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DEVELOPMENT OF A DYNAMIC MODEL FOR INVESTIGATING THE INTERACTION BETWEEN RURAL TRANSPORT AND DEVELOPMENT: A CASE OF SOUTHEAST SULAWESI, INDONESIA

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Abstract: A lack of tool in understanding the dynamic relation between rural transport intervention and development level has contributed to the ignorance of policy makers to develop a pro-poor investment. A dynamic model for an interaction between rural transportation, i.e. accessibility and mobility, and development was proposed with a simultaneous equation block using regression analysis and a Gauss-Seidel iteration procedure. Data were obtained from three districts in Southeast Sulawesi (Tinanggea, Poleang Timur, and Watubangga Districts), using 360 HH and 984 respondents. The equation sets were tested against 5 provinces in Indonesia to acquire nation-wide data on the link between rural transport and development. The result shows that rural transport has a significant impact on rural development indicators with a diminishing return principle. The role of rural transport intervention disappears as the mobility increase. This conclusion of the research can be use as a base for future investment prioritization and budget allocation.

Keywords: dynamic modelling, rural transport, development, prioritization

1. INTRODUCTION: DEVELOPMENT CHALLENGES OF RURAL TRANSPORT

In 1994, the World Bank issued annual report *World Development Report* entitled *Infrastructure for Development.* The report recognizes that “while there is still no consensus on the magnitude or exact nature of the impact of infrastructure on growth, many studies on the topic have concluded that investment role of infrastructure in growth is substantial, significant and frequently greater that of investment in other form of capital.” The report is a reaction against the need for funding for infrastructure development which is dilemmatic in developing countries. Developing countries invest $ US 200 billion per year to construct new infrastructure - 4% of national product and 20 % of total investment. In one respect, physical infrastructure is continuously needed as prerequisite of development. In the other respect, it always needs an immense amount of funding and becomes political issue which is difficult to neglect.

Transport improvement itself does not alleviate poverty nor provide a long-term guarantee for employment. Labour based road construction and maintenance provide employment and considered important during inter harvest season and during agriculture production failure. The most immediate poverty alleviation effect of investing in road is the local employment created in its improvement and subsequent maintenance. If suitably targeted however, the poor can benefit directly through earnings (Howe, 1997). The creation of road funds for road maintenance in African countries provides worldwide examples of success and failures of rural road maintenance in providing employment and alleviating poverty (Heggie, 1995).

A study from Economic and Social Commission for Asia and the Pacific/ESCAP-UN (1997) entitled Transport and Communication Intervention in the Alleviation of Poverty supported the argument that rural transportation, combined with appropriate method of construction is an important element in sustaining regional economy in efforts to alleviate poverty. The report stated "…that transport intervention can be used as a policy instrument and an entry point for poverty alleviation" (pp. 103-104). Further, it says that "The impact of transport infrastructure on poverty reduction may be direct, indirect or a combination of both, depending upon the type of infrastructure and services provided through the programme" (pp. 104).

Transport improvement provides a greater opportunity to access economic, social and education facilities without which such opportunity is not possible. In the development context, this issue is very critical since it covers a fundamental aspect of rural revitalization. The occurrence of urbanization is by and large due to the inability of rural area to provide economic and social wealth to its residents. The lack of transport facilities has lead to the isolation of rural area. Agricultural products can not be transported to the market; fertilizer and agricultural know-how and technology are not able to reach the farmer. The local people have limited access to the social, education, economic and health facilities. The extent of such isolation is largely dependent upon the investment availability for construction and maintenance.

Worldwide experience has also shown that poor rural transportation has dis-benefited women for carrying heavier, often by head-loading, and farther for collecting firewood and water. Women in developing countries spend more time in transport activities than men. This consumes a relatively high proportion of their day. This is in a context where women typically work 12-13 hours more per week than men in Africa, Asia, and the Pacific (Fernando and Porter, 2003). Surveys in a number of African countries have shown that women account for about 65% of the all household time spent in transport activities and between 66-84% of all energy (Doran, 1996). This creates an imbalance distribution of the transport burden and unequal access to transport technologies. In studies of several African countries, 70% goods from the village are carried by women simply because there are not accessible, trafficable or even passable by intermediate modes of transport. Some previous research also demonstrated that the opportunity of women in income generating activities in rural transport sector is large provided that funding assistance is available.

