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**Cost Comparison between Labour-Based and
Equipment-Based Methods for Roadworks:
A Case Study from Ghana**

**Prepared for
The Department for International Development**



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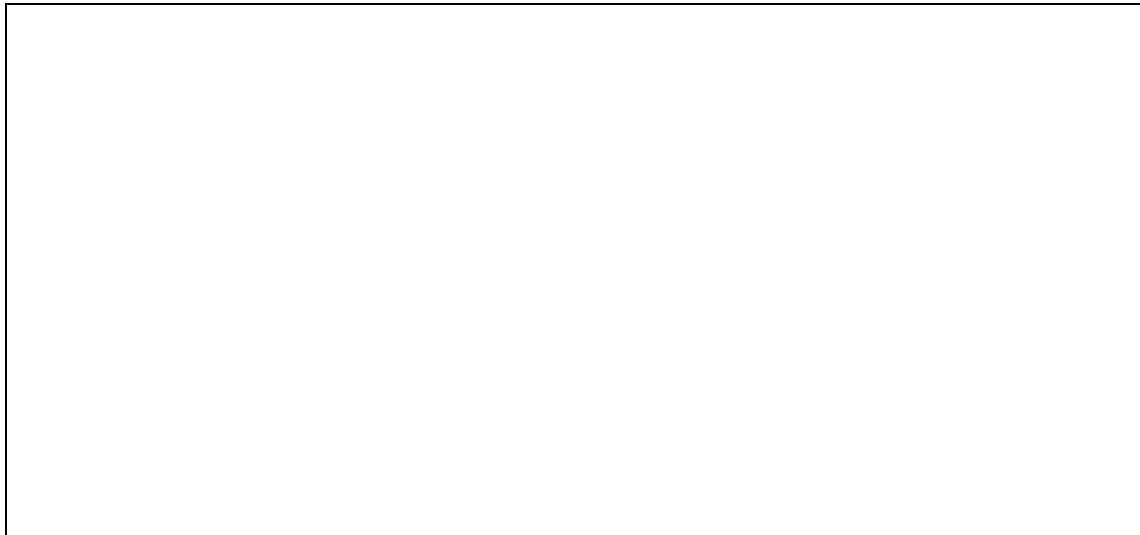
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Gary Taylor
27 July 1998



Equipment-based Feeder Road Rehabilitation, Ghana



Labour-based Feeder Road Rehabilitation, Ghana

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List of Abbreviations

DFID	Department for International Development
DFR	Department of Feeder Roads
EBM	equipment-based methods
LB	labour-based
LBM	labour-based methods
P&G	Preliminary and General
TRL	Transport Research Laboratory

Map of Ghana (showing regional boundaries)

Chapter 1 Introduction

In April 1995 I.T. Transport was awarded a contract under the UK Department for International Development's (DFID's) Engineering Division's Technology Development and Research Scheme. The full title of the project is "Rural Transport Research Programme - Sub-Saharan Africa (R6239)". The overall objective of the project is to increase understanding of key transport problems contributing to, and perpetuating, rural poverty in Sub-Saharan Africa. This, in turn, has the aim of assisting policy makers and development planners to focus on the solution of important problems and issues.

I.T. Transport was the prime contractor for the project with the Transport Research Laboratory (TRL) and Silsoe College of Cranfield University sub-contracted to undertake two of the four components. I.T. Transport has direct study responsibility for the other two components, namely:

- a) Production of guidelines on the design and implementation of off-road infrastructure projects; and
- b) Development of a methodology for rapid comparative assessment of the cost-effectiveness of equipment-based and labour-based road works.

This report concerns a case study related to item (b) above. The aim of the case study is to establish a cost comparison between the use of labour-based and equipment-based methods for the rehabilitation of rural roads. This, together with other available literature, will then be used to propose a methodology for similar comparative assessments, to assist in identifying in what situation it may be cost effective to use labour-based methods for road works.

The original intention of the study had been to collect rural road cost data from a number of countries in Sub-Saharan Africa. However, due to budget constraints, it was decided that this part of the study should be limited to Ghana.

Ghana was chosen because of its large programme of feeder road development under the Department of Feeder Roads (DFR) and the use, side by side, of both labour-based and equipment-based technologies. Moreover, private contractors carried out both equipment and labour-based projects. It was assumed that this would mean that the costs of individual contracts would be relatively easy to isolate.

Chapter 2 Background to Cost Comparison

In the economic and social situation existing in Sub-Saharan Africa, labour-based methods of road works are quite often financially cheaper than equipment-based methods. However, for a variety of reasons, equipment-based methods have become entrenched as the conventional way of executing road construction work in the region.

Labour-based technologies usually provide other benefits over equipment-based methods including savings in foreign exchange and the creation of employment opportunities. This has generated considerable interest amongst governments and donor agencies in expanding their use. However, a starting point for the consideration of labour-based methods is their “financial cost¹” compared to conventional, equipment-based methods.

Unfortunately, reliable cost comparisons between labour-based and equipment-based methods are often difficult to achieve. This is particularly due to the paucity of accurate information on costs and the lack of truly comparable data.

Early studies on the costs of labour-based methods of construction were carried out in the 1970s and 1980s. These relied on extrapolating from a limited amount of pilot project data on the costs of labour-based methods: and also on hypothesising the costs of carrying out the same works by equipment-based methods.

Since that time a great deal more data on the costs of labour-based methods has become available. However, this has not been collected and compared with equipment-based methods in any systematic way. Comparisons, such as they are, continue to rely heavily on the evidence and methods from the early studies. Because of this many government policy makers and development agencies have identified the need for more detailed studies of comparative costs.

The first step in such a comparative analysis is to decide on the methodology to be used. This determines the type of data that must be collected.

Methodology for the Cost Comparison Case Study

Three different methods for comparing the cost of road works by labour-based and equipment-based methods were considered for this case study. These are described, with their strengths and weaknesses, below.

Firstly, **individual tasks** can be analysed. The main strength of this type of comparison is that it is reasonably easy to obtain accurate measurements. From this data, resource inputs for a given unit of output can be established. The major disadvantage is that the method does not provide a reliable guide to the comparison of overall project costs. This is because isolating

¹ Financial cost in this context means the full direct costs of construction including the ownership or hire costs of any equipment used.

activities loses the myriad linkages and effects of the organisation and management of construction works. For example, equipment availability and utilisation rates can have a significant effect on overall costs, but are usually inadequately measured from an examination of individual tasks. Therefore, although these studies provide a useful insight into the structure of comparative costs, they were rejected for the purposes of the present case study.

