Analysis of Strategic Variables for Sustainable Infrastructure and Transportation in Rural Area of Serang Regency, Banten Province

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Abstract. Infrastructure and transportation are important sector in the realization of Sustainable Development Goals in rural area. The understanding of strategic variables of infrastructure and transportation is very crucial. Therefore, this paper aim to present how we used structural analysis method to identify the sustainability variables of infrastructure and transportation in rural area. Kendayakan village in Serang Regency, a rural area, is studied due to its location as a hinterland to the coastal area of Banten province. The methodology of study is using the Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) software for analysing the strategic variables. The three pillars of Sustainable Development Goals (SDGs) elements of environmental, economic and social, represented by environmental quality index, income per capita and population density variables, respectively, were included in the analysis. Variables of infrastructure/transportation sustainability analysed were as follows: roads, bridges, water supply, water conservation, drainage and sanitation system, flood management, and housing/building/public facilities. The result shows that bridge infrastructure is classified as key factor which has the highest influence and independent. However, further research should be performed with more variables within the SDGs dimensions of economic, social and environmental.

Keywords: Infrastructure, transportation, MICMAC, sustainability

1. Introduction
Infrastructure and transportation are very important for economic development. They are ranging from transport system to housing/public facilities and water and sanitation/drainage system that enable economies to thrive. As a result, both infrastructure and transportation are the driver to meet the Sustainable Development Goals (SDGs) [1]. They play a key role in all 3 (three) pillars of SDGs [2]: the environmental, economy and social sustainability. Some studies were performed to find the most effective development strategy to meet the SDGs. But firstly, we need to determine its key variables of sustainability.

Serang Regency in Banten Province consist of 2 different geographical types: rural and coastal area. The sustainability of infrastructure and transportation in the coastal area should be assured to support
tourism and industrial activities [3]. The infrastructure and transportation should be sustained toward natural disaster risk [4,5,6,7] and scarcity [8,9,10]. The coastal area development depends on hinterland area development in order to fulfil the SDGs goals. Therefore, in this paper, we were doing a study in a hinterland and rural area of Kendayakan village, Kragilan District, Serang Regency, Banten Province. Structural analysis approach are widely used to evaluate the variables that influence the sustainability of various areas, such as: empowering local people for monitoring biological resources [11], natural resource management [12,13,14], critical factors in applying innovation small and medium scale manufacturing enterprises [15], human-environment interaction [16], ecotourism development [17], solid waste management [18], rural development [19], and residential area policies [20]. This study objectives are: 1. to describe how we used the structural analysis method for building a first causal-loop diagram; 2. to understand key variables that affected the sustainability of infrastructure and transportation in rural and coastal area.

2. Methodology

2.1. Study Area

Banten Province (Figure 1) is situated at $5^\circ07'50''$ and $7^\circ01'01''$ south latitude and at $105^\circ01'11''$ and $106^\circ07'12''$ east longitude, with the total area of 9662.92 km$^2$. Banten population in 2019 were 12,927,316 people. The population growth is 2.14%. Serang Regency has an area of 17.95% of Banten Province [21].

![Figure 1. Study area of Kendayakan Village, Serang Regency, Banten Province, Indonesia](image)

2.2. Structural Analysis – MICMAC

A structural analysis program called MICMAC (The Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) is utilized in this study. It structures ideas into an organisational system. This tool was developed by Godet [22]. This software is using an approach of qualitative system dynamics [23]. Structural analysis is perform by mapping into a matrix (see Table 1), the relationship of the driver (influence variables) and dependence variables, among the elements or components of a system [24]. This matrix called Direct Influences or MDI. In this matrix, the software performs replication and consideration regarding all aspects of variables group as a system. Therefore, we could get further prediction on the present consequences of current activities. The procedure of MICMAC program [22], are as follows: (1) Classifying the variables; (2) Evaluating the correlation among the variables, (3) Determining the key variables. Stage 1: Classifying the variables.
It is to assess which characterise the model under infrastructure and transportation, economy, environment and social aspect in which the model operates.

