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Evaluation of Sustainability Performance in Building Construction : Case of Under Construction Government Buildings of PUDBC, Kathmandu

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Abstract
Sustainable building construction is directly concerned with environment protection, reduction of resource consumption, quality enhancement, application of life-cycle costing and reuse & recycling of resources and hence it is extremely vital for achieving sustainable development goals. Proper site selection, adoption of flexible and durable designs, discrete project planning and management of construction activities are the pre-requisites for Sustainable building construction. In this research, scoring and evaluation criteria from Green Globes Building Sustainability Rating tool, after validation from three experts of the field, was used to score and evaluate the level of sustainability performance in four governmental building projects of PUDBC, Kathmandu for two major assessment areas of Project Planning & Design and Site Management. It was found that all projects demonstrated initial level of commitment towards sustainability integration in both the assessment areas with mean score of 42.99% and 57.45%. The sustainability performance in site management was higher than that in project planning & design for the studied projects, however there were major areas of improvement in both areas. For attainment of higher sustainability, Performance of LCCA, Integrated design practices and Building Commissioning and Building Operators' Training were found to be instrumental in Project Planning & Design stage whereas Proper mitigation of constructions impacts, landscaping practices and efficient storm-water management were vital for enhancing sustainable site management. It was also determined that sustainability performance in Project Planning & Design has dependency on overall project cost whereas sustainable site management was not found to be in strong relation to overall project costs with adjusted R-square value obtained from linear regression being 0.78074 and -0.20608 respectively. RII analysis was performed on the responses on Likert scale provided by direct stakeholders of the 4 selected projects regarding their perceptions on barriers and drivers for sustainable building practices. Inadequate Government Initiatives towards sustainability application and Lack of Proffessional capability for sustainability application were found to be most impactful barriers with RII of 0.81667. The barrier which was perceived to be most difficult to eliminate was Additional Economic Burden associated with sustainability application with RII of 0.80833. Moreover, the most effective driver to enhance sustainable building construction was found to be Economic Incentives (Budgetary Provisions) for sustainability integration while the driver with highest level of ease in execution was believed to be Development of Green Design Manual, Guidelines, Construction Standards supported by Assessment Tools and Frameworks with RII of 0.85000 and 0.71667 respectively.

Keywords
Sustainable Building Construction, Green Globes Framework, RII analysis, Barriers, Drivers, Project Planning & Design, Site Management

1. Introduction

The construction industry being one of the largest industries in the world, plays an instrumental role in the social and economic development of any country [1, 2, 3]. On one hand, construction sector is having such humongous effect on socio-cultural and economic development while on other hand, it is also taking its toll on the environment through acute resource exploitation and release of pollutants. Construction and operation of buildings is responsible for consumption of 45% of global energy, 50% of global water usage and for 23% of global air pollution and Green House Gases (GHGs) emissions. [4] As per Hou et al.,[5], contribution to global CO2 emissions from building construction sector will be more than 52% by 2050, resulting in extensive environmental impacts world-wide such as climate change.

Most of the developing countries of the world like Nepal are giving limited attention to sustainability issues with more priority given to rapid infrastructure construction [6]. Such prioritization of infrastructure development without due consideration to sustainability will ultimately lead to irreparable environmental degradation in the long run [7]. Chawla et al. [8] argued that construction projects must embrace sustainability approach to achieve desired economic expansion along with simultaneous protection of environment. Other international literature have also discussed about the global impact of sustainability for attainment of sustainable economic growth [9, 10]. The ardent need for sustainability application in construction projects and industry as a whole is un-questionable and undeniable but still limited academic attention has been given to its actual implementation.

