**Committee: C20 Appropriate Development**
**Sub-Themes: Appropriate rural planning for rural road development and management**

# Impact of road maintenance on accessibility benefits to rural communities in Indonesia

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## Abstract

*The conventional approach that has been commonly used for rural road investment appraisal focuses mainly on road-users as the main beneficiaries of roads. Road user costs, travel time costs and road agency costs are the main transport cost components considered in conventional road appraisal. The benefits to road users are measured in terms of savings in road user costs, the magnitude of which depends largely on traffic volumes. This approach may not be appropriate for the appraisal of rural roads where traffic volumes are generally low. Other impacts (costs and benefits) of road investment projects on the rural communities should be identified and included in the planning and appraisal of rural roads. For rural people, the need for access to locations or facilities where they can carry out economic or social activities is much more important than benefits such as savings on road user cost which may not be passed down to them from transport operators. Therefore, accessibility benefit impacts need to be included in rural road appraisal, in addition to the road-user impacts.*

*Accessibility benefits are directly related to the condition of road infrastructure. Different levels of road maintenance will impact differently on the accessibility benefits that can be realised by the rural people. In order to model this variation in accessibility benefits with changes in road condition due to different levels of road maintenance strategies, a field survey was conducted on people's travel behaviour in three rural districts of Indonesia. A cross-sectional analysis was carried out using the data collected to develop accessibility benefit models. The study aimed to develop a new approach for rural road appraisal that incorporates consideration of both savings in road-user costs and accessibility benefits to the rural community. The new framework developed provides a logical methodology for incorporating accessibility benefits in the economic analysis of road investments, which can be used in Road Management Systems (RMS) such as the Highway Development and Management tools (HDM-4). Applications will include determination of optimum funding allocation and derivation of optimum maintenance standards and strategies for rural roads, which is based on a combined engineering-economic-social approach.*

*Keywords: Rural road appraisal; accessibility; maintenance; funding allocation*

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## Introduction

Most rural roads in Indonesia are in a very poor condition due to the lack of maintenance. This is because the budget allocated for road maintenance is constantly inadequate. The approach used for budget allocation is generally based on the result of economic appraisal methodology, which mainly focuses on traffic volumes and savings in road user costs. This approach, in use for a few decades, has generally been based on road users only [Dickey and Miller, 1985]. Measurement of benefits to road-users in terms of savings in Vehicle Operating Cost (VOC) and travel time cost are also commonly used in many road appraisals. Although the economic benefit approach is widely used, it does not consider accessibility benefits, which maybe most important for rural communities, where traffic volumes are generally very low. Consequently, focusing on traffic volumes only may not be appropriate for or relevant to, rural road appraisal. By continuing to apply the present appraisal system, rural roads will show less benefits and will therefore appear to merit a lower priority compared to roads with higher traffic volumes.

Dickey and Miller [1985] also pointed out that road appraisal should be relevant to the goals or impacts expected from the road. The main objective of rural roads is to provide good access for a community to carry out its activities rather than to obtain savings in vehicle operating costs and travel time. Accessibility benefits should therefore be incorporated in rural road appraisals. However, this has rarely been considered explicitly due to the difficulties in expressing the benefits in monetary terms [Robinson, 1999; Fouracre, 2001]. For this reason, the approach used in a Road Management System (RMS) for road appraisal is usually based on engineering and economic factors, such as road agency costs and road user costs. As the road appraisal is critical in determining the funding allocation for road maintenance, lack of a comprehensive assessment in the road appraisal process will adversely affect the funding allocation.

## Aim and objectives

The aim of this study is to improve the allocation of budget for rural road maintenance. To achieve this aim, four objectives are set:

1. To analyse and model the impact of road maintenance and road condition on accessibility-benefits to communities
2. To develop a comprehensive framework for rural road appraisal by embracing both economic and accessibility benefits,
3. To determine the optimum strategy for road maintenance, using the new appraisal framework developed,
4. To demonstrate through a case study the application of the new framework for rural road appraisal and budget allocation.

## What is accessibility benefit?

In this study, accessibility is defined as the ability of an individual to take part in a particular activity or set of activities [Burns, 1979]. Improving road conditions will reduce the travel time of road-users, thereby increasing the time available to individuals

to carry out their activities (Figure 1). For instance, when road conditions are very poor, people may be able to only reach a small market for their shopping. But when the road is improved, they will have more time available, which can be used for shopping in more distant markets within their same time budget. This accessibility benefit obtained by rural people gives them more socio-economic value such as having higher incomes, happiness, better education, and good health. The problem, however, is that accessibility benefit is rarely considered explicitly in rural road appraisals. This is due to the difficulty of quantifying it in monetary terms. Hence, many studies have used indirect measures [Parikesit, 2000; Lebo and Schelling, 2000; Lal, 1989] or an index [Hine, 2002; Taylor, 1999] to value the accessibility benefit. As the main requirement for rural people is to have good access to fulfil their needs, it is necessary to improve the conventional appraisal methodology of rural roads to incorporate accessibility benefit measures.

