STRUCTURAL MODEL FOR SUSTAINABLE CAMPUS ASSESSMENT: A CASE OF ANDALAS UNIVERSITY

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ABSTRACT

Universities can generate a significant impacts to environment through their activities and operations. Thus, sustainability should be implemented in achieving a sustainable campus. Evaluating the implementation of sustainable campus become a need to achieve a higher performance. This paper develops a structural model for sustainable campus assessment conducted to a case of Andalas University. It begins with identification of KPIs of sustainable campus assessment through literature study. Interpretive Structural modeling (ISM) method is applied to determine the interrelationships amongst the categories of KPIs. The results indicated setting and infrastructure, energy and climate change, waste, and water as the basic categories, while transportation and education appears to be the leading categories. The structural model can aid the universities in achieving a higher performance of sustainable campus.

Key words: assessment, structural model, sustainable campus.

1. INTRODUCTION

In recent years, sustainable campus has became a critical issue among universities around the world. Campus sustainability is an increasingly issue of global concern for university policy makers and planners as a result of the realization of the impacts the activities and operations of universities have on the environment (Alshuwaikhat and Abubakar, 2008). University can generate a significant impact to environment due to the high usage of energy, extensive transportation, massive waste, high consumption of materials, and extensive development of buildings and facilities (Gunawan et al., 2012). Therefore, sustainability concept needs to be implemented in the development of an university.

A sustainable university can be defined as a higher educational institution, as a whole or as a part, that addresses, involves and promotes, on a regional or global level, the minimization of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfill its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyle (Velazquez et al., 2006). According to the definition, sustainable campus must address the integration all the triple bottom line of sustainability consist of environmental, economic, and social.

Campus has many activities and complex operations which potentially generate the significant environmental impacts. Thus, sustainability should be applied to all aspects of a university, from the classrooms, offices, and laboratories, housing, transportation and other services, as well as to the entire campus (Alshuwaikhat and Abubakar, 2008). Therefore, assessing the sustainable campus has become a necessity to evaluate the implementation of sustainability in a university.

In this research, attemp is made to develop a structural model of sustainable campus assessment. The study is conducted to a case of Andalas University located in Padang, Indonesia. It begins with identification of initial Key Performance Indicators (KPIs) for sustainable campus assessment through literature review. Then, the KPIs validated to experts from the university. Finally, the interrelationships amongst the categories of KPIs is analyzed using the Interpretive Structural Modeling (ISM) methodology.

2. THEORETICAL BACKGROUND

2.1. Description of Study Area

This study is focused on the main campus of Andalas University, a leading university in Indonesia established in 1956. The campus is located in Limau Manis, Padang, West Sumatra. It built in a landmass of 502 ha and 255 m above the sea. Currently, Andalas University has a total of 15 faculties and more than 25,000 students. For the teaching activity, it supported by 1,385 lecturers. In 2014, Andalas University has accredited by National Accreditation Board for Higher Education with a rank of A (excellent).

Andalas University has made various efforts to achieve a sustainable campus. At the beginning of the campus development in 1980, it has allocated about 160 ha for the Biology Education and Research Forest. The forest is used to conduct various activities of biology education and research on diversity and ecology of plants, animals and their mirobes.

In 2004, it increased about 15 ha allocated to arboretum and 7 ha for dill garden. With those efforts, in 2015 Andalas University has successfully getting an fourth ranking among Indonesian universities in the UI Greenmetric World University Ranking. It is a world university ranking for universities to assess and compare campus sustainability efforts (www.greenmetric.ui.ac.id). The UI Greenmetric World University Ranking is the first attempt to make a global ranking of universities' sustainable behavior (Grinsted, 2011).

2.2. Interpretive Structural Modeling (ISM) Methodology

Interpretive Structural Modeling (ISM) is proposed by Warfield in 1973 as computer assisted methodology (Agarwal et al., 2007). ISM is an interactive learning process that enables the decision makers to develop a map of the complex relationships among many elements involved in a complex problem (Kannan et al., 2009). ISM methodology helps in building an interaction map to identify the interrelationships among system variables. It provides a better understanding of a system structure and draws up a useful guideline in generating a graphical representation of the structure (Chen and Wu, 2010).

ISM is interpretive as the judgment of the experts decides whether and how the system variables are related. It is structural as on the basis of relationship and overall structure is extracted from the complex set of system variables. The first step of ISM is to identify the variables relevant to the problem. A structural self interaction matrix (SSIM) is then developed based on a pair-wise comparison of variables. SSIM is then converted into a reachability matrix. Noted that the reachability matrix is under Boolean operations. Its transitivity is then checked. The transitivity is a basic assumption of ISM methodology, which stated that if variable-A related to variable-B and variable-B related to variable-C, then variable-A necessarily related to variable-C (Kannan et al., 2009).

