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Factors Influencing Sustainability of Infrastructure Projects

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Abstract: ***Sustainable development is forward looking and also a continuous mission for the development of human society. This paper aims to identify the key factors of sustainability for infrastructure projects to create and operate a healthy built environment based on resource efficiency and ecological design. A questionnaire survey has been conducted to identify the important factors that influence more on the sustainability of a project. Based on previous literature survey, 30 factors that influence sustainability were summarized. Software Package for Social Science was used for ranking of variables.***

Keywords: Sustainability, Key factors, SPSS, Questionnaire survey, Factors.

1. Introduction

Over recent years, construction projects are rapidly increasing. The developing structures should be healthy for the human comfort as well as environment. Sustainability is the key to creating a healthy, happy and thriving economic climate in communities around the world. It is important to our future success and plays a critical role in creating and enhancing development. Sustainable development is often defined as, 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'. For most companies, countries and individuals who do take the subject seriously the concept of sustainability embraces the preservation of the environment as well as critical development-related issues such as the efficient use of resources, continual social progress, stable economic growth, and the eradication of poverty. In the world of construction, buildings have the capacity to make a major contribution to a more sustainable future for our planet. The OECD, for instance, estimates that buildings in developed countries account for more than forty percent of energy consumption over their lifetime (incorporating raw material production, construction, operation, maintenance and decommissioning). Add to this the fact that for the first time in human history over half of the world‟s population now lives in urban environments and it‟s clear that sustainable buildings have become vital cornerstones for securing long-term environmental, economic and social viability.

The purpose of the sustainability assessment tool is to gather and report information for decision making during different phases of the design, construction, operation and maintenance of the building. A variety of sustainable assessment tools presently available in the industry such as life cycle assessment tools (ATHENA, BEES4.0, Eco-quantum) and criteria assessment tools (BREEAM, CASBEE, LEED). The assessment tools either life cycle or criteria based, is under evolution because of their limitations. The main goal, at present is to develop and implement a methodology that helps in the designing phase itself. The paper aims to develop the most influencing key factors of sustainability. This methodology keeps a proper balance between all the dimensions of sustainability, namely environmental, economical and social aspects.

2. Literature Review

Sustainable development is often defined as, 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'. A sustainable building should balance environmental, economical and social elements. Even though, various sustainable assessment tools are available now researches on the development of the assessment tools are in progress. [12] H J Kang et al. have formed a structural framework for sustainable building assessment tool. A detailed algorithm was assigned to develop a systematic model. The application of this systematic model enhances the decision making capability of the tool and eventually contribute to the realization of sustainable buildings. While [10] Y Peng et al. have discussed about an alternative model for measuring the sustainability of urban regeneration. A general decision making framework was developed based on sustainability and urgency of urban regeneration.

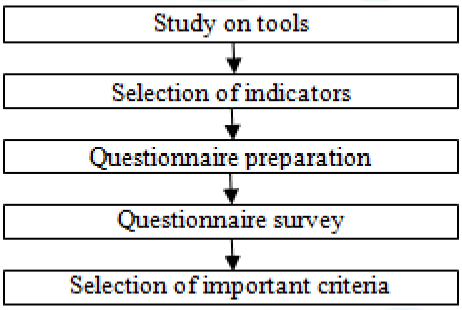
[7] NTNU SBP was presented for the evaluation of urban planning situation. NTNU SBP Model evaluates the sustainability of buildings from several perspectives, and it considers how a project interacts with its surroundings. In case of urban planning [9] Y Xing et al. have developed a UD SAM which allows decision makers to identify sustainable indicators and evaluate sustainability impact of urban environment. UD SAM integrated different values and perspectives to a single framework, it made the assessment relevant. [11] Z Xu et al. have developed a sustainability analysis of urban residential development. The integration empirical models, GIS technology and 3D data visualization were the proposed tools. The empirical method is applied to construct the evaluation model for benchmark land price and then integrated with GIS and data visualization technology to generate the Geo-spatial simulation and 3D data display.

Principles and practice of marketing applied to the promotion of sustainability services offered by engineering and construction consultancies and contractors. [3]R Padfield et al. have considered the constraints and barriers, together with the opportunities for sustainability service markets in developed and developing countries. And [2] C A Poveda have given a review of the status of sustainability rating systems. Study results in the classification of assessment tools as generic, strategic, and integrated.

Most of the assessment tools do not evaluate all the three criteria such as environmental, economical and social for sustainability of building. In addition they do not satisfy needs of stakeholder, do not deal with financial aspects, difficult to determine the direction to which the sustainable building should progress and lack objectivity and accuracy. The main problem is on the selection of the indicators. The indicators should satisfactorily influence the sustainability in all the three elements.

