Effectiveness of Rural Road Improvement Using the "Do-nou" Method in Developing Countries: Economic Analysis with RED Model

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The improvement of rural transport infrastructure is necessary for sustainable development and poverty reduction in developing countries. However, it is likely that there is insufficient budget to improve and maintain rural feeder roads with low traffic volume. As a result, many roads are kept unpaved or in an unsustainable condition. The "do-nou" method was invented to solve this problem, by making roads strong with relatively low investment and easy work. Though the method has already been implemented, its economic impact has not been thoroughly examined. Therefore, there is no clear indication on the advantages and conditions for the application of the method in terms of investment efficiency in comparison with other options.

Based on the background, this study evaluates the economic impact expected from the do-nou method by using the Road Economic Decision (RED) model developed by the World Bank. Do-nou and other improvement alternatives are evaluated by the model under a hypothetical project setting. The results of the model analysis provide basic findings on the magnitude of the economic impact of do-nou method and the way of effective utilization to rural road projects. Finally, this study discusses issues to be considered for more reliable economic evaluation and prevalence of "do-nou" method to practice based on the analysis result.

Key Words : *Do-nou, Road Economic Decision (RED) Model, Rural Feeder Road, Labour-Based Technology (LBT), Economic Analysis*

1. INTRODUCTION

(1) Background

a) Importance of rural feeder roads

In developing countries, poverty is more pervasive in areas with little or unreliable means of access [1]. Rural road development enhances residents' access to markets for both inputs and outputs through a reduction in transaction and trade costs (i.e. transport and logistics costs) [2]. Numerous studies have also pointed out that rural roads allow producers to reach additional productive opportunities. In addition, rural roads contribute to improving the living environment through opening access to social services such as health clinics and schools. In this manner, improved rural feeder roads contribute to poverty alleviation in remote areas.

Though international development partners and (national and/or local) governments conduct great many rural road development programs, there are difficulties in allocating a sufficient amount of budget to rural feeder roads with low-volume traffic (i.e. less than 200 annual average daily traffic (AADT) as a rough indication). That is because such roads are often regarded as not having a high priority in terms of investment efficiency. As a result, roads to marginal villages are kept unpaved and impassable especially in wet seasons.

b) Effective rural feeder road development

Labour-Based Technology (LBT) is expected to provide infrastructure of adequate quality in a cost-effective manner and to ease the shortage of improved rural road networks. LBT is characterized as an appropriate mix of labour and light equipment [3] and has been promoted by the International Labour Organization (ILO) and many other development partners.

As a sort of LBT, the "do-nou" method was invented by a Japanese NGO, Community Road Empowerment (CORE), and has been applied rural road improvement projects. Do-nou, which represents soil bag in Japanese, can make road maintenance so simple and effective with the full utilization of locally available material and labour [4] (see **Fig.1** and **Fig.2**). This method has also been used in projects by some international development partners such as Asian Development Bank (ADB) and Japan International Cooperation Agency (JICA).

c) Economic analysis of rural feeder road projects

Though LBT has been already applied to actual projects in various countries, the economic impact has not been clearly revealed (both in micro and macro levels). Because of this, some donors and governments are not willing to adopt LBT as it is sometimes regarded as a "primitive" approach [5].

Fig.1 Construction work of the do-nou method (Ghana)

