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PREFACE

The papers contained in this volume of proceeding report from the "2015 International Conference on Green Development in Tropical Regions". Keynote speakers and authors of selected contributed oral and poster presentation were given the opportunity to submit a manuscript for publication.

The manuscripts were reviewed by the Editors and members of the editorial boards. Only those papers judge suitable for publication following the author's consideration of review suggestions appears in this volume.

The committee acknowledges and appreciates the contribution of all editors and reviewers. They have made a significant contribution to improving the quality of this publication.

Padang, October 2015

Chairman,
Prof. Rudi Febriamansyah, PhD

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INTERPRETIVE STRUCTURAL MODEL OF SUSTAINABLE TRANSPORTATION PLANNING IN PADANG CITY

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ABSTRACT

Transportation is an integral part of the human life. Transportation facilities support the human activities related to the distance, location, and mobilization of goods and people. Nowadays, Padang people need a safe, convenient, and fast transportation system. However, like other big cities in Indonesia, Padang is also facing the transportation problems caused by the increasing of population as well as increasing of the amount of vehicles. The transportation system in Padang city generally doesn't meet the sustainability criteria yet as it can be seen from the low quality of roads, increasing number of accidents, high traffic, fuel wastage, increasing pollution, low quality of public transportation, and incomplete of road facilities. Therefore, Padang city requires the sustainable transportation planning assessed based on the appropriate indicators. In this research, the initial indicators are identified and derived from literature and validated by experts. As a result, sixteen indicators consist of six economic indicators, five social indicators, and five environmental indicators have been proposed as the indicators of sustainable transportation. Interpretive structural modeling (ISM) methodology is applied to develop a network structure model of the indicators. The results show the social indicators are regarded as the basic indicators, while the economic indicators are indicated to be the leading indicators. Of those indicators, accessibility of region, management of public transportation, infrastructure of public transportation, level of traffic congestion, land use to improve transportation facilities, and transportation for people with special needs are regarded as the most influencing indicator. The ISM model hoped can aid the policy makers by providing a better insight in developing the sustainable transportation in Padang city.

Keyword : indicator, interpretive structural model, sustainable transportation

INTRODUCTION

Nowadays, Indonesia is facing many problems in the public transportation such as traffic, emission, and energy use. Land transportation has contributed to 89% of emissions in Indonesia and 56% of energy consumption (Pramyastiwi et al., 2012; Tamin, 2011). During 2000-2010, the energy consumption of transportation sector increased 6.3% per year and estimated will increase 6.9% in 2010-2030 (Sugiyono, 2012). Furthermore, the traffic congestion caused by the increasing number of vehicles resulting the roads unable to accomodate the high number of vehicles and unbalancing of the road capacity compare to the number of vehicles (Sugiyono, 2012). Therefore, it is needed to implement the sustainable transportation system.

Like other cities in Indonesia, Padang city as the capital of West Sumatra province require a transportation system as physical access to various activities of society. Padang people need a safe, convenient, and fast transportation system called as sustainable transportation. However, the transportation system in Padang city generally doesn't meet the sustainability criteria yet as it can be seen from the low quality of roads, increasing number of accidents, high traffic, fuel wastage, increasing pollution, low quality of public transportation, and incomplete of road facilities. Therefore, Padang city requires the sustainable transportation planning assessed based on the appropriate indicators.

Sustainable transportation is defined as transportation that does not endanger public health or ecosystems and meets mobility needs consistent with (a) use of renewable resources at below their rates of regeneration and (b) use of non-renewable resources at below the rates of development of renewable substitutes (OECD, 1996). The goal of sustainable transportation is to ensure that environment, social, and economic considerations are factored into decisions affecting transportation activity (MOST, 1999).

It has been suggested that sustainable transportation has to be evaluated based on the triple bottom line of sustainablity of economic, environmental, and social aspects [7] as well as to consider their interdependencies [8]. In this research, attempt is made to analyze the relationships amongst the indicators. A network structure model has been developed using the Interpretive Structural Modeling (ISM) methodology.

METHODOLOGY

The methodology has three main stages:

Stage 1: Identification of KPIs

This study starts with the identification of initial indicators for sustainable transportation evaluation. A literature review was carried out to determine indicators most commonly used. The initial indicators are constructed based on the triple bottom line of sustainability consist of economic, environmental, and social aspects. As a result, the initial indicators consist of three aspects divided into sixteen indicators are identified as shown in Table 1.