The implementation and attainment of sustainability in construction for any country is a long and complex process

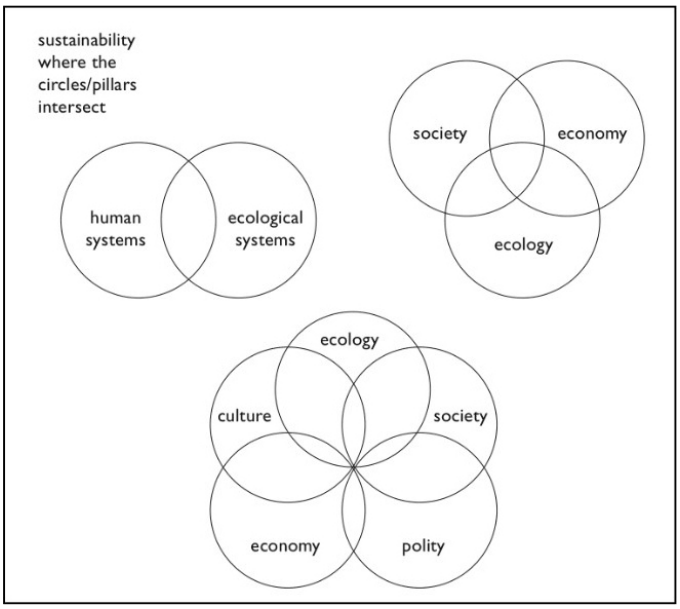

Figure 1: Pillar Concepts of Sustainability [16]

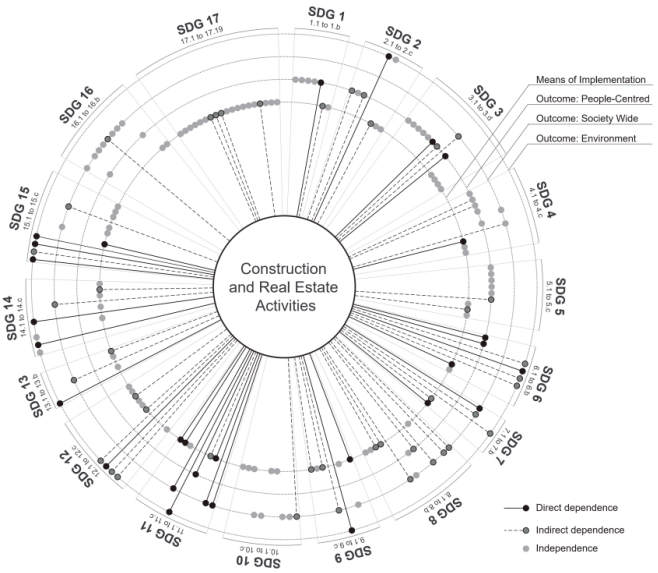

Figure 2: Visual Map showing dependency of SDGs on construction and real-estate activities [19]

involving large number of environmental, social and economic indicators but the starting point is determining the existing situation of that country [11, 12]. In our context, we don't have concrete information on how sustainable our construction practices are. At the same time, we neither have any mechanism in place to precisely measure the degree of sustainability in our existing practices nor do we have any information regarding the obstructing and driving factors for attainment of said sustainability [13, 10]. The existing building codes are more concerned about safety and architectural and structural adequacy of buildings and don't give any dedicated attention to sustainability issues and there are limited practices of sustainability assessment of buildings [14]. This notable dearth of information and holistic research to acquire those realities especially within the context of a developing country like Nepal, provides justification for this present study, which aims to evaluate sustainability of current practices in specific building projects in the capital city of the country, Kathmandu itself.

2. Literature Review

2.1 Sustainability and Importance of Sustainable Construction

Sustainability is defined as the act of meeting the needs of the present without compromising the ability of future generation to meet their needs [15]. The concepts of sustainability can also be depicted as in Figure 1.

Globally, construction industry is often labelled as a non-sustainable industry particularly due to its high energy and material consumption coupled with excessive release of environmental wastes and pollutants [17]. Moreover, construction industry value chain has direct contribution to adverse impacts on the environment, economy and human well-being ultimately [18]. A study by Goubran[19] mentioned that 17% of the SDG targets are directly dependent and 27% of the targets are indirectly dependent on construction and real-estate activities as depicted in Figure 2. So, in a way, it is not possible to achieve these goals and targets within prescribed duration and effectiveness without first applying and ensuring sustainable infrastructure development practices.

Sustainable construction is the overall process of developing and managing an appropriate built environment hinged on the discreet use of resources and ecological principles [20]. This type of construction is premised on the triple bottom line (TBL) tenets of "people, planet, and profit."