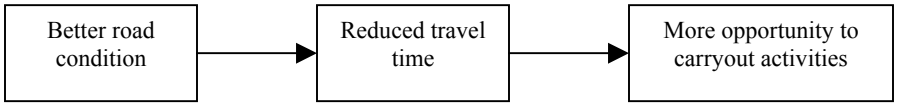


Figure 1. Effect of road condition to accessibility benefit

**Developing an approach for rural road appraisal**

The new road appraisal framework developed in this study includes accessibility benefits to communities, quantified in monetary terms. It incorporates accessibility benefits within the conventional framework for economic appraisal of rural roads. A comparison between the conventional and the new approach is shown in Table 1.

| Conventional approach | New approach |
|---|---|
| ▪ Based on economic-benefits in rural road appraisal<br>▪ Based on savings on total transport cost (savings in road user costs and road agency costs)<br>▪ Total benefits = ΔVOC + Δ TTC – ΔRAC …. (1) | ▪ Combining economic and accessibility-benefits in rural road appraisal<br>▪ Based on saving total transport cost (savings on road user cost and road agency cost, and accessibility benefit)<br>▪ Accessibility benefits to community (ΔDmv) = difference between accessibility benefits with road project alternative and with 'do-nothing' base case alternative)<br>▪ Total benefits = ΔVOC + ΔDmv – ΔRAC …..(2) |
| Where:<br>▪ Difference in Road Agency Cost (ΔRAC) = RAC with project alternative – RAC with 'do-nothing' or base case alternative<br>▪ Road User Cost benefits (ΔRUC) = [VOC without project alternative – VOC with project alternative] + [travel time without project alternative – travel time with project alternative]<br>▪ ΔVOC = savings in vehicle operating cost<br>▪ ΔTTC = savings in travel time cost<br>▪ ΔRAC = different in road agency cost<br><br>Note that TTC is omitted from equation (2) in order to avoid the effect of double counting | |

Table 1. Conventional and new approach comparison

## Field study

Field surveys were conducted on a number of rural roads selected from three kabupatens* namely Grobogan, Jepara, and Badung representing low, medium and high income of Kabupaten respectively. The aim was to observe travel behaviour of individuals on different road conditions e.g. very poor, poor, fair, and good, which was used as a basis for modelling the changes in accessibility benefits on the impact of road maintenance. Comparisons of the travel speeds on very poor road conditions against those on other road conditions were made to reflect the improvement of road condition due to road maintenance. By using questionnaires and direct interview methods, the respondents (sample size of 1750 households) were asked about their daily activities, including their general socio-economic characteristics such as income, education background, etc. Average travel speeds between origin and destinations by different modes on different roads were also observed. Nine transport modes were observed: passenger car, pick-up, motorcycle, bus, minibus, taxi motor horse drawn buggy, bicycle and walking.

## Accessibility benefit measures

Recent studies [Odoki et. al, 1998, 2001] developed a model for quantifying accessibility benefits and showed how the benefit of road accessibility (BM) to individual can be expressed in monetary terms. In expressing accessibility benefit in monetary terms, they quantified the change in monetary travel cost, which produces the same accessibility benefit, as does the change in travel speed. Thus, the change in monetary travel cost calculated represents the accessibility benefit in monetary terms (Δmv) of the change in travel speed. This is formulated as follows:

$$\Delta m_v = \alpha I \left\{ \frac{1}{v_1} + \left( \frac{\gamma}{2x} \log_e \left[ \frac{\tau - (2x/[v_1 + \Delta v])}{\tau - (2x/v_1)} \right] \right) - \frac{1}{(v_1 + \Delta v)} \right\} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

where :

$\Delta m_v$ = The change in monetary travel cost ti an individual that produces the same accessibility-benefit as does the change in speed (currency/km)
$\Delta v$ = Change in speed as a result of intervention (e.g. road maintenance) in km/hr
$\tau$ = Total time budget (hour)
$v_1$ = Initial speed (km/hr)
$\gamma$ = Time utility component
$\alpha$ = Value of travel time coefficient
I = Average income per hour
x = Distance (km)

The initial travel speed ($v_1$) reflects the speed on the road before the road improvement and the change of speed ($\Delta v$) reflects the effects on improvement of the road condition.

