Influencing factors of sustainable highway construction

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Abstract. The triple bottom line, which consists of the three pillars of the environment, society, and economy, must be balanced to achieve sustainable development. Integrating social, economic, and environmental aspects in construction projects is still a challenge. The construction industry tends to use non-renewable and unsustainable resources with energy values contained therein. One of the infrastructures that need to be considered in the concept of sustainable development is highway infrastructure. Highway infrastructure projects are quite complex because they involve a lot of resources, require a wider location, and significantly impact the community and the government. Environmental, social, and economic issues are just a few of the persistent issues that frequently surface during highway construction. Common environmental difficulties include water and energy consumption, road landscape issues, and wildlife conservation. Social issues are common in road projects and include issues with land acquisition, relocation, and worker comfort. Instead, bid prices and production costs that are elevated as a result of the usage of eco-friendly materials could cause economic issues. This study aims to investigate the TBL factors that influence the construction of sustainable roads and highways. A literature study is carried out by searching articles related to sustainable road projects. There are seven factors and 29 sub-factors for sustainable highway development, according to the literature review. Technology, project management, ecology, materials, government, community, and value system are the seven factors. These seven elements all contribute significantly, are interrelated, and are necessary for the realization of a sustainable highway.

1 Introduction

Sustainable development is an important issue in the world that has been echoed recently, even though it has been conceptualized for decades. Countries all across the world are working toward sustainable development as a result of worries about the world's population growth that is outpacing the availability of natural resources [1]. Sustainable development is defined as the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs [2-4]. The 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development are a set of 17 global objectives that the entire globe hopes to accomplish by 2030. The SDGs were created by the UN General Assembly on September 25, 2015, and on January 1, 2016, they were ratified by 193 nations.

Construction plays a crucial role in putting the concept of sustainable development into practice because it is closely tied to SDGs 9 (Industry, Innovation, and Infrastructure) and 11 (Sustainable Cities and Settlements) [5]. The complete burden of building a healthy project environment, effective resource utilization, and ecological foundation rests with the construction industry [6].

Sustainable development is a balance between the three pillars consisting of environment, economy, and, social [7]. While the environment promotes industries to benefit the world as much as possible through sustainable practices, including considering the negative effects on the environment, economics aims to achieve the main goal of producing a long-term and beneficial economic impact. The goal of social responsibility is to make the lives of individuals who are involved in the programs better [8]. Integrating social, economic, and environmental aspects in construction projects is still a challenge. The use of non-renewable and unsustainable resources with energy values is common in the building sector. As a result, the building industry is thought to be a significant user of non-renewable resources and is also accountable for about 50% of carbon dioxide emissions [9]. Many construction processes are still running traditionally, that is, only in the form of “take, make, waste” taking materials or raw materials from nature, using them for construction, and leaving the facility after use or disposing of debris to landfills [10]. The building and construction industry has received criticism for being one of the primary contributors to environmental problems, notably in the operations that result in excessive pollution [11]. The construction sector is also under tremendous pressure to stop such damages and take extra steps to make up for such losses because it is a significant contributor to global warming [8].

Highway infrastructure is one of the infrastructures that must be considered in the concept of sustainable development because it is the foundation of a nation's

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economic development [12]. Highway construction spans enormous areas and accounts for a sizable portion of a country's infrastructure development [13]. Highway infrastructure projects are quite complex because they involve a lot of resources, require a wider location, and significantly impact the community and the government [14]. This is because the sector focuses primarily on the economic (profit) side of things while ignoring the social and environmental components.

Environmental, social, and economic issues are just a few of the persistent issues that frequently surface during highway construction. Common environmental difficulties include water and energy consumption [11, 15], road landscape issues, and wildlife conservation [13]. Social issues are common in road projects and include issues with land acquisition [8], relocation, and worker comfort [16]. In the meantime, bid prices and production costs that are elevated as a result of the usage of eco-friendly materials could cause economic issues [17].

Several scholars have studied environmentally friendly highways. Research on the green road concept was conducted by [11], which links it to the green economy concept. In addition, several researchers such as [18-19] link sustainable road development with BRI (The Belt and Road Initiative). Meanwhile, several studies from [17, 20]discuss green construction in road infrastructure that emphasizes environmental aspects. Research that discusses the TBL concept holistically in road projects is quite difficult to find. To fill this gap, this study aims to investigate the TBL factors that influence the construction of sustainable highways based on literature studies.