2.2 Building Construction and Impacts on sustainability in Global and Nepali Context

The real-estate construction sector is one of the most rapidly growing industry throughout the globe. A study by Allied Market Research in 2022 found out that the global investment in real-estate sector was around 11444.7 billion US dollars in 2021 and it is expected to surge up to 30575 billion US dollars by 2031. In Nepal, the characteristics such as unique parameters of durability, high transaction cost, heterogeneity and direct linkage to fulfillment of citizen's basic human rights distinguishes it with other construction sectors [21]. Kathmandu, capital city of Nepal, is at the heart of urban explosion and the construction sector, especially building sector is growing at an alarming rate. As per Nepal Land and Housing Developers' Association, the annual demand for houses and apartments in Nepal is around 140000 units and Kathmandu valley alone accomplishes 42% of the demand but only 17% (about 25000 units) can be fulfilled. Another study by Shrestha[22] shows similar trends regarding the rapid rise in the demand for real-estate construction in the capital.

Since the growth of building construction is continuing at tremendous pace, its impacts on ecology, environment and climate is also multiplying with each passing day in an ominous manner. In Nepal, around 87% of country's overall final energy consumption is shared by households [23]. And this demand is expected to grow at a rate of 3.9% through 2030 with total energy demand being 5.58 million GJ if no proper

interventions are made. But if proper interventions are made in terms of sustainable energy practices, the demand can be rapidly decreased as found by B. Bhandari et al [24]. It was also found that building sector in Kathmandu expelled 1444.86 Metric tons(Mt) of embodied carbon in its full life-cycle [25]. More than 5% of municipal wastes in Kathmandu was found to be construction wastes [26]. A study by Dahal et al [27] discussed about the ecological impacts of unsustainable extraction of construction materials such as sand, gravel for building and other construction activities. The scientific waste management practice at construction site was found to extremely essential for negotiating issues with construction wastes [28]. These studies and their outputs clearly point towards the introduction of sustainability in existing building practices to minimize or eliminate adverse impacts on environment. Besides being environment friendly, sustainable building construction practices are also expected to significantly reduce life-cycle cost and enhance staff productivity [29]. Kibert et al [30] described seven principles of sustainable building construction that act as guidelines for different stages of building construction projects, which have been shown in the Figure 3.

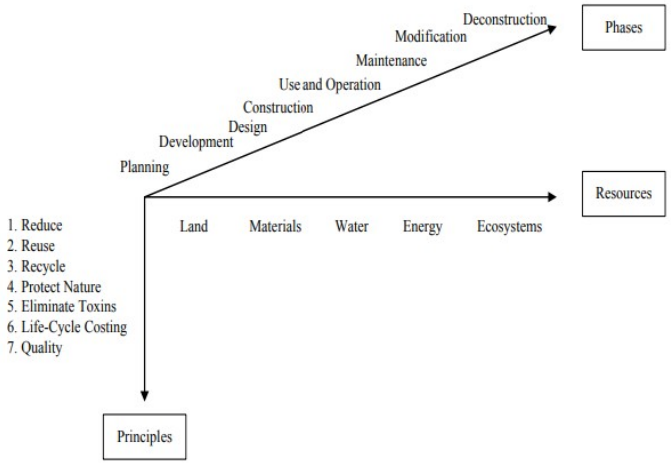

Figure 3: Frameworks of Sustainable Building Construction [30]

With the introduction of federalism,in additional to central government, there are now 7 provincial governments and 753 local governments and so the demand for government administrative building and service infrastructures has reached an all-time high. To incorporate administrative restructuring and share of responsibilities after federalism, there is requirement for large governmental funding and budgets for construction of federal and provincial parliaments, administrative office buildings of local levels, ministries administrative and executive buildings, minister's quarter buildings and so on. Pertaining to such high investment and simultaneous construction throughout the nation, it is extremely important to considerate the sustainability issues associated with governmental buildings constructions at present. Moreover, to implement sustainable construction in the nation, it is first necessary that government owned construction set the ship sailing.