Secondly, the costs of carrying out a project by labour-based methods can be compared with the **hypothetical cost** of carrying out the same works by equipment-based methods, or vice versa. The main use of this type of analysis is in the ex-post evaluation of individual projects. Its main drawback is that the accuracy of the hypothetical costs will always be open to question. This makes the use of this type of analysis deficient for the establishment of generalised conclusions on cost comparisons. For this reason this method was also rejected for the case study.

Thirdly, the costs of a number of **similar projects** carried out by labour-based and equipment-based methods can be compared. The major problem with this type of analysis is that of identifying sufficient appropriate data. There are many labour-based road programmes and even more equipment-based road programmes. However, there are few programmes where a large number of essentially similar works are carried out by both labour-based and equipment-based methods and where the costs can be easily isolated. The example of the Ghana feeder road programme provides one of the few exceptions. For this reason this approach was chosen for the analysis in this case study using the example of Ghana.

On close examination even the Ghana programme had certain differences between labour-based and equipment-based contracts. Primarily, it was found that road rehabilitation contracts with either high earthworks or long haul distances for gravel surfacing material tended to be reserved for equipment-based contracts. This bias had to be addressed to provide a proper basis for a cost comparison between the two methods. The details are discussed further in the “Results” section below. Firstly, some background details of the Ghana programme are given.

The Ghana Feeder Roads Programme and Development of Labour-based Methods

DFR, a department of the Ministry of Roads and Highways, is the agency responsible for the planning, design, construction and maintenance of feeder roads² in Ghana. A large part of the feeder road network is composed of un-engineered, earth roads. The Government of Ghana has embarked on an ambitious programme of feeder road rehabilitation and maintenance. The main aims of the current programme, the National Feeder Roads Rehabilitation and Maintenance Project (NFRRMP), are to: -

- bring 12,000 km of the existing feeder road network to a maintainable condition;
- institute a regular programme of road maintenance on this network.

Part of the DFR’s strategy for improvement of the feeder road network has been to develop a local, labour-based contracting capacity. The purpose of this is twofold. Firstly, it is believed that labour-based methods are particularly appropriate and effective for a significant portion of the rehabilitation and maintenance work required on the feeder roads, both now and in the future. This is primarily because the work is small-scale, fragmented and requires limited use of sophisticated materials or equipment. It is also because unemployment and under-

² Feeder roads in Ghana are rural roads that connect villages and rural communities to the trunk road network. The total feeder road network of about 23,000 km compares with a total of about 14,400 km of trunk and urban arterial roads in the country.

employment is widespread in rural areas and a priority of government is to create more jobs. Secondly, the secondary benefits of local employment creation and multiplier effects resulting from the use of labour-based methods support overall government objectives. The main multiplier effects result from the spending power of labour employed on the road. Their wages tend to be spent locally generating further employment in, for example, local retail and service businesses.

It is the intention that labour-based contractors³ should complement the existing equipment-based contracting capacity. Eventually the choice of technology for each project may be decided in open competition. For now, the strategy has been to reserve a certain portion of the rehabilitation and maintenance work for labour-based contractors only. The main reason for this is the need to guarantee a continuous workload for newly trained labour-based contractors so that they can repay the equipment loans that were organised through the project.

The training of labour-based contractors commenced in 1987. By 1997 a total of 93 labour-based contractors had been trained, of which 54 had been equipped. A total of about 2,000 km of feeder roads have been rehabilitated by labour-based methods since 1987 using contractors.

At the same time as the development of labour-based contractors has taken place, a significant proportion of the feeder road rehabilitation work has continued to be carried out by equipment-based contractors. These contracts have been awarded based on competitive tenders using both international and local bidding procedures.

By contrast, labour-based contracts have been awarded on the basis of fixed rates. These rates are negotiated periodically between the DFR and representatives of the contractors. Contracts are allocated to contractors by DFR such that contractors carry out one contract at a time. The aim of the system, as mentioned above, is to provide continuity of work to enable the labour-based contractors to become established and, importantly, continue to repay their bank loans. For various reasons, perfect continuity of work is not always achieved.

There is no restriction on competition for those contracts undertaken by the equipment-based contractors. However, the size of contract packages and other contract conditions effectively exclude the existing, newly-emerging, labour-based contractors.

The required final road standards for both labour-based and equipment-based contracts are essentially similar. Generally they comprise a 6-metre wide gravel road with full drainage works to provide all weather access in rural areas. However, certain construction details differ. For example, labour-based contracts usually have a trapezoidal side ditch whereas equipment-based contracts usually have a vee-shaped side ditch. These variations are to suit the convenience of the method used and do not prejudice the engineering standard of the road.

³ The term labour-based contractors is used here to denote those contractors that primarily use labour for carrying out construction work but supported by light equipment for operations such as haulage or compaction which would be economic using labour only.

Chapter 3 Collection of Data

The data was collected from DFR records and extracted mainly by DFR staff. An initial screening of available project data was carried out. The aim of this was to obtain data relating to projects that were:

- complete with final costs (including any variations)
- carried out at a similar time

Although there was a considerable amount of cost data, this was significantly reduced after initial screening. Finally, 19 equipment-based projects totalling 227 km and 18 labour-based projects totalling 157 km were included in the analysis. The lists of the roads and their lengths are given in Tables 1a and 1b. The reference numbers in these tables are those used for this study. Details of each contract are given in data sheets in Annex 1.

Table 1a: Equipment-based Roads

Ref. No.	Road Name	Length km
E1	Tokpo-Adjakope	13.10
E2	Kasseh-Luhor	6.15
E3	Kitampo-Suamere	17.60
E4	Kwame-Danso-Bator	20.60
E5	Paga-Manyoro & Others	14.50
E6	Kayilo-Paga & Others	12.00
E7	Paga-Manyoro & Others	15.00
E8	Adaklu-Waya & Others	2.80
E9	Dordoekorpe-Kajanya	13.90
E10	Ntonkrom-Kunsu Ph1	12.00
E11	Bodom-Kokompe	6.10
E12	Essamen Jn – Abrem Agona	11.60
E13	Zabzugu-Nakpali Ph1	8.04
E14	Pusiga-Nware	5.70
E15	Bouku-Ahwene-Brohari	21.00
E16	Asemasa-Tawomanye etc.	8.63
E17	Juapong-Volo Ph II	22.46
E18	Aworowa-Chimela	9.40
E19	Gyankobo-Afiaso Ph II	6.20
Total Length		226.78
Average length		11.94