This research aims at investigating the dynamic link between rural transport intervention and local economic development. The result of the exercise will then be used to test several policy scenarios for improving rural development in the Indonesian selected regions.

2. THEORETICAL FOUNDATION FOR RURAL TRANSPORT MODELLING

Theoretical views on rural development in developing countries since the early 1970s, with various perspectives have risen as a reaction against rural development practices in the past, especially in response to the imbalance between rural and urban areas, agricultural productivity and rural quality of life. This development growth has taken migration from rural areas to urban areas as a natural process so as to shift the human sources from regional zones with no marginal products, to the city with positive marginal product has already developed into an issue which is increasing, rather than reducing unemployment (Todaro et.al, 2003). Todaro's three level thesis of rural development has also developed into promoting the needs for both off-farm activity and the process to increase rural productivity. Various approaches on rural infrastructure development have likewise taken an advanced pace as reviewed by Leinbach and Cromley (1989), starting from *value path* of Chilling, Revelle, and Cohon and Hill's *goal achievement matrix*, up to a recent approach in form of goal-programming in which prominently every goal is modelled as an impact of inequality representing the desired extent.

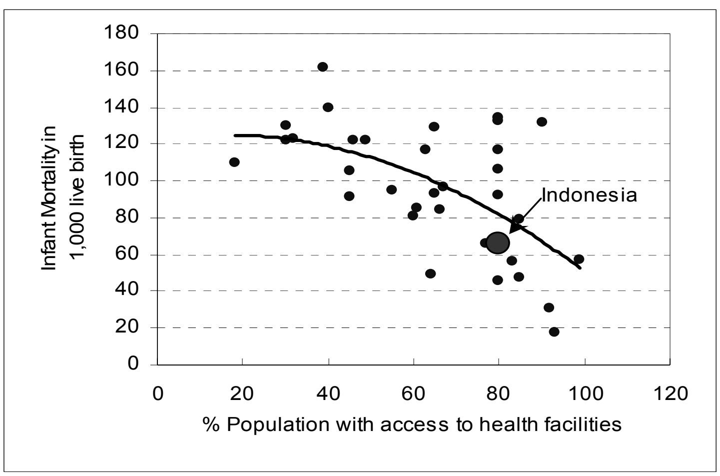

Figure 1. Infant Mortality and Access to Health Service in 34 Developing Countries, 1985-1995 (source: Edmonds, 1998, pp.11)

Providing basic access to daily household activities is the focus of many researches that were reviewed. Figure depicted above for example, demonstrates a link between health and transport development using descriptive analysis (Edmonds, 1998). The development issue of rural transport addressed the issue of gender equality as put forward by Fernando and Porter (2003) in two aspects: to find ways to systematically involve women in the planning process and design of transport intervention and of the technology and to consider also the "non-economic" benefits that can accrue to women.

A review of Simon (1996) on Transport and Development in the Third World is a good start to understand the issues of transport and development. Parikesit et.al (1999) in their research, investigated the impacts of road investment to the Indonesian economic development, looking at the change in the national economics' productivity and employment creation using macroeconomic model.

Attempts to quantify impacts of rural transport investment was numerically developed by Carnemark et.al (1976) which utilizes producer surplus approach (as oppose to a conventional model, road user cost savings, consumer surplus approach). The method was to quantify the change in the farmers' productivity and lower costs of production inputs (such as fertilizers, seeds, technology). Major assumptions underlying this particular approach are as follows:

a. Transport cost savings due to the road project are fully passed along to the farmer, in terms of a higher ex-farm price for outputs and a lower delivered price for inputs.

b. Production costs per ton decline due to greater use of modern inputs, made accessible by the road project, and due to complementary investment.

c. Cultivated land area is fixed.

d. Any additional quantity of crop produced as a result of the project is not sufficient to cause a price decline on the market.

e. All of the crops produced are marketed over the improved road.

f. Economic costs measured in efficiency prices are used throughout the analysis.