Table 1: Most popular Building Sustainability Assessment Tools [31]

Rating System	Year/Country of origin	Buildings Certified	Certification Levels
BREEM	1990 United Kingdom	> 250000	Pass
			Good
			Very Good
			Excellent
			Outstanding
LEED	1998 United States	>103000	Certified
			Silver
			Gold
			Platinum
Green Globes	2000 Canada	>3300	1 Globes
			2 Globes
			3 Globes
			4 Globes
Green Star	2002 Australia	>800	4 Star
			5 Star
			6 Star

2.3 Sustainability Rating Tool/ Assessment Framework for building

Different sustainability assessment system (framework), also called the rating tools are being used globally with primary objective to determining and then addressing the environmental impacts of the buildings.The rating system for sustainability must have proper certification system, incorporate all the possible areas of sustainability and a mature finished system. According to Portalatin et al.[31], there are fifteen system that meet those requirements and are used extensively world-wide and among them four systems are most widely accepted based on the total number certifications provided by them, which have been shown in Figure 1.

2.3.1 Green Globes Framework

Green Globes framework is a scientific building rating and certification system for building stakeholders to select and address sustainability features in buildings, first launched in 2005 in US and has undergone multiple additions, modifications and updates in reaching the present state. The existing version of framework incorporate three modules, namely New Construction (NC), Existing Buildings (EB) and Sustainable Interiors (SI). This framework was developed by Green Building Initiative (GBI), a non-profit organization with standards developer accreditation from American National Standards Institute (ANSI), dedicated to reducing climate impacts by enhancing built environment. GBI acquired global rights to globally expand Green Globes framework from Jones Lang LaSalle Incorporated (JLL) in 2018 [32, 33].

2.3.2 Green Globes for New Construction (NC)

This module has scoring method based on a 1000 points system and is applicable for newly constructed enclosed permanent structures designed for human occupancy and having minimum total area in excess of 4000 sq. The assessment sub-areas, point system for this study based on

Project Planning & Design and Site Management and evaluation criteria from this module, after validation from expert opinion are shown in Tables 2 and 3.

Table 2: Assessment Areas of Green Globes for NC (Project and Site Management)

S.N	Assessment Area		Sub-assessment Area (Max. Points)
1	PROJECT PLANNING & DESIGN (Max.Weighted Score: 50 points)	1.1	Team & Owner Planning (36)
		1.2	Environment Management (8)
		1.3	LCCA -Life Cycle Cost Analysis (12)
		1.4	Moisture Control Provisions (6)
		1.5	Building Commissioning Or Systems Manual / Training (20)
2	SITE MANAGEMENT (Max. Weighted Score: 115 points)	2.1	Development Area (35)
		2.2	Transportation (29)
		2.3	Construction Impacts (26)
		2.4	Stormwater Management (21)
		2.5	Landscaping (21)
		2.6	Light Pollution (5)

Table 3: Evaluation Criteria for sustainability integration (with Reference of Green Globes Framework Certification) [32]

Weighted Score in %	Description of Evaluation
85-100%	Demonstrates national leadership in sustainability application.
70-84%	Demonstrates leadership in applying good practices of sustainability.
55-69%	Demonstrates good progress towards sustainability integration.
35-54%	Demonstrates Commitment towards sustainability integration.
<35%	Insufficient Commitment towards sustainability integration.

2.4 Barriers and Drivers for sustainability application in Building Construction

The study is also aware about the importance of evaluating the critical factors that can constrict and navigate sustainability integration into our practices from the perspectives of different stakeholders directly involved in the building construction sector [34]. Many studies and research have been carried out in multiple countries of the world to identify the barriers and drivers of sustainable construction, among which top 5 most repeated ones have been summarized in the Table 3, after validation for Nepali context from some key stakeholders of building construction sector.

Table 4: Major Drivers and Barriers for Sustainability Application

	Barriers
1.	Lack of Knowledge/Awareness on Sustainability.
2.	No sufficient government Initiatives for Sustainability Integration.
3.	Additional Economic Burden associated with sustainability application.
4.	Risk associated to new technology in sustainable practices.
5.	Lack of Professional Capability. (Human and Non-human).
	Drivers
1.	Integration of sustainability in Academics and Training Programs for professionals.
2.	Economic Incentives for Sustainability Promotion.
3.	Formulation of appropriate rules, regulations and policies.
4.	Application of Constructability/Integrated Design Approach.
5.	Development of Green Design manuals, Guidelines, Assessment tools and frameworks.

