer precise data. Previous studies have also used the Likert-scale pattern to identify and rank important factors. A questionnaire was created after carefully reviewing all pertinent research, and it contained 34 crucial elements that were found in the literature (Table 1). The questionnaire sought the opinions of the respondents on each element, evaluating their perception of its seriousness or agreement on a five-point Likert scale. In this study, participants were asked to express their thoughts on a specific subject based on the severity, such as (1) extremely disagree, (2) disagree, (3) neutral, (4) agree, and (5) extremely agree. In addition, the survey included a component asking stakeholders' opinions regarding the region where the sustainable project would be implemented.

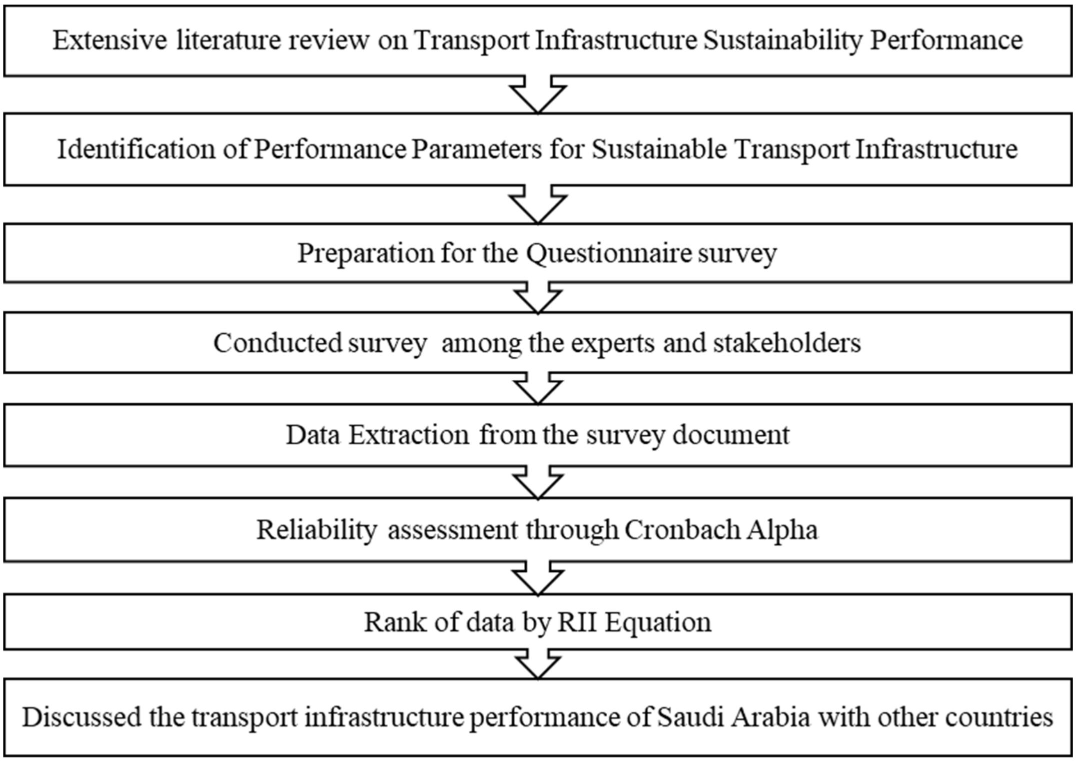

Figure 1. Flowchart of the process from initiation to completion.

Table 1. The questionnaire form of the outcome of transport infrastructure sustainability performance.

SI	The Outcome of Transport Infrastructure Sustainability Performance	Reference
F1	Minimize pollution and environmental impacts	[36]
F2	A balanced development	[36]
F3	Promoting the decrease of carbon emissions	[36]
F4	Protect native/aquatic wildlife	[47]
F5	Evaluation of water harvesting	[47]
F6	Meeting waste management standards	[48]
F7	Maximizing rainwater harvesting and re-use	[48]
F8	Protection of water quality	[48]
F9	Prevention of land contamination and degradation	[48]
F10	Encourage the use of energy-efficient clean technology	[47]
F11	Air quality and dust suppression	Local Expert
F12	Noise and vibration minimization	Local Expert
F13	Fit for purpose and quality	[46]
F14	Minimize maintenance and operation costs	[47]
F15	Minimization risk	[47]
F16	Enhancing construction performance	[46]
F17	Promoting productivity	[46]
F18	Complete on time	Local Expert
F19	Reducing project delivery time	[46]
F20	Protect cultural heritage	[46]
F21	Save travel time and vehicle operating costs	[36]
F22	Public acceptance	[36]
F23	Promoting financial and investment opportunities	[36]
F24	Enhancing project safety and health performance	[36]
F25	Promote interagency collaboration	Local Expert
F26	Safe construction	Local Expert