The consumer surplus is intended to identify benefit at a project level. The method was not able to identify area-wide impact of rural transport investment. It has a critical assumption that the price of agriculture product is stable because of the vast supply of the commodity (that a marginal change of the commodity produced by a region having a road investment will not change the market price). The second assumption that might not hold true is the reduced agriculture production input. The idea that transportation margin is transferred to the farmer may not be happening in the reality since the intermediary may try to exercise their bargaining position and to increase their profit margin by controlling the distribution system.

Integrated Rural Accessibility Planning (IRAP) approach developed by The International Labour Organization (Donnges, 1999) has been successfully applied in various countries such as Cambodia, India, Laos and Indonesia as well as other African countries like Ghana, Mozambique to identify access needs and priority for a particular village. Its formulation was based upon a simplified sum of product moment of priority and weight.

The accessibility indicator (IA) has the following mathematical formulation:

$$IA_{min} = i_{max} \times k_{min} \times \Sigma R_a \qquad (1)$$

$$IA_{max} = i_{min} \times k_{max} \times \Sigma R_a \qquad (2)$$

$$\Delta = (IA_{\max} - IA_{\min}) / n \quad (3)$$

$$IA_n = IA_{\min} + n\,\Delta \quad (4)$$

$$IA_n = IA_{\max} \quad (5)$$

$$IA = \sum_{i=1}^{n} k \times \sum R_a \quad (6)$$

Where:

IA	: Value of Accessibility Indicator
i	: Accessibility Indicator for a particular sub-sector
k	: Sub-sector accessibility value
ΣR_a	: Number of respondents
Δ	: Interval
n	: number of category

IRAP combines a participatory approach and quantification of rural access factors, including its weight based on the priority. While it is successfully applied in several regions, it is still to be developed to suit local priority and weight, making it a lengthy and rigorous process. It suffers from the capability to identify link between providing access and economic development potentials of the region. The later argument is quite understandable because since its inception, IRAP approach is an instrument for identifying problems of access to basic services and livelihood activities.

Producer surplus and IRAP approaches described above are appropriate for its original intention. Producer surplus approach is adequate to demonstrate benefits accrued to agricultural farmer and IRAP is a powerful tool to identify factors/variables determining rural travel characteristics and to indicate the lack of access currently experienced by the rural households and individuals. Both models/approaches are however, not able to produce region-wide analysis of rural transport investment nor to simulate the ability for rural investment to generate economic activity and demographical dynamics. In many political processes, the understanding of dynamic processes in an area wide analysis is often more important than a decision to invest in a single project. Transport intervention to reduce poverty requires an ability to set up a policy framework for improving the rural economy and how can transport be part of measures to "pull" rural development. A tool to demonstrate area-wide dynamic interaction between transport and local economic development is necessary to support policy making in rural transport investment.

3. DEVELOPMENT OF RURAL TRANSPORT DYNAMIC MODEL

A dynamic model for linking rural transport and development is based on the theoretical relationship between three broad factors in rural development, namely physical, demography, and economic development. Each of the factors consists of various variables and sub variables having individual importance and weights. Since every variable or sub variable has its own unit, it is important to acquire information on the interval they operate in a given circumstances and the order of importance according to local condition before all of them can be amalgamated into a single or set of formulas. Other consideration to determine the variables is that they should be uncomplicated and available in village statistics to avoid cumbersome data acquisition for model replication. Therefore a trade-off should be made between incorporating every factor that can contribute to the link between transport and rural economic development (which is probably impossible to be identified) and practicality of the proposed model for policy formulation.

Preliminary investigation using IRAP approach is conducted to identify rural travel characteristics and variables to be included in the dynamic model. By adding up the variables with demographic and economic variables, the proposed model consists of the following variables: development variable (X_1), income per capita (X_2) mobility (X_3), accessibility (X_4), population density (X_5), and activity density (X_6). Those variables are main variables which are explained by their first order and second order variables. Simultaneous regression was developed based on the relation between main variables (each of which was established from sub-variables' linear equation).