3. Methodology

In order to achieve the objectives of this study, a systematic procedure was applied which has been detailed in Figure 4.

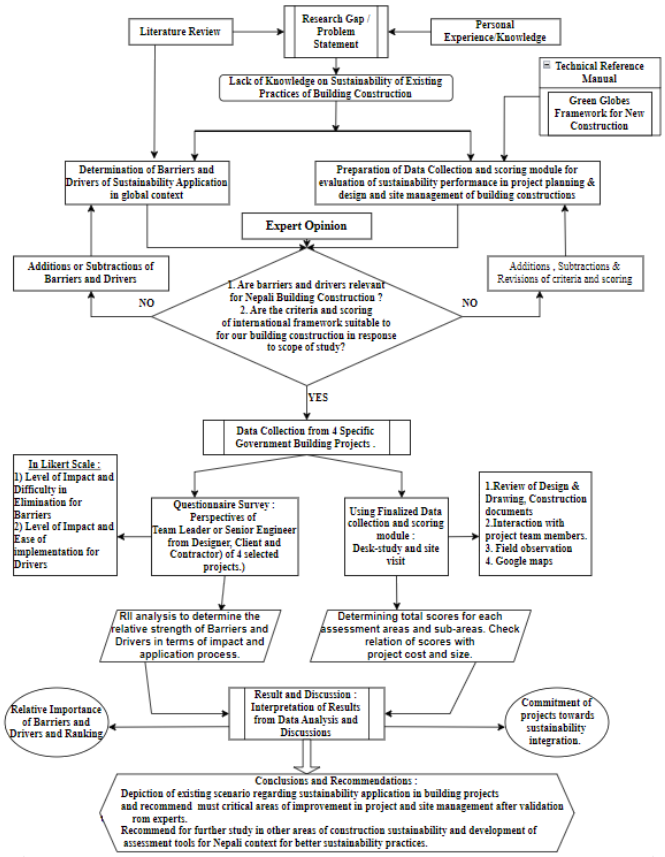

Figure 4: Research Methodology and Design

This research involves the study of RCC building projects administered by Project Office of Urban Development and Building Construction (PUDBC) in Kathmandu district, which are presently at various stages of construction and having cost estimates of more than 200 million Nepali Rupees. Department of Urban Development and Building

Construction (DUDBC) under Ministry of Urban Development (MoUD) is the apex body for administering all kinds of government building projects in Nepal with PUDBC, Kathmandu being one of its sub-division looking after government building projects in the capital, which has been appraised for this study. At the same time, this study examines the sustainability performance for project design & planning and site management stages only, for which only four building projects presently at various stages of construction are deemed viable through purposive or judgemental technique of selection.

For determination of sustainability points and evaluation scores in the above mentioned assessment areas, review of design,drawing,tender and construction documents, interaction with project team members and site visit and verification was carried out for each project. After evaluation of sustainability performance and determination of major areas of weakness/improvements in attainment of sustainability in the studied projects, the study was focused on determining the constricting and driving factors for sustainability attainment along with their level of significance from the perspectives of client, designer and contractors of those projects. Extensive review of literature was carried out for determination of barriers and drivers of sustainable building construction in global context. At the same time, data collection and scoring module was developed from technical reference manual developed by Green Building Initiative (GBI) for evaluating the sustainability application in project planning & design and site management stage of the selected four projects. Both the data collection/scoring module and summarized list of barriers and drivers were validated from expert opinion. Three senior personal with more than 15 years of experience in construction sectors were consulted in the validation process.The study is divided into two parts: qualitative and quantitative. Because both qualitative and quantitative data are analyzed, a mixed method approach strengthens the research [35].

The scores/points were obtained under **5** and **6 different sub-assessment areas** for **2** primary assessment areas, namely **Project planning & design** and **Site management** respectively. Based on the total score under each main assessment area, the sustainability performance or commitment of each project for that assessment area was assigned by using evaluation criteria mentioned in Table 2. The areas of improvement under each assessment area were also identified based on the scores obtained by each project.