Table 1. *Cont.*

SI	The Outcome of Transport Infrastructure Sustainability Performance	Reference
F27	Minimize health and safety risk	[46]
F28	Clear terms of instruction and approval within the timeframe	[46]
F29	Enhancement of infrastructure life span	[49]
F30	Uninterrupted material supply	[49]
F31	Increase design innovation	[49]
F32	Long-lasting and high-quality products	[49]
F34	No dispute	Local Expert

3.2. Data Collection

In this study, the developed questionnaires were delivered to the respondents, who included government officials, project managers, engineers and planners, contractors and construction companies, environmental experts, and non-governmental organizations. Then, 197 responses were gathered using 2 different methods, including (1) in-person interviews and (2) email. The authors issued invites to employees of their business, students at the university with which they are linked, residents of the city in which they reside, and so on. This is known as "convenience" sampling since it is likely to add some bias to recruit only a specific segment of the population unless the targeted user group is confined to those individuals [50]. The majority of the study's participants were selected from recent construction areas. The procedure of gathering the data took six weeks. Nearly 70% of the participants had more than five years of experience in construction, and all had a background in the industry. Two hundred and fifteen respondents were asked to rate the importance level on a five-point Likert scale as part of the survey's congenial rating component. The study employed 197 datasets after removing the incomplete and incorrect ones. Consequently, an estimated 91.6% of respondents responded.

3.3. Respondent Demographics

The backgrounds of the 197 respondents who took part in the survey are summarized in Table 2. Government agencies (31%), engineers and design professionals (28%), project owners (25%), and contractors (16%) made up the respondents' range of construction-related roles in Saudi Arabia. The data also show that 34% of the respondents had more than ten years of building experience, while 48% of the respondents were older than 30. Of the respondents, 15% had less than five years of experience. These figures show the current makeup of the Saudi Arabian construction sector, which is primarily dependent on youthful workers to meet the strong demand for construction projects. The information gathered from the respondents can be considered typical of construction professionals in Saudi Arabia, considering the backdrop of the country's building sector. The study's sample includes people with a range of responsibilities and degrees of expertise, which offers important insights into the viewpoints and practical knowledge of experts in this field.

Table 2. Respondents' characteristics.

Respondents' Characteristics	Frequency (n = 197)	Percentage
Types of respondents		
Government agencies	62	31%
Engineers and design professionals	56	28%
Project owners	50	25%
Contractors	29	16%
Sex		
Male	191	97%
Female	6	3%

Table 2. *Cont.*

Respondents' Characteristics	Frequency (n = 197)	Percentage
Age		
21–30	103	52%
31–40	83	42%
41–50	11	6%
Working Experience		
≤5 years	30	15%
6–10 years	101	51%
11–20 years	54	28%
≥21 years	12	6%

3.4. Data Analysis

The investigation attempted to assess the owners' and stakeholders' overall viewpoints on the idea of transportation sustainability. According to Boone and Boone [51], the data gathered from a Likert-scale-based questionnaire are ordinal and nonparametric, and nonparametric data are typically not normally distributed. As a result, all the real datasets were gathered from the powerful responders and examined using the RII, a descriptive statistical parameter.

3.4.1. Relative Important Index (RII)

The range of the RII value demonstrates its significance among the causes affecting the project's catastrophic predicament. The commonly utilized and well-liked analytical technique known as RII is appropriate for this kind of research activity [52]. Due to its proportionate contribution when recording data from each respondent and assessing them in combined conditions from all the respondents, the RII method for statistical analysis of the data was specifically adopted here. A more important project management element is acting behind the critical condition, as indicated by the higher RII score. The Results and Discussion Sections have assigned the prospective critical management success elements a substantive rank as a result of the RII method's analysis of the survey data. The RII can be analyzed using the following equation:

$$\mathrm{RII} = \sum \frac{W}{A * N} \times 100 \tag{1}$$

where W = weight each respondent assigned to each element, A = maximum weight, and N = total respondents. In order to assess the nature of the reaction, the standard deviation and coefficient of variation among the data were also examined. The ranking of the group factors was then completed using RII. To compare the factors and assess their severity for the construction sector, the factors' percentage contribution and group factor percentage were also taken into consideration.

