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ANALYSING THE SIGNIFICANT FACTORS FOR LAND USE IMPACT ASSESSMENT IN BUILDING CONSTRUCTION PROJECTS IN SRI LANKA
Whole Life Cycle Analysis Approach

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Abstract: This research paper focuses on analysing the significant factors for land use impact assessment in building construction projects in Sri Lanka using a whole life cycle analysis approach. The study recognizes the importance of land use in achieving sustainability and highlights the potential environmental consequences of land use changes and occupation. Through a questionnaire survey and the application of the Relative Importance Index (RII) method, the study identifies and ranks the key factors for land use impact assessment. The findings reveal that factors such as site selection, erosion and sedimentation control, site assessment and development, and on-site renewable energy play a crucial role in assessing the land use impact of building construction projects. A comprehensive assessment framework is proposed, which allocates credits to these factors based on their significance. The developed framework provides a practical tool for evaluating and promoting sustainable land use practices in the construction industry.

The research underscores the need for considering land use impacts throughout the entire life cycle of buildings and emphasizes the importance of integrating sustainable practices into construction processes. By adopting the identified factors and assessment framework, construction projects in Sri Lanka can enhance their sustainability performance and minimize their land use impacts, leading to a more environmentally responsible built environment.

Keywords: *Land use impacts; RII; construction industry*

1. Introduction

Land is one of the most valuable resources for humanity, serving as a base for both human habitation and economic activity as well as a refuge for ecosystems (Barlowe, Adelaja and Babladelis, 2013 ; Department of Land Use Policy Planning, 1996). However, at different scales, the complexity and intensity of interactions between the natural and man-made worlds present problems with food security, environmental sustainability, biodiversity loss, and land quality (Grandgirard *et al.*, 2002). As such, it must be protected from potential negative effects of human activity to prevent irreversible damage from occurring.

The term "land use" refers to how humans utilise land. It describes the economic and cultural activities that take place in a certain area, including those that are industrial, mining, residential, and of an agricultural character (Kanianska, 2016). Changes in land use occur often on a range of scales, and they may have several discrete and accumulative effects on factors like air and water quality, the operation of watersheds, waste generation, the amount and quality of wildlife habitat, climate, and human health. Some land use practises may influence the environment and public health (Ross and Randhir, 2022).

Land use change and land occupation are two types of land use practices which generate environmental harm (Koellner and Scholz, 2007). Further to the authors, land use change (land transformation) refers to a man-made switch from one type of land use to another (e.g., from forests to agricultural crop). Such kind of changes may generate dramatic environmental harm (decreases in biodiversity, etc.); but they may also have a positive impact, i.e. transformation of built-up areas to gardens or secondary forests (Grandgirard *et al.*, 2002). Further, land development and agricultural uses are two of the key areas of concern, with a wide range of potential effects (Kanianska, 2016). The term "land occupancy" refers to the ongoing usage of a certain region for a particular land use type over a pre-determined amount of time. Such various land occupations may have different effects on the ecosystem (negative or positive). Deforestation, the expansion and intensification of agriculture and livestock

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management, the dam construction projects, irrigation projects, and highways, and the quickly spreading of urbanisation are some of the landscape's most prevalent changes. Each of these changes has significant health repercussions that are sometimes underappreciated in addition to the well-known environmental costs (Kamara, Koroma and Gogra, 2015).

The construction industry has a huge environmental impact to the environment in different ways, among them the use of land for building construction is vital to consider (Alsanad, 2015). This mostly begins with choosing the project's site, which has an impact on the other sustainable categories, including energy, water, indoor air quality, and choosing eco-friendly materials and resources (Ghaffarianhoseini *et al.*, 2017). As stated by Swenson and Chang (2023), one of the permanent representations of human society and the process of development are buildings. Further to the authors, a considerable number of raw materials are needed for construction and maintaining process while creating a huge environmental impact on the environment due to land use change and land occupation.