2 TBL in sustainability construction

Sustainable development must meet the triple bottom line or Triple P or TBL, which consists of social aspects (people), environmental aspects (planet), and economic aspects (profit). Sustainability development is a concept that can be interpreted as an approach to development that balances different needs with awareness of environmental, social, and economic limitations. This tripartite description is often, but not always, presented in the form of three intersecting circles of society, environment, and economy, with sustainability being placed at the intersection, as shown in Fig. 1.

This graphic in Fig.1 is found in various forms as a descriptor of ‘sustainability’ within the academic literature, policy documentation, business literature, and online, and whilst often described as a ‘Venn diagram’, it commonly lacks the strict logical properties associated with such a construction. Alternative manifestations include the three depicted visually as nested concentric circles or literal ‘pillars’, or independent of visual aids as distinct categories for sustainability goals or indicators [21].

The term "sustainable construction" refers to building that incorporates the idea of sustainable development. Sustainable building is defined as building that incorporates a healthy working environment, work effectiveness, and quality of life through effective design processes, sustainable sourcing, and sustainable building implementation [22].

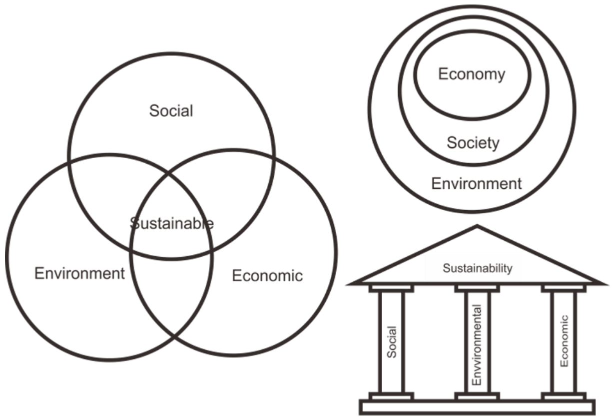

Fig. 1. Various forms of sustainability [21].

The concept of social sustainability integrates processes to improve the safety, health, and quality of life of the community during the project life cycle [23-24]. The social pillar of sustainable construction emphasizes improvement in the quality of life of humans and the environment that requires and includes community involvement, Corporate Social Responsibility (CSR), and handling of safety aspects in the design phase. This pillar also emphasizes the value of the social welfare of society, particularly that of employees and building occupants. It addresses issues like social equality, health, human rights, education and job training, workload alignment, security, cultural preservation, integrity, accessibility, and stakeholder involvement. According to several studies [25-26], the social pillar is the most significant pillar in sustainable development since it refers to people and their interactions with one another.

The environmental sustainability pillar on construction relates to the analysis of the impact of construction activities on the environment directly which includes land use, election materials, energy conservation, water efficiency, waste reduction, pollution control, and biodiversity preservation [27]. Environmental sustainability in construction attempts to maintain harmony between the built and natural environments over the duration of a structure.

The economic pillar of sustainable construction consists of several characteristics including minimizing all costs incurred during the project life cycle, using project resources as efficiently as possible to produce maximum results as well as short-term capital returns with long-term benefits. The primary objective of economics is to create a sustained, favorable economic impact [24].

In fact, there are currently several barriers preventing sustainable construction from being further improved. These barriers include a lack of funding to cover initial costs, construction being slowed to meet the additional sustainability requirements, and sustainable buildings' market values rising to cover the higher initial costs [7].

3 Application of TBL concept in highway construction

To achieve sustainable infrastructure development, it is important to remember the relationship between infrastructure projects and the principle of sustainability. Infrastructure is said to be sustainable if it meets environmental sustainability (such as reduced greenhouse emissions, low pollution levels, and lack of waste disposal into rivers). Due to their scarcity, resources must be used through a system of conservation, reuse, and renewable energy. For the purpose of social sustainability, by enhancing air quality, paving access for locals, and enhancing road safety Regarding the economic side, specifically through a tax and regulatory framework that supports the private sector and ensures a sufficient return on investment [28]. Fig. 2 is an application of sustainability principles in infrastructure development especially in highway project.