3.4.2. Data Validation Test

The Cronbach's alpha test, which measures data dependability, was performed using SPSS software. The entire dataset was employed for reliability analysis, which is required to ensure the model's construct across time. As the information gathered from the questionnaire using the Likert scale is ordinal and nonparametric in nature, Cronbach's alpha test is a highly effective method for evaluating the data reliability [53]. When it is close to 1.00, Cronbach's alpha value is more suitable [54]. There is no clarity on what constitutes an appropriate border because several variables increase the value of Cronbach's alpha. As a general guideline, the following ranges are frequently used to evaluate the caliber of the alpha coefficient (α): An excellent alpha coefficient is $1 \geq \alpha > 0.9$, while good alpha coefficient is $0.9 > \alpha > 0.8$. It can be an acceptable alpha coefficient if $0.8 > \alpha > 0.7$, and the alpha coefficients of $0.7 > \alpha > 0.6$ are regarded as uncertain. A low alpha coefficient is $0.6 > \alpha > 0.5$, while alpha coefficients of $0.5 > \alpha$ are regarded as poor. The alpha coefficient, which is frequently used to evaluate the internal consistency or reliability of a scale or measure, can be interpreted generally using the ranges provided [54].

3.4.3. Spearman Correlation Test

Using Spearman's rank correlation coefficient, agreement research was performed to evaluate the relationship between crucial project management success factors. The nonparametric Spearman's correlation test does not make any assumptions about variance homogeneity. By comparing the ranked values of the two sides' assessments, it gauges the level of agreement between them [55]. This correlation analysis method uses medians rather than means to reduce the impact of any outliers in the dataset. The purpose of the correlation analysis is to ascertain whether there is a correlation between the important variables, as seen by the respondents. The correlation coefficient, which ranges from 1 to -1, shows how strongly and in what direction the variables are related [56]. A strong association between two parties and similarity in their points of view are indicated by a correlation number near 1. A correlation coefficient that is close to one suggests a weakly negative association between the parties, in contrast.

The formula to calculate Spearman's rank correlation coefficient is as follows:

$$\rho = 1 - \frac{\left(6\sum d^2\right)}{n(n^2-1)} \tag{2}$$

where ρ represents Spearman's rank correlation coefficient, Σd^2 is the sum of the squared differences between the ranks of corresponding pairs of variables, and n represents the number of observations or pairs of data points.

4. Results and Discussion

4.1. Reliability Assessment

Two reliability tests were carried out to verify the accuracy of the data collected during the field survey. Using Cronbach's alpha test, the internal data consistency was examined. The Cronbach's alpha reliability statistics show that the value among the covariance of items as 0.832, while the standardized value as 0.830. When there is fluctuation in the questionnaire's response scale, the standardized value is normally employed. However, a consistent five-point response-based questionnaire was used in this study to collect data. Consequently, 0.832 was the study's alpha value, which is a good alpha value, indicating that the collected data is reliable. It is also important to note that this study confirmed the comparatively low representation of female stakeholders in Saudi Arabia's construction sector. This demographic trait is consistent with the existing worker composition of the sector, which is dominated by male professionals.

4.2. Spearman Correlation Assessment

Table 3′s results show that there is typically a very significant agreement between two respondent categories in determining the RII of each crucial element. The amount of agreement between project owners, engineers, and design professionals was the highest, even when there were slight differences in their opinions, but the government agencies, engineers, and design professionals had the lowest level of agreement. The following can be inferred from the degree of difference between the responder groups: engineers and design professionals > project owners > contractors > government agencies. For instance, recognizing that engineers and design professionals exhibited greater agreement implies a shared understanding of key sustainability aspects among technical experts involved in the project. By understanding these differences, stakeholders can engage in informed discussions, negotiate solutions, and ultimately make more balanced decisions that take into account both technical and administrative perspectives.

Table 3. Spearman's rank relationship of the stakeholders.