3. RESEARCH METHOD

The methodology has two main stages. First, identify the key performance indicators (KPIs) for sustainable campus assessment through literature review. The KPIs were then validated to a case of university. Second, determine the interrelationships of KPIs using Interpretive Structural Modeling (ISM) method.

3.1. Identification of Key Performance Indicators

This study starts with development of key performance indicators (KPIs) for sustainable campus assessment. The related literatures were then extensively reviewed to identify the KPIs. It mostly adopted from the UI Greenmetric World University Ranking (Guidelines of UI GreenMetric World University Ranking, 2014). In addition, the KPIs were also taken from the Alshuwaikhat and Abubakar's campus sustainability framework (Alshuwaikhat and Abubakar, 2008), sustainable UKM programme's framework (Fadzil et al., 2012), University of Nottingham's campus sustainability indicators (Sustainability Report of University Nottingham, 2013), and University of

Connecticut's campus sustainability indicators (Campus Sustainability Design Guidelines of University of Connecticut, 2004). As a result, the initial KPIs of sustainable campus assessment consist of six categories divided into a total of 35 indicators were identified. The initial KPIs were then validated by conducting interviews to five members of green campus team of Andalas University. The experts suggested that all categories and indicators of the initial KPIs are highly important in assessing the sustainable campus. Thus, proposed as the KPIs for sustainable campus assessment (Amrina and Imansuri, 2015) as shown in Table 1.

Table 1. KPIs of Sustainable Campus Assessment

Categories	Indicators
1. Setting and Infrastructure	1. Open space area/total area 2. Open space area/total people 3. Area on campus covered in forested vegetation 4. Area on campus covered in planted vegetation 5. Non-retentive surfaces/total area 6. Sustainability budget/total university budget
2. Energy and Climate Change	7. Energy efficient appliances usage 8. Renewable energy usage policy 9. Total electricity use/total people 10. Energy conservation program 11. Green Building 12. Climate change adaptation and mitigation program 13. Greenhouse gas emission reduction policy 14. Smooking area policy on campus 15. Sustainable food program on campus
3. Waste	16. Recycling program for university waste 17. Toxic waste recycling 18. Organic waste teatment (garbage) 19. Inorganic waste teatment (rubbish) 20. Sewerage disposal 21. Policy to reduce the use of paper and plastic on campus
4. Water	22. Water conservation program 23. Piped water
5. Transportation	24. Total cars entering/total people 25. Total bicycles/total people 26. Transportation policy on limiting vehicles on campus 27. Transportation policy on limiting parking space 28. Campus buses 29. Bicycle and pedestrian policy
6. Education	30. Sustainability courses / total courses 31. Sustainability research funding/total research funding 32. Sustainability publications 33. Sustainability events 34. Sustainability organizations (student) 35. Sustainability website

3.2. Developing Network Model

A network model of sustainable campus assessment then developed based on the proposed KPIs. Interpretive Structural Modeling (ISM) method was applied in the developing of the model. A questionnaire was then designed and sent to a total of 30 experts consist of Dean, Vice Dean, Head of Department and Green Campus Committe of Andalas University. They were selected based on their knowledge and experience in

achieving sustainable campus. Those experts were consulted in identifying the relationships amongst the categories of KPIs. The results are used to develop a structural model of the sustainable campus assessment. Details are given in the following section.

4. DEVELOPMENT OF NETWORK MODEL OF SUSTAINABLE CAMPUS ASSESSMENT

The following steps show the development of a structural model of the six categories of KPIs for sustainable campus assessment.

4.1. Structural Self-Interaction Matrix (SSIM)

A total of 30 experts were consulted to determine the relationships amongst the categories of KPIs of sustainable campus assessment. Answer to the questions from the experts were averaged. The results indicated 10 direct relationships amongst the categories of KPIs. The SSIM is shown in Table 2.

Table 2. Structural Self-Interaction Matrix

Categories	1	2	3	4	5	6
1	-	X	O	V	A	O
2		-	X	X	A	A
3			-	O	O	O
4				-	O	O
5					-	O
6						-

Four symbols are used to denote the direction of relationship between the categories (i and j):

- V for the relation from i to j
- A for the relation from j to i
- X for both directions, relations from i to j and j to i.
- O if the relation between the categories does not appear valid.