* Kabupaten is a rural district in Indonesia

**The new framework for rural road appraisal**

In this new approach, the total benefit calculated from the rural road projects does not only arise from savings to road users, but it also includes accessibility benefits to villagers or communities. The new framework that combines accessibility benefit and savings in road-user costs is illustrated in Figures 3, 4 and 5. As shown in Figure 3, impact of road maintenance and road condition on accessibility benefit to rural communities is taken into account in road appraisal, in addition to the traffic-based analysis used in conventional approach. Data on rural communities (e.g. number of population) is required in order to assess the change on accessibility benefit.

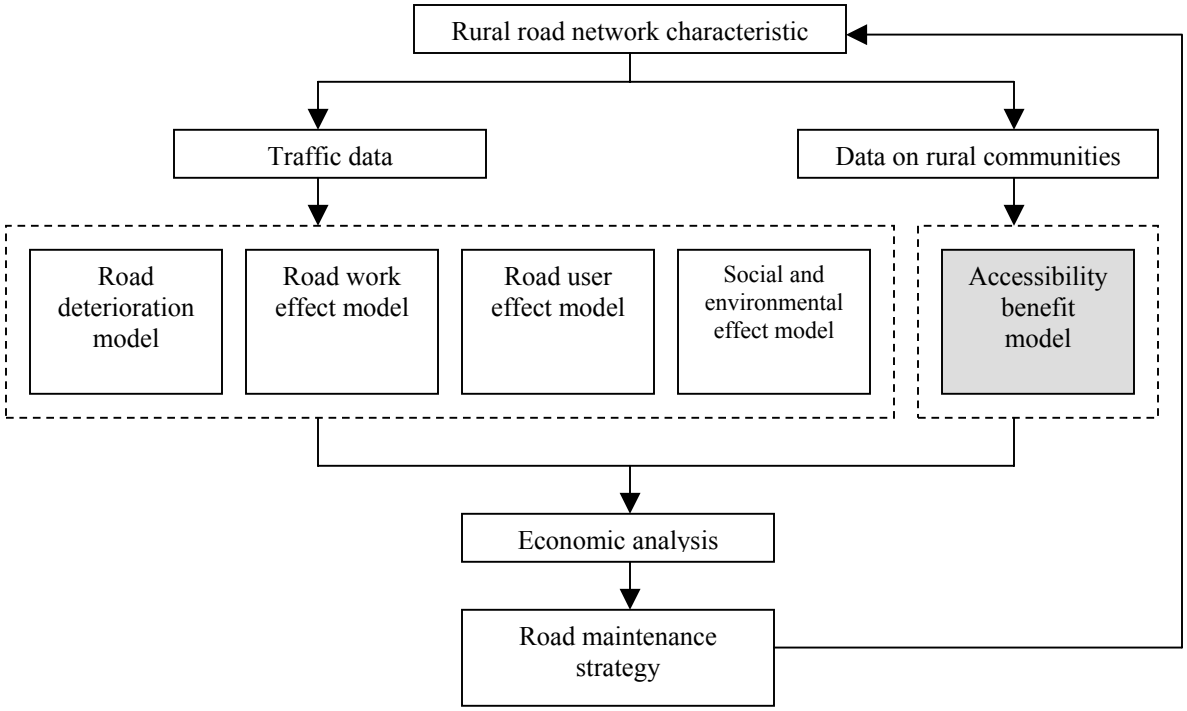


Figure 3. The new framework for rural road appraisal

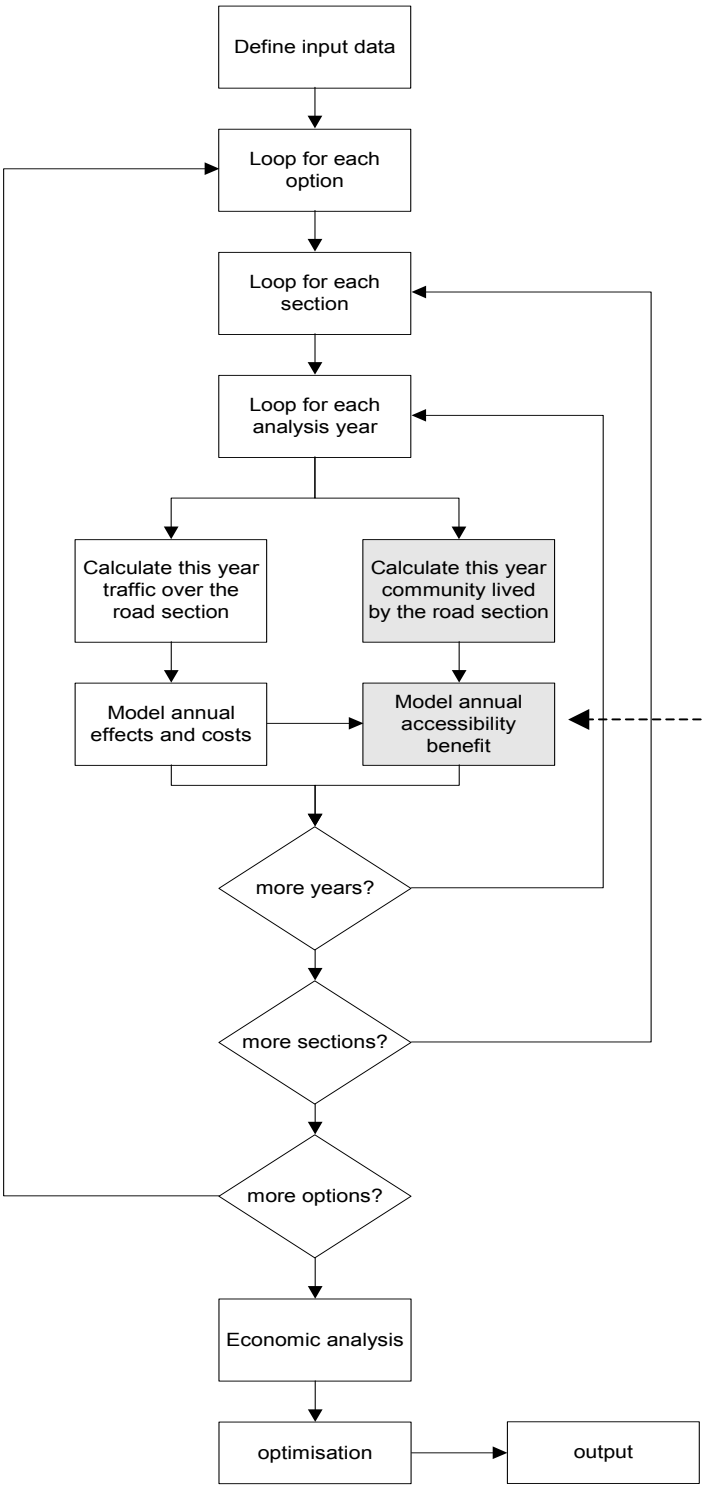


Figure 5

Figure 4. Flowchart of analysis sequence logic for the new framework of rural road appraisal