Numerous environmental evaluation methodologies have been developed to measure these effects of buildings and to promote sustainable development. The life cycle analysis (LCA) is one of the numerous techniques for measuring environmental effect throughout the whole life cycle of buildings (Rozas and Golsteijn, 2023). LCA evaluates all phases of a building, from raw material extraction to final disposal, and calculates how much each stage contributes to a variety of environmental effects, including global warming, human toxicity, terrestrial eco-toxicity, and the land use. European Commission (EC) policies also recognize the importance of considering building environmental consequences from a life cycle perspective, particularly in terms of land use, resource efficiency, construction and demolition waste, and energy consumption (European Commission, 2012). A large variety of models have been created in this area to aid future land-use, planning and environmental impact assessments of land-use change activities (Asanidze *et al.*, 2017). Further, there have been numerous ways created to analyses the influence of land use on the environment. However, a rigorous synthesis of all these approaches is required to identify the most widely utilized and effective strategies (Dyke, Lund and Girardot, 2009). There are many research available related to land use assessment, however most of the research studies have been focused on other industries, such as agriculture, mining, energy, and transportation, which justifies the necessity of conducting research to establish a way to assess the land use impact of building construction (Nedd *et al.*, 2021). Considering above, this research aimed at proposing a framework to assess the land use impact of building construction limiting to building construction projects in Sri Lanka.

To achieve the research aim, three objectives were formulated as, (i) To identify the land use impact of buildings on environment, (ii) To identify existing methods, guidelines and models apply globally to assess the land use impact of building construction, and (iii) To assess the land use impact of building construction projects in Sri Lanka.

2. Literature Review

2.1. LAND USE IMPACT OF BUILDINGS ON ENVIRONMENT

The increasing level of land use and the associated environmental effect describe the current stage of economic growth in the world (Foley, 2005;Lambin and Meyfroidt, 2011)). Land is one of the most valuable resources for humanity, serving as a base for both human habitation and economic activity as well as a refuge for ecosystems. However, at different scales, the complexity and intensity of interactions between the natural and man-made worlds present problems with food security, environmental sustainability, biodiversity loss, and land quality (Grandgirard *et al.*, 2002). As such, it must be protected from potential negative effects of human activity to prevent irreversible damage from occurring. The construction industry has a huge environmental impact to the environment in different ways, among them the use of land for building construction is vital to consider (Alsanad, 2015). The construction site that is chosen must meet the needs of both the building project and the municipality that will oversee the project. As a result, any building on a real property must be built in a way that does not negatively impact the ecosystem or the surrounding natural environment.

2.2. THE IMPORTANCE OF LAND USE IMPACT ASSESSMENT IN ACHIEVING SUSTAINABILITY

The importance of paying attention to the environmental effects of land and land plus buildings from a life cycle perspective in terms of resource efficiency, construction and demolition waste, and energy is introduced by several European Commission and policies (EC 2009; EC 2010a, b; EC 2011a; EC 2012). The European EN15804 (CEN 2011) and EN15978 (CEN 2012) standards suggest the use of Life cycle assessment (LCA) for evaluating construction items and buildings to effectively address these concerns. The EN15804 and EN15978, NEN 8006 (NEN 2004), and NF P 01-010, among other national and European norms and standards, do not currently include it (Allacker, Souza and Sala, 2014). In widely used sustainability certification systems for buildings like the BRE Environmental Assessment Method (BREEAM) (BRE 2007, 2013), Leadership in Energy and Environmental Design (LEED) (USGBC, 2013), and the German Sustainable Building Council (DGNB 2013), consideration of land use related to resource extraction, production, transport, and end-of-life treatment of building products is similarly disregarded. As a result, these certification programmes only focus on restricted aspects of land usage. Additionally, even though LCA is a widely accepted methodology for evaluating a building's environmental impact (Mirabella and Allacker, 2018 , Allacker, Souza and Sala ,2014) the majority of LCA studies of buildings have concentrated on the effects of energy use (Helgeson and Lippiatt, 2009; Nemry *et al.*, 2010; Valderrama *et al.*, 2012)). As Mirabella and Allacker (2018) and

Allacker, Souza and Sala (2014) highlighted in their environmental cost evaluation, strengthening, and elevating the validity of LCA studies in the building industry is a significant requirement to be considered. Nevertheless, an analysis of impact assessment approaches in LCA, which was conducted by Werner and Richter showed that the present models for estimating land use impact are vulnerable to a great deal of ambiguity (Werner and Richter, 2007). The impact of land use of building has been considered by many sustainable and green rating systems, such as Leadership in Energy and Environmental Design (LEED), BREEAM and GREENSL.