Table 1b: Labour-based Roads

Ref no.	Contract No.	Road Name	Length km
L1	NRO8	Nyemaliga-Changbuni	5.00
L2	UE06	Yorogo-Dua	5.00
L3	UW04	Lambussie-Bagwan	5.50
L4	UW05	Wa-Jonga	7.50
L5	UW06	Katua-Holumuni	5.00
L6	AS01	Fiakoma-Mile 9	17.90
L7	AS02	Kyebi-Abofour	25.00
L8	AS07	Agona-Dombabra	5.50
L9	AS08	Bosomyekye-Ouagadougou	5.00
L10	BA03	Tatekwa Jn-Tetekwa	14.40
L11	BA08	Mensin-Bremi	4.40
L12	NR05	Tamale-Kupula-Pakyina	5.00
L13	BA01	Ayomso-Gyasikrom	16.00
L14	BA02	Nyamebekyere-Nsonyameye	14.85
L15	BA07	Yamfo-Asen	5.80
L16	NR07	Janagbe-Wovogu	5.00
L17	NR06	Wulugu-Kpassenkpe	5.00
L18	UE04	Bawku-Bansi	5.00
Total Length			156.85
Average length			8.71

From tables 1a and 1b it can be seen that the average length of the labour-based roads (8.7km) is shorter than that of the equipment-based roads (11.9km). The main reason for this is that the labour-based contracts include a number of trial contracts for new contractors. These are typically restricted to about 5 km long each. If these trial contracts were excluded the average lengths would be similar.

Chapter 4 Results of Data Analysis

Costs per kilometre

The costs for each contract used in the analysis are shown in Tables 2a and 2b. All costs are shown in US dollars. Dollars have been used as the unit because dollar costs have remained substantially stable over the period of these contracts, whereas the Ghanaian cedi has depreciated by about 20% in value. Price fluctuation clauses were included in all contracts.

Some of the preliminary and general (P&G) items included in the equipment-based contracts were often found to be significantly different in nature and scope from those in the labour-based contracts. For this reason, those P&G items not included in labour-based contracts were eliminated from the cost of equipment-based contracts. Details are given in the data sheets in Annex 1. The resulting costs for equipment-based contracts are summarised in Table 2a.

Table 2a: Equipment-Based Contract Costs
(contracts based on competitive bidding)

Ref no.	Road Name	Length Km	Total cost less nonLB P&G cedis/km	Average ex.rate cedis-> \$	Total cost less nonLB P&G US \$/km
E1	Tokpo-Adjakope	13.10	11,036,081	879	12,555
E2	Kasseh-Luhor	6.15	15,852,846	849	18,672
E3	Kitampo-Suamere	17.60	17,167,819	879	19,531
E4	Kwame-Danso-Bator	20.60	10,065,347	888	11,335
E5	Paga-Manyoro & Others	14.50	16,523,456	872	18,949
E6	Kayilo-Paga & Others	12.00	19,192,396	896	21,420
E7	Paga-Manyoro & Others	15.00	15,138,352	1,097	13,800
E8	Adaklu-Waya & Others	2.80	13,357,143	955	13,987
E9	Dor-Doekompe-Kajanya	13.90	12,031,739	879	13,688
E10	Ntankrom-Kunsu Ph1	12.00	25,436,459	1,035	24,576
E11	Bodom-Kokompe	6.10	14,135,194	525	26,924
E12	Essamen Jn – Abrem Agona	11.60	13,919,570	959	14,515
E13	Zabzugu-Nahpali Ph1	8.04	25,232,768	974	25,906
E14	Pusiga-Naware	5.70	21,640,779	969	22,333
E15	Bouku-Ahwene-Brohari	21.00	17,819,311	1,189	14,987
E16	Asemasa-Tawomanye etc.	8.63	47,219,003	976	48,380
E17	Juapong-Volo Ph II	22.46	20,256,233	1,000	20,256
E18	Aworowa-Chimela	9.40	16,779,255	1,058	15,959
E19	Gyankobo-Afiaso Ph II	6.20	45,442,064	1,108	41,013
	Totals	226.78		-	-
	Averages (weighted)*	11.94	-	-	19,311

*average cost weighted by road length i.e. average cost = 3(cost x length)/3length

A complication with the labour-based contracts was that rehabilitation works on certain roads were carried out in two stages. Because trained contractors did not immediately take receipt of their equipment, some were given “advanced culverting contracts”. These were contracts to carry out drainage works on roads in advance of full rehabilitation. Once they had taken receipt of their equipment, the contractors were given a rehabilitation contract on the same road. The total cost of rehabilitation was, therefore, the addition of the cost of the two contracts.

However, the contracted lengths for advance culverting and rehabilitation did not always exactly coincide. Also the delay between the two contracts led to some extra work being required. For these reasons and due to higher overheads, the total cost of the two separate contracts will tend to be slightly higher than if a single contract had been awarded for the same works. The result is that the cost per kilometre of about two-thirds of the labour-based contracts may be slightly overstated.

Table 2b summarises the costs per kilometre for the labour-based projects. Contracts where advance culverting costs have been included are marked with an asterisk. Further details are given in Annex 1.

Table 2b: Labour-Based Contract Costs
(contracts based on fixed rates)

Ref no.	Contract no.	Road Name	Rehab. Length km	Final costs/km		
				adv.works US \$/km	Rehab. US \$/km	Total US \$/km
L1	NRO8	Nyemaliga-Changbuni*	5.00	7,148	5,882	13,030
L2	UE06	Yorogo-Dua*	5.00	4,119	7,923	12,042
L3	UW04	Lambussie-Bagwan*	5.50	4,693	9,710	14,403
L4	UW05	Wa-Jonga*	7.50	3,793	7,824	11,617
L5	UW06	Katua-Holumuni*	5.00	5,067	6,656	11,723
L6	AS01	Fiakoma-Mile 9	17.90	0	9,491	9,491
L7	AS02	Kyebi-Abofour	25.00	0	8,306	8,306
L8	AS07	Agona-Dombabra*	5.50	3,616	7,971	11,587
L9	AS08	Bosomyekye-Ouagadougu*	5.00	7,845	7,948	15,793
L10	BA03	Tatekwa Jn-Tetekwa	14.40	0	10,973	10,973
L11	BA08	Mensi-Bremi*	4.40	4,954	7,209	12,163
L12	NR05	Tamale-Kupula-Pakyina*	5.00	8,397	8,915	17,312
L13	BA01	Ayomso-Gyasikrom	16.00	0	10,987	10,987
L14	BA02	Nyamebekyere-Nsonyameye	14.85	0	14,125	14,125
L15	BA07	Yamfo-Asen	5.80	0	14,758	14,758
L16	NR07	Janagbe-Wovogu	5.00	0	10,895	10,895
L17	NR06	Wulugu-Kpassenkpe*	5.00	1,350	7,136	8,486
L18	UE04	Bawku-Bansi*	5.00	1,948	9,610	11,558
		Totals	156.85	-	-	-
		Averages (weighted)**	8.71	1,755	9,685	11,441