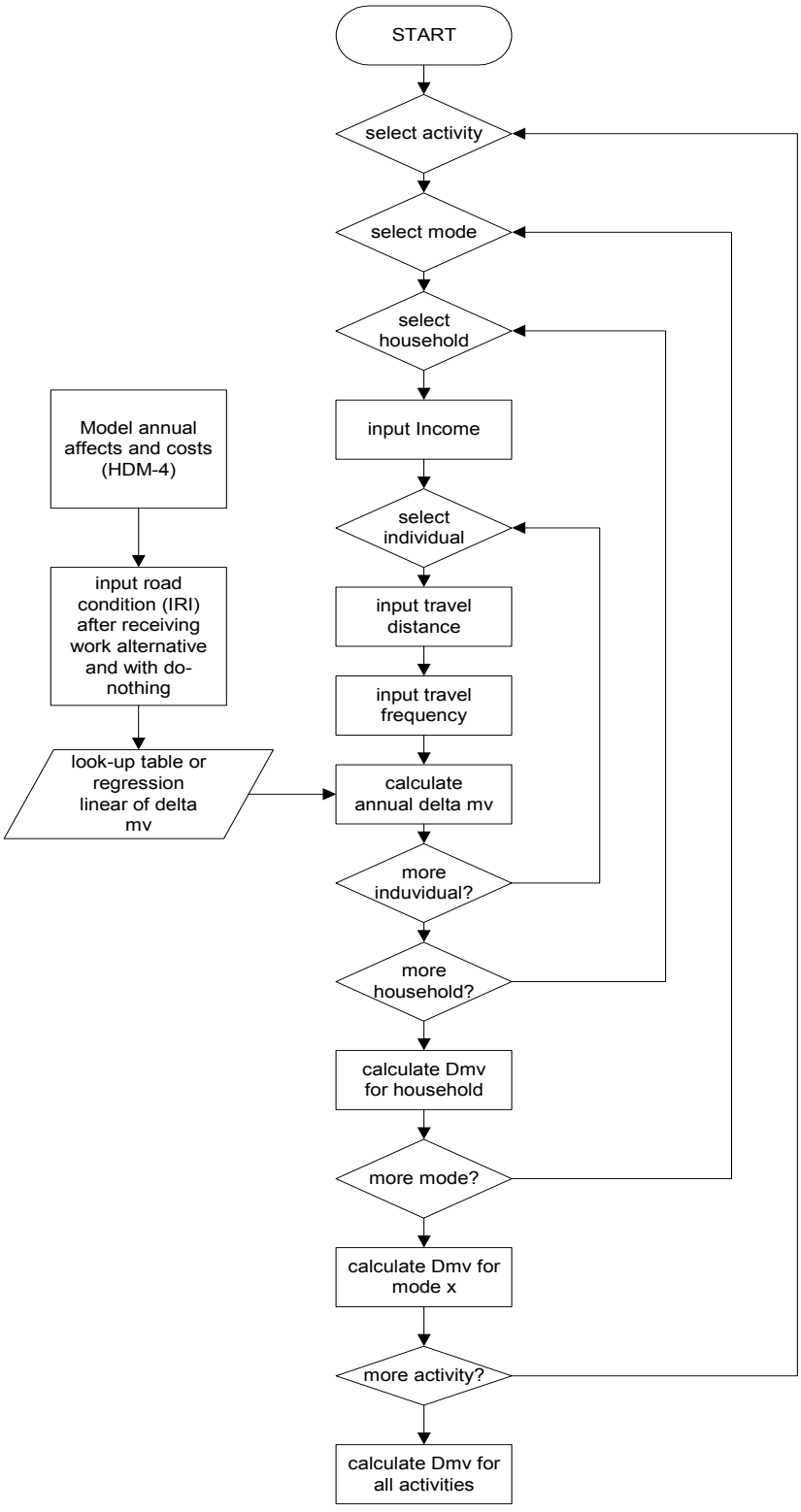


Figure 5. Flow chart of accessibility benefit calculation

## Optimum road maintenance strategies

One of the primary aims of road appraisal is to provide a sound basis for determining budget requirements for entire road networks. The strategy of optimal funding allocation should ensure that only projects with the highest benefits are selected (Figure 6). By using the new appraisal framework, the optimisation used for budget allocation will not only be based on an engineering-economic approach, but on a combined engineering-economic-social approach. In a constrained budget situation, the best road strategy and budget allocation should be based on the principle of maximisation of total benefits.

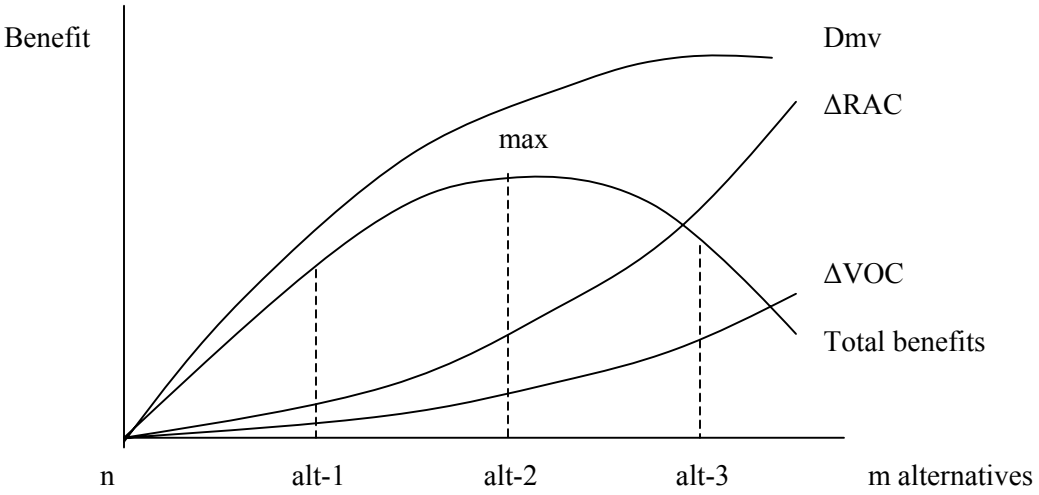


Figure 6. Optimum road maintenance strategy for maximising total benefits

Where:
ΔRAC = increase in road agency cost
Max Total benefits = Max [ΔVOC + Dmv – ΔRAC] ……. (4)

From figure 6, it is shown that road project alternative-2 (alt-2) produce the highest benefit compared with other alternatives. Therefore, in order to obtain the optimum funding allocation, the best strategy will select alternative 2.