4.2. Initial Reachability Matrix

The SSIM is then transformed into the Initial Reachability Matrix by substituting the symbols of V, A, X, and O into a binary matrix of 1 and 0, where 1 means there is relationship between the categories and otherwise, 0 means there is no relationship between the categories. The substituting process is as per the following rules:

1) If (i, j) entry in the SSIM is V, then (i, j) entry in the reachability matrix is 1 and (j, i) entry is 0.
2) If (i, j) entry in the SSIM is A, then (i, j) entry in the reachability matrix is 0 and (j, i) entry is 1.
3) If (i, j) entry in the SSIM is X, then entry for both (i, j) and (j, i) is 1.
4) If (i, j) entry in the SSIM is O, then entry for both (i, j) and (j, i) is 0.

The Initial Reachability Matrix of the categories of KPIs for sustainable campus assessment is obtained by the rules above and the result is presented in Table 3.

Table 3. Initial Reachability Matrix

Categories	1	2	3	4	5	6
1	1	1	0	1	0	0
2	1	1	1	1	0	0
3	0	1	1	0	0	0
4	0	1	0	1	0	0
5	1	1	0	0	1	0
6	0	1	0	0	0	1

4.3. Final Reachability Matrix (SSIM)

The Final Reachability Matrix is developed from the Initial Reachability Matrix by incorporating the transitivities amongst the categories of the KPIs of sustainable campus assessment using the following equation:

$$M = M^k = M^{k+1}, k > 1 \qquad (1)$$

where *k* denotes the powers and *M* is the reachability matrix. It is noted that the reachability matrix under the Boolean operations. The transitivities are a basic assumption of ISM methodology which stated that if variable-A related to variable-B and variable-B related to variable-C, then variable-A necessarily related to variable-C (Kannan et al., 2009). The Final Reachability Matrix of the categories of KPIs of sustainable campus assessment is shown in Table 4.

Table 4. Final Reachability Matrix

Categories	1	2	3	4	5	6	Driving power
1	1	1	1	1	0	0	4
2	1	1	1	1	0	0	4
3	1	1	1	1	0	0	4
4	1	1	1	1	0	0	4
5	1	1	1	1	1	0	5
6	1	1	1	1	0	1	5
Dependence power	6	6	6	6	1	1	

The driving power and dependence power for each category are also presented in the table. The driving power is the total number of categories (including category itself) which it may relate, while the dependence power is the total number of categories which may relate to it.

It can be seen that two categories of transportation and education have the highest driving power with a value of 5. On the other hand, these two categories are not affected by any other indicators, indicated by the zero value of dependence power. In term of dependence power, four categories of setting and infrastructure, energy and climate change, waste, and water are determined as the most dependent categories. Those categories have affected by any other categories. In addition, it can also be concluded those four categories have strong interrelationships amongst them, indicated by the their value of driving power and dependence power.

4.4. Level Partitions

Based on the Final Reachability Matrix, it can be obtained the reachability set and antecedent set (Warfield, 1974) for each category. The reachability set consists of the category itself and the other categories, to which it may relate. The antecedent set consists of the category itself and the other categories, which may relate to it. Then, the intersection of reachability sets and antecedent sets is derived for all categories. The categories for which have the same reachability sets and the intersection sets are put into the first-level categories in the ISM structure. Those categories are then discarded from the other remaining categories in the level determination. Next, the reachability sets and antecedent sets are determined for the remaining categories. The iteration is continued until the level of all categories of KPIs for sustainable campus assessment obtained as presented in Table 5.

Table 5. Level Partition

Categories	Reachability set	Antecedent set	Intersection set	Level
1	1,2,3,4	1,2,3,4,5,6	1,2,3,4	I
2	1,2,3,4	1,2,3,4,5,6	1,2,3,4	I
3	1,2,3,4	1,2,3,4,5,6	1,2,3,4	I
4	1,2,3,4	1,2,3,4,5,6	1,2,3,4	I
5	1,2,3,4,5	5	5	II
6	1,2,3,4,6	6	6	II

From the table, it can be seen that the categories of KPIs of sustainable campus assessment consist of two levels. In the first level, identified four categories of setting and infrastructure, energy and climate change, waste, and water. Two categories of transportation and education are determined to be placed in second level. The identified levels of the categories aid in building the structural model of Interpretive Structural Modeling (Kannan et al., 2009).

4.5. Micmac Analysis

The categories of KPIs of sustainable campus assessment are then classified based on their driving power and dependence power using MICMAC analysis. The MICMAC analysis is used to analyze the driving power and the dependence power of the categories (Mandal and Desmukh, 1994). The categories are classified into four clusters named autonomous, dependent, linkage, and driver as depicted in Figure 1.