For obtaining perceptions on barriers and drivers, the key respondents who can provide the correct and logical answers or responses were adjudged to be team leaders and senior engineers as since sustainability itself is a multi-disciplinary topic and hence only experienced and expert personnel are capable to provide perceptible reactions [36, 37]. As a result, only team leaders and senior engineers from the sides of designer/consultant, owner and contractor of the selected building project are surveyed through questionnaire.The responses provided for barriers and drivers in 5-point Likert-scale[38] from the project team leaders and senior engineers of the selected projects were analyzed through RII (Relative Importance Index) method in order to determine the most significant factors in terms of their impact on sustainability application and also in terms of level of difficulty or ease in their eradication or implementation respectively for barriers and drivers.

4. Scope and Limitation

The scope of this study only covers the government building projects of PUDBC, Kathmandu having cost estimates of more than 200 million Nepali rupees and currently under construction. The respondents for perceptions on barriers and drivers are the key personnel (team leader and senior engineer) from the sides of client, designer and contractor of each project. The sustainability performance has been evaluated for two major assessment areas of Project design & planning and Site management by using criteria from Green Globes Rating Tools for New Construction, 2021.

5. Result and Discussion

5.1 Sustainability Commitment of Building Projects

The points obtained by each project under different sub assessment areas were summed up to obtain final score in the two main assessment areas. It was found that all 4 projects demonstrated **commitment towards sustainability integration** in terms of project planning and design with mean score of 42.99%. Similarly, in terms of site management, 3 projects demonstrated **good progress towards sustainability integration** whereas 1 project showed only **commitment towards sustainability integration**. The summarized result have been presented in the Table 4. It is clear from this observation that, although the projects have shown commitment and good progress towards sustainability integration, there is still a long way to go for reaching peak level of sustainability integration such as leadership and national leadership in sustainability application for all the 4 projects in both of the assessment areas. The possible areas of improvement in each of the assessment areas can be viewed from the Figure 5 and Figure 6. It is seen that lack of Life Cycle Cost Anlysis (LCCA) is the most critical area for improvement with no scores for all projects. Team & Owner Planning and Building Commissioning and Training are other two lowest scored sub areas with average score of 45.14% and 50% respectively, demanding improvement.

Table 5: Summary of Sustainability Scoring and level of sustainability commitment of each project

S.N	Description	Project - 1	Project - 2	Project - 3	Project - 4	Mean
1	Estimated Project Cost (in NRs.)	20000000.00	300000000.00	700000000.00	695000000.00	
2	Total Built-Up Area (in sq.m)	1975.43	4114.84	11900.00	11859.90	
3	Estimated Construction Duration (in months)	18.00	24.00	30.00	27.00	
4	Project Planning and Design					
4.1	Sustainability scores in % for project planning & design	35.37	37.80	46.34	52.44	42.99
4.2	Evaluation of Sustainability Application	Demonstrates Commitment towards sustainability integration.	Demonstrates Commitment towards sustainability integration.	Demonstrates Commitment towards sustainability integration.	Demonstrates Commitment towards sustainability integration.	
5	Site Management					
5.1	Sustainability scores in % for site management	57.25	64.89	51.15	56.49	57.45
5.2	Evaluation of Sustainability Application	Demonstrates good progress towards sustainability integration.	Demonstrates good progress towards sustainability integration.	Demonstrates Commitment towards sustainability integration.	Demonstrates good progress towards sustainability integration.	

Similarly, for site management, it was found that Storm-water management, construction impacts mitigation and

Landscaping practices were found to be most lacking sub areas with mean score of 26.19%, 39.42% and 45% respectively. Rest of the sub areas have obtained fairly good scoring.