Table 1 summarises the criteria considered in sustainability rating systems for assessing land use impact of buildings.

Table 1: Land use impact assessment in sustainability rating systems

Rating system	**Main criteria**	**Sub criteria**
LEED	Sustainable sites	Site selection Development density and community connectivity Brownfield redevelopment Alternative transportation - public transportation access Alternative transportation - bicycle storage and changing rooms Alternative transportation - low-emitting and fuel-efficient vehicles Alternative transportation - parking capacity Site development - protect or restore habitat Site development - maximize open space Storm water design - quantity control Storm water design - quality control Heat Island effect - no roof Heat Island effect - roof Light pollution reduction
	Water efficiency	Water efficient landscaping
	Energy and atmosphere	Onsite renewable energy
	Materials and Resources	Construction waste management
	Indoor Environmental Quality (IEQ)	Outdoor air delivery monitoring Thermal comfort - design Daylight and views - daylight Daylight and views - views
BREEAM	Site selection	Ecology strategy Land use Water pollution Enhancement of ecological value Landscape Rainwater harvesting
GREENSL	Sustainable sites	Erosion and Sedimentation Control Site Selection Site Assessment and development Development Density and Community Connectivity Reuse of Previously Developed sites and Allowance for Connectivity of Green Lands Alternative Transportation Public Transportation Access Parking Capacity Encourage use of green modes of transport Reduced Site Disturbance Protect or Restore Habitat Greenery Provisions Development footprint Storm Water Design, Quantity and Quality Control Heat Island Effect, non – Roof Heat Island Effect, Roof Light Pollution Reduction

The factors identified in Table 1 were evaluated as the next step to identify the significant land use impact assessment factors.

Research methodology adopted in the research is described subsequently.

3. Research Methodology

Research methodology is essentially the "how" a given piece of research is properly carried out. It places more emphasis on the stringent study design employed by researchers to provide reliable findings that satisfy their goals and objectives (Jansen and Warren, 2023). Quantitative approach was selected since the search aimed at determining significant land use impact factors influencing buildings. Quantitative analysis is the foundation of quantitative research, and one or more quantities are used to represent or characterise this process (Gounder, 2012). Survey strategy was adopted as the suitable research strategy since the research outcome is quantitative and the research question is concerned with "how and what" research phenomena (Boru, 2018).

Data is collected through a questionnaire survey, which was conducted among 65 randomly selected professionals in the relevant fields of sustainability, building construction and land use impact. This method was chosen to ensure that every professional in the relevant fields had an equal chance of being included in the study, thus minimizing potential biases. The professionals were chosen based on their qualifications, experience levels, and expertise to ensure that the sample represents a diverse and knowledgeable perspective. The population from which the sample was drawn comprises professionals actively engaged in practices related to sustainability, building construction, and land use impact within the specified region. This population was identified through industry directories, professional organizations, and academic institutions, ensuring a comprehensive and relevant pool of participants for the study. Among them, 31 was responded with the response rate of 53%. The factors were incorporated into the questionnaire, which were evaluated by using Likert scale, Likert scale is the most common method used in research for respondents to state the level of significance based on their experience. Thus, five points of Likert scale i.e. 1 = Very Low significance, 2 = Low significance, 3 = Medium significance, 4 = High significance and 5 = Very High significance was adopted. The collected data were analysed by using Relative Important Index (RII) to determine the significance of each factor. The Relative Important Index (RII) was calculated using the following formula:

$$RII = (\text{Mean score of the factor}/\text{Maximum possible score}) * 100 \quad [1]$$

RII was employed to assess the relative significance of each factor identified in the research. By standardizing the scores and comparing them to the maximum possible score, RII provided a clear understanding of the importance of each factor in relation to the overall research objectives. The Weighted Mean Average (WMA) was calculated using the following formula:

$$WMA = \sum(X_i \times W_i) / \sum W_i \quad [2]$$

Where:

X_i represents the individual factor score.
W_i represents the weight assigned to each factor.