## Modelling the changes in accessibility benefit due to road maintenance

In modelling the changes in accessibility benefit due to changes in road condition following road maintenance, it was necessary to compare the travel time spent by individuals using a particular mode on various road conditions (i.e. very poor, poor, fair and good). It is assumed that roads in very poor, poor and fair conditions will be improved to good condition after the road maintenance has been carried out. From the field survey, it has been shown that accessibility benefits to individuals (Δmv) for all activities will increase as the road conditions improve as shown in Figure 5. Using the case study of Kabupaten roads in Indonesia, the study derived 225 models from three Kabupatens, nine activities and several modes of transport.

The model of impact of road maintenance on accessibility benefit on individuals can be used as the basis for calculating the annual accessibility benefit. The value of annual accessibility benefits to an individual is summarised in the look-up table labelled as Table 2. Alternatively, these values can be computed by a linear regression given by equation (7). The linear regression model has been derived as a function of roughness. Since most analyses in many RMS, e.g. HDM-4, uses International Roughness Index (IRI) as a measure of road condition, it is appropriate to this study to express the road condition in terms of IRI. As economic analysis uses the annual cost and benefit streams, the accessibility benefits for the whole community need to be summed on an annual basis.

The total annual value of accessibility benefit for all the communities in a village can be formulated as follows:

$$\text{Total annual accessibility benefit for a community } (Dmv)_{(m-n)} = \Sigma\ \text{individual}_{ij} \times \text{average travel distance}_{ij} \times \text{average annual frequency}_{ij} \times \Delta mv_{ij\ (m-n)} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

Where:

$Individual_{ij}$ = individual who carryout i activity by using j transport mode

$Average\ travel\ distance_{ij}$ = average distance travelled (km) by an individual from home to i location by using j transport mode

$Average\ annual\ frequency_{ij}$ = average trip frequency per year of an individual for i activity by using j transport mode

i = type of activity, such as farm, office, market, school, shopping, hospital, recreation, social, others.

j = type of transport mode

m = road work alternatives

n = 'do-nothing' or base case alternative

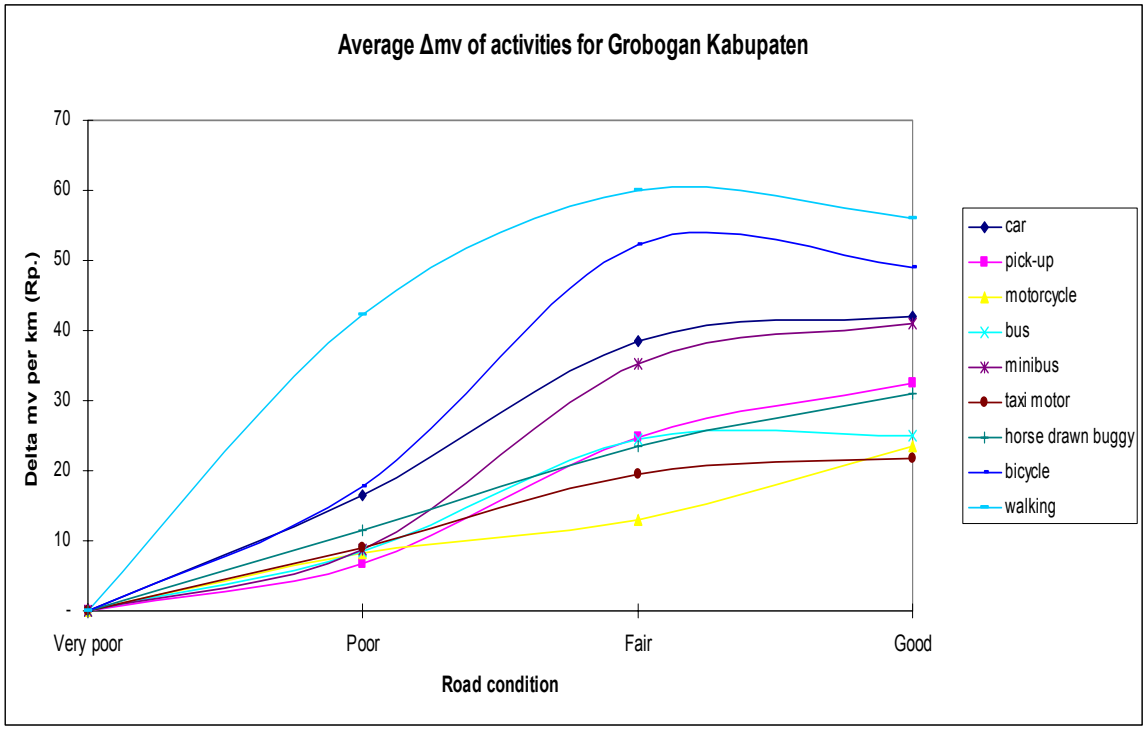


Figure 7. Average accessibility benefit in different road condition over all activities