Table 1 The initial indicators

Aspects	Indicators
1. Economic	1. Accessibility of region 2. Economics and low cost 3. Management of public transportation 4. Operational cost 5. Maintenance cost 6. Infrastucture of public transportation
2. Environmental	7. Passenger safety 8. Passenger convenience 9. Level of transportation safety 10. Transportation for people with special needs 11. Level of traffic congestion
3. Social	12. Use level of nonrenewable resources 13. Land use to improve transportation facilities 14. Level of noise 15. Level of emission 16. Proportion of vehicles meeting emission standard

Stage 2: Conducting industry survey

The initial indicators were then validated by the experts from Departement of Transportation, Communication and Informatics of Padang city. A total of 5 experts of transportation and facilities division were asked to rate the importance level of each initial indicators of sustainable transportation evaluation. A five-point Likert scale ranging from 1 (not important at all) to 5 (very important) was used to rate the perspective of experts on the importance level of the initial indicators. The mean importance values ranged from 3.8 to 4.8 as shown in Table 2.

Table 2 The mean importance values of initial indicators

Aspects	Indicators	Mean
1. Economic	1. Accessibility of region	4,2
	2. Economical and low cost	3,6
	3. Management of public transportation	4,8
	4. Operating cost	4,0
	5. Maintenance cost	3,8
	6. Infrastructure of public transportation	4,4
2. Social	7. Passenger security	4,2
	8. Passenger convenience	4,2
	9. Level of transportation safety	4,8
	10. Transportation for people with special needs	3,8
	11. Level of traffic congestion	4,6
3. Environmental	12. Level of use of nonrenewable resources	3,8
	13. Land use to improve transportation facilities	3,8
	14. Level of noise	3,4
	15. Level of emission	4,0
	16. Proportion of vehicles meet emission standard	4,2

From the table, it can be seen that management of public transportation and level of transportation safety had the highest mean importance value of 4,8. It followed by level of traffic congestion with a mean importance value of 4,6 and infrastructure of public transportation with a mean importance value of 4,4. On the other hand, level of noise was ranked as the least important indicator, but the mean importance value is at an importance level. Therefore, it can be concluded from the results that all the indicators are perceived at high important level.

Stage 3: Conducting ISM survey

An ISM survey was conducted to develop a network structure model of the indicators for sustainable transportation evaluation. A questionnaire was then designed to determine the interrelationships amongst the indicators and sent to 10 experts from the Department of Transportation, Communication, and Informatics of Padang city, Indonesia. Those experts were carefully selected based on their knowledge and experience in the transportation area. Experts were asked through the questions such as "will indicator *i* affect indicator *j*?" to indicate the direct influence that they believe each indicator on each of the other indicator according to an integer scale ranging from 0 = there is no relationship to 1 = there is a relationship.

RESULTS AND DISCUSSIONS

The following steps show the development of an interpretive structural model of the sixteen indicators for sustainable transportation evaluation in Padang city based on the ISM methodology.

1) *Developing structural self-interaction matrix (SSIM)*

   Through the ISM survey, ten experts were consulted to identify the relationships amongst the indicators of sustainable transportation evaluation in Padang city. The answers to each questions from the experts were averaged. The results indicated a total of 41 direct relationships amongst the indicators. The SSIM for the indicators of sustainable transportation evaluation is presented in Table 3. Four symbols are used to denote the direction of relationship between the indicators (*i* and *j*) where 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*, and O if the relation between the indicators does not appear valid.

Table 3 The structural self-interaction matrix (SSIM)

Indicators	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	-	O	X	V	O	A	O	O	O	A	A	O	A	O	O	O
2		-	O	X	O	O	O	O	O	O	O	O	O	O	O	O
3			-	V	V	O	O	V	V	O	A	O	V	O	O	V
4				-	A	O	O	O	O	O	O	X	O	O	O	V
5					-	A	O	O	O	O	O	O	O	O	O	V
6						-	O	V	O	O	V	O	A	O	V	O
7							-	O	V	O	A	O	O	O	O	O
8								-	O	X	O	O	O	O	A	O
9									-	A	A	O	O	O	O	O
10										-	O	O	O	O	O	O
11											-	O	A	V	V	O
12												-	O	O	O	O
13													-	O	O	O
14														-	O	O
15															-	A
16																-

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 indicators and otherwise, 0 means there is no relationship between the indicators. 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 indicators for sustainable transportation evaluation is obtained by the rules above and the result is shown in Table 4.