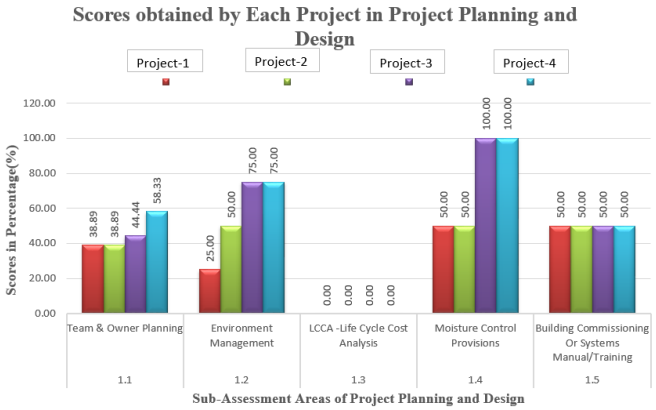

Figure 5: Detailed Summary of Points in Project Planning & Design

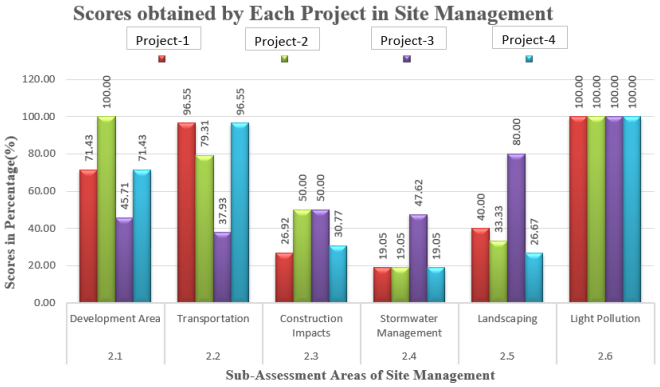

Figure 6: Detailed Summary of Points in Site Management

The scores obtained in each assessment areas were also plotted against the project cost to obtain linear regression and the goodness of fit was checked with Adjusted R squared value. Adjusted R-square tends to correct the overestimation made by traditional R-square value for a regression model.Adjusted R-square is always less than or equal to R-square. A value of 1 indicates a perfect goodness of fit while a value less than or equal to 0 indicates a poor fit [39].

The adjusted R-square value of 0.7807 (closer to 1) as shown in Figure 7 suggests that integration of sustainability in project planning & Design is dependent upon the project cost whereas for site management, the project cost does not seem to pose any significant impact on sustainability integration as depicted by Figure 8.

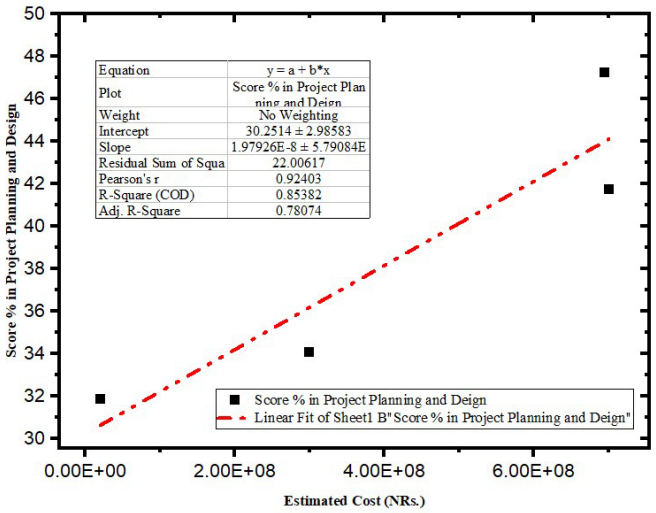

Figure 7: Sustainability Score (in Project Planning & Design) - Project Cost Fit Curve