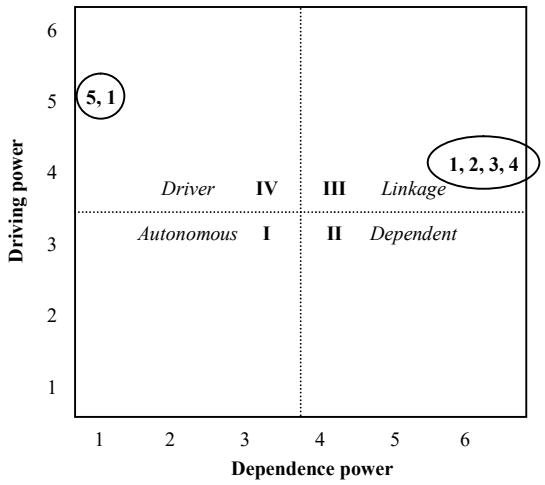

Figure 1. Micmac Diagram

From the diagram, it can be seen that there is no autonomous and dependent category (in the first and second quadrant). This clearly indicated there is no independent category of the KPIs of sustainable campus assessment due to has no affected by any other categories. It can be concluded that all categories are having an interrelationship and influencing the sustainable campus assessment. Similarly, it also indicated no dependent category of the KPIs of sustainable campus assessment.

Four categories of setting and infrastructure, energy and climate change, waste, and water identified in the third quadrant as the linkage categories. These categories are regarded as unstable categories. The categories have a high driving prower as well as a high dependence power. Any changes on these four categories will have an affect on the other categories and also provide a feedback effect on them. The universities should pay more attention to these categories.

In fourth quadrant, two categories of transportation and education are identified as the most driver categories. Those categories are driving all other categories but not driven by any other categories. Any action on these categories will have a significant effect on the other categories. Thus, the universities should manage these categories in a stable condition due to their influences to other categories.

4.6. Structural Model

Finally, a structural model of categories of the KPIs of sustainable campus assessment is then developed based on the Final Reachability Matrix. The transitivities of the categories are removed from the matrix. The categories of the KPIs are organized into two levels as depicted in Figure 2.

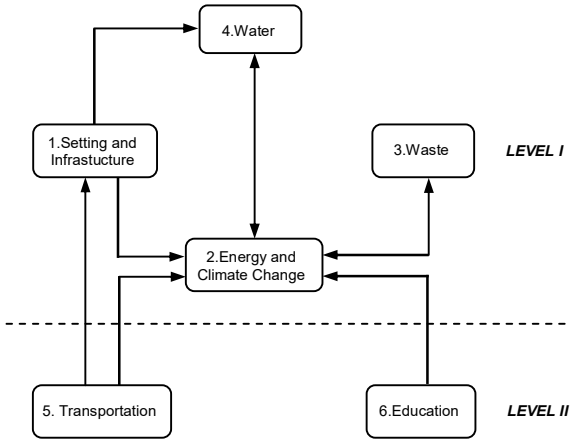

Figure 2. Structural Model

Based on the structural model of categories of the KPIs, four categories of setting and infrastructure, energy and climate change, waste, and water are regarded as the basic categories in assessing sustainable campus. Of those categories, energy and climate change has influenced by any other categories. This issue has become a global problem in any campus in the world. An effort to generate an alternative energy source need to be campaigned. For that purpose, the faculty member can support by conducted research on renewable energy. In term of climate change, universities need to design an appropriate strategy to tackle the related problems.

Transportation and education appear to be the leading categories in achieving sustainable campus. It might due to transportation being related closest to environmental impact. The transportation used around the campus are very extensive, thus need pay more attention to reduce the impact. Education as a main function of a campus plays an important role in achieving a higher performance of sustainable campus. Universities have responsibility in

sustainable development to promote the sustainability culture to its students, staff, and community (Gunawan et al., 2012).

5. CONCLUSIONS

University can generate a significant environmental impacts due to the high usage of energy, extensive transportation, massive waste, high consumption of materials, and extensive development of buildings and facilities. Thus, it is essential to assess the implementation of sustainable campus. This paper has developed a structural model of categories of Key Performance Indicators (KPIs) for sustainable campus assessment. The KPIs are identified and derived from the literature and then validated to a case of Andalas University. As a result, six categories divided into a total of 35 indicators are proposed as the KPIs of sustainable campus assessment.

A structural model of categories of the KPIs is then developed using Interpretive Structural Model (ISM) methodology. The categories of KPIs are structured into two levels. The structural model establishes the interrelationships amongst the categories of KPIs. The interdependencies amongst the categories of KPIs are also given by micmac diagram. The structural model provides a better understanding of the interrelationship amongst the categories of KPIs. The model can aid the universities with a more realistic representation of interrelationships amongst the categories of KPIs for sustainable campus assessment. Future work will further incorporate the structural model into Analytical Network Process (ANP) methodology to the development of sustainable campus assessment tool.

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