*Rupiah (Rp.) is a money currency used in Indonesia (1 US$=Rp.9000)

| Before treatment | After treatment | | | |
|---|---|---|---|---|
| | Very poor (IRI=20) | Poor (IRI=13) | Fair (IRI=9) | Good (IRI=6) |
| Very poor (IRI =20) | 0 | 157.66 | 159.17 | 185.03 |
| Poor (IRI=13) | -157.66 | 0 | 1.51 | 27.37 |
| Fair (IRI=9) | -159.17 | -1.51 | 0 | 25.86 |
| Good (IRI=6) | -185.03 | -27.37 | -25.86 | 0 |

Table 2. Look-up table of accessibility benefit (Rp./km) for farm activity by walking

The amount of accessibility benefit trigged from the changes in road condition can be computed by the linear regression model, which is shown as follows:

$$\Delta mv_{(m-n)} = f(IRI)_{(m-n)} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

For instance, the model of changes in accessibility benefit for individuals to go to the farm by using a car is:

$$\Delta mv_{(m-n)} = [170.22 + 0.44\,(IRI)^2 - 0.04\,(IRI)^3]_{(m-n)} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$R^2 = 0.983$$

**Social-economic impact due to improvement in road condition**

The models of changes in accessibility developed in this study show that accessibility benefits have strong correlation with social impact. For instance, in Grobogan Kabupaten, improvements related to social welfare such as people's income, number of people who were able to access health facilities, betterment in academic standards were in line with associated improvement in road condition. The development in these social impacts appears similar with the improvement in the changes in accessibility benefit developed by this study, in terms of the magnitudes (Figure 8 and 9).

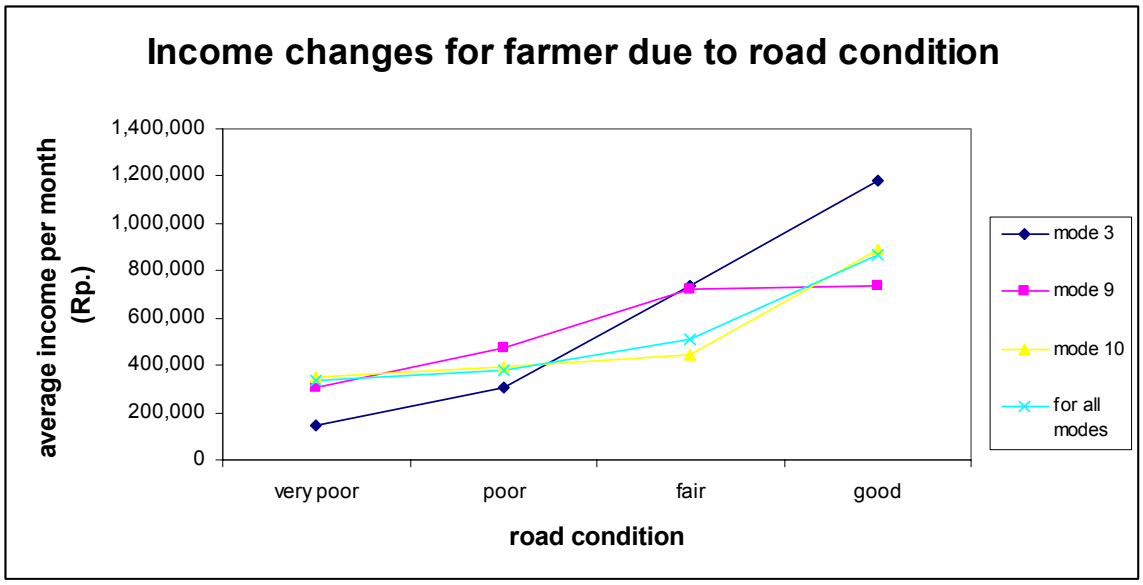


Figure 8. Income changes due to road improvement

A comparison between the improvement in income and the change in accessibility benefit for working activity of the farmer by using a car, shows a good correlation (R), for instance for mode-3 motorcycle R = 0.936, for mode-9 bicycle R = 0.963, and for mode-10 walking R = 0.762.