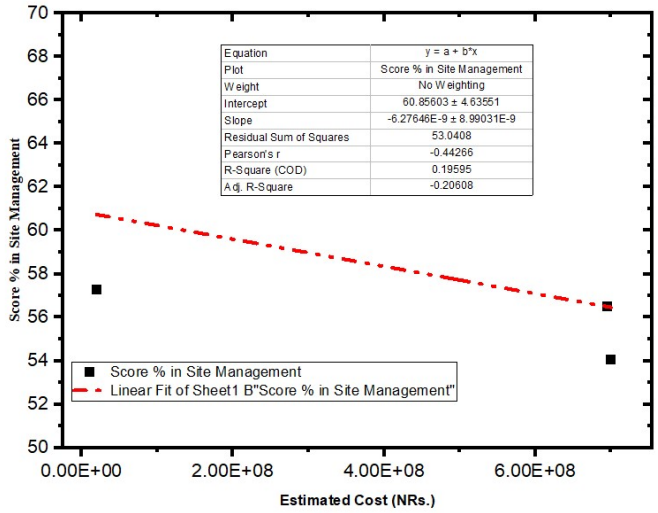

Figure 8: Sustainability Score (in Site Management) - Project Cost Fit Curve

5.2 Barriers and Drivers

RII analysis of the responses from the 24 respondents of the selected 4 projects showed that **Inadequate Government Initiatives** is the most significant barrier for hindering sustainability integration in project planning & design stage while for site management phase, **Lack of Professional Capability for Implementation** prevents the sustainability application. Similarly, the barriers which is most difficult to eradicate was found to be **Additional Economic Burdens associated with sustainable construction**. In the case of drivers, **Economic Incentives for Sustainability Promotion** was found to have highest impact on promoting sustainability practices in building construction while the driving factor which was easiest to implement was believed to be **Development of Green Design Manual, Guidelines, Construction Standards supported by Assessment Tools and Frameworks**. The detailed ranking and listing of barriers and drivers are shown in Table 6 and Table 7.

Table 6: Ranking of Barriers based on RII

Ranking of Barriers			
A.	**Level of Impact on hindering sustainability application**	RII	Rank
A.1	**In terms of Project Planning and Design**		
1	Lack of Knowledge/Awareness of Sustainability	0.75000	4
2	Inadequate Government Initiatives	0.81667	1
3	Additional Economic Burden	0.76667	3
4	Risk associated with new technology	0.66667	5
5	Lack of Proffessional Capability for Implementation	0.78333	2
A.2	**In terms of Site Management**		
1	Lack of Knowledge/Awareness of Sustainability	0.75833	3
2	Inadequate Government Initiatives	0.73333	5
3	Additional Economic Burden	0.80833	2
4	Risk associated with new technology	0.75000	4
5	Lack of Proffessional Capability for Implementation	0.81667	1
B.	**In terms of Level of Difficulty in elimination**		
1	Lack of Knowledge/Awareness of Sustainability	0.61667	5
2	Inadequate Government Initiatives	0.71667	3
3	Additional Economic Burden	0.80000	1
4	Risk associated with new technology	0.68333	4
5	Lack of Proffessional Capability for Implementation	0.76667	2

Table 7: Ranking of Drivers based on RII

Ranking of Drivers			
A.	**Level of Impact on promoting sustainability application**	RII	Rank
1	Integration of sustainability in academics, coupled by Training/Awareness programs for professionals	0.76667	4
2	Formulation of appropriate rules, regulations and policies from government	0.53333	5
3	Development of Green Design Manual, Guidelines, Construction Standards supported by Assessment Tools and Frameworks.	0.80833	2
4	Economic Incentives for Sustainability Promotion.	0.85000	1
5	Application of Integrated Design/Constructability Approach.	0.80000	3
B.	**In terms of Level of Ease in Implementation**		
1	Integration of sustainability in academics, coupled by Training/Awareness programs for professionals	0.68333	3
2	Formulation of appropriate rules, regulations and policies from government	0.66667	4
3	Development of Green Design Manual, Guidelines, Construction Standards supported by Assessment Tools and Frameworks.	0.71667	1
4	Economic Incentives for Sustainability Promotion.	0.63333	5
5	Application of Integrated Design/Constructability Approach.	0.70833	2

6. Conclusion

The use of Green Globes Criteria- an international framework allowed us to visualize the degree of sustainability integration in the project planning & design stage and site management stage of building construction for the selected cases of 4 building projects. It was found that there is good level of commitment towards consolidating sustainability principles in both phases of these projects. However, it was evident that there are multiple areas of improvement to be made so as to achieve a high level of sustainability application in the future. It was also found that sustainability application is not fully associated with project costs as certain aspects of it are not impacted by the estimated costs of the buildings. Moreover, use of rating tools has also succeeded in pinpointing the crucial areas of improvement for higher sustainability attainment for the building projects under study. At the same time, determining existing scenario is only one part of the solution, the another part is to determine the critical factors that are strongly impacting our progress into sustainable building construction practices. This study has given overview of these critical factors that are hindering and driving sustainability application from the perspectives of the sides of all critical stakeholders of the projects in terms of their level of impact and strength.

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