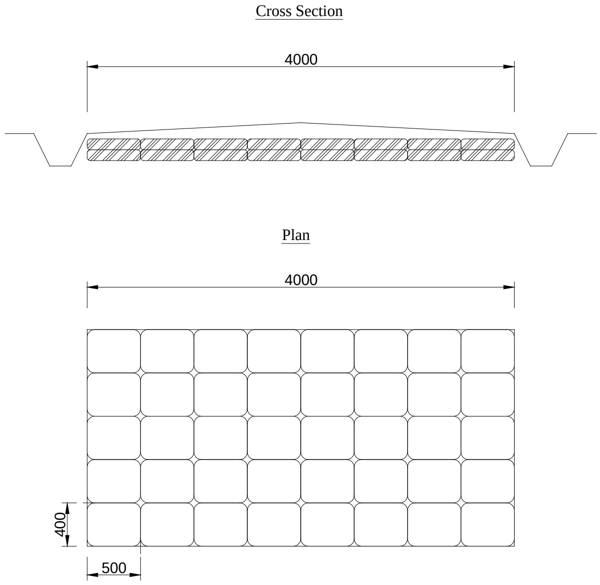


Fig.2 Example of road improvement using do-nou bags

In addition, there is not enough quantitative verification of the economic impact generated from rural road improvement using the do-nou method. Therefore, conditions have not been indicated yet in which the do-nou method might be the most efficient investment option among others in terms of the economic impact. Though engineering characteristics and advantages of the method have been examined in practical fields, it is also essential to reveal conditions that would maximize the financial advantage of the method in order for it to prevail as a common development option even in a constrained budget.

(2) Objective

The main objective of this study is to estimate the economic impact of the do-nou method for the improvement of rural feeder roads in developing countries. To this end, this study aims to examine conditions where the do-nou method can be applied effectively in comparison with other improvement methods. Through the analysis, this study derives implications for the incorporation of do-nou method in rural infrastructure development programs.

(3) Scope of the study

This study focuses on rural feeder roads with low-volume traffic in developing countries. The main concern of this study is the economic impact of paving a certain section of such roads, which can be quantified as users' savings of cost and time. This study limits the benefits in the aforementioned items as a starting point of discussion, though there are many other impacts expected from the improvement of rural roads such as employment generation. It is also noted that this study, as a preliminary examination, assumes experimental values of projects.

In the following chapter, the methodology applied to this study is described. Chapter 3 sets an assumption of the projects to be determined in Chapter 4. Chapter 5 summarizes the findings and concludes with a discussion of further issues to be examined.

2. METHODOLOGY

(1) Review of appraisal method for rural feeder road projects

Rural road projects in developing countries are appraised through a process of screening and ranking, which prioritizes investment areas/sections. There are several ranking methods available such as multi-criteria analysis (MCA), cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA).

Among them, CBA is the most frequent-used technique to estimate the impact of road investment in a quantifiable manner. The outcome of CBA permits for the ranking of investment alternatives based on the specific indicators represented by net present value (NPV), internal rate of return (IRR) and benefit-to-cost (B/C) ratio [6].

(2) Outline of RED model

For the execution of CBA on road investments in developing countries, the most commonly utilized software is the Highway Development and Management Model (HDM) that was developed by the World Bank. However, HDM mainly focuses on investments in higher volume roads, so there is a need to use a specifically designed tool for the appraisal of rural roads characterized by low traffic volumes. For this reason, the Road Economic Decision Model (RED) was developed as an appraisal tool of rural roads by the World Bank [7].

The RED model reduces the number of input values required in HDM model, and the simplified RED software can be handled with a series of Excel workbooks. The RED model consists of four main components as shown in **Fig.3**. The main evaluation module performs the economic evaluation of a subject road section and compares investment alternatives. The benefits are calculated from defined relationships between vehicle operation costs (VOC) and speeds to roughness. Road roughness is represented by the international roughness index (IRI) [8], which is measured by the cumulative displacement in the vertical direction of road surface per kilometer (m/km). And,