Stakeholders	ρ (Correlation Coefficient)	α (p-Value)
Government agencies vs. project owners	0.652	0.01
Project owners vs. engineers and design professionals	0.741	0.01
Government agencies vs. engineers and design professionals	0.341	0.01
Contractors vs. project owners	0.541	0.01
Contractors vs. engineers and design professionals	0.611	0.01

4.3. Overall Ranking of Factors

The ongoing research into the sustainability of the transportation infrastructure has provided factual knowledge about how these elements affect how quickly building projects move overall. A thorough and descriptive statistical analysis was carried out to gain a deeper understanding of these variables. The Relative Importance Index (RII) for each of the 34 identified factors was to be determined by this evaluation. Table 4 provides a thorough and descriptive statistical overview of the study's findings, including the ranks of these criteria. Moreover, Figure 2 presents the respondent rate with respect to all factors.

Table 4. Summary of RII, mean, SD, and ranking according to overall findings.

SI	Factors	Mean	Standard Deviation	RII	Rank
F1	Minimize pollution and environmental impacts	3.543	1.685	0.709	2
F2	A balanced development	3.380	1.628	0.676	14
F3	Promoting the decrease of carbon emissions	3.568	1.626	0.714	1
F4	Protect native/aquatic wildlife	3.385	1.363	0.677	13
F5	Evaluation of water harvesting	3.304	1.345	0.661	22
F6	Meeting waste management standards	3.411	1.470	0.682	7
F7	Maximizing rainwater harvesting and re-use	3.345	1.132	0.669	17
F8	Protection of water quality	3.395	1.200	0.679	11
F9	Prevention of land contamination and degradation	3.406	1.307	0.681	9
F10	Encourage the use of energy-efficient clean technology	3.461	1.427	0.692	3
F11	Air quality and dust suppression	3.350	1.315	0.670	16
F12	Noise and vibration minimization	3.436	1.596	0.687	5
F13	Fit for purpose and quality	3.263	0.906	0.653	27
F14	Minimize maintenance and operation costs	3.375	1.248	0.675	15
F15	Minimize risk	3.324	1.135	0.665	19
F16	Enhancing construction performance	3.411	1.540	0.682	7
F17	Promoting productivity	3.258	1.265	0.652	28
F18	Complete on time	3.157	1.030	0.631	33
F19	Reducing project delivery time	3.172	1.107	0.635	32
F20	Protect cultural heritage	3.284	1.055	0.657	24
F21	Save travel time and vehicle operating costs	3.329	1.307	0.666	18
F22	Public acceptance	3.431	1.670	0.686	6
F23	Promoting financial and investment opportunities	3.441	1.323	0.688	4
F24	Enhancing project safety and health performance	3.324	1.405	0.665	19
F25	Promote interagency collaboration	3.284	1.227	0.657	24
F26	Safe construction	3.396	1.298	0.679	10
F27	Minimize health and safety risks	3.218	1.413	0.644	31
F28	Clear terms of instruction and approval within the timeframe	3.238	1.135	0.648	30
F29	Enhancement of infrastructure life span	3.304	1.201	0.661	22
F30	Uninterrupted material supply	3.309	1.125	0.662	21
F31	Increase design innovation	3.258	1.256	0.652	28
F32	Long-lasting and high-quality products	3.142	1.114	0.628	34
F33	No dispute	3.273	1.685	0.655	26