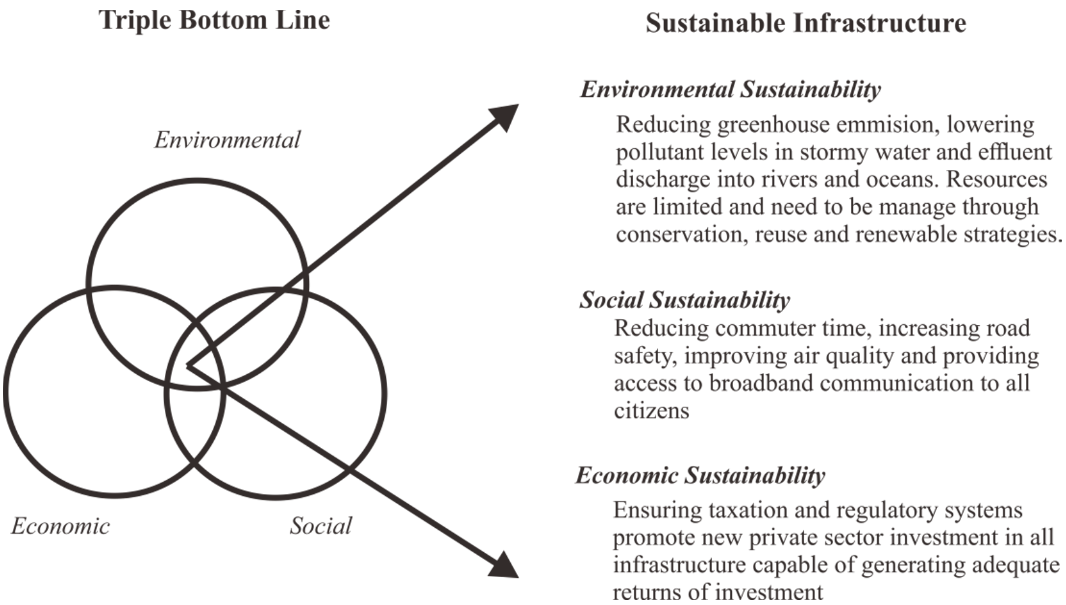

Fig 2. An application of sustainability principles in infrastructure development [28].

A highway project is an example of an infrastructure project that has an impact on human existence. The development of a highway is one of the most important infrastructure projects in the building sector [29]. The daily lives of people are directly correlated with road and highway projects. They are crucial to the social and economic advancement of a country. Some literature frequently refers to highway construction projects that adhere to sustainable or green construction principles as “green highway construction” [13]. It means ensuring that highway projects are environmentally, socially, and economically sustainable. Same with [30] implied that in order for a transportation infrastructure to be considered "sustainable," it must satisfy all sustainability goals during its entire life cycle, including those for mobility, safety, resource efficiency, economy, ecological preservation, and environmental quality.

The TBL concept can be applied in various ways to ensure that the project has a positive impact on the surrounding communities, the environment, and the economy. Highway construction projects can have significant impacts on local communities, including noise pollution, traffic congestion, and reduced access to amenities [31]. A TBL approach would involve engaging with local communities early in the project planning process, seeking their input, and addressing their concerns. This could involve public consultation, stakeholder engagement, and the use of social impact assessments to identify and address potential negative impacts.

Highway construction projects may have a large negative impact on the environment, including habitat loss, air and water pollution, and greenhouse gas emissions [32]. A TBL strategy would involve detecting and mitigating these effects by taking steps like using sustainable materials, cutting back on energy consumption and greenhouse gas emissions, and causing the least amount of harm to natural habitats. Including green infrastructure, such as vegetated swales and bioswales, could also help regulate stormwater runoff and enhance water quality.

TBL's economic component comprises making sure that highway development projects are both financially viable and benefit society in the long run [33]. The long-term costs and benefits of various building materials and construction methods could be evaluated using life cycle cost analysis, and opportunities for cost reduction and efficiency might be found. It might also entail considering the project's economic advantages, such as the expansion of employment possibilities and the local economy.

According to [28], sustainability in highway projects is represented in 3 categories:

1. High ideal-covering human and planetary safety,

2. Semi broad ideal - includes the balance of the triple bottom line for the welfare of the human population and the environment,
3. Project level-related to project issues such as Occupational Safety and Health (OSH), and effective use of resources.