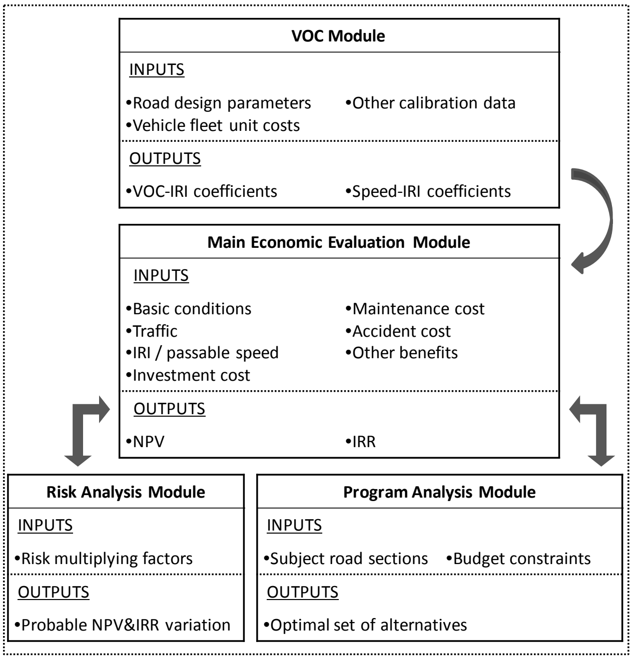


Fig.3 Structure of the RED model

traffic components including normal, generated, induced and diverted traffic can be incorporated into input values.

For more detailed analysis, the software contains VOC calibration modules, risk analysis modules and program analysis modules. The program analysis module is a tool to evaluate many road sections at once and obtain optimized program results under certain budget constraints.

(3) Methodology of this study

This study evaluates economic impacts such as the NPV and IRR expected from investments in a rural feeder road by using the main analysis module of the RED model. Project alternatives to improve an earth road include three pavement types: graveling, bituminous sealing and do-nou pavement in both forms of full and spot improvement. This study, which aims at experimental evaluation, assumes a virtual project setting and assigns investment costs and performance indicators based on existing data as input values to RED.

Using the evaluation result, risk analysis and program analysis are executed. The risk analysis tests the sensitivity of the do-nou method's impacts when some input parameters are varied. Finally, the program analysis examines change in the choice of alternatives in different budget constraints.

3. PROJECT CONDITION ANALYSIS

(1) Characteristics of Do-nou method

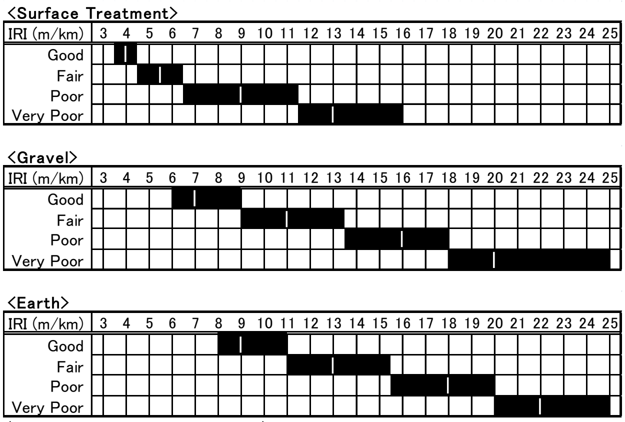
The do-nou method is a simple way of road improvement, and it needs do-nou bags, fill, covering soils, and labour power. The first step of the method is the replacement of surface with do-nou bags filled with locally available soil (with the exception of clay). The standard size of one do-nou bag is 40cm x 40cm x 10cm and it is filled with approximately 20kg of soils [9]. The arrangement of do-nou bags can be flexible depending to the point to improve.

The do-nou bags are compacted with hand rammers to increase their firmness. By compaction, polyethylene bags get tension and it inhibits moves of the soil particles. After that, the road surface is covered by soils like gravel, which protect do-nou bags from deterioration. According to the results of previous experiments, one do-nou itself has a high bearing capacity of 200-300kN. It was also found that a do-nou paved path is more resistant to rutting than when just covered by gravel [10].

Though the investment cost of the do-nou method fluctuates on a case by case basis, this study adopts 21.3 US dollars (31,596 Tanzanian shillings) per meter as a reference amount based on the actual cost used in a project in Tanzania [11]. Do-nou paved roads need periodic maintenance activities after every wet season, including cutting grass, re-gravelling of surface, replacing of worn out do-nou bags, and adding of do-nou bags to sunken parts of the road as necessary.

