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Abstract

This paper examines the various cost comparisons that have been carried out between the use of labour–based and equipment-based methods for road construction and maintenance.

Despite the fact that a large number of labour-based road programmes have been implemented in sub-Saharan Africa, there have been relatively few rigorous cost comparisons with existing conventional methods of construction. Recently there have been a number of attempts to compare costs by reviewing programmes that have been in existence for a number of years and for which a reasonable amount of cost data is available.

The paper firstly examines the methodological issues surrounding such cost comparisons. Three case studies are described in order to illustrate the problems encountered with cost comparison analyses. Finally conclusions are drawn on what has been learnt so far about the comparison of the cost of construction by labour-based and equipment- based methods.

Early studies looked solely at the financial costs of activities undertaken by both methods. Studies during the 1990s started to look into the economic effects of the choice of technology and began to build economic models for the direct and indirect effects.

When economic efficiency and return on investment is needed to justify the choice of technology, then the direct economic benefits need to be included in any cost comparison analysis through shadow pricing of all items. When the purpose of choosing a more labour-intensive method of construction is to contribute to a higher level socio-economic developmental goal, this can only be captured if a full macro-economic analysis is carried out.

A common fact is that conducting even the simplest cost comparison study has proved difficult. Perhaps surprisingly, it is the costing of EBM that has proved most problematic. EBM are characterised by high fixed costs and low variable costs. Any cost comparison where only the marginal cost of using equipment (i.e. running costs only) is used will usually show a clear cost advantage for EBM. As countries decentralise the smaller more scattered projects can gain significant cost advantage from the use of LBM by local roads authorities. Even in countries where LBM appear financially cheaper, EBM continue to predominate. This suggests that there are considerable barriers to entry into the market for labour-based contractors - an area warranting further investigation.

A sustained and high-level political commitment is required if LBM are to become established in the market as an available technology choice for construction works.

1 INTRODUCTION

Despite the fact that a large number of labour-based road programmes have been implemented in sub-Saharan Africa[1], there have been relatively few rigorous cost comparisons with existing conventional methods of construction. This is perhaps indicative of the fact that these labour-based programmes have been driven more by ideology than economics - an issue to which this paper will return in the conclusions. Recently there have been a number of attempts to compare costs by reviewing programmes that have been in existence for a number of years and for which a reasonable amount of cost data is available.

This paper firstly examines the methodological issues surrounding such cost comparisons. Three case studies are then described in order to illustrate the problems encountered with cost comparison analyses. Finally conclusions are drawn on what has been learnt so far about the comparison of the cost of construction by labour-based and equipment- based methods. The illustrations are based on rural road construction, but most of the conclusions could apply equally to the wider construction sector.

2 METHODOLOGICAL ISSUES

Definition of LBM.

The first point to clarify is what constitutes a labour-based approach. Labour-based methods (LBM) is the term used for construction carried out using labour as the central resource. Equipment is used for operations that would clearly be uneconomic using labour in order to achieve an optimum combination of labour and equipment. The amount and type of equipment used is determined by the performance and productivity of labour.

The two classic examples of operations for which equipment is used as part of a labour-based project are the compaction and haulage of materials. The amount and size of equipment used for LBM is determined by the productivity of the labour force. Thus, small pedestrian operated rollers are commonly used for labour-based compaction operations as their output is better matched to that of the labour gang engaged on the other parts of the filling or gravelling activity.

A qualification to the above example of the use of equipment in labour-based construction is the scale of the operation. Where small volumes of material need compacting, such as for the backfilling of culverts, the use of hand rammers is usually more appropriate. Similarly, for haulage distances up to a few hundred metres, the use of wheelbarrows will usually be more efficient that tippers. This is significant as it illustrates the importance of the "scale of operation" in the choice between labour and equipment – another point to which this paper will return in the conclusions.

Level of Aggregation.

In comparing the cost of LBM and equipment based methods (EBM), the first decision is what scale of aggregation is to be used. Conceptually, it is convenient to consider three levels:

[1] Although this paper focuses on Sub-Saharan Africa, many of the issues apply equally well to countries in other areas including Asia and Latin America.

1. Individual operations
2. Single project
3. Programme comprising many projects

The first approach is attractive in that it is the simplest to measure. The problem is that it is not very informative. For example, comparing the use of labour with shovels and an excavator with a backhoe for excavating a trench can give information on the productivity, and hence cost, for the individual operation. But, because it does not include the costs of mobilising/demobilising nor downtime nor any of the other multiple linkages surrounding construction works, it is a poor indicator of the issue of most interest – the overall project cost.

The second option of using a singe project does include all the non-productive as well as productive time used and is potentially a more useful indicator for future decisions on the choice of method to use. The main problem is the individual nature of construction