*rehabilitation works carried out under two contracts

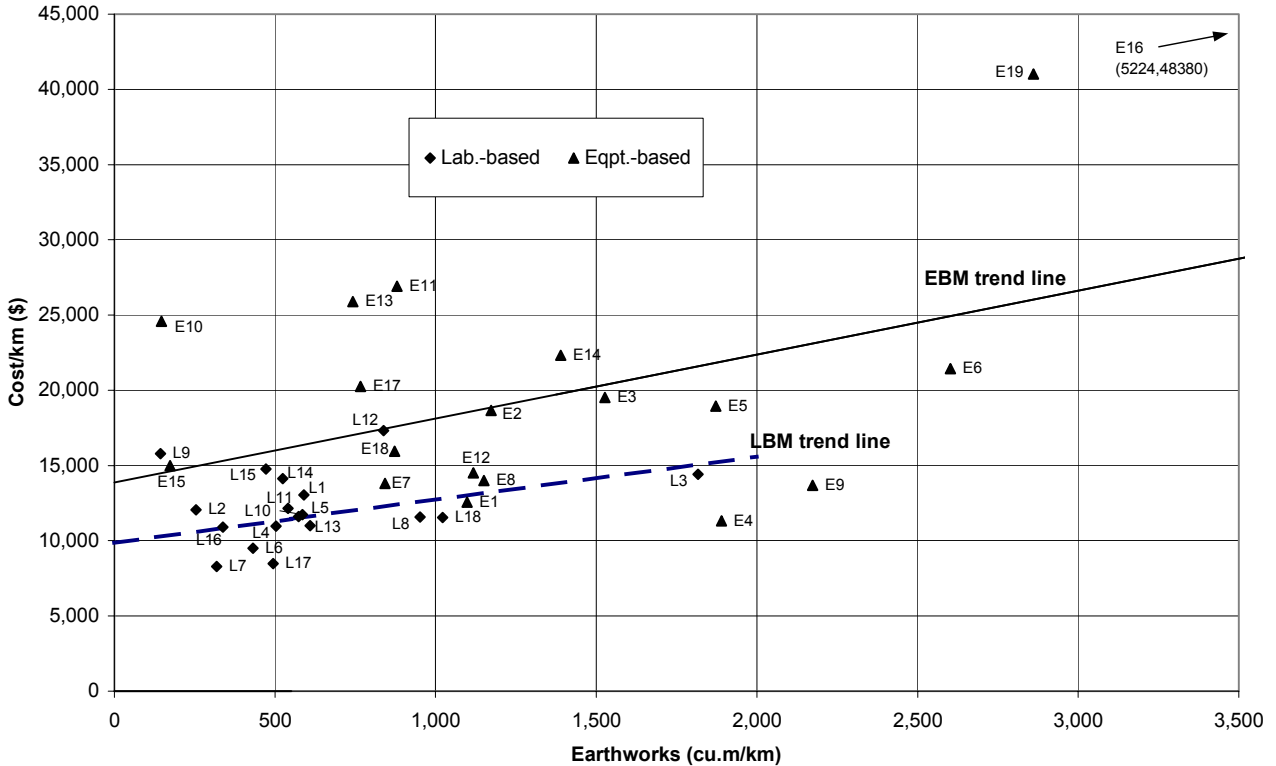
**average costs are weighted by road length i.e. average cost = $3(\text{cost} \times \text{length})/3\text{length}$

From Tables 2a and 2b it can be seen that the average cost per kilometre for the labour-based contracts is US \$ 11,441 compared to US \$ 19,311 for the equipment-based contracts: a difference of some 40%. However, this crude comparison needs refinement for reasons described above.

Cost per km vs Earthworks per km

The average quantity of earthworks per kilometre, weighted by road length, was calculated separately for the labour-based contracts and the equipment-based contracts. The averages were 550 cubic metres per kilometre and 1,401 cubic metres per kilometre respectively. To establish whether the higher earthworks for the equipment-based contracts explained their higher cost, a graph was drawn of cost per kilometre against earthworks per kilometre. This is shown in Figure 1⁴.

**Fig 1: COST PER KM vs EARTHWORKS PER KM
Labour-based & Equipment-based Projects**



Least-squares trend lines were drawn on the graph for the labour-based and equipment-based contracts. These indicated that the labour-based contracts had a lower cost per kilometre over the full range of the data. It had been expected that, due to economies of scale, the equipment-based contracts would be cheaper for the higher earthworks volumes. However, the trend lines do not indicate any convergence that would indicate a break-even point between the two alternative methods.

⁴ In this Figure and all subsequent figures the calculation of the least-squares trend lines does not assume equal weight for each point on the graph. Instead each point has been assigned a weight according to the project road length. Hence, a 20 kilometre long road has twice the weight of a 10 kilometre long road when calculating the least-squares trend line.

For any given earthworks quantity, labour-based methods are approximately 30% lower in cost than equipment-based methods. This is less than the 40% difference between the crude averages, indicating that the difference in earthworks quantities does explain some of the cost difference between the two sets of data. The results of linear regression analyses of the data are:-

	Labour-based	Equipment-based
Coefficient of correlation, r	0.3690	0.5765
intercept, a	US \$ 9,865 per km	US \$ 13,025 per km
slope, b	US \$ 2.86 per m ³	US \$ 4.49 per m ³

note: formula for linear regression line is **Cost per km = a + b x (m³ per km)**

The value for the coefficient of correlation is relatively low for the labour-based projects indicating a fair degree of scatter of the data points about the trend line. The coefficient of correlation for the equipment-based projects is higher due mainly to a larger range of cost and earthworks data for a similar number of data points.

