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Dynamic System Modeling in the Selection of Regency Road Pavement Construction Types

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***Abstract*—The selection of pavement construction type is influenced by several factors, such as technical conditions, economic conditions and conditions in the area. These factors have different criteria in each region, resulting in a different selection of road pavement. This paper aims to model the most suitable pavement type in an area. Types of pavement designed in this paper are flexible pavement, rigid pavement and penetration pavement. The research areas in this paper are those that represent develop regions (Central Java), developing regions (West Kalimantan), and regions that will develop (East Nusa Tenggara) with a focus on district roads. Methods used in this paper are descriptive analysis based on secondary data and literature studies to build a model for selecting pavement types which can later be further analyzed using a dynamic system.**

Keywords: dynamic system, pavement, road length, causal loop, topography

I. Introduction

The policy and strategy for 2015-2019 Medium-Term Development Plan (RPJM) is to accelerate the development of border areas in various fields, especially economic, social and security, and to make the border region as an integrated and environmental-friendly gateway for economic and trade activities with neighbouring countries. To accelerate development of the border area, a strategy was adopted; such as building connectivity from the main transportation hub of the national strategic activity center to villages in the priority border location with surrounding sub-districts, regional activity centers (district capital), national activity centers (provincial capitals) and connecting with neighbouring countries, and also build connectivity through sea transportation services to improve the quality and intensity of services to the border region. The second RPJM in 2010-2014 has predicted that the length of district road needed is almost 498,687 km, meaning that the role of decentralization and regional autonomy is crucial in the administration of regional roads. The number of vehicles utilizing district roads is generally in the low-moderate category (ranging from no more than 1000 vehicles per day), which is indicated by a range of road widths of 3.0 to 7.0 meters. Along with the development, economic equality is expected to occur in each region. Until now, the selection process of pavement construction for the state, provincial and district/city roads is still based on the strength of the soil, traffic volume and vehicle load. In choosing the pavement type, factors that usually become the variable are traffic volume, design life, and soil bearing capacity. However, there has never been a selection of district road pavement construction types that relate to the development of budget allocation by the district government. Thus this research aims to provide a recommendation for the type of pavement that suits the needs of the conditions of an area.

II. Literature Review

Road pavement designs in developing countries which are usually based on industrialized countries can be irrelevant because they are not economically feasible. That is because there are significant differences in socioeconomic conditions between the two. The study of optimal pavement design and its relationship to the development stage of a country results in the optimal trade-off between initial financing for construction and subsequent maintenance depending on the stage of economic development [1].

Many researchers have developed studies on road construction models with several variables including soil and material properties, traffic loads, climate factors, and unit prices [2]; traffic loading, loop of economics, loop of pavement design, maintenance options [3]; low income, penalty cost, population, fuel price, residential location [4]. The study of the proposed policy model for construction type and district road width by taking into account regional potential has been carried out before. The district road pavement selection model was then developed using the Analytical Hierarchy Process (AHP) method based on regional economic conditions [5]. Variables used include pavement types, road construction budget allocations, subgrade strength, topography, vehicle loads, and economic growth. The same variable is done by the econometric method to see simultaneous equations based on the dominant variable [6]. Mathematical models are built using the Simultaneous Equation Method through Cobb-Douglas theory [7]. From the AHP method, a Matrix and Nomogram are produced that shows the relationship between the Road Length and the Type of Pavement and the percentage of GRDP that can be used by district decision-makers in making decisions to determine the type of pavement to be selected based on local conditions.

The dynamic system is a computer simulation model that helps users to learn complex dynamics in planning decisions effectively [8]. The dynamic system model is an approach to parse complex problems which can analyze causal relationships (between stocks, flows and feedbacks loops) so that they can describe the almost real conditions of an environment. Besides this model is also object-oriented simulation use and has been used widely both in the industry [9], and civil engineering [10] [11].

III. METHODOLOGY

This study uses existing theoretical approaches and then constructs the variables forming the type of road pavement based on the theory. Based on previous research [12], there are three caused components, such as technical, regional condition, and economic condition. Technical consists of soil bearing capacity, traffic, and vehicle load variable; regional condition consists of population, road length, topography, and accessibility variable; economic condition consists of regional economic activity, %GDRP of the transportation sector and local government budget allocation for development. The relationship between the three components is shown in following Fig. 1 below.