Table 1 Pre-condition cases and assigned IRI

Case No.	Min. IRI (Dry season)	Max. IRI (Wet season)	Annual Average
1	20	25	22.5
2	18	23	20.5
3	16	21	18.5
4	14	19	16.5
5	12	17	14.5



(White bars represents mode values.)

Fig.4 IRI levels by surface type

(2) Setting of project condition

This study assumes sections divided per 100m have five different standards of IRI at the initial condition as given in **Table 1**. Target AADT of each section ranges from 25 to 300 as a sum of eight vehicle types and ADT in wet season equals 60% of that in dry season. The evaluation period is 10 years with a 12% social discount rate and a conversion factor to the economic cost set as 0.85.

For improvement of the section, three construction methods are prepared: bituminous sealing, gravel surfacing and the do-nou method. In addition, a without-project case is prepared for comparison, which consists of grading works scheduled every sixty days to maintain the current condition of earth roads. The timing of maintenance is fixed, but the cost varies in accordance with traffic volume.

Construction and maintenance costs are compiled based on the existing data. The World Bank provides cost information relating to road construction in a database called the Road Cost Knowledge System (ROCKS), from which this study obtained the values on bituminous and gravel roads. On the other hand, the cost of do-nou pavement is given from the record of an actual project in Tanzania as mentioned above. Another input data is IRI and it is hypothetically set based on a model scale guided by the World Bank [12] as shown in **Fig.4**.

Based on the series of information, attribute values of three alternatives and without project case are assigned as summarized in **Table 2**.

Table 2 Attributes of project alternatives

	Without	Alter. 1	Alter. 2	Alter. 3
Name	**Grading**	**Bituminous**	**Gravel**	**Do-nou**
Surface	Earth	Paved	Gravel	Gravel
Min. IRI	12-20 (Table 1)	5.5 (Fair)	11.0 (Fair)	10.0 (Fair+)
Max. IRI	17-25 (Table 1)	9.0 (Poor)	16.0 (Poor)	14.5 (Poor+)
Construction*	0.00	57.27 – 69.61	15.94 – 19.38	17.35 – 21.30
Maintenance**	1.06-2.21	1.39-2.39	0.73-1.26	0.73-1.26

* Financial cost (thousand dollar/km), varying by initial IRI levels; ** Financial cost (thousand dollar/km/year), varying by AADT levels

4. EVALUATION BY RED MODEL

(1) Evaluation of alternatives

The main evaluation module of the RED model calculates the economic impact of each project alternative based on the conditions set in the previous chapter. The evaluation was conducted by cases of IRI level and AADT volumes, with a total of 60 sets of comparison.

The evaluation result of the "do-nou" alternative is shown in **Fig.5** by IRI cases. The alternative is judged as "feasible", i.e. net present value of 12% for the social discount rate is positive, when AADT is over 50 in case 1 and over 150 in case 5 for example. Comparing with results of other alternatives, the NPV slope is sharper than that of the gravelling alternative and less sharp than that of the bituminous alternative in every case.

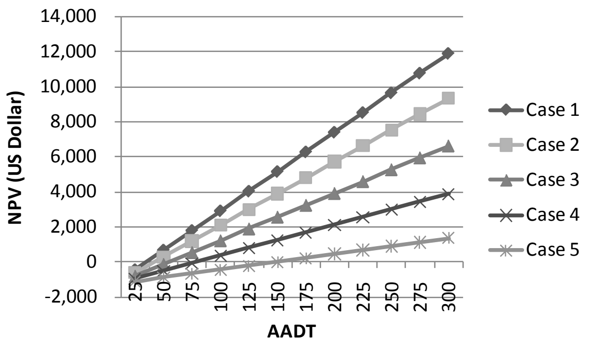


Fig.5 NPV of "do-nou" alternative by initial IRI levels

Table 3 Risk analysis multiplying factors

Variable (do-nou alternative)	Min. possible value	Model input value	Max. possible value
Dry season IRI	0.85	1.00	1.30
Wet season IRI	0.85	1.00	1.30
Investment costs	0.70	1.00	1.15
Maintenance costs	0.85	1.00	1.30