It could be argued that the average and trend line for the equipment-based projects is unduly influenced by those projects with significantly more earthworks than any of the labour-based projects. To test this hypothesis the analysis was repeated eliminating, firstly, the three equipment-based projects with earthworks over 2,500 m³ per kilometre (points E6;E16;E19) and, secondly, the four projects with earthworks over 2,000 m³ (points E6;E9;E16;E19). In both cases the coefficient of correlation for the remaining equipment-based projects indicated a much higher degree of scatter and a negative correlation between cost per kilometre and earthworks per kilometre. The key results are shown in the table below:-

	Equipment-based	
	Only projects < 2,000 m ³ /km (15 projects)	only projects < 2,500 m ³ /km (16 projects)
average earthworks, m ³ /km	1,040	1,118
average cost, US \$/km	17,524	17,257
coefficient of correlation, r	-0.2840	-0.3481
intercept, a	US \$ 19,876 per km	US \$ 20,064 per km
slope, b	US \$ -2.26 per m ³	US \$ -2.51 per m ³

note: formula for linear regression line is **Cost per km = a + b x (m³ per km)**

Therefore, eliminating those equipment-based projects with higher earthworks than any of the labour-based projects:

- produces a negative trend line for the equipment-based project costs
- significantly reduces the value of the coefficient of correlation
- reduces the average cost per kilometre from just over US \$19,000 per kilometre to just over US \$17,000 per kilometre
- suggests that equipment-based projects are about twice as expensive as labour-based projects at very low earthworks per kilometre but similar in cost at about 2,000 m³ per kilometre. For example, at 200 m³ per kilometre the labour-based cost is \$10,437 per kilometre and the equipment-based cost \$19,424. The costs at 2,000 m³ per kilometre are \$15,585 and \$15,356 for labour-based and equipment-based methods respectively.

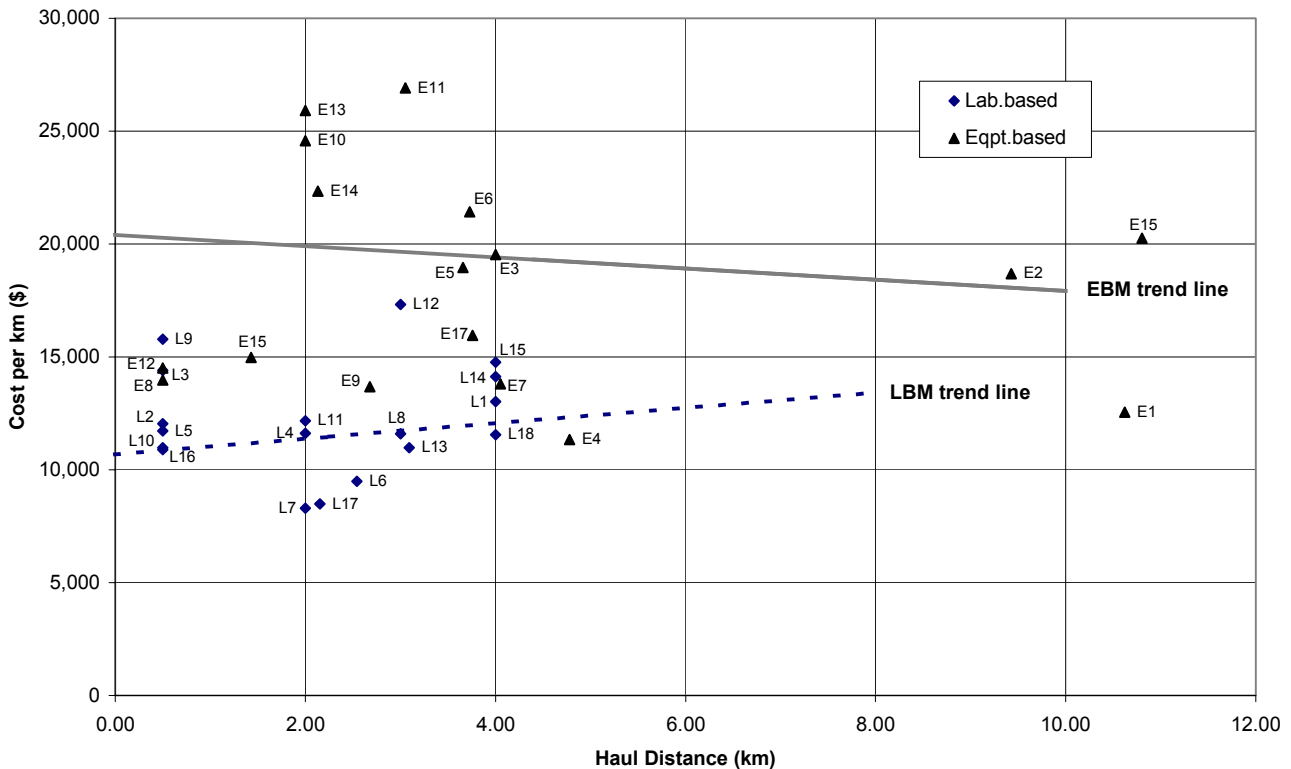
It was concluded that the inclusion of those equipment-based projects with higher earthworks per kilometre produces a better correlation than eliminating them. Therefore, the observations based on the reduced set of data should be treated with caution.

Cost per km vs Average Haul Distance for Gravel Surfacing

The next part of the analysis examined the effect of average haul distance on project costs per kilometre. All road projects included in the analysis were fully gravelled. The average gravel haul distance for most projects was between zero and 4 kilometres. Three of the equipment-based projects had significantly higher average hauls of around 10 kilometres. The average haul distance for all labour-based projects, weighted by road length, was 2.25 kilometres. For the equipment-based projects the overall weighted average was 4.40 kilometres. These haul distances are relatively short by Sub-Saharan African standards indicating the ready availability of gravel in most parts of Ghana⁵.

Cost per kilometre was plotted against average haul distance for each project. This is shown in Figure 2. The trend lines, established by the least squares method, were plotted for labour-based and equipment-based projects separately. These are also shown in Figure 2.

**Fig 2: COST PER KM vs AVERAGE HAUL DISTANCE
Labour-based & Equipment-based Projects**



Surprisingly little correlation was found between average haul distance and total cost per kilometre for both labour-based and equipment-based projects. The results of the linear regression analyses of the data are:

⁵ For comparison, in the Central Province of Kenya typical haul distances for gravel are 10 to 20 kilometres. In Lesotho average gravel haul distances are typically 5-10 kilometres for labour-based road projects.

	Labour-based	Equipment-based
coefficient of correlation, r	0.1858	-0.0959
intercept, a	US \$ 10,689 per km	US \$ 20,409 per km
slope, b	US \$ 343 per km haul	US \$ -249 per km haul

note: formula for linear regression line is **Cost per km = a + b x (haul distance in km)**

The coefficient of correlation is close to zero for both the labour-based and equipment-based projects, indicating a lack of correlation between the variables. The slope of the trend line for the equipment-based projects is slightly negative, indicating a decrease in cost per kilometre with increasing haul distance. This is due to the relatively high cost of a few projects with low haul distances, for example, E11, E13 and E10 combined with the low cost of project E1.

The trend lines indicate that on average labour-based projects have a lower cost than equipment-based projects over the full range of haul distances contained in the data. The cost advantage varies from nearly 50% at haul distances of less than one kilometre to nearly 30% at a haul distance of 8 kilometres.