The WMA was used to determine the average significance level of various factors identified in the study. This method was chosen due to its ability to incorporate the varying degrees of importance assigned to different factors by the respondents.
Data analysis and findings are presented below.

4. Data Analysis and Findings

The authors conducted a thorough review of literature, analysing various sustainability rating systems. They identified commonalities and recurring themes across these systems. Factors that appeared consistently in multiple rating systems were considered fundamental to land use impact assessment and combined several common themes as one factors. The land use impact factors identified in literature were evaluated through a questionnaire survey. The respondents were asked to rate the significance of each factor using the 5-point Likert scale. The collected data were analysed using RII technique and ranked based on the relative importance of each factor. The importance or capabilities were classified as high-level important, medium-level important, and low-level important. RII values greater than 70% were recognised as highly significant factors, RII value between 50% and 70% were recognised as medium level significant factors. RII is below 50% were considered as less significant factors.

The main purpose of using the RII method for this study was to rank factors based on professionals' responses. At this stage of analysis, RII values greater than 70% were chosen based on the main purpose of this analysis. Accordingly, high level important factors were ranked in Table 2 as per the RII value.

Table 2: Highly significant land use factors

Factors for preparing Land Use Impact assessment	**WMA**	**RII**	**RII (%)**	**Rank**
Site selection / land acquiring/ Ecology strategy	4.71	0.94	94%	1
Erosion and Sedimentation Control	4.48	0.90	90%	2
Site Assessment and development	4.42	0.88	88%	3

Factors for preparing Land Use Impact assessment	WMA	RII	RII (%)	Rank
On-site renewable energy	4.32	0.86	86%	4
Alternative transportation - low-emitting and fuel-efficient vehicles	4.13	0.83	83%	5
Encourage use of green modes of transport	4.16	0.83	83%	6
Reduced Site Disturbance	4.16	0.83	83%	7
Construction waste Management	4.16	0.83	83%	8
Site development - protect or restore habitat	4.10	0.82	82%	9
Optimize energy performance	4.10	0.82	82%	10
Buffer capacity for surface water	4.06	0.81	81%	11
Brownfield redevelopment /Reuse of Previously Developed sites and Allowance for Connectivity of Green Lands	4.06	0.81	81%	12
Daylight and views - daylight	4.03	0.81	81%	13
Daylight and views - views	4.00	0.80	80%	14
Greenery Provisions	3.97	0.79	79%	15
Protection against physical emissions (noise, dust)	3.94	0.79	79%	16
Water-efficient landscaping	3.94	0.79	79%	17
Thermal comfort - design	3.90	0.78	78%	18
Heat Island effect - roof	3.84	0.77	77%	19
Development density and community connectivity	3.81	0.76	76%	20
Light pollution reduction	3.77	0.75	75%	21
Storm water design - quality control	3.55	0.71	71%	22
Outdoor air delivery monitoring	3.55	0.71	71%	23
Site development - maximize open space / Development footprint/ landscape quality	3.52	0.70	70%	25

Based on the provided ranking analysis, the factors for preparing a Land Use Impact Assessment are listed in descending order of their Relative Importance Index (RII) and corresponding RII percentages. Site selection / land acquiring/ Ecology strategy factor has the highest RII of 0.94 (94%), indicating its significant importance in the Land Use Impact Assessment. Erosion and Sedimentation Control has an RII of 0.90 (90%), this factor is ranked second and is considered highly important. Site assessment and development has also ranked in third (RII of 0.88) in importance.