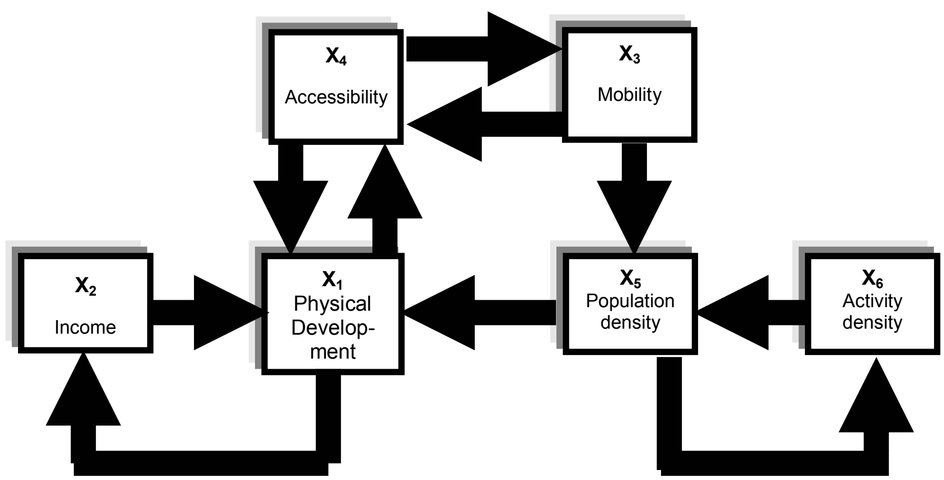

Figure 2. Conceptual Formulation of Rural Transport Dynamic Modelling

The following table shows the variable structure of the simultaneous equation.

Table 1. Variable structure

No	Main variables	Sub – Variables		Sub-Sub Variables	
X_1	**Physical Development**	X_{11}	Rural Service Facilities	X_{111}	Education facility
				X_{112}	Religious facility
				X_{113}	Health facility
				X_{114}	Security post
				X_{115}	Economic facility
				X_{116}	Post and telecommunication facility
		X_{12}	Housing	X_{117}	Electricity
				X_{118}	Clean water
		X_{13}	Human resource quality		
		X_{14}	Natural resources	X_{131}	Agriculture land potentials

				X_{132}	Farming potentials
				X_{133}	Animal farming potentials
X_2	**Accessibility**				
X_3	**Mobility**	X_{31}	Vehicle numbers and quantity		
		X_{32}	Road quality		
		X_{33}	Road utilization	X_{331}	Road density (km/km2)
				X_{332}	Road density (km/1,000 pax)
X_4	**Yearly income per capita**				
X_5	**Population density**	X_{51}	Population		
		X_{52}	Area		
X_6	**Activity density**	X_{61}	Population density		
		X_{62}	Ratio of productive population		

The problem statement for the above conceptual modal can be mathematically written as follows.

Let n be the number of linear equation with n equations

$$
\begin{array}{c}
a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \ldots + a_{1n}X_n = b_1 \\
a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + \ldots + a_{2n}X_n = b_2 \\
\cdot \quad\quad \cdot \quad\quad \cdot \quad\quad\quad \cdot \quad\quad \cdot \\
\cdot \quad\quad \cdot \quad\quad \cdot \quad\quad\quad \cdot \quad\quad \cdot \\
\cdot \quad\quad \cdot \quad\quad \cdot \quad\quad\quad \cdot \quad\quad \cdot \\
a_{n1}X_1 + a_{n2}X_2 + a_{n3}X_3 + \ldots + a_{nn}X_n = b_n
\end{array}
\tag{7}
$$

where a_{ij} is the parameter, x_i is the variable, and b_i (where at least one $b_i \neq 0$) is non-homogenous constant related to the other variables. The problem is to estimate parameter a_{ij} that satisfy b_n given that b_n is also determined by other variables.

There are several methods in solving simultaneous regression equation, namely Gauss and Gauss Jordan elimination, Doolitle method, Cholesky Decomposition, Jacobi iteration method and Gauss – Seidel iteration method. While it is important to recognize the efficiency of each method, the difference between Jacobi and Gauss-Jordan with the other methods is that the earlier methods use iterative procedure whereas the later can be regarded as deterministic methods.