Table 4 The initial reachability matrix

Indicators	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	1	1	1	0	0	1	1	0	0	0	1	0	0	1
4	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1
5	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
6	1	0	0	0	1	1	0	1	0	1	1	0	0	0	1	0
7	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
11	1	0	1	0	0	0	1	0	1	0	1	0	0	1	1	0
12	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
13	1	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

3) *Final reachability matrix*

The final reachability matrix is developed from the initial reachability matrix by incorporating the transitivities using the following equation:

$$M = M^k = M^{k+1}, k>1 \tag{1}$$

where k denotes the powers and M is the reachability matrix. Noted that the reachability matrix is under the Boolean operations. 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). The final reachability matrix of the indicators for sustainable transportation evaluation is shown in Table 5. The driving power and dependence power for each indicator are also presented in the table. The driving power is the total number of indicators (including indicator itself) which it may relate, while the dependence power is the total number of indicators which may relate to it.

Table 5 The final reachability matrix

Indicators	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Driver Power**
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
2	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	1	6
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
4	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	1	6
5	0	1	0	1	1	0	0	1	0	0	0	1	0	0	1	1	7
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
7	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
12	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	1	6
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	2
16	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	3
Dependence Power	6	10	6	10	7	6	7	13	8	6	6	10	6	7	12	11	

It can be seen from the table, six indicators of accessibility of region, management of public transportation, infrastructure of public transportation, transportation for people with special needs, level of traffic congestion, and land use to improve transportation facilities have the highest driving power, but gave the least dependence power. On the other hand, indicator of passenger convenience has the highest dependence power but the least driving power. It indicated three indicators of passenger convenience, level of transportation safety, and level of noise that are not affecting the other indicators.

4) *Level partitions*

From the final reachability matrix, the reachability set and antecedent set (Warfield, 1974) for each indicator can be obtained. The reachability set consists of the indicator itself and the other indicators, to which it may relate. The antecedent set consists of the indicator itself and the other indicators, which may relate to it. The intersection of these sets then is derived for all indicators. The indicators for which the reachability and the intersection sets are the same are put into the top-level indicators in the ISM hierarchy. After the identification of the top-level indicators, those indicators discarded from the other remaining indicators. This iteration is continued until the level of all indicators is obtained as shown in Table 6.

Table 6 The level partitions

Indicators	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
8	8	1, 2, 3, 4, 5, 6, 8, , 10, 11, 12, 13, 15, 16	8	I
9	9	1, 3, 6, 7, 9, 10, 11, 13	9	I
14	14	1, 3, 6, 10, 11, 13, 14	14	I
7	7	1, 3, 6, 7, 10, 11, 13	7	II
15	15	1, 2, 3, 4, 5, 6, 10, 11, 12, 13, 15, 16	15	II
16	16	1, 2, 3, 4, 5, 6, 10, 11, 12, 13, 16	16	III
2	2, 4, 12	1, 2, 3, 4, 5, 6, 10, 11, 12, 13	2, 4, 12	IV
4	2, 4, 12	1, 2, 3, 4, 5, 6, 10, 11, 12, 13	2, 4, 12	IV
12	2, 4, 12	1, 2, 3, 4, 5, 6, 10, 11, 12, 13	2, 4, 12	IV
5	5	1, 3, 5, 6, 10, 11, 13	5	V
1	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	VI
3	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	VI
6	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	VI
10	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	VI
11	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	VI
13	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	1, 3, 6, 10, 11, 13	VI

The process of level partitions for the indicators involved six iterations. In the first iteration, passenger convenience, level of transportation safety, and level of noise are identified as the indicators to level I. Then, two indicators of passenger security, and level of emission were determined to be placed at level II through the second iteration. In the third iteration, proportion of vehicles meeting emission standard is indicated as indicator in level III. Three indicators of economical and low cost, operating cost, and level of use of nonrenewable resources are included into level IV. In the fifth iteration, maintenance cost is determined as indicator in level V. Finally, the remaining six indicators were determined into level VI. The identified levels of the indicators will aid in building the digraph and the final model of ISM (Kannan *et al*., 2009). The final reachability matrix then is converted into the canonical matrix by arranging the indicators according to their determined levels as shown in Table 7.