4 Influencing factors of sustainable highway construction

Understanding the TBL elements that affect efforts to achieve sustainable construction for road projects is essential. The use of sustainable principles by a road project might be successful or unsuccessful depending on these variables. To achieve sustainable highway construction, this sustainable principle needs to be used throughout every project cycle. [34] implied that to build a green highway, efforts should now be focused on establishing a balance between the needs of the highway and local ecological protection issues, figuring out how to stop future environmental degradation and excessive resource consumption, and implementing sustainable development ideas into highway projects.

According to [35], application of sustainability in project management is affected by a number of factors: Project context, stakeholders, project specifications, costs, benefits, project organization, scheduling, materials used, procurement, risk management, stakeholder engagement, project communication, reporting, handover, and organizational learning are just a few of the factors that need to be considered. Furthermore [36] has identified seven crucial elements that must be considered when building sustainability:

1. Profitability,
2. Safety,
3. Transparency,
4. Ethicality,
5. Environmental friendliness,
6. Social acceptability, and
7. Meeting stakeholder and customer expectations.

Efficiency, mobility, safety and comfort, community involvement, emission restrictions, natural resources, habitats, and ecosystems are the guiding principles for implementing sustainable roads [37]. Ecology, landscaping, materials, waste reduction, water conservation, and energy conservation are among the environmental elements that [13] discovered impact the building of sustainable roads and highways. Along with [29] was identified ten social factors that affect road and highway projects. They are as follows:

1. Respecting and caring for communities,
2. Improving quality of living,
3. Diversity with employees and community during construction projects,
4. Vitality of a community during the construction project,
5. Minimizing the usage of non-renewable resources during projects construction,
6. Changing attitudes and practices,
7. Tracking measures for social sustainability,
8. Awareness of social sustainability,
9. Global networking for social sustainability, and
10. Responsibility and accountability of organizations.

Based on the findings of a literature review, Table 1 provides a summary of the variables influencing the use of sustainable construction on highway projects.

Table 1. Influencing factors of sustainable highway construction.

Influencing factors of sustainable road highway construction		Source
	A. Project Management	
1.	Cost and benefits	[35-36]
2.	Project Organization	[35]
3.	Risk Management	[35]
4.	Occupational Health and Safety	[7, 36]
5.	Project Scheduling	[35]
6.	Human resources	[2]
7.	Corporate Social Responsibility (CSR)	[38]
8.	Fulfilling Customer and stakeholder expectations	[36]
	B. Ecology	
1.	Landscaping	[13]
2.	Water Conservation	[13, 15]
3.	Biodiversity conservation	[13, 27]
4.	Using Renewable Energy	[11, 13, 15]
5.	Ecological functions of drainage corridor	[13]
6.	Pollution Control	[15, 27]
	C. Materials	
1.	Using environmentally friendly materials	[13, 27]
2.	Selection of automated /IBS working methods	[13]
3.	Minimization of waste during the construction process	[13, 29, 37]
4.	Application of durable material	[13]
5.	Application of Reduce, Reuse, Recycle (3R) Principle	[13, 17, 20]
	D. Government	
1.	Government Role	[39]
2.	Land use policy	[40]
3.	Transport policy	[40]
4.	Taxation and regulatory system	[28]
	E. Communities	
1.	Community participation	[29, 37]
2.	Efficiency and mobility	[28, 37]
3.	Safety and comfort access	[28, 37, 39]
	F. Value System	
1.	Ethicality	[36]
2.	Culture and heritage	[28, 39]
	G. Technologies	
1.	Tools and Technologies for Sustainable Construction	[41-42]

The factors in table 1 above are factors that include the Triple Bottom Line (TBL) of economic, social, and environmental sustainability (TBL) as determined by the findings of a literature review. Table 1 above shows seven main factors and 29 sub-factors that influence sustainable highway construction. The seven main factors are Project management, Ecology, Materials, Government, Communities, Value System, and technologies.

5 Discussion

The first factor influenced sustainable highway construction is project management. Project management is a required method for handling a project's complexity. In order to maximize the likelihood of a project's efficacy and success, the project management technique is utilized as a strategy for handling project tasks in a systematic way. Project-based companies can set standards for the implementation of activities and reap the benefits of optimal resource utilization by using and adapting the approach as formal processes [43]. Incorporating sustainability into project management represents a paradigm shift from the strategy that relies on predictable and controllable processes and outcomes, as opposed to merely adding to or altering current processes and standards. To guarantee the success and sustainability of highway projects, project management is essential [44]. Good project management techniques can be used to recognize and address possible risks and difficulties that could have an adverse effect on the project's sustainability. All stakeholders should be included in the planning, design, and execution of the road project, according to project management. Being involved with regional communities, governmental organizations, environmental organizations, and other interested parties is part of this. Possible hazards are identified and solutions to reduce them are developed with the aid of good project management procedures. By doing so, the possibility of delays or cost overruns, which could affect the project's viability, can be decreased. In addition, effective project management techniques ensure that resources are used wisely, minimizing waste, and lowering the project's environmental impact.

