Review of the Methods Required in Measuring the Sustainability of Infrastructure Projects

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Abstract. Rapid growth in an area is indicated by the increasing of the population proportion, thereby the need of good infrastructure increases. The sustainable infrastructure is a crucial part of the nation development with considering the economic, social, and environment aspects and works to balance all these three aspects. Therefore, the rapid development is expected to contribute in the increasing of economic growth and social welfare without damaging the surrounding environment. Recently, a lot of researches has been discussing about sustainable infrastructure using various methods, it is important to conduct a study of what methods are used in previous researches. By knowing these various methods, it is expected to provide method recommendations for further research in the field of sustainable infrastructure. This paper aims to find out what methods are used to determine the level of sustainability in infrastructure projects. The method used is the literature review of 20 relevant international papers from year of 2007 to 2019. Based on previous researches, the result of this study indicates that there are variety of methods used to determine the level of infrastructure projects’ sustainability. This paper shows AHP is the most widely used because it has some advantages.

1. Introduction
Sustainable development is a development that considers three main pillars of sustainability, such as the potential impact on community (social), economic, and environmental [1]. The development and management of sustainable infrastructure projects requires diligent conception, feasibility and environmental studies, careful design for life cycles, and costs that should be optimized, including considering future climate change and enhancing natural and human development [2]. Development of infrastructures is the foundation for social and economic development. Development in infrastructure is particularly important in developing countries. From 1970 to 2005, more than 30% of the World Bank’s investments were in developing countries for implementing various infrastructure projects has been making significant contributions to the development of developing countries analytic hierarchy process (AHP) is the most widely used [1], [2], [10], and [11] because it has some advantages [3].

Recently, there are several measurement frameworks that must be used to assess the sustainability of infrastructure projects such as leadership in energy and environmental design (LEED), which are used as a framework for evaluating the sustainability of infrastructure projects [1] [2]. To measure and analyze the sustainability of infrastructure projects, various methods can be used, such as AHP, Fuzzy, complex proportional assessment (COPRAS), Delphi survey, and structural equation modeling (SEM). The example AHP method used is shown in researches [1], [2], and [10], and research [3] used fuzzy analysis method. These methods can be used to determine the sustainability of an infrastructure.
examples show that there are several methods that can be used in assessing the sustainability of an infrastructure. This journal focuses on mapping the methods that will be used to assess the sustainability by applying the theoretical mapping.

2. Conceptual Background

2.1 Sustainability Assessment

Sustainable development is a basic principle that underlies efforts to ensure a decent quality of life for future generations, so a sustainability assessment system is needed. Sustainability assessment itself has been developed by several organizations around the world, which is applied in both new construction and rehabilitation of existing assets, and deteriorates to assess the sustainability of buildings, roads, bridges, or other public assets [1]. Sustainability assessments have been carried out in recent years, such as studies on bridge sustainability assessments that have been carried out for a long time. Research of Ali et al [1] used the survey method and was analyzed by analytic hierarchy process (AHP). Sustainability assessments of residential area using the complex proportional assessment (COPRAS) methods were found in the research by Viteikiene et al [9].

2.2 Methods of Previous Research

2.2.1 Research Philosophy. In general, research methods can be divided into two types, that are quantitative and qualitative research method. Quantitative research method can be interpreted as a research method based on the philosophy of positivism, that is used to examine the specific populations or samples. Sampling techniques are generally carried out randomly, and the data collection uses the research instruments and the quantitative or statistical data analysis with the aim to test the hypotheses that have been set [21]. Qualitative research method is a research method that emphasizes the aspect of in-depth understanding of an issue. The qualitative method prefers to use in-depth analysis techniques, which are used to examine the cases, because the qualitative methodology believes that the characteristic of one problem will be different from the other problems [21].