In some cases, iterative methods are superior in the existence of sparse matrices, i.e. matrices with many zero elements, resulting in the simplicity of iterative equations. Using an initial approximation, this method can also be used to solve non-linear equation. However, iterative method will not be in favour if the convergence speed is low.

In the research, Gauss-Seidel iteration method was employed since it can reduce the number of iterations than using Jacobi iteration methods. In Gauss-Seidal iteration, an initial vector of x = [0, 0, 0, ..., 0] is introduced. The solution of X is as follows:

$$S = \sum_{k=1}^{i-1} a_{ik} X_k + \sum_{K=i+1}^{n} a_{iK} X_K \text{ , } i = 1, 2, 3, ..., n \tag{8}$$

$$X_i = -(S - b_i) / a_{ii} \tag{9}$$

For example, an equation system having three X variables exists. The first equation in the equation system (2) is substituted with any value of X_2^0, X_3^0 (usually zero), then:

$$X_1^1 = \frac{(b_1 - a_{12} X_2^0 - a_{13} X_3^0)}{a_{11}} \tag{10}$$

new equation of X_1^1 is then substituted into the second equation of the system, and therefore

$$X_2^1 = \frac{(b_2 - a_{21} X_1^1 - a_{23} X_3^0)}{a_{22}} \tag{11}$$

which then is continued with third equation of the system substituting new values of X_1^1 and X_2^1. Thus the following equation can be developed:

$$X_3^1 = \frac{(b_3 - a_{31} X_1^1 - a_{32} X_2^1)}{a_{33}} \tag{12}$$

The equation is then tested using classical assumptions in the linear equation model as follows.

Table 2. Tests Procedure for the Proposed Model

No.	Classical assumptions	Diagnosis of a deviation against classical assumptions
1	Multi-colinearity	Using $t_{calculated}$, R^2, and F Ratio. When R^2 and F is high, and some or most of regression coefficients are insignificant, multi-coliniearity is expected.
2	Heterocedastisity	Correlation of coefficient approaching 1. This assumption is tested using Spearman ranking test
3	Auto-correlation	Using Durbin-Watson test (D_w)

4. RESULTS OF SIMULATION: CASE OF INDONESIA

Indonesia can be categorized as country bearing the heaviest problem of economic crises occurring in Asia. Based on World Bank and IMF's estimation (IMF, 2002) Indonesian short term-economic prospect is not satisfying. SMERU (The Social Monitoring and Early Response Unit) estimates that poverty figure will increase in 1999 from 11% up to

13% (other institutions, including ILO, predicts that the increase will have reached 48%). The World Bank estimate (2003) indicated that geographical disparity reveals the sector associated with poverty. Although the employment sectors receiving the hardest-hit were urban sector such as manufacturing, trade and services, agriculture sector remains the poorest sector.

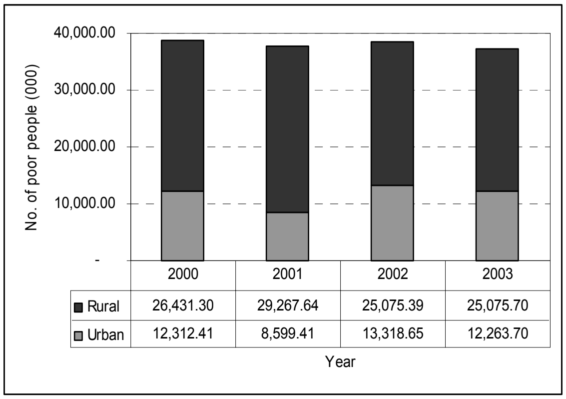

Figure 3. Number of People Living below Poverty Line in Urban and Rural area (source: www.kpk.org)

An important policy to be put immediately in place is therefore a strengthening of rural and agricultural economy as a foundation for economic growth and poverty reduction. Rural transport is an important element for sustaining rural economic growth since it represents 5 – 25% of total market price of community-own agriculture commodity (DGLT, 2004).