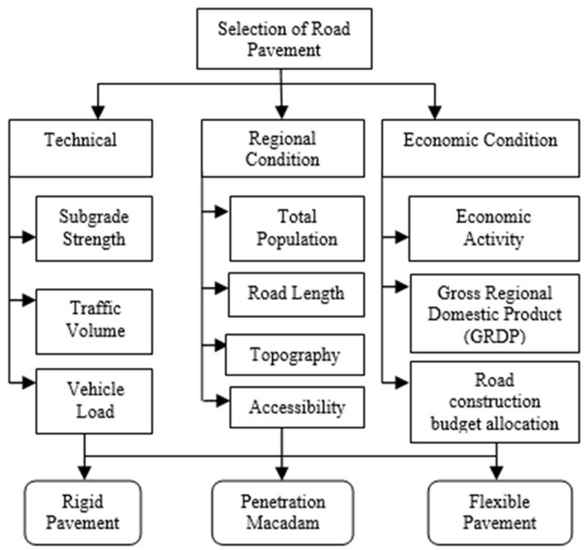

Fig. 1. Scheme of selection of road pavement construction types [12].

The variables of each three conditions are proceed by The Analytic Hierarchy Process (AHP) method. Thus, there are only a few variables have got the highest weighting that constructs the model of the selection of road pavement types model, such as:

- Total population
- Topography
- Accessibility
- Road length
- GDRP

Furthermore, the variables obtained are formed into a model that will be analyzed using a Dynamic System. The data used in this study are secondary. The calculation model is performed using a Dynamic Systems approach; using the Pavement Type equation (X_1) that has been developed [12]:

$$X_1 = a + b_6 * total\ population + b_7 * topography + b_8 * accesibility + b * road\ length + \mu \quad (1)$$

And equation:

$$\hat{Y} = f\,(pavement\ type) + f\,(\%\ GRDP) \quad (2)$$

Or in trans-log:

$$\ln \hat{Y} = \ln \text{pavement type} + \ln\%\ \text{GRDP} \quad (3)$$

Where:

total population	b_6	= 7.333868119127E-07
topography	b_7	= 0.4396737
accessibility	b_8	= 0.1150738
the length of built up road	b	= 0.0026773

The following Fig. 2 is a Causal Loop Diagram illustrating the relationship of variables in determining the type of pavement and Fig. 3 shows its stock and flow diagram.

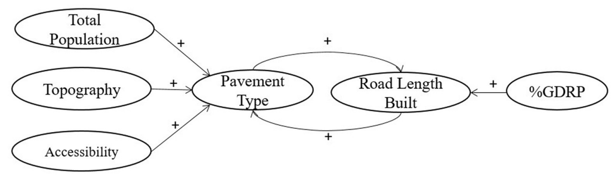

Fig. 2. Causal Loop Diagram.

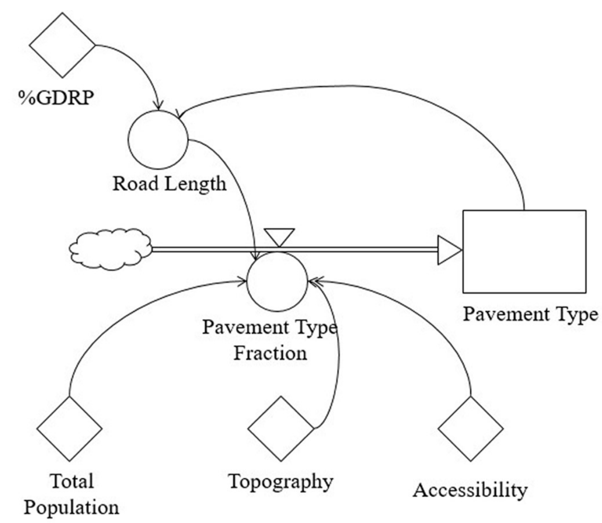

Fig. 3. Stock and Flow Diagram.

IV. RESULTS

This study uses secondary data on population, topography, GDRP, accessibility and length of district roads. There are 61 regencies from the provinces of East Nusa Tenggara, Central Java and West Kalimantan, which are used as input models.

For data processing, the variables used are grouped according to the type of data i.e. district population data, topography is categorized into 6 classes (1 = flat; 2 = bumpy; 3 = sloping; 4 = rather steep; 5 = steep; 6 = very steep), accessibility (0 = accessible; 1 = inaccessible), GRDP and road length obtained from Statistics Indonesia (BPS).

Model simulations are carried out using Powersim software. The following TABLE I shows the type of pavement that can be applied to local roads in 61 districts (East Nusa Tenggara, Central Java and West Kalimantan) based on input variables in the model.