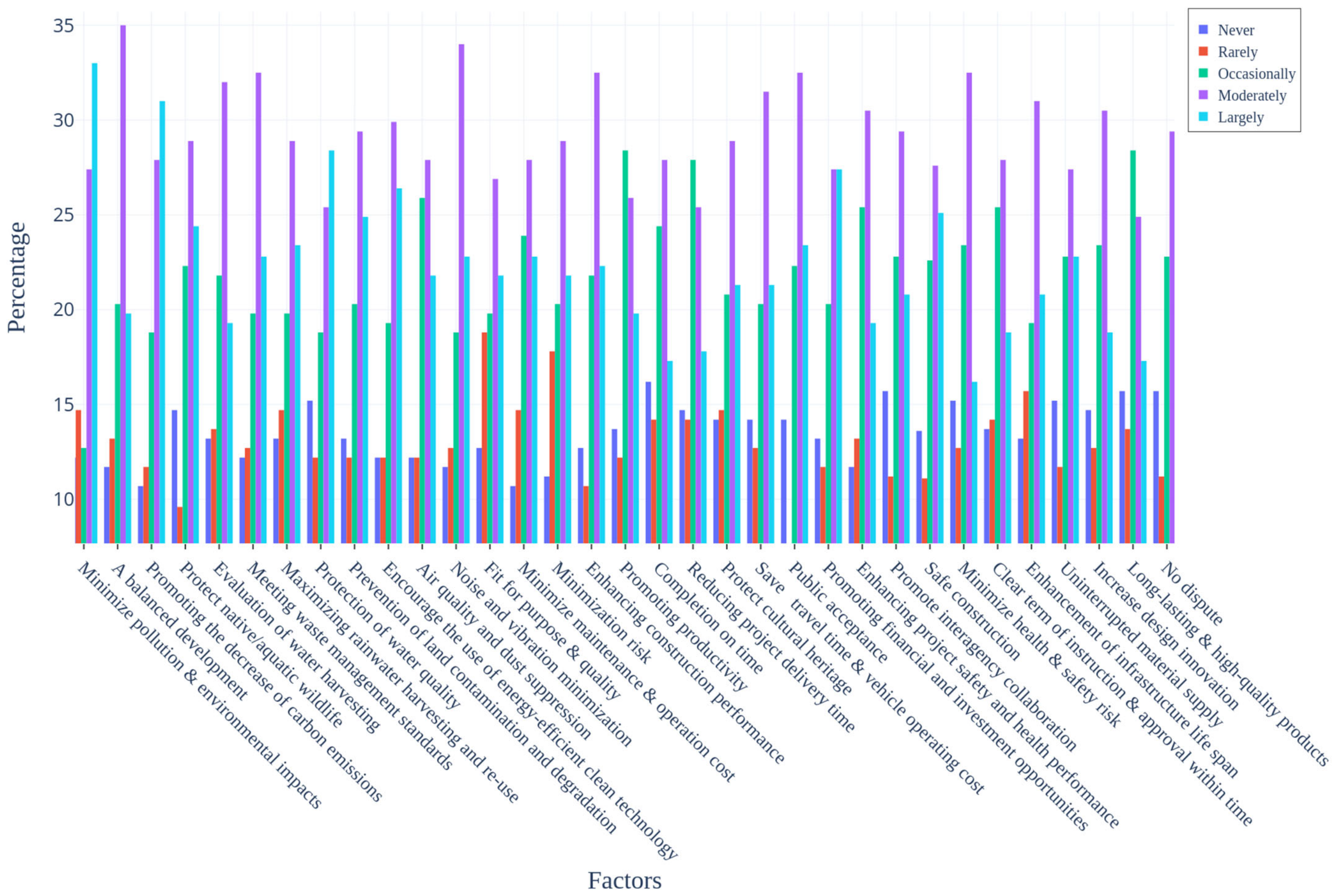

Figure 2. Percentage contribution of transportation sustainability factors.

The rank provides the top five transport infrastructure sustainability factors in project management as: (1) promoting the decrease of carbon emissions, (2) minimize pollution and environmental impacts, (3) encourage the use of energy-efficient clean technology, (4) promoting financial and investment opportunities, and (5) noise and vibration minimization.

The standard deviation ranged from 1.11463 to 1.626776, as presented in Table 4. By evaluating the top five major factors, it was observed that "promoting the decrease of carbon emissions" is a major factor that results from the sustainability of the transportation infrastructure in Saudi Arabia. "Minimize pollution and environmental impacts" and "encourage the use of energy-efficient clean technology" had the second and third highest RII scores, with a standard deviation of 1.685942 and 1.685942, respectively. This was followed by the "promoting financial and investment opportunities" factor (RII 0.688, SD 1.323027) and the "noise and vibration minimization" factor (RII 0.687, SD 1.596997). Similarly, the lowest-ranked factor was the "long-lasting and high-quality products" of the project (RII 0.628, SD 1.11463).

The top five criteria, as determined by the Relative Importance Index (RII), are graphically depicted in Figure 3. The RII evaluates each factor's relevance (respondent rate) and frequency of occurrence in the survey responses to determine its relative significance. The element with the highest ranking, as shown in Figure 3, "promoting the decrease of carbon emissions", highlights how important it is to minimize carbon footprints in projects involving transportation infrastructure. This discovery is consistent with the expanding concern for environmental sustainability around the world. "Minimize pollution and environmental impacts" and "encourage the use of energy-efficient clean technology" come closely behind as the second- and third-ranked considerations. These findings underline how crucial it is to reduce harmful environmental effects and encourage the use of energy-efficient technologies in projects involving transportation infrastructure. The fourth-ranked component, "promoting financial and investment opportunities", shows that stakeholders value financial considerations and investment potential in sustainable transportation projects. The "noise and vibration minimization" element, which is placed fifth overall, emphasizes the need to lower noise pollution and vibration in transportation infrastructure to ensure a higher quality of life for communities.