The research used the travel characteristics data collected from three districts in Southeast Sulawesi (Tinanggea, Poleang Timur, and Watubangga Districts). The subject of data collection is 360 household and 984 individual respondents, representing 3% standard error. The research used household and individual travel characteristics to ensure that they are complimentary. A questionnaire containing household and individual travel characteristics were devised and interviews were conducted.

Using a simultaneous equation with Gauss-Seidel iteration, the following equation was obtained.

Table 2. Coefficient and Simultaneous Regression Equation Test Results

No.	Dependent Variable	Constant	Development	Income	Mobility	Accessibility	Density	Activity
1	**Development X_1 (R^2: 0.99)**	2.5		0.322		0.318	0.135	
	T-test	H_0 rejected		H_0 rejected		H_0 rejected	H_0 rejected	
	F-test	H_0 rejected						
2	**Income X_2 (R^2: 0.95)**		1.047					
	T-test		H_0 rejected					
	F-test	H_0 rejected						
3	**Mobility X_3 (R^2: 0.83)**	-12.037				2.084		

	T-test	H_0 rejected				H_0 rejected		
	F-test	H_0 Ditolak						
4	**Accessibility X_4 (R^2: 0.87)**	5.247	0.316		0.211			
	T-test	H_0 rejected	**H_0 accepted**		**H_0 accepted**			
	F-test	H_0 rejected						
5	**Density X_5 (R^2: 0.96)**	-4.679			0.734			0.687
	T-test	H_0 rejected			H_0 rejected			H_0 rejected
	F-test	H_0 rejected						
6	**Activity X_6 (R^2: 0.94)**						0.935	
	T-test						H_0 rejected	
	F-test	H_0 rejected						

From the table above, equation X_4 contains a problem of multi-colinearity and thus should be improved using a-priory information. The new equation for X_4 is as follows:

Table 3. New Equation for X_4

Dependent Variabel		**Constant**	**Independent Variabel (X_i)**	**R^2**	**Keterangan**
X_4	**Accessibility**	5.2466	0.3162	0.87	X_i = Development + 0.6688(Mobility) Accessibility = 5.2466 + 0.3162. X_i
	$t_{calculated}$	5.5567	6.7018		
	$F_{calculated}$	44.9138			

The classical assumption test shows that the above equations in Table 2 and Table 3 can not avoid heterocedasticity. This is a typical case for data using cross sectional analysis (Gujarati, 1999) since a member in the population has a relationship with other members. Table 4 below summarizes the results of assumption tests.

Table 4. Results of Classical Assumption Tests

Equation model	**Multi-colinearity**	**Hetero-cedasticity**	**Autocorrelation Coefficient**	
			Score	**Remarks**
Development	No	Exist	1.95	No autocorrelation but not too convincing
Income	No	Exist	1.94	No autocorrelation
Mobility	No	Exist	1.06	No autocorrelation but not too convincing
Accessibility	No, modified data	Exist	0.93	No autocorrelation but not too convincing
Density	No	Exist	2.09	No autocorrelation
Activity	No	Exist	1.28	No autocorrelation

The equation can be utilized using an initial value to be hold as a constant and accordingly, subsequent values can be obtained. When the above sets of equation were simulated using X_1=10 and X_1=20 as initial values, they yield the following result.

Table 5. Summary of the Simulation

Var.	Simulated Variables											
	X_1		X_2		X_3		X_4		X_5		X_6	
X_1	**10**	**20**	10.01	16.53	10.39	16.52	9.58	23.09	11.15	13.94	11.29	13.82
X_2	10.47	20.94	**10**	**20**	10.88	17.29	10.03	24.18	11.67	14.60	11.82	14.47
X_3	9.81	21.59	9.82	17.50	**10**	**20**	8.80	29.64	11.16	14.45	11.33	14.31
X_4	10.48	16.14	10.49	14.17	10.65	14.70	**10**	**20**	11.13	12.71	11.21	12.64
X_5	7.05	31.22	7.07	22.83	7.44	27.96	4.98	47.74	**10**	**20**	10.51	19.56
X_6	6.59	29.19	6.61	21.34	6.95	26.14	4.66	44.64	9.35	18.70	**10**	**20**

It is now possible to estimate the relative impacts of a marginal increase in its variable toward the other variables in the simulataneous equation above. A marginal change in its independent variables can be obtained by estimating the relative difference in its value as shown in Table 6 below.