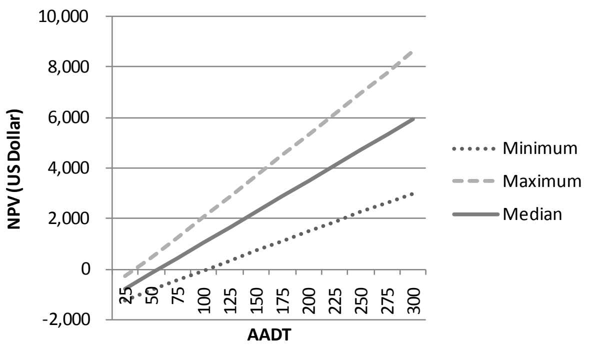


Fig.6 NPV variation of do-nou alternative in case 3

(2) Sensitivity analysis

Risk analysis module of RED requires possible multiplying factors of variables in the main module as its inputs. This study sets the risk factors for the do-nou alternative as shown in **Table 3** and tests the sensitivity of the project.

The output of the analysis is given as minimum and maximum values of NPV and IRR as well as frequency distribution for which probable values are returned from simulation. **Fig.6** is a result of risk analysis for case 3 calculating minimum and maximum range of NPV under the given scenarios.

(3) Program analysis

RED's program analysis module chooses a set of optimal alternatives which maximize the value of NPV and IRR of a road network under a certain budget constraint. The result of program analysis under no constraint of budget is summarized in **Fig.7**, which illustrates the selected alternatives by the levels of IRI and AADT. According to this, the do-nou alternative is chosen when AADT values range from 50 to 175. The lower traffic road is treated by grading (without project) alternative and the higher one is covered by bituminous treatment. The do-nou method is more likely to be chosen for higher IRI cases.

The module can be used for finding optimal alternatives under an insufficient budget to choose alternatives with the highest NPV. This study assumes 70% of the unconstrained budget amount that allows choosing for the highest NPV alternatives, and **Fig.8**

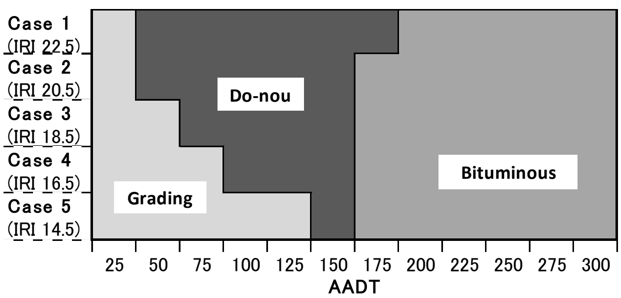


Fig.7 Relationship between initial condition and choice of alternative

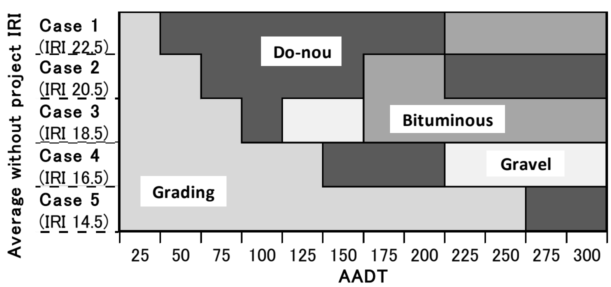


Fig.8 Relationship between initial condition and choice of alternative at 70% budget constraint

summarizes the analysis result. Under the constraint, the do-nou method substitutes for bituminous alternatives in higher traffic roads, whereas the do-nou alternative is replaced by grading in some lower traffic sections.

(4) Summary

The series of analysis using the RED model showed the extent to which the do-nou alternative turns out to be the best option in the hypothesized project condition. According to the result, the do-nou method can be chosen for roads with AADT ranging from 50 to 175, though this is dependent on the initial condition of roads. The do-nou method is more suitable for road with a higher IRI in its initial condition. When there is not enough budgets to invest, the do-nou alternative can be used in higher traffic road sections as a substitute for bituminous pavement.