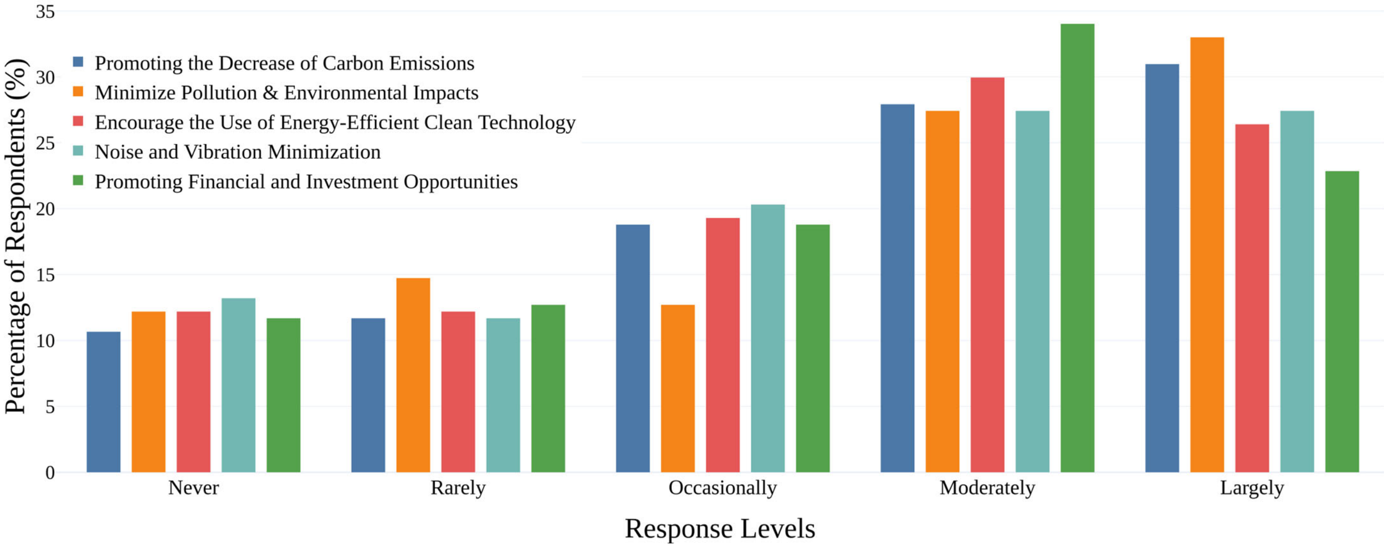

Figure 3. Top five transportation infrastructure sustainability performance factors' respondent rates.

4.3.1. Promoting the Decrease of Carbon Emissions (RII = 0.714)

According to the response rate, Figure 3 shows the top five sustainability performance parameters for transportation infrastructure. This reveals the amount of significance that survey respondents assigned to these issues. With the highest RII value, this component acknowledges the urgent need to reduce the environmental impact of transportation systems and the urgent global concern of climate change. As a prominent actor in the global energy sector, Saudi Arabia understands the need to move toward sustainable and low-carbon policies [57]. The nation wants to support international efforts to prevent climate change and achieve long-term sustainability by encouraging the reduction of carbon emissions in transportation infrastructure projects. The emphasis on cutting carbon emissions is consistent with the objectives described in global frameworks and agreements, such as the Paris Agreement, which intends to slow global warming by cutting greenhouse gas emissions [58]. Transportation projects in Saudi Arabia can support the nation's dedication to environmental sustainability and show leadership in the transition to a low-carbon economy by giving this element top priority [59]. It is significant to highlight that different transportation projects and their unique surroundings may employ different specialized tactics and measures to encourage the reduction of carbon emissions. The above-mentioned study investigates the sustainability performance of transportation projects in Saudi Arabia, most likely evaluating how much carbon emission reduction methods are incorporated into these projects as well as their overall sustainability impact. Saudi Arabia can contribute to the country's overall sustainable development goals and international efforts to combat climate change by emphasizing the reduction of carbon emissions in transportation projects. This would pave the way for a more sustainable and environmentally conscious transportation industry.