The lack of correlation between gravel haul distance and overall cost may be explained by a number of factors:

- haul distance affects transit time⁶ and, for the relatively short haul distances contained in the data, this has only a marginal effect on overall cycle time for gravel haulage
- there may be significant differences in the quality of the haul routes which would also affect transit times and this has not been taken into account here (haul routes vary from rough forest tracks to bitumenised roads)
- gravel haulage cost is only a relatively small percentage of overall cost per kilometre and differences in haulage cost can easily be masked by other differences between projects.

⁶ Transit time is the time taken in moving between the quarry and the road site. It excludes all on-loading and off-loading time, waiting time and manoeuvring time that go to make up the total cycle time.

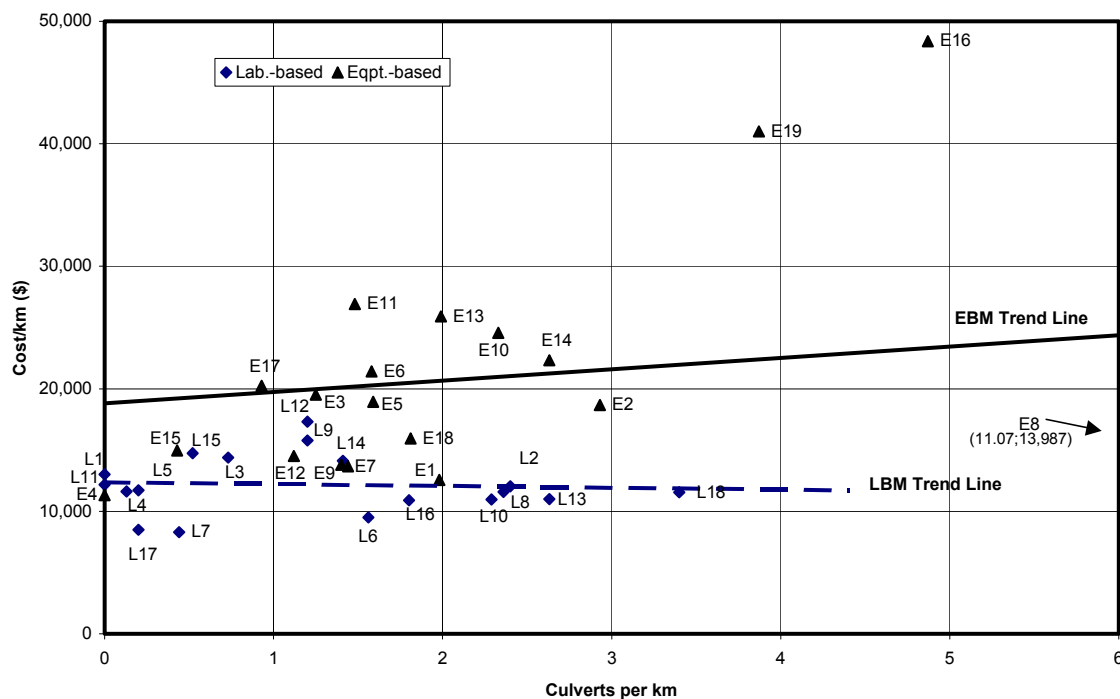
Other Relationships

Costs per kilometre were also compared with number of culverts per kilometre and with the size of each project. Neither of these analyses produced significant correlation.

The comparison with **culverts per kilometre** suffered from lack of reliable data. As explained above, some labour-based projects consisted of two contracts, advance culverting followed by rehabilitation. As the two contracts did not always exactly coincide, it was not possible with the data available to reliably determine the culverts per kilometre. The number of culverts per kilometre used was based on the number constructed under the major contract only. This excludes those constructed as part of the advance culverting works.

The graph of cost per kilometre against culverts per kilometre is shown in Figure 3. The labour-based projects indicate virtually no correlation, probably due to the data problems. However, even the equipment-based projects show only a weak positive correlation with a wide scatter of results for projects with more than 3 culverts per kilometre (points E19, E16 and E8)⁷.