TABLE I. MODELLING RESULTS USING DYNAMIC SYSTEM

No	Districts	Total population (people)	Topography type	Accesibility	GRDP (%)	Road length built (km)	Pavement Type	Predicted Road Length (km)
1	Alor	212793	4	1	4	0	3	0
2	Belu	402825	3	1	5	0	1	6.6196
3	Ende	254845	3	1	4	0	1	4.5762
4	East Flores	274737	1	0	5.6	0	1	7.84564
5	Kupang	330322	2	1	5.2	76	1	7.02828
6	Lembata	127590	1	0	6.5	0	1	9.6847
7	Manggarai	314224	3	1	4.8	0	1	6.21092
8	West Manggarai	255277	1	0	4.7	0	1	6.00658
9	East Manggarai	263142	1	0	5	9.71	1	6.6196
10	Ngada	162984	4	1	6	5	3	1.4682
11	Nagekeo	154168	3	1	4	0	3	0
12	Rote Ndao	151937	1	0	7	80.03	1	10.7064
13	Sabu Raijua	85321	1	0	6	0	1	8.663
14	Sikka	315582	1	0	4	32.96	1	4.5762
15	West Sumba	145575	4	1	5	0	3	0
16	Southwest Sumba	367771	2	1	4	0	2	0.9788
17	Central Sumba	82999	4	1	5.6	0	3	0.65084
18	East Sumba	241822	3	1	4.8	0	3	0
19	Central South Timor	461555	3	1	4.6	0	3	0
20	Central North Timor	264106	4	1	4.6	6.25	3	0
21	Banjarnegara	923971	6	1	5	0	3	0
22	Banyumas	1551076	1	0	5.6	0	1	7.84564
23	Batang	886476	6	1	5.7	0	3	0.85518
24	Blora	760799	1	0	5.2	0	1	7.02828
25	Boyolali	932814	5	1	6.1	0	3	1.67254
26	Brebes	1764041	4	1	4	0	3	0
27	Cilacap	166586	1	0	4.9	0	3	0
28	Demak	1064475	1	0	5.9	0	2	4.86126
29	Grobogan	1179448	1	0	5.2	0	2	3.43088
30	Jepara	1137608	1	0	5	0	2	3.0222
31	Karanganyar	744965	4	1	5.2	0	3	0
32	Kebumen	1301590	1	0	6	0	1	8.663
33	Kendal	948493	1	0	4.9	0	1	6.41526
34	Klaten	1156043	3	1	5.3	0	2	3.63522
35	Kudus	743291	1	0	5.1	0	2	3.22654
36	Magelang	1129490	1	0	4.9	0	2	2.81786
37	Pati	1092230	1	0	5.4	0	2	3.83956
38	Pekalongan	886478	6	1	6.5	0	3	2.4899
39	Pemalang	1493454	1	0	4.3	0	1	5.18922
40	Purbalingga	907526	7	1	6.5	0	3	2.4899
41	Purworejo	738728	4	1	6.1	0	3	1.67254
42	Rembang	598318	1	0	6.4	0	2	5.88296
43	Semarang	987177	7	0	4.6	0	2	2.20484
44	Sragen	741142	4	1	6.3	0	1	9.27602
45	Sukoharjo	741366	1	1	5.9	0	1	8.45866
46	Tegal	1379489	1	1	4.8	0.46	1	6.21092
47	Temanggung	719553	4	1	4.5	0	1	5.5979
48	Wonogiri	842708	3	1	4.5	0	1	5.5979
49	Wonosobo	810323	4	1	4.8	0	3	0
50	Bengkayang	266741	4	1	4.5	0	3	0
51	Kapuas Hulu	242795	2	1	4.5	0	1	5.5979

No	Districts	Total population (people)	Topography type	Accesibility	GRDP (%)	Road length built (km)	Pavement Type	Predicted Road Length (km)
52	North Kayong	124935	2	1	4.4	0	1	5.39356
53	Ketapang	544309	2	1	4.9	0	1	6.41526
54	Kubu Raya	566394	2	1	5.2	12.67	1	7.02828
55	Landak	388840	4	1	5.1	0	3	0
56	Melawi	222932	4	1	5.3	0	3	0.03782
57	Pontianak	294623	2	1	5.1	0	1	6.82394
58	Sambas	622757	2	1	5.3	0	1	7.23262
59	Sanggau	467080	2	1	3.2	0	1	2.94148
60	Sekadau	209381	2	1	3.5	0.37	1	3.5545
61	Sintang	393755	4	1	5.1	0	1	6.82394

Based on the results obtained, the formulation that has been developed can be simulated using Dynamic System modelling.

V. Conclusions and Recommendations

The analysis shows that there is a relationship between pavement type selection, road length built, and% the GRDP; which is presented in the form of Dynamic System modelling based on the road selection formulation developed.

A dynamic system model for selecting pavement types needs to be developed by simulating factors such as population growth and increasing GRDP for the next few years.

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