4.3.2. Minimize Pollution and Environmental Impacts (RII = 0.709)

Projects involving the construction of transportation infrastructure may have a large negative impact on the environment, including habitat destruction, air and water pollution, and ecosystem disruption. For sustainable development to occur and the environment to be protected, pollution must be reduced, and these environmental effects must be mitigated [60]. Transportation plans in Saudi Arabia could use a variety of strategies and tactics to handle this factor. These can include implementing cutting-edge emission control technologies to lessen air pollution from cars and construction sites, managing stormwater runoff to prevent water body contamination, reducing noise pollution by using sound barriers or acoustic design, and putting in place suitable waste management and recycling systems [61]. The overall environmental impact of transportation projects can also be decreased by using sustainable building methods and materials. This can entail implementing energy-efficient designs, employing environmentally friendly materials, and taking into account the ecological sensitivity of project sites during the planning and building phases. Transportation projects in Saudi Arabia aim to strike a balance between infrastructure growth and environmental preservation by giving priority to the reduction of pollutants and environmental impacts [62]. This characteristic emphasizes the nation's dedication to sustainable development, which is in line with international and national sustainability frameworks. The aforementioned study probably examines the sustainability performance of Saudi Arabian transportation projects by evaluating the degree to which these projects include controls to reduce pollution and environmental effects. The efficiency of pollution control measures, compliance with environmental laws and standards, and the projects' overall environmental sustainability may all be examined [63]. Transportation projects in Saudi Arabia can help preserve the environment, safeguard public health, and guarantee the long-term viability of the nation's transportation industry by emphasizing the reduction of pollution and environmental impacts.

4.3.3. Encourage the Use of Energy-Efficient Clean Technology (RII = 0.692)

This element acknowledges how critical it is to move away from traditional, high-emission technologies and toward cleaner, more sustainable alternatives. Saudi Arabia hopes to lower energy use, eliminate negative environmental effects, and improve the overall sustainability of its transportation infrastructure by promoting the adoption of energy-efficient clean technology [64]. Various energy-efficient clean technologies may be included in Saudi Arabian transportation projects. The use of hybrid or electric vehicles, the incorporation of renewable energy sources to power transportation systems, and the adoption of intelligent transportation systems that optimize energy consumption and traffic flow are some examples of these technologies. Using energy-efficient clean technology has several advantages. It lessens greenhouse gas emissions, such as carbon dioxide, which aids in preventing climate change [65]. By lowering pollutant and particle matter emissions, it also contributes to better air quality. Furthermore, because they use less energy and have lower operating costs, energy-efficient devices frequently save money. Transportation initiatives in Saudi Arabia support the country's commitment to environmental sustainability and are in line with international efforts to move toward a low-carbon economy by placing a priority on the adoption of energy-efficient clean technologies [66]. This component demonstrates the understanding of how technology can create positive environmental change and guarantee a more sustainable transportation industry. By evaluating the degree to which energy-efficient clean technologies are integrated into these projects, the aforementioned study most likely examines the sustainability performance of transportation projects in Saudi Arabia. It might assess how quickly these technologies are being adopted, how well they work to cut down on energy use and emissions, and how much they ultimately contribute to the transportation industry's sustainability objectives [67].

Saudi Arabia can foster innovation, lessen environmental impacts, and pave the way for more durable and resilient transportation infrastructure by promoting the use of energy-efficient clean technology.

4.3.4. Promoting Financial and Investment Opportunities (RII = 0.688)

The evaluation of transportation projects' environmental, social, and economic implications, as well as their compliance with sustainable development objectives, is referred to as transportation infrastructure sustainability performance. Construction of new roads, highways, railroads, airports, and ports, as well as the implementation of sustainable transportation systems, including public transit networks and bicycle infrastructure, could fall under this category in Saudi Arabia [68]. A detailed assessment of transportation projects was carried out to promote financial and investment potential. The project's environmental impact, resource consumption, social benefits, economic viability, and compliance with the nation's sustainability goals are just a few of the many factors that this analysis looks into [69]. It also entails evaluating the projects' financial sustainability, taking into account prospective revenue streams, estimated returns on investment, and associated risks. To pique their interest and solicit their investment in these transportation projects, the investigation's findings are presented to prospective investors, including private businesses, institutional investors, and governmental organizations. Reports, presentations, or investor forums may be used for this communication, which will emphasize the projects' sustainable performance and financial potential [69]. It promotes investment from both domestic and foreign sources, supporting economic progress, environmental stewardship, and social well-being in the nation by showing the beneficial impact and profitability of these projects.