Table 7 The canonical matrix

Indicators	**8**	**9**	**14**	**7**	**15**	**16**	**2**	**4**	**12**	**5**	**1**	**3**	**6**	**10**	**11**	**13**	**Driver Power**
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
7	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	2
16	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	3
2	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	1	6
4	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	1	6
12	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	1	7
5	0	1	0	1	1	0	0	1	0	0	0	1	0	0	1	1	6
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
Dependence Power	13	8	7	7	12	11	10	10	10	7	6	6	6	6	6	6	

5) *MICMAC analysis*

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

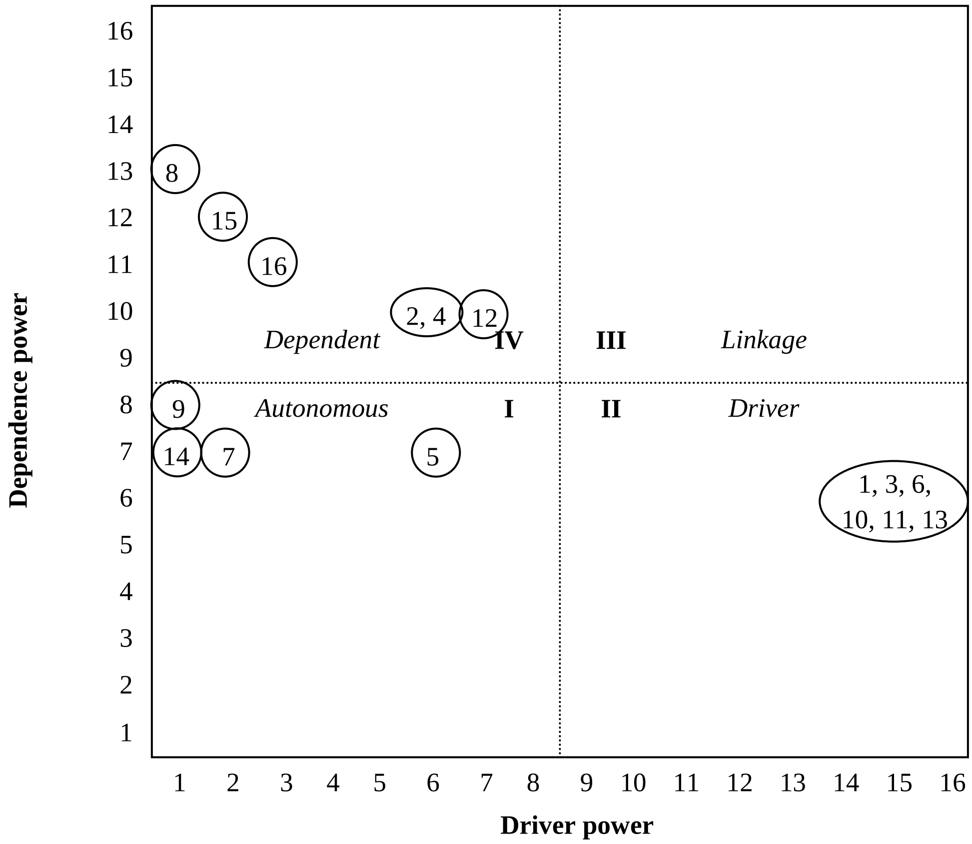

Figure 1 Driver-dependence power diagram

It can be seen that there is no linkage indicator (in the third quadrant) in the driver–dependence power diagram. This indicated no dominant indicator of the sustainable transportation indicators which has both high driving power and dependence power. In the first quadrant, four indicators of maintenance cost, passenger security, level of transportation safety, and level of noise identified as autonomous indicators. These indicators have both low driving power and low dependence power. Level of transportation safety and level of noise are not driving any other indicators. Six indicators of accessibility of region, management of public transportation, infrastructure of public transportation, transportation for people with special needs, level of traffic congestion, and land use to improve transportation facilities are in second quadrant as the driver indicators. All of those indicators are driving all other indicators of sustainable transportation evaluation but only driven by six other indicators. Those indicators were identified as the most driving indicators. Any action on these indicators will have a significant effect on the other indicators. Thus, the decision makers should pay more attention to these indicators in the context of sustainable transportation evaluation. On the other hand, passenger convenience, level of emission, proportion of vehicles meet emission standard, economical and low cost, operating cost, and land use for improving transportation facilities in fourth quadrant identified as the dependent indicators. Of those indicators, passenger convenience is suggested as the most dependent indicator since driven by other thirteen indicators.

6) *ISM-based network model*

An ISM-based network model is then generated based on the relationships of indicators given in the canonical matrix. The transitivities of the indicators are removed from the matrix. The indicators are organized in a hierarchical structure into six levels as shown in Figure 2.