5. CONCLUSION

(1) Effective Application of Do-nou Method

The previous chapter evaluated the economic impact of the do-nou method through the analysis based on the RED model. The evaluation results can imply effective ways to utilize do-nou.

Roads with low traffic volumes (less than 200 AADT) can be improved by the spot installation of do-nou to poorly-conditioned sections, as the do-nou method shows the positive NPV values in such sections. For example in a road with 75 AADT, it can be recommended that do-nou should be used only for sections over IRI 18.5 as annual average (e.g. sections prone to become wet mud) and remaining sections should be kept earth and graded periodically according to **Fig.7**. It can increase the total benefit of a road link in a reasonable condition.

In addition, do-nou can be utilized as a pavement option for roads with relatively high traffic volume, when project budget is limited.

(2) Implication for Practice

In terms of economic benefit, this study shows that the do-nou method is a viable option for the improvement of rural feeder roads with low traffic volumes. However, it should be noted that the evaluation was based on a hypothetical condition and estimated values would change by projects in practice. Continuous data collection through actual projects is quite important for more reliable evaluation; such data may include life cycle maintenance costs and surface conditions. In addition, country/area specific information is also needed by projects.

Though this study limited the scope into economic impact represented by VOC and travel time savings, other quantitative and non-quantitative benefits may be expected from the do-nou method. One of these impacts is the potential employment and income generation for rural residents. Thus, the impact of rural road improvement is worth analyzing also from a macroscopic viewpoint. For example, it is also worth estimating the impact to a district/country when it allocates a certain amount of budget to the installation of “do-nou” as a rural road improvement program.

REFERENCES

1) Lebo, J. and Schelling, D. : Design and appraisal of rural transport infrastructure: ensuring basic access for rural communities, *World Bank Technical Paper*, No. 496 p. 4, 2001.
2) Raballand, G., Macchi, P. and Petracco, C. : Rural road investment efficiency, *The World Bank*, p. 4, 2010.
3) Tajgman, D. and de Veen, J. : Employment-Intensive Infrastructure Programmes: Labour Policies and Practices, *International Labour Office*, p. 3, 1998.
4) Fukubayashi, Y. and Kimura, M. : Approach for empowering community through the participatory maintenance of rural roads using do-nou technology, *Journal of International Development Studies*. *JASID*., Vol. 18, No. 2, p. 166, 2009.
5) Hanaoka, S., Kawasaki, T. and Tokunaga, T. : Economic impact of the implementation of LBT in Tanzania and cost comparison between LBT and EBT, *Paper prepared for the 13th Regional ILO Seminar for Labour-Based Practitioners*, p. 1, 2009.
6) Lebo, J. and Schelling, D. : Design and appraisal of rural transport infrastructure: ensuring basic access for rural communities, *World Bank Technical Paper*, No. 496 pp. 24-28, 2001.
7) Lombard, P. and Coetzer, L. : The estimation of the impact of rural road investments on socio-economic development, *International Seminar on Sustainable Road Financing & Investment*, pp. 8-9, 2007.
8) Archondo-Callao, R. : Roads Economic Decision Model software user guide & case studies, *SSATP Working Paper*, No. 78 pp. 2-3, 2004.
9) Kimura, M. and Fukubayashi, Y. : Establishment of design for all-weather rural access road in East Africa using labour-based-technology for empowerment of agricultural community, *The Sixth ATWS KENYA CHAPTER International Conference*, pp. 3, 2005.
10) Fukubayashi, Y. and Kimura, M. : Approach for empowering community through the participatory maintenance of rural roads using do-nou technology, *Journal of International Development Studies*. *JASID*., Vol. 18, No. 2, pp. 157-158, 2009.
11) Sanupe Workshop Enterprise : Pilot project for road maintenance using labour based technology (‘do-nou’ technology), *Final report for Rungwe district*, p.5, 2010
12) Archondo-Callao, R. : RONET Road network evaluation tools user guide, *SSATP Working Paper*, No. 89-A p. 11, 2009.