2.2.2 Research Techniques. Following are some of the methods used in previous research on sustainable infrastructure projects.

a. Analytic hierarchy process (AHP) is a method developed firstly by Satty (1980), for the determination of weighting, which can be used to determine the weighting of each variable used to assess sustainability, that has been shown in research done in [1], [2], and [10]. It is capable of dealing systematically with different kinds of qualitative, imprecise information, or even unstructured decision problems. AHP provides convenience in making decisions on multi-criteria issues, which will later be used to measure the sustainability of infrastructure projects [10].

b. Fuzzy set theory is applied to help identify variables that can affect the sustainability of infrastructure projects. Since Zadeh (1965) introduced the fuzzy set theory, it has been widely applied in many scientific disciplines, including science, engineering, agriculture, medicine, and social science [3].

c. Complex proportional assessment (COPRAS) method assumes direct and proportional dependence of significance and priority of investigated versions on a system of criteria which is adequately describing the alternatives and the values and significances of the criteria led to establishment of the rank of priorities of infrastructure areas in respect of their sustainability [9]. The most important feature that makes COPRAS method superior to other methods is that it can be used to calculate the utility degree of alternatives indicating the extent to which one alternative is better or worse than other alternatives taken for comparison [9].

d. Delphi surveys of the expert panel were conducted to: (1) identify the elements needed to be part of the rating system, (2) allocate appropriate credits for the elements identified, and (3) develop a feasible structure for implementation of the rating system. The researchers conducted three rounds of surveys. It was decided to identify all of the possible elements in the first round, gaining consensus on the elements and their ratings as the rounds progressed, and finalizing the structure of the rating system in the third round.
e. Structural equation modeling (SEM) quantifies a structural correlation among independent constructs. SEM provides a robust analysis which is widely utilized by the construction management researchers worldwide and is applicable both for simple correlations between constructs and for more complex analyses of first and higher-order variable [12].

f. Principal Component Analysis (PCA) is an effective method for identifying clusters or related variables and compressing large number of variables into the framework that is easier to understand so that variables that are compatible with sustainability can be identified [13].

3. Results and Discussion

3.1 Methodology

The scope of this research is to find out what methods are used in measuring the sustainability of infrastructure projects. Various sources are available about the sustainability of infrastructure projects, including reputable journal articles to ensure the academic standards of the literature analyzed in this study. In this literature review, there are 20 publications, published year of 2007 to 2019, here is a list of journals that are used along with their rankings based on the SJR which can be seen in Table 1.

| Journal Publication | SJR | Q Cartegory | Number of papers |
|----------------------|-----|-------------|------------------|
| International Journal of Project Management | 2.2 | Q1 in Environmental Science Management, Monitoring, Policy and Law | 1 |
| Environmental Politics | 1.67 | Q1 in Environmental Science Environmental Science (miscellaneous) Social Sciences Sociology and Political Science | 1 |
| Journal of Cleaner Production | 1.62 | Q1 in Environmental Science (miscellaneous) | 2 |
| Structure and Infrastructure Engineering | 1.14 | Q1 in Building and Construction | 2 |
| Journal of Construction Engineering and Management – ASCE | 1.04 | Q1 in Building and Construction | 2 |
| Sustainability Accounting, Management and Policy Journal | 0.78 | Q1 in Business, Management and Accounting Business, Management and Accounting (miscellaneous) Energy Renewable Energy, Sustainability and the Environment | 1 |
| Construction Management and Economics | 0.78 | Q1 in Business, Management and Accounting Management Information Systems Engineering Building and Construction Industrial and Manufacturing Engineering | 3 |
| Journal of Building Engineering | 0.59 | Q1 in Architecture, Building and Construction, Civil and Structural Engineering Mechanics of Materials Safety, Risk, Reliability and Quality | 1 |
| Journal of Civil Engineering and Management | 0.59 | Q2 in Civil and Structural Engineering | 5 |
| Built Environment Project and Asset Management | 0.54 | Q2 in Civil and Structural Engineering | 2 |

To explore the methods of 20 articles used in measuring the sustainability of infrastructure projects, the analysing of this paper is done by grouping the data in Table 1.

3.2 Result

Based on literature reviews, it is known that there are a number of research methods that can be used to assess the sustainability of infrastructure projects, where the methods are divided into quantitative and qualitative data types, namely primary data and secondary data. Following are the different methods used in previous studies based on the method and type of data. Y (Yes) is used to state using of the appropriate method or type of data and N (No) is used to state the use of method or type of data that is not appropriate, which is shown in Table 2.
In measuring the sustainability of infrastructure projects, three main aspects are used namely economic, social, and environmental aspects. These three aspects are used to assess whether the development of infrastructure in each aspect has a balance between one aspect to the other aspects. The development of sustainable infrastructure projects is expected to be able to improve the economic and social conditions of the community without damaging the surrounding environment. Previous studies conducted by [2], [3], [4], [5], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], and [20] used three aspects of sustainable measurement. Whereas [6] only reviewed environmental aspects, [7] reviewed environmental, and technical aspects and [1] reviewed the sustainability of infrastructure projects from technical aspects.