3. Methodology

First step of the project is to study about the existing sustainability assessment tools. Next step was to choose most appropriate criteria to formulate an indicator set which will consider the buildings performance in relation to the dimensions of sustainability namely environmental, social, culture and economy. The appropriate indicators which form the basis of framing the questionnaire surveys were selected by reviewing the literatures and the importance of the indicators was found by the survey. The reliability of the collected data was done during data collection. Later the data was analyzed using Statistical Package for Social Sciences (SPSS).Then criteria were selected from the survey. They named as key factors for considering a sustainability assessment tool.



4. Survey

Referring various journals, most influenced factors of sustainability were identified. 30 indicators were selected for questionnaire survey. Table 5.1, table 5.2 and table 5.3 shows the selected indicators for questionnaire survey in each elements of sustainability.

Table 5.1: Selected indicators of economical aspect

Economical	Analysis of market supply and demand
	Technical advantage
	Project budget
	Project financing channels
	Project investment planning
	Life-cycle cost
	Life- cycle benefit/ profit
	Financial risk
	Payback period
	Internal Return Ratio(IRR)

Table 5.2: Selected indicators of social aspects

Social	Effects on local development
	Provision of employment opportunities
	Project function
	Scale of serviceability
	Provision of ancillary amenities to local economic activities
	Public safety
	Land use and its influence on the public
	Protection to culture heritage
	Promotion of community development
	Public sanitation

Table 5.3: Selected indicators of environmental aspects

Environmental	Ecological effect
	Effect on land pollution
	Effect on air quality
	Effect on water quality
	Noise effect
	Waste generation
	Influence on public health
	Environment protection measures in project design
	Energy savings
	Protection to landscape and historical sites

All indicators were summarized under the three phases of an infrastructure project. The first phase is production phase that includes the design, planning and analysis of a project. It also includes the collection, transportation of materials etc. The second phase is construction phase which includes the site works, waste generation, energy consumption etc. Finally, the operational phase which comes after the completion of the project. It includes maintenance, comfort and efficiency of the constructed structure.

The importance of each indicator was ranked as „less important", „important" and „very important". Questionnaire survey was conducted with various experienced engineers, contractors and architects. And the results were analysed using the "Software Package for Social Sciences" (SPSS) developed by IBM. It was also analysed by Relative Important Index (RII) method.

5. Analysis

SPSS statistical package is one of the most popular statistical packages which can perform highly complex data manipulation and analysis with simple instructions. It is frequently used in the social science. In this paper, SPSS was used to find the important factors from the questionnaire survey. Table 6.1 shows the list of factors with their notation that represents each indicator in SPSS.

Table 6.1: Indicators with notations

EC1	Analysis of market supply and demand
EC2	Technical advantage
EC3	Project budget
EC4	Project financing channels
EC5	Project investment planning
EC6	Life-cycle cost
EC7	Life- cycle benefit/ profit
EC8	Financial risk
EC9	Payback period
EC10	Internal Return Ratio(IRR)
S1	Effects on local development

S2	Provision of employment opportunities
S3	Project function
S4	Scale of serviceability
S5	Provision of ancillary amenities to local economic activities
S6	Public safety
S7	Land use and its influence on the public
S8	Protection to culture heritage
S9	Promotion of community development
S10	Public sanitation
EN1	Ecological effect
EN2	Effect on land pollution
EN3	Effect on air quality
EN4	Effect on water quality
EN5	Noise effect
EN6	Waste generation
EN7	Influence on public health
EN8	Environment protection measures in project design
EN9	Energy savings
EN10	Protection to landscape and historical sites

By comparing the means of each indicator, the most important factor was selected that have greater mean. Each phase were separately analysed and find the common key factors. Table 6.2, 6.3, 6.4 shows the calculated mean of each indicator through SPSS. The greater mean value from each phase was selected as the key factors for sustainability.

Table 6.2: Mean of indicators in production phase

Notation	*Mean*	*Notation*	*Mean*	*Notation*	*Mean*
EC1	1.428	S1	1.524	EN1	1.428
EC2	.952	S2	.7143	EN2	.6667
EC3	1.238	S3	.8095	EN3	.7143
EC4	.8571	S4	1.571	EN4	.7143
EC5	.7143	S5	1.571	EN5	.4762
EC6	1.571	S6	1.238	EN6	.3810
EC7	.6667	S7	1.381	EN7	1.428
EC8	1.476	S8	.2857	EN8	1.476
EC9	1.428	S9	.7619	EN9	1.809
EC10	1.476	S10	.4762	EN10	.5238

Table 6.3: Mean of indicators in construction phase

Notation	*Mean*	*Notation*	*Mean*	*Notation*	*Mean*
EC1	1.095	S1	1.714	EN1	1.476
EC2	1.524	S2	.8095	EN2	1.524
EC3	1.619	S3	.8095	EN3	1.381
EC4	.8095	S4	1.714	EN4	1.524
EC5	.8095	S5	1.143	EN5	.8571
EC6	1.619	S6	1.571	EN6	.9524
EC7	1.095	S7	1.428	EN7	1.428
EC8	1.667	S8	.2857	EN8	1.047
EC9	1.047	S9	.7619	EN9	1.857
EC10	1.191	S10	.7143	EN10	.8571