**Table 1.** An Example of Structural Analysis Matrix (M) with 4 (four) variables

| Variables | Var1 | Var2 | Var3 | Var4 | Influence |
|-----------|------|------|------|------|-----------|
| Var1      | 0    | 0    | 1    | 3    | 4         |
| Var2      | 1    | P    | 1    | 0    | 2         |
| Var3      | 0    | 2    | 0    | 0    | 2         |
| Var4      | 0    | 1    | 3    | 0    | 4         |
| Dependence| 1    | 3    | 5    | 3    | -         |

Source: [25]

Stage 2: Evaluating the correlations among variables. The correlations among variables are described in a table. This table called a dependence/influence matrix or MDI. A cell of this matrix consist of i, and j, where i is the row and j is the column. If between i and j, there is no correlations, then a zero number or ‘0’ was typed in the matrix cell. If between I and j, there is a direct influence, then a one number or ‘1’ and two number or ‘2’, for low and strong relationship, respectively, was typed in the matrix cell. Based on Table 1, a diagram of correlation among variables was structured (Figure 2).

![Figure 2. A Structural diagram [25]](image)

Stage 3: Determination or Identification of the key variables. Identification of the key variables are conducted by: a. utilizing the direct classification in the dependence/influence matrix, b. enhancing the power the matrix, to create a Matrix of Indirect Influences (MII). A total summation of each row represents the influence strength from one variable to others (see equation 1). A total summation of a column shows dependence level from one variable to other variables (see equation 2). Then, each of the variables has direct influence and dependence classification. It established through the paths and loops.

\[
DI = \sum_{j=1}^{n} V_{ij} \quad (1)
\]

\[
DI = \sum_{j=1}^{n} V_{ij} \quad (2)
\]

where:

i = 1,2,..,n
j = 1,2,..,n

The indirect classification is gained after enhancing the power of the matrix M (e.g. M^2, M^3, ...). From Figure 2, we can see that var1 has direct influence on var3 ( DI_{13} ) through the path var1 to var3 = 1. Then, indirect influence on var3 ( II_{13} ) on the path of v1 to v4 to v3. The MICMAC enables the researcher to understand the distribution of the impacts by using the loops and paths. In general, the stable classification is attained after a 3, 4 or 5 degree of multiplication [26].
Map of indirect and direct dependence-influence shows the various functions that the plays by the variables. The classification of each quadrant are as follows [19]: I. Input variables: they use a strong influence, but independent to other variables; II. Relay variables: they are highly influential and dependent. III. Dependent variables: they have low influence and highly dependent; IV. Excluded variables: they are nearly unconnected and have insignificant correlations within the system. Stage 1 of structural analysis in this study was performed by identifying key variables of sustainable infrastructure and transportation in the Kendayakan village from statistics of Banten Province 2015-2019 [21], UNOPS [1], National laws, ministry of public work and housing policies and studies. Dimensions of variables consist of: 1. Infrastructure/transportation, 2. Economic, 3. Environmental and 4. Social. Stage 2 and 3 were conducted by determine the relationship between key variables using MICMAC program by Lipsor.

3. Result and Discussion
There are 10 variables which distributed among sustainability dimension of infrastructure/transportation, economy, environment and social aspects (Table 2).

Table 2. Variables for Sustainable Infrastructure and Transportation

| Dimensions                  | Short label | Variables                        |
|-----------------------------|-------------|----------------------------------|
| Infrastructure/Transportation| watsup      | 1. Water Supply                  |
|                             | drainsys    | 2. Drainage & Sanitation System  |
|                             | road        | 3. Roads                         |
|                             | bridge      | 4. Bridges                       |
|                             | floodmng    | 5. Flood Management              |
|                             | watcon      | 6. Water Conservation            |
|                             | house       | 7. Housing/Public Facilities     |
| Economic                    | income      | 8. Income per capita             |
| Environmental               | EQI         | 9. Environmental Quality Index   |
| Social                      | popdens     | 10. Population Density           |