Ecology is essential for highway developments to be sustainable [45]. Sustainable highway projects can reduce adverse environmental effects while fostering long-term sustainability by avoiding habitat fragmentation, enhancing water quality, lowering carbon footprint, and encouraging biodiversity. Highway construction may also have a negative impact on water quality by speeding runoff, sedimentation, and erosion. Sustainable highway projects aim to lessen these consequences by adding components like eco-friendly stormwater infrastructure and erosion control methods. Highway construction can have a substantial carbon footprint because of the energy and materials needed for construction as well as emissions from moving traffic. By using renewable energy sources, promoting alternate forms of transportation, and putting emission-controlling measures in place, sustainable road projects seek to reduce their carbon footprint.

Materials are essential to the success of sustainable highway construction. Sustainable highway projects can lessen their environmental impact and advance long-term sustainability by choosing materials with low environmental impact, reducing embodied energy and greenhouse gas emissions, selected method and promoting durability and minimal maintenance. Sustainable highway projects strive to employ locally sourced, recyclable, and renewable materials that have a minimal negative impact on the environment [46]. For instance, employing recycled concrete and asphalt minimizes the quantity of new material needed for highway construction, lowering the project's environmental effect.

Government is the 4th factor that influenced sustainable highway construction. Government plays important role to obtain sustainable highway construction. Governments can establish policy and rules to support sustainable highway construction [47]. This can involve establishing requirements for environmental impact assessments, supporting alternate forms of transportation, and establishing standards for building materials and construction techniques. Moreover, Sustainable highway construction may be funded by governments through grants and low-interest loans. This may help make financially viable and appealing to private investors sustainable highway developments with Public Private Partnership (PPP) scheme.

Sustainable highway project success depends on community involvement [48]. Communities can aid in ensuring that road projects are designed and built in a way that promotes long-term sustainability and satisfies community needs by offering input and feedback, engaging stakeholders, educating the public, taking part in implementation, and monitoring and evaluating the project's long-term impacts. Sustainable highway projects should engage a broad range of stakeholders, including community residents, businesses, and environmental groups, to ensure that the project's aims and objectives are aligned with their needs and interests.

A value system is a set of beliefs and standards that directs people or organizations in choosing what to do and how to do it. Value systems can significantly affect the construction process and its results in the context of sustainable highway construction. The ethics, culture, and historical significance of the value system in highway project [28, 36, 39]. The needs of the town and its culture must come first while building a highway [49]. Decisions may be made with the community's wants and concerns in mind if the construction of the roadway is in an area of the local community's historical and cultural heritage. Likewise, the design, materials, and construction techniques of a highway construction project will be influenced by its core value of sustainability. The use of recycled materials or reducing waste generation, for instance, may be prioritized as sustainable practices.

The last factor that influenced sustainable highway construction are technologies, which is playing crucial role. Innovative technologies are being explored to generate sustainable highway materials that are durable, low-carbon, and recyclable [50]. Both pollution reduction and transportation efficiency can benefit from new technologies. Electric and hybrid vehicles, for instance, can lower greenhouse gas emissions while also improving traffic flow and reducing congestion. Remote sensing and Geospatial Information Systems (GIS) are two examples of technologies that can be used to track the environmental effects of highway projects and assess their long-term viability.

6 Conclusion

Sustainability development is a concept that can be understood as a method of development that balances various needs while being conscious of social, economic, and environmental constraints. It remains difficult, but not impossible, to incorporate social, economic, and environmental considerations into highway construction projects if we are aware of the variables that affect sustainability.

There are seven factors and 29 sub-factors for sustainable highway development, according to the literature review. Technology, project management, ecology, materials, government, community, and value system are the seven factors. These seven elements all contribute significantly, are interrelated, and are necessary for the realization of a sustainable highway.

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