4.3.5. Noise and Vibration Minimization (RII = 0.687)

During the building and operation phases, transportation projects, including motorways, railroads, airports, and ports, can produce large levels of noise and vibration. These may have detrimental effects on the environment, wildlife, and people's health. In order to ensure sustainable and habitable surroundings close to traffic infrastructure, it is essential to reduce noise and vibration. It is critical to evaluate the project's possible noise and vibration effects while examining the sustainability performance of transportation projects in Saudi Arabia [70]. The project's proximity to residential areas, delicate natural habitats, or noise-sensitive locations such as schools, hospitals, or cultural heritage sites may be considered as part of this study. The investigation can help identify and put into practice the right noise and vibration reduction strategies. This can entail utilizing cutting-edge construction methods, installing noise barriers and soundproofing materials, putting in place efficient traffic management plans, and improving the design and operational facets of the transportation infrastructure.

For instance, noise barriers can be put in place alongside railroads and highways to lessen the noise reaching surrounding neighborhoods [71]. Road traffic noise can be reduced by using low-noise pavement. Creative engineering approaches can be used to lessen the effects of vibration, such as vibration isolation methods or ground-stabilizing techniques.

Transportation plans in Saudi Arabia can improve societal well-being, public health, and environmental preservation by reducing noise and vibration.

5. Conclusions

This study set out to investigate how different stakeholders, such as government organizations, project owners, engineers and design experts, and contractors, viewed the relative importance of the many aspects affecting Saudi Arabia's transportation sustainability performance. The novelty of this paper comes from its unique focus on assessing the sustainability performance, specifically in the context of Saudi Arabian transportation infrastructure projects. This article aimed to evaluate the sustainability performance of transportation infrastructure projects concerning Saudi Arabia. A total of 34 probable outcomes were identified based on a thorough examination of the literature and professional opinions. One hundred and ninety-seven respondents participated in a structured interview to determine the most important outcomes relating to transportation sustainability performance.

The top five results of sustainable transportation practices were identified through analysis utilizing the RII, and they were as follows: "Promoting the reduction of carbon emissions", which highlights the need to lower carbon emissions to mitigate the effects of transportation on the environment. "Minimizing pollution and environmental impacts", which stresses the significance of reducing pollution and unfavorable environmental effects related to transportation-related activities. The third highest ranked factor was "encouraging the use of energy-efficient clean technology", which promotes the use of energy-efficient and clean technologies to improve sustainability in transportation, encouraging the use of energy-efficient clean technology. The "noise and vibration minimization" factor recognizes the need to limit noise and vibration disruptions originating from transportation infrastructure and activities. However, "promoting financial and investment opportunities" emphasizes the development of financial and investment prospects in sustainable transportation projects.

These findings serve as a basis for formulating strategies and policies to promote sustainable transportation practices in the region and offer insightful information about the major outcomes linked to transportation sustainability in Saudi Arabia. Policymakers, government organizations, project owners, engineers, design experts, and contractors participating in Saudi Arabian transportation projects should take these facts seriously. The knowledge gathered from this study serves as a foundation for creating effective plans and regulations that prioritize sustainability, environmental preservation, and popular support. Stakeholders may improve transportation networks, lessen harmful environmental effects, improve building methods, and guarantee worker and public safety and well-being by concentrating on these essential outcomes. In the future, it will be crucial for stakeholders to incorporate these findings into their project planning, policy formulation, and decision-making procedures. Saudi Arabia can make great progress toward developing a robust, effective, and environmentally conscious transportation infrastructure that benefits the present and future generations by embracing sustainable transportation practices and prioritizing the outlined outcomes.

The goal of this study was to provide a thorough set of data about the human perceptions of Saudi Arabia's transportation infrastructure sustainability performance. These suggestions will be developed while taking into account economic and social considerations in order to be consistent with the nation's long-term sustainability objectives. Policymakers, transportation authorities, and other stakeholders participating in all stages of project design, development, and operation will be able to use them as practical guidance. In addition, future prescriptive research utilizing action and constructive research methodologies will help in thoroughly examining the strategic aspects of transport infrastructure sustainability performance through a model, or to develop a sustainability performance index.

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