Figure 3. Matrix of Direct Influence
Each of these 10 variables were evaluated to developed 10 x 10 cross-impact matrix of called Matrix of direct Influence presented in Figure 3. The analysis result of this matrix are presented in direct influence/dependence map (Figure 4). Based on Figure 4 map of sustainable variables in infrastructure and transportation of Kendayakan village can be categorized into 4 (four) qualifications as follows:

1. First quadrant: Input variable are bridge infrastructure
2. Second quadrant: Key or relay or stake variable are flood management, housing/public facilities and roads infrastructure
3. Third quadrant: Output variable consist of water supply, drainage system and environmental quality index (EQI).
4. Fourth quadrant: Autonomous variable consist of water conservation, population density and income per capacity.

Moreover, we can see the intensity of the direct influence variable (Figure 5), showed by the color of a line that connected among variables. Based on Figure 5, bridge infrastructure is the strongest variable influenced access to support infrastructure and transportation sustainability. The variable of bridge infrastructure is classified as dominant variable (quadrant I), so that it must be prioritized. It has the highest influence as a main connector from coastal area and urban area; and has strong influence to other variables within economic (income per capita), social (population density) and environmental (EQI) aspects. On the other hand, it has the lowest dependency with other variables because bridge construction, maintenance and operation are fully supported by the government.

The variables under quadrant II of relay or key variables are flood management, housing/public facilities and roads. These variables characterized as highly influential and dependent. These variables have strong influence within three pillars of sustainability, especially housing/public facilities and roads toward economic and social sustainability in Kendayakan village. On the other
hand, they have strong dependency with other variables, as follows: drainage system for flood management and roads.

**Figure 5.** Direct influence variable intensity.
Finally, we can determine the level of dependence and influence variables. Figure 7a presents the rank of influence comparison among variables (MDI matrix). After the calculation of indirect influence (Figure 6), there are some rank rearrangement among variables (MII matrix). As an example, previously, variable water supply (watsup) was in rank 5 under the MDI matrix, but now it is in rank 7 under the MII matrix. Water supply has been substituted by drainage system once the indirect influences were introduced into the system. Variable income per capita in rank 7 was move to rank 6, and variable drainage system in rank 6 was move to rank 5, from MDI matrix and MII matrix, respectively.
Figure 7 shows three infrastructure/transportation elements of road, drainage & sanitation system, and housing/public facilities are consistent in the highest level of dependence variables. The variable of water conservation has been displaced from rank 8 under MDI matrix to rank 9, after the indirect influence has been evaluated. This shows that variable water conservation is not a priority at this specific area. This condition is in alignment with the fact that Kendayakan village located in a hinterland-downstream area, where hydrogeology is not ideal for water conservation. The social dimension represents by population density shows the lowest dependency in the sustainability of infrastructure/transportation. This indicates that there is an effect of population density variable in infrastructure/transportation sustainability, however the intensity is low compare to other variables.
4. **Conclusions**

Structural analysis method provides a way to systematically think and conceptualize complex issues and can support model building process. It categorized a qualitative approach. Furthermore, the structural analysis mapped into a matrix, the influence variables (driver) and dependence variables correlations among the components. After that, MICMAC tool developed a map of direct and indirect influence-dependence. It show the various functions that plays by the variables in this system. Each quadrant was classified within this map consist of input variables, relay variables, dependent variables and excluded variables quadrants. The variable of bridge infrastructure is classified as dominant variable (quadrant I), so that it must be prioritized. It has the highest influence as a main connector from coastal area and urban area; and has strong influence to other variables within economic (income per capita), social (population density) and environmental (EQI) aspects. The finding could give insight for policy makers to determine which variables become the priority in infrastructure and transportation development plan of Kedayakan village. Variables that have the highest influence level and the lowest dependence level, must be prioritized.

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