Table 6. Marginal Change in the Independent Variables

Var.	Name of Variable	Change in the variable					
		X_1	X_2	X_3	X_4	X_5	X_6
X_1	Development		0.65	0.61	**1.35**	0.28	0.25
X_2	Income	1.05		0.64	**1.41**	0.29	0.27
X_3	Mobility	1.18	0.77		**2.08**	0.33	0.30
X_4	Accessibility	0.57	0.37	0.41		0.16	0.14
X_5	Pop. Density	**2.42**	**1.58**	**2.05**	**4.28**		**0.91**
X_6	Activity density	2.26	1.47	1.92	**4.00**	0.93	

Table 6 indicated that the change in the accessibility gives a higher impacts to other variables, indicated by the bold figures. On the other hand, the population density has been a variable most affected by the marginal change of the other variables. However, the impact of the provision of accessibility on population density is far superior than other variables. Providing access is thus important to maintain the population in the village boundary creating an environment for rural industrialization. The presence of various off-farm activities is also shown by higher population density.

In oder to test the result of the equation. The reseach collected data from 5 provinces in Indonesia (West Sumatera, South Sumatera, Central Java, Central Kalimantan and West Nusa Tenggara). The following figure demonstrates the result of the simulation using a mobility ratio as a proxy indicator.

Mobility ratio is reflected by the ratio of distance and time reflecting travel speed (kph) for rural community to reach closest economic centre, i.e. market. Using the above graph, one can now devise an instrument for regional prioritization by allowing, for instance the quartile categorization as demonstrated for West Sumatra Province below. First priority is defined as data falls under the 1st quartile. This approach is adequate given that it will provide 25% of the lowest region having a highest elasticity in response with an increase in the mobility ratio.

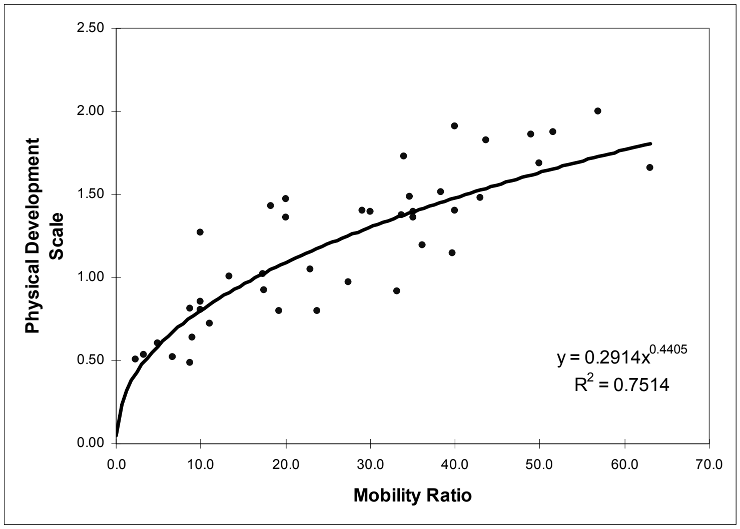

Figure 4. The Relation between Mobility Ratio and Physical Development Data Generated by the Model (data for 5 provinces)