Based on this analysis, it appears that factors such as site selection, erosion and sedimentation control, site assessment and development, and on-site renewable energy are considered the most important in the Land Use Impact Assessment. Factors related to alternative transportation, site disturbance reduction, construction waste management, and habitat protection or restoration also hold significant importance. The ranking allows for a better understanding of the relative significance of each factor in the assessment process.

To assign credit values (weights) to the selected 27 factors based on their importance in the impact assessment analysis, a simple mathematical calculation was used. The credit values were required to fall within the range of the highest weighted mean value of 4.71 and the lowest value of 3.48, as shown in Figure 4.6.

Credit Value = Round [(Highest Weighted mean - Lowest W mean) / 4) + 1]

[3]

Table 3: Credit value of land use factors

Factors for preparing Land Use Impact assessment	RII	Weighted of mean	Credit Value
Site selection / land acquiring/ Ecology strategy	0.94	4.71	5
Erosion and Sedimentation Control	0.90	4.48	4
Site Assessment and development	0.88	4.42	4
On-site renewable energy	0.86	4.32	4
Alternative transportation - low-emitting and fuel-efficient vehicles	0.83	4.13	3

Factors for preparing Land Use Impact assessment	RII	Weighted of mean	Credit Value
Encourage use of green modes of transport	0.83	4.16	3
Reduced Site Disturbance	0.83	4.16	3
Construction waste Management	0.83	4.16	3
Site development - protect or restore habitat	0.82	4.1	3
Optimize energy performance	0.82	4.1	3
Buffer capacity for surface water	0.81	4.06	3
Brownfield redevelopment /Reuse of Previously Developed sites and Allowance for Connectivity of Green Lands	0.81	4.06	3
Daylight and views - daylight	0.81	4.03	3
Daylight and views - views	0.80	4	3
Greenery Provisions	0.79	3.97	3
Protection against physical emissions (noise, dust)	0.79	3.94	2
Water-efficient landscaping	0.79	3.94	2
Thermal comfort - design	0.78	3.9	2
Heat Island effect - roof	0.77	3.84	2
Development density and community connectivity	0.76	3.81	2
Light pollution reduction	0.75	3.77	2
Storm water design - quality control	0.71	3.55	1
Outdoor air delivery monitoring	0.71	3.55	1
Heat Island effect - no roof	0.70	3.48	1
Alternative transportation - public transportation access	0.69	3.48	1
Site development - maximize open space / Development footprint/ landscape quality	0.69	3.52	1

5. Land use impact assessment framework for building construction projects in Sri Lanka

Based on the provided data, an assessment framework has been developed for land use impact for building construction projects in Sri Lanka. Table 5 includes 26 factors for preparing the assessment, the maximum number of credits that can be given for each factor, and the number of marks obtained by the project.

The percentage achieved by the project can be calculated using the formula:

$$\text{Percentage} = (X / 70) * 100\% \qquad [4]$$

Where X represents total marks obtained by the project

Table 4 shows the land use impact assessment framework prepared for building construction projects in Sri Lanka.

Table 4: Land use impact assessment framework

No.	Factors for preparing Land Use Impact assessment	Maximum number of credits that can be given	The number of marks obtained by the project
1	Site selection / land acquiring/ Ecology strategy	5	
2	Erosion and Sedimentation Control	4	
3	Site Assessment and development	4	
4	On-site renewable energy	4	
5	Alternative transportation - low-emitting and fuel-efficient vehicles	3	
6	Encourage use of green modes of transport	3	
7	Reduced Site Disturbance	3	