Table 6.4: Mean of indicators in operational phase

Notation	*Mean*	*Notation*	*Mean*	*Notation*	*Mean*
EC1	.7143	S1	1.476	EN1	.6667
EC2	.5238	S2	.3333	EN2	.6667
EC3	.3810	S3	.2857	EN3	1.238
EC4	.6190	S4	1.476	EN4	1.857
EC5	.6667	S5	1.381	EN5	.4762
EC6	.9048	S6	1.810	EN6	.3810
EC7	.5238	S7	1.191	EN7	1.476
EC8	.8571	S8	.2857	EN8	.8095
EC9	.3333	S9	.7619	EN9	1.809
EC10	.0952	S10	.4786	EN10	.4762

The result of survey was also verified using RII method. The questionnaire survey was ranked by three points such as „0", „1", „2". Hence here 3 point scale was used to calculate RII value. Relative Important Index for 3 point scale can be calculated using the following equation;

$$RII = (3n_3+2n_2+1n_1)/3(n_1+n_2+n_3)$$

Where n_1, n_2, n_3 are the number of samples for „0", „1", „2" points respectively. Table 6.5, table 6.6, table 6.7, shows the calculated RII values for each indicator in each phases of the project. From the tables it is found that some factors have greater RII value and higher mean value in SPSS. Hence as result these factors were selected as key factors of sustainability.

Table 6.5: RII value of factors in production phase

Notation	RII	Notation	RII	Notation	RII
EC1	.816	S1	.816	EN1	.85
EC2	.65	S2	.541	EN2	.533
EC3	.716	S3	.533	EN3	.533
EC4	.55	S4	.85	EN4	.491
EC5	.541	S5	.841	EN5	.491
EC6	.866	S6	.775	EN6	.491
EC7	.525	S7	.808	EN7	.808
EC8	.825	S8	.475	EN8	.833
EC9	.816	S9	.558	EN9	.858
EC10	.825	S10	.491	EN10	.516

Table 6.6: RII value of factors in construction phase

Notation	*RII*	*Notation*	*RII*	*Notation*	*RII*
EC1	.64	S1	.9	EN1	.85
EC2	.833	S2	.766	EN2	.833
EC3	.842	S3	.583	EN3	.8
EC4	.566	S4	.9	EN4	.85
EC5	.575	S5	.633	EN5	.566
EC6	.842	S6	.841	EN6	.558
EC7	.575	S7	.491	EN7	.791
EC8	.841	S8	.566	EN8	.616
EC9	.583	S9	.558	EN9	.883
EC10	.583	S10	.566	EN10	.55

Table 6.7: RII value of factors in operational phase

Notation	RII	Notation	RII	Notation	RII
EC1	.566	S1	.783	EN1	.516
EC2	.525	S2	.475	EN2	.541
EC3	.491	S3	.416	EN3	.783
EC4	.516	S4	.858	EN4	.958
EC5	.533	S5	.808	EN5	.525
EC6	.583	S6	.875	EN6	.466
EC7	.508	S7	.6	EN7	.841
EC8	.533	S8	.483	EN8	.55
EC9	.433	S9	.558	EN9	.891
EC10	.408	S10	.516	EN10	.508

Initially key factors were selected for each of the phases separately. Then common factors were selected from each phases. Table 6.8 gives the key factors obtained from the analysis of questionnaire survey. These are the factors having greater mean obtained in all the three phases.

Table 6.8: Key factors

Economical	Analysis of market supply and demand
	Technical advantage
	Project budget
	Life-cycle cost
	Financial risk
	Payback period
	Internal Return Ratio(IRR)
Social	Effects on local development
	Scale of serviceability
	Provision of ancillary amenities to local economic activities
	Public safety
	Land use and its influence on the public
Environmental	Ecological effect
	Effect on land pollution
	Effect on air quality
	Effect on water quality
	Influence on public health
	Environment protection measures in project design
	Energy savings

6. Conclusions

Sustainability is a process and strategy of the existence of structures and processes that allow evidence based and evidenced informed programs and services to continue, effectively leveraging resources to respond to the needs of the community. Every construction should be environmentally, economically and socially sustainable. Assessment tools are available for sustainability assessments of the new projects. These tools should contain relevant factors which affect all the area of sustainability. In this paper, the key factors were identified using questionnaire survey and its influence in the three bottom line of sustainability; economical, social and environmental. The factors were also summarized under the three phases of a project such as production phase, construction phase and operational phase.

In future studies, an assessment tool can be developed by considering these key factors. Then the developed tool can overcome the limitations of the existing tools. Increasing the number of construction projects is not development, but constructing sustainable buildings leads to the healthy development.

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