Fig 3: COST PER KM vs CULVERTS PER KM

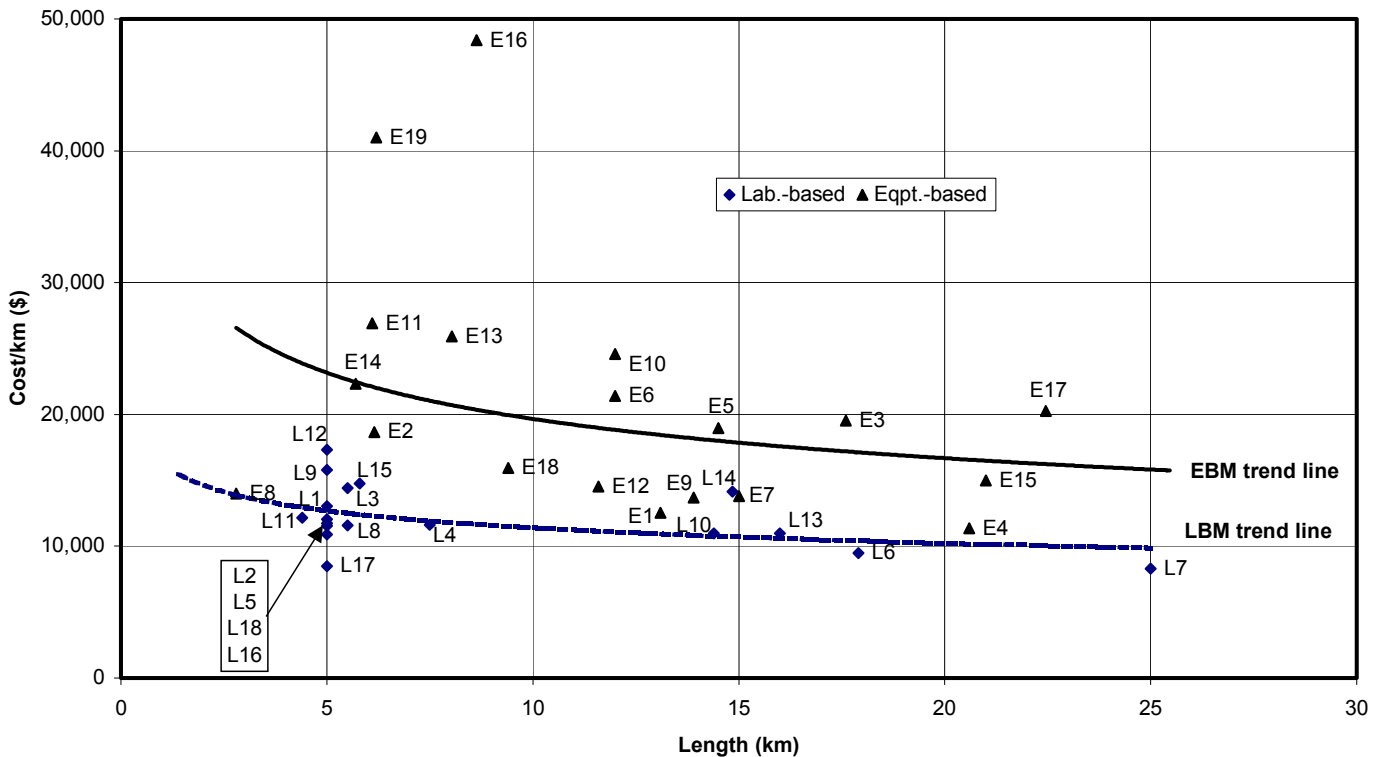


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⁷ It is to be noted that this is contrary to the findings of recent work carried out by the University of Science and Technology in Ghana. Their findings suggest a good correlation between numbers of culverts per kilometre and cost per kilometre for labour-based roads. In their study, data for earthworks was only available for a few of the projects. It is, therefore, not possible to determine whether earthworks per kilometre would have been a better explanatory variable. See "A Comparative Study of the Cost of Labour-based and Equipment-based Feeder Road Construction in Ghana, Preliminary Research Report" Dr S.K.Ampadu, UST, Kumasi, Ghana, 1997.

The comparison of cost per kilometre with **project size** suffered from insufficient data and an apparent non-linear relationship. Comparisons were tested using project cost and using project length as indicators of project size. Both gave similar results. The plot of cost per kilometre against project length, expressed in kilometres, is shown in figure 4. The trend lines did suggest, as expected, a negative correlation (i.e. lower cost per kilometre for larger projects). However, the relationship appeared to be complex and non-linear, and it was difficult to establish with any degree of certainty due to too few points. The trend lines shown in figure 4 are based on a power relationship. The trend lines for labour-based and equipment-based projects are nearly parallel over the available data ranges. This indicates that, based on the range of data contained in the study, there is not a point beyond which equipment-based projects become financially cheaper than labour-based projects.

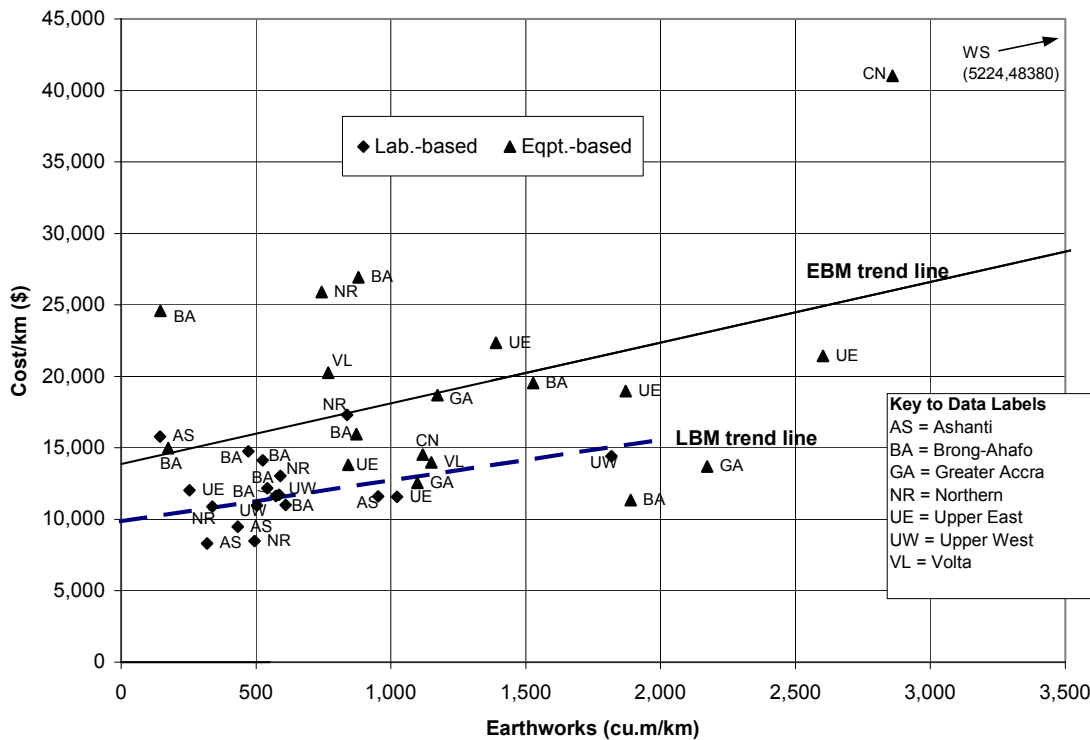
Fig 4: COST PER KM vs PROJECT LENGTH



Finally, the costs per kilometre were compared for different regions to determine whether “remoteness” had any clear effect. With the available data, the location of projects was only identifiable down to the level of region. Labour costs did not vary significantly from region to region. Each point on the graph of cost per kilometre against earthworks per kilometre was labelled with the region in which the project was located. The resulting graph is shown in Figure 5.

The costs per kilometre of projects in Ashanti Region (AS), and Greater Accra (GA) appeared to show lower average costs and less scatter about the trend line than those from Brong-Ahafo (BA) and Northern (NR). This may indicate both lower, and less variable, costs for projects close to the major urban centres of Accra and Kumasi. However, projects from the remoter Upper East (UE) and Upper West (UW) Regions showed similar characteristics of lower average costs and lower variability to those from Ashanti and Greater Accra. Therefore, there was no clear conclusion to be drawn from the results. Although remoteness does have a direct effect on the cost of certain inputs, the efficiency of project management and effectiveness of supervision is probably more significant.

Fig 5: EFFECT OF REMOTENESS
Points Labelled by Region of Project



Chapter 5 Conclusions and Recommendations

Conclusions

A total of 37 projects (19 equipment-based and 18 labour-based) were included in the analysis for this case study. The total length of the sampled projects was 384km (227km equipment-based and 157km labour-based).

The main conclusion to be drawn from a comparison of the costs for feeder road rehabilitation in Ghana is that the **projects using labour-based methods were, on average, financially cheaper per kilometre than those using equipment-based methods**. Even when allowance is made for the fact that the equipment-based projects had, on average, higher earthworks, labour-based methods were still on average about 30% lower in terms of financial cost per kilometre.