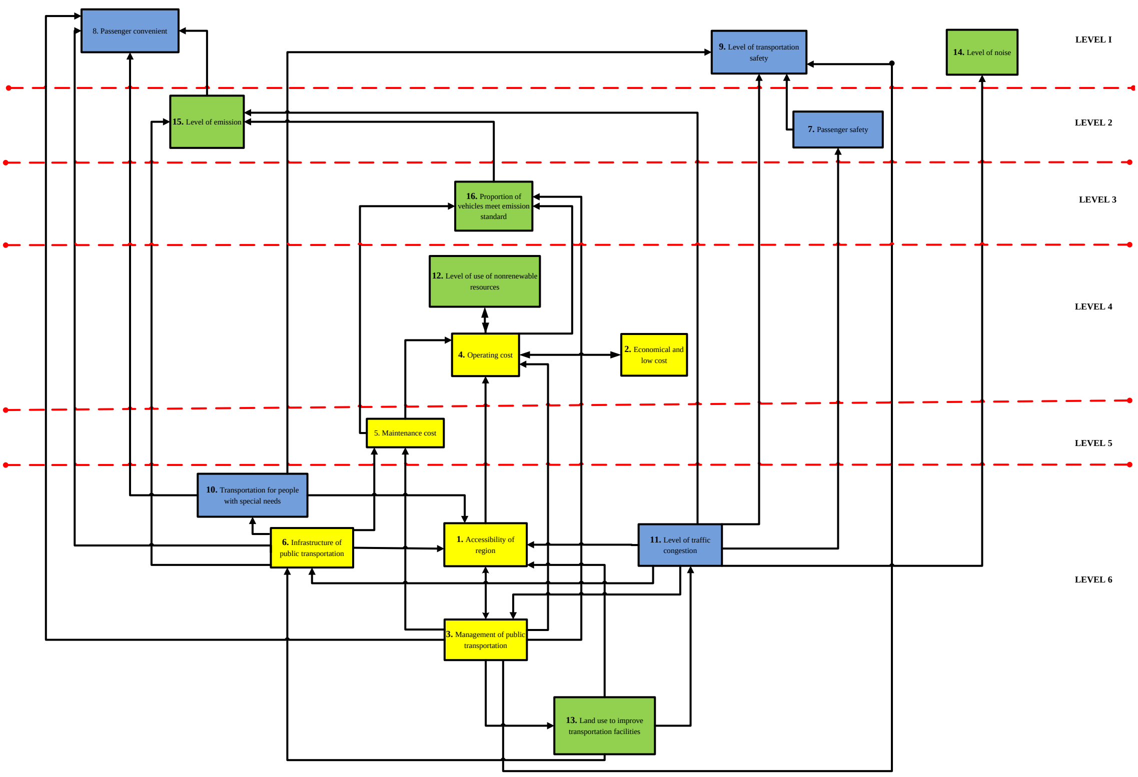

Figure 2 The ISM model

Passenger convenience, level of transportation safety, and level of noise are regarded as the basic indicators in evaluating sustainable transportation consist of two indicators of social aspect and one indicator of environmental aspect. It can be concluded that social aspect has get more attention in evaluating the sustainable transportation. Level II consists of one indicator of social aspect of passenger security and one indicator of environmental aspect of level of emission. Air emission and labor relationship are indicated as intermediate indicators at level III. It can be concluded that the cement industry has been put much effort to reduce air emission as one of sustainability issue in the cement industry. At level IV, two indicators of economic aspect of economical and low cost, and operating cost, and one indicator of environmental aspect of level of use of nonrenewable resources. It followed by one indicator of economic aspect of maintenance cost at level V. Six indicators at level VI consist of accessibility of region, management of public transportation, infrastucture of public transportation, transportation for people with special needs, level of traffic congestion, and land use to improve transportation facilities were indicated to be the leading KPIs in achieving sustainable transportation in Padang city. Those are consist of three indicators of economic aspect, two indicators of social aspect, and one indicator of environmental aspect. All those indicators are regarded as the most influencing indicator for sustainable transportation evaluation in Padang city.

IV. CONCLUSION

Nowadays, Padang city needs a sustainable transportation planning to overcome the increasing transportation problems. This paper has developed an interpretive structural model (ISM) of indicators for sustainable transportation evaluation in Padang city. The indicators are structured into six levels. The network model establishes the interrelationships amongst the indicators. The interdependencies amongst the indicators are also given by driver-dependence power diagram. The ISM-based model provides a better understanding of the interrelationship amongst the indicators. The model can aid the policy makers with a more realistic representation of relationships amongst the indicators for sustainable transportation evaluation in Padang city. Future work will further incorporate the model into Analytical Network Process (ANP) methodology to the development of sustainable transportation policy for Padang city.

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