In measuring the sustainability of infrastructure projects, the methods used are different, such as the uses of distribution of questionnaires and expert opinions to collect data which have been shown in the researches conducted by [1], [2], [3], [10], [11], [13], [17], and [18], which will later be processed using multi criteria decision making, analytical hiercary process (AHP), fuzzy, principle component analysis (PCA), and life cycle energy analysis (LCEA). The literature review and survey methods such as those conducted by [4], [9], [12], [14], [15], [19] will later be processed using complex proportional assessment (COPRAS), structural equation modeling (SEM), and also the use of delphi techniques to measure the sustainability of infrastructure projects that are conducted by research [7].

3.3 Discussion

Literature review in previous studies for theoretical mapping can be seen in Table 2. Based on Table 2, there are two ways to collect data based on the type of data, namely primary data and secondary data. Primary data is the data which is directly obtained from research objects such as conducting surveys, interviews, questionnaires, and experiments, while secondary data is the data obtained indirectly from data sources such as through literature, books, and media. The analytical methods used in previous research journals can be divided into two methods namely the quantitative analysis method and the qualitative method. The quantitative analysis takes measurements and finds out the causal relationship between the various variables presented with statistics and programs to analyze the data. Qualitative analytical methods emphasize processes and meanings that are not rigorously assessed or measured, and emphasize the nature of socially constructed reality and emphasize the close relationship between what

| Table 2. Literature review and theoretical mapping of previous research |
|---------------------------------------------------------------|
| **Concept of Infrastructure**                                 |
| **Sustainability**                                            |
| **Types of Method and Data**                                  |
| **Methods**                                                   |
| Quantitative | Qualitative | Primary Data | Secondary Data | Questionnaire and AHP |
| N           | Y           | Y            | N              | Expert Judgment and AHP |
| N           | Y           | Y            | N              | Questionnaire and Fuzzy |
| N           | Y           | N            | N              | Survey and Experiment |
| N           | Y           | N            | N              | Comprehensive literature review |
| N           | Y           | Y            | N              | Survey |
| Y           | N           | N            | Y              | Delphi Survey |
| Y           | N           | Y            | N              | Expert Judgment |
| Y           | N           | Y            | N              | Survey and COPRAS |
| Y           | N           | N            | Y              | Expert judgment and AHP |
| Y           | N           | N            | Y              | Expert judgment and AHP |
| Y           | N           | Y            | N              | Literature review and PLS-SEM |
| Y           | N           | Y            | N              | Literature review and Survey |
| N           | Y           | Y            | N              | Literature review and PLS-SEM |
| N           | Y           | N            | Y              | Literature review and semi structure interview |
| N           | Y           | N            | Y              | Interview and Questionnaire |
| N           | Y           | Y            | N              | Interview and Questionnaire |
| Y           | N           | N            | Y              | Literature Review and Survey |
| Y           | N           | Y            | N              | LCEA and Survey |

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is researched by the researcher, and highlight how social experiences arise as well as the acquisition of their meanings. Position diagram of each study in the literature is shown in Figure 1. Based on the figure, it can be seen that the most widely used analytical method is quantitative method with primary data type, where the data is obtained directly from the research object of the study.

![Figure 1. Mapping Diagram](image)

4. Conclusion

Based on the result above, it can be concluded that the most widely used method and data types used in measuring the sustainability of infrastructure projects is quantitative methods with primary data types as explained in journals [1], [2], [3], [8], [9], [13], [14], [18], and [20], and their difference is in their data analysis methods which are AHP, fuzzy, and SEM. From some of the analyzes, AHP is the most widely used [1], [2], [10], and [11] because it has some advantages. For example, the weighting is clearer than the analysis of the other methods. It is hoped that this paper can help further research in the assessment of sustainability to find out what methods and analyzes are appropriate in sustainability assessments.

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