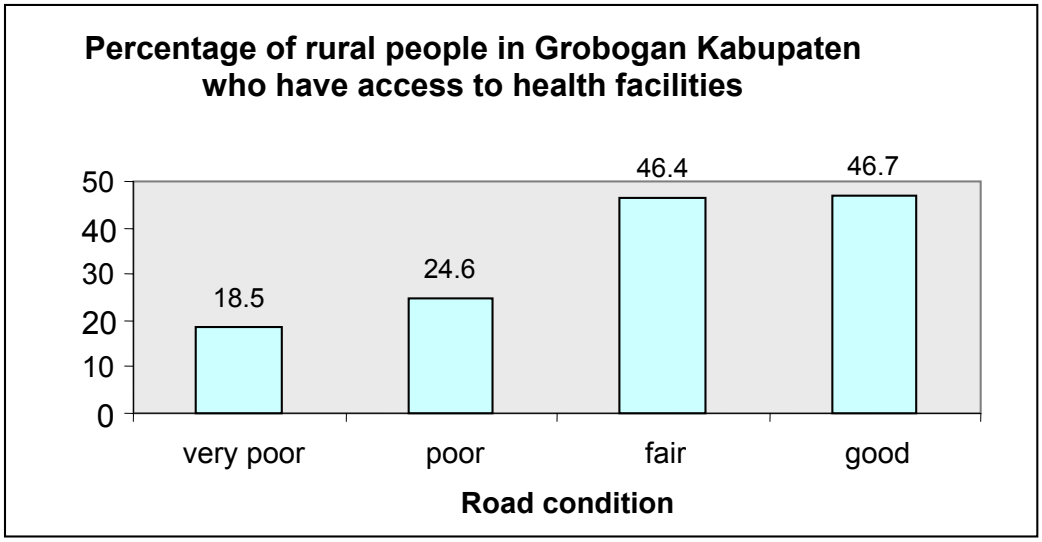


Figure 9. Effect of road condition on access to health facilities

Improving the road condition also affects the access of the communities to health facilities. It shows that fewer people who live near the roads in very poor condition have access to health facilities such as hospital, compared to those households who live near roads in better conditions. In addition to this, people who have access to only very poor

roads also have difficulties to obtain sufficient education. The impact of lack of access to schools due to very poor roads can be demonstrated by the lower educational standards of those communities living near very poor roads.

**Application of the new appraisal framework for budget allocation**

To demonstrate the application of the new framework developed for rural road appraisal, a case study using Grobogan Kabupaten road network in Indonesia was considered. A comparison of the results of road project appraisal and prioritisation obtained using the conventional approach and the new approach is given in Table 3 and 4. All the inputs, including traffic volume and the number of village communities are considered in assessing the costs and benefits from investments in the road network. The result of rural road appraisal obtained using the new approach shows a different project priority ranking compared to that obtained from the conventional method. Changes in the road project priorities will affect budget allocation to different classes of needs.

| Link no. | Link | AADT | Village's population | Conventional approach | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | NPV/Cost | | | | Alt. selected | Rank |
| | | | | Base | Alt-1 | Alt-2 | Alt-3 | | |
| 53 | Kandangan | 1379 | 8890 | 0 | 0.597 | -0.472 | -0.472 | 1 | 1 |
| 16 | Godong | 573 | 5573 | 0 | -0.081 | 0.587 | 0.35 | 2 | 2 |
| 33 | Jatilor | 21 | 2864 | 0 | 0 | -0.295 | -0.295 | Base | 4 |
| 25 | Sedadi | 65 | 6430 | 0 | 0 | 0.2052 | -0.052 | 2 | 3 |

Table 3. Result from conventional approach

| Link no. | Link | AADT | Village's population | New approach | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | NPV/Cost | | | | Alt. selected | Rank |
| | | | | Base | Alt-1 | Alt-2 | Alt-3 | | |
| 53 | Kandangan | 1379 | 8890 | -172.6 | -1.2 | -91.3 | -91.3 | Base | 4 |
| 16 | Godong | 573 | 5573 | -30.4 | 0.97 | 25.2 | 16.9 | 2 | 2 |
| 33 | Jatilor | 21 | 2864 | -15.9 | -15.9 | 24.7 | 14.2 | 2 | 3 |
| 25 | Sedadi | 65 | 6430 | 0 | 0 | 26.5 | 15.6 | 2 | 1 |

Table 4. Result from the new approach

**Conclusions**

This study has shown that accessibility benefit to rural communities is influenced by the changes in road condition. Therefore, improving road condition through appropriate maintenance interventions will affect the accessibility benefit to the rural people concerned, and this may enhance socio-economic development for rural communities by maintaining the road network will generate social benefits for them. Applying the new framework for rural road appraisal that incorporates accessibility benefits gives increased amounts of budgets allocated for rural roads. Having an adequate maintenance budget allocated to rural roads will ensure that road network condition is kept at an acceptable

level to provide better access to services and facilities for the people. Therefore, incorporating accessibility benefits in rural road appraisals is useful to meet the objectives of improving the living standards of people in rural communities.

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