The cost advantage of labour-based methods over equipment-based methods was found to be similar over the full range of average earthworks per kilometre contained in the sample of projects. This is surprising as equipment-based methods would normally be expected to show economies of scale such that they become relatively cheaper at higher earthworks volumes. This means that the amount of earthworks per kilometre is not a relevant variable in the relative costs of labour-based and equipment-based methods over the range of earthworks volumes contained in this study (approximately 200-3,000 m³ per kilometre).

This generalised comment is based upon averages derived from linear regression. It cannot be extended to each and every project as, for any given earthworks volume per kilometre, cases can be found where equipment-based projects were financially cheaper than labour-based projects. For example, at between 1,700 and 2,000 m³/km equipment-based project E4 was cheaper than labour-based project L3 (see Figure 1).

No correlation was discernible between average gravel haul distance and average cost per kilometre for the sampled projects. It is concluded that the effect of haul distance on total cost per kilometre was small compared with other factors.

Similarly, there was little discernible correlation between the average number of culverts constructed per kilometre and average cost per kilometre. In this case this may be due to inadequacies in both the quantity and detail of the data used.

There appeared to be some apparent correlation between project size and cost per kilometre. Larger projects tended to have lower costs per kilometre for both labour-based and equipment-based projects. However, there was insufficient data to establish any clear relationships.

Remoteness, based on the region in which each project was located, did not indicate any consistent trend.

For all these variables – haul distance, number of culverts, size of project and remoteness – the cost difference between labour-based and equipment-based methods was similar over the full range of the data contained in the sampled projects. None of these factors was shown to be a significantly relevant variable in the cost comparison.

Break-even Wage Rate

In Ghana the labour wage rate, at the time that the sampled projects were carried out, averaged about \$1.50 per day. The DFR has calculated that the average percentage of unskilled labour cost in labour-based projects is 30% compared to 4% in equipment-based projects. Using these figures and assuming non-wage costs stay the same, it can be determined that the wage rate could rise to \$4.10 per day before the average financial cost of labour-based projects would equal that of equipment-based projects. Thus the break-even wage rate for this sample of projects is **\$4.10 per day**. This figure will change as non-wage costs, such as fuel and vehicle repairs, change.

Guideline for Cost Comparison

The original international guideline for taking decisions between the use of labour-based or equipment-based methods was based on early studies carried out in the 1970s. This proposed the use of a break-even wage rate of, initially, \$1.00 dollar a day although this was later raised to \$4.00 per day.

The case study presented in this report **supports the use of this simple guideline**. Although earthworks per kilometre were found to have a positive correlation with costs per kilometre, the percentage cost difference between labour-based and equipment-based methods did not vary over the range of earthworks per kilometre in the sample. Therefore there was no evidence that earthworks per kilometre need be considered in comparing the relative cost of labour-based and equipment-based methods.

Little clear relationship was found between total cost per kilometre and other parameters such as gravel haul distance, project size and culverts per kilometre. Moreover, the analysis suggested that these parameters also did not affect the cost comparison between labour-based and equipment-based methods. The use of a more complex indicator of viability than daily wage rate was not found to be justified by this case study.

The extent to which the results of this case study may be extended to other Sub-Saharan African countries is open to question. The haul distances for gravel were fairly short which is typical for areas with extensive deposits of laterite. The country is medium-size compared to other African countries with a reasonable trunk road system. The degree of remoteness of road projects may not correspond to that found in parts of other African countries. The private sector in Ghana is fairly active and reasonably efficient. The results of this case study may, therefore, be typical of many average projects in Sub-Saharan African countries: but the range of data does not cover the more extreme situations of the various parameters that may be encountered.

Another question mark over the results of the study is the difference in tendering procedures for equipment-based and labour-based contracts. The fact that the latter were awarded on fixed rates would save the labour-based contractor, and hence the client, bidding costs. If these were included, the cost difference may have narrowed by about 5 – 10%.

Economic or Financial Cost Comparisons?

This case study has compared the financial cost of road rehabilitation using labour-based and equipment-based methods. However, the most commonly-quoted advantages for choosing labour-based methods are:

- creation of employment
- saving of foreign exchange
- putting cash into the “local” economy, followed by multiplier effects
- positive distribution effects through wages reaching poorer sections of the population
- contributing to the reduction of rural to urban migration.

These factors can only be captured if an **economic** rather than a financial cost comparison is carried out. In the situation prevailing in most Sub-Saharan African countries, an economic cost comparison will favour labour-based methods more than equipment-based methods. Thus, if labour-based methods are cheaper than equipment-based methods in financial terms, the cost advantage will be even greater in economic terms.

Financial cost comparisons are, however, important. Greater use is now being made of the private sector to carry out road works in Sub-Saharan Africa. For road contractors, it is financial cost that is relevant. If labour-based methods can be shown to be financially cheaper, then there is a greater chance of adoption and sustainability of these methods in the private sector. This would avoid the need for governments to have recourse to the application of premiums or weights to take account of the economic benefits of labour-based methods compared to equipment-based methods.

This then begs the question of why (cheaper) labour-based methods are not taking off spontaneously in Ghana. There could be a number of reasons to explain this, although these are beyond the scope of this study. However, this does warrant further investigation.

One clear fact to emerge from the case study was that currently the monitoring of comparative labour-based and equipment-based road rehabilitation costs is not routinely carried out. The conclusion to be drawn is that currently the choice of technology may have more to do with ideology than economics. This is not a sustainable approach in the longer term.

Another factor to emerge was that a large amount of data is required if reliable conclusions on cost comparison are to be drawn.

Recommendations

Labour-based methods are expected to have an increasingly important role in road maintenance and improvement in Sub-Saharan Africa in the immediate future. It is reasonable to assume that most road authorities will use a mixture of labour-based and equipment-based methods. For this reason it is recommended that:

- further cost comparison studies are carried out between the use of labour-based and equipment-based methods
- systems of monitoring are put in place in each road authority to establish the change in comparative costs as factor prices change over time
- parameters are established for each country such that the economic benefits of labour-based methods can be properly taken into account.

Without this action it is difficult to see how road engineers will be able to make rational choices of technology for the improvement of Sub-Saharan Africa's road network for the future. Engineers cannot be expected to work from first principles whenever a choice of technology has to be made. More reliable and easily accessible cost comparison data is one essential part of the data required.

Finally, the study established that labour-based methods were, on average, financially cheaper than equipment-based methods for feeder road rehabilitation in Ghana. However, there has been no spontaneous take-up of these methods by road contractors in Ghana. This warrants further study to establish what other significant factors affect the choice of method. This is necessary if a sustainable and competitive labour-based road contracting capability is to be established in Ghana and in Sub-Saharan Africa as a whole.

ANNEX 1

PROJECT DATA SHEETS