No.	**Factors for preparing Land Use Impact assessment**	Maximum number of credits that can be given	The number of marks obtained by the project
8	Construction waste Management	3	
9	Site development - protect or restore habitat	3	
10	Optimize energy performance	3	
11	Buffer capacity for surface water	3	
12	Brownfield redevelopment /Reuse of Previously Developed sites and Allowance for Connectivity of Green Lands	3	
13	Daylight and views - daylight	3	
14	Daylight and views - views	3	
15	Greenery Provisions	3	
16	Protection against physical emissions (noise, dust)	2	
17	Water-efficient landscaping	2	
18	Thermal comfort - design	2	
19	Heat Island effect - roof	2	
20	Development density and community connectivity	2	
21	Light pollution reduction	2	
22	Storm water design - quality control	1	
23	Outdoor air delivery monitoring	1	
24	Heat Island effect - no roof	1	
25	Alternative transportation - public transportation access	1	
26	Site development - maximize open space / Development footprint/ landscape quality	1	
		70	**X**

Each factor is assigned a maximum number of credits that can be earned, indicating its significance in terms of sustainable land use practices. During the evaluation of a specific project, assessors award marks to the project based on how well it addresses or fulfills each factor's requirements. Assessors, often experts in sustainability and construction, evaluate the project's documentation, site visits, and other relevant information to determine the extent to which the project complies with the requirements of each factor. Marks are awarded based on the level of compliance or excellence (project initiatives, practices, features of each category) demonstrated by the project in each category. For example, if Factor 1 is 'Site selection / land acquiring/ Ecology strategy' with a maximum of 5 credits, a project might earn 3 marks if it demonstrates a strong ecological strategy in site selection and land acquisition.

The project has obtained a total of X marks, which needs to be substituted in the formula to calculate the percentage. The percentage represents the achievement of the project in terms of the Land Use Impact assessment. However, the specific sustainable low-impact benchmark is not mentioned in the study, as it depends on various project-specific factors such as project type, location, and construction method. Nevertheless, based on the percentage achieved in the Land Use Impact framework, if the percentage is high, it indicates that the project has performed well in terms of sustainable land use practices. A higher percentage suggests that the project is recommended as a sustainable project, showcasing its commitment to minimizing land use impacts.

When compared with the global land use impact assessment frameworks (LEED, BREEAM) the developed framework addresses unique environmental challenges in Sri Lanka, considering factors like local biodiversity, climate, and social factors since the framework was developed based on the collaboration with local experts, policymakers, and practitioners to ensure relevance and applicability within the Sri Lankan context. Moreover, this framework has a simple scoring system, which is included the traditional and indigenous sustainable practices, promoting local wisdom and eco-friendly construction techniques. By embracing both the strengths of global models and the contextualized approach of the Sri Lankan framework, the construction industry can create a more sustainable and regionally sensitive built environment, ensuring a balance between global standards and local needs.

6. Conclusions

This research aimed to analyse the significant factors for land use impact assessment in building construction projects in Sri Lanka using a whole life cycle analysis approach. The study identified the factors through a questionnaire survey and applied the Relative Importance Index (RII) method to rank their significance. The analysis revealed that factors such as site selection, erosion and sedimentation control, site assessment and development, and on-site renewable energy were highly important in the land use impact assessment.

The research highlighted the importance of considering land use impacts in achieving sustainability in the construction industry. Land use changes and occupation can have significant environmental consequences, affecting biodiversity, ecosystem health, and overall land quality. Therefore, it is crucial to protect land from negative effects of human activity and adopt sustainable practices.

The study emphasized the need for a comprehensive assessment framework to evaluate the land use impact of building construction projects. Such a framework should consider factors like site selection, transportation alternatives, habitat protection, waste management, and energy optimization. The developed assessment framework provided a basis for evaluating and allocating credits to these factors based on their importance.

It is important to note that the specific sustainable low-impact benchmark was not determined in this study, as it depends on various project-specific factors. However, a higher percentage achieved in the land use impact framework indicates a project's strong commitment to sustainable land use practices.

Overall, this research contributes to the understanding of the significant factors in land use impact assessment for building construction projects in Sri Lanka. It provides valuable insights for policy makers, practitioners, and researchers involved in sustainable construction practices. By considering and implementing these factors, construction projects can minimize their land use impacts and contribute to a more sustainable built environment.

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