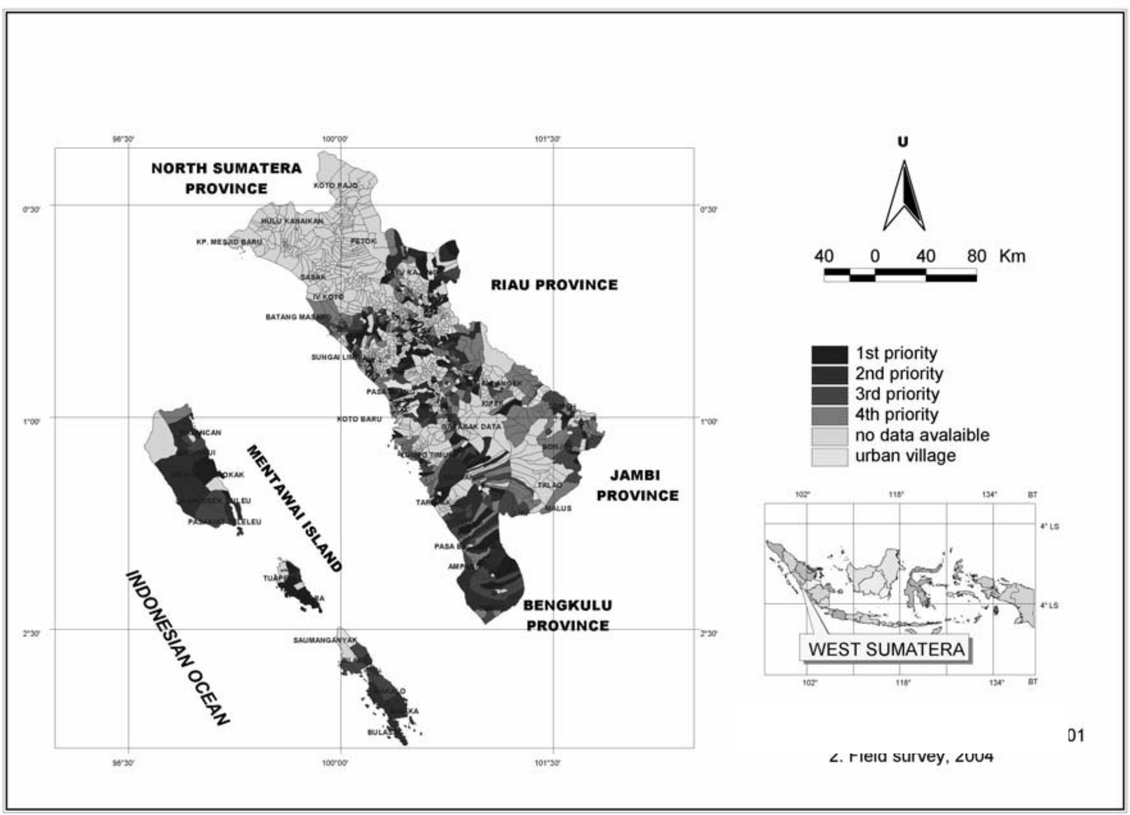

Figure 5. Result of Village Prioritization for West Sumatra Province

The Figure 5 above shows the map of West Sumatra Province and its villages. It contains village with adequate and inadequate information to undertake simulation procedure, and urban villages. Urban villages are excluded from the simulation.

Simulation procedure has resulted that villages in the provinces can be categorized into 1st – 4th priority according to their characteristics and responses to transport intervention. First priority villages mean that those villages have higher economic development elasticity then other categories when their mobility ratio is improved. When improved at the same level with other category, 4th priority villages will increase their economy but at much less extent.

The above figure has indicated the geographical representation of villages with various priority levels for rural transport intervention. The prioritization will enable local and central governments to allocate their development budget in cost effective manner. Important to note that the model is applied to rural village, that is a village having at least 60% of its economic activities on agriculture sector. The current statistical data make it not possible to identify all villages due to the miss-match of geographical and statistical information, which perhaps is attributed to the village expansion and the emergence of new villages.

5. CONCLUDING REMARKS

The above exercise has demonstrated that it is possible, and it is the scientific contribution of this paper, to numerically estimate the link between rural transport and social and economic development of the area. Rural transport has a diminishing impact toward development. That is, when development was at its initial stage, rural transport intervention in improving its mobility will give higher impacts than when it was already achieved higher development stage. This will explain the condition for “pull” and “push” effect of transportation investment. In the area where development was at the beginning stage, rural transportation will be the leading instrument for bringing the area onto the next level of development – making it as a sound measure for poverty reduction programme.

Proposed simultaneous equation can also be used to generate simulated physical development indexes and to prioritize development strategy based on the ability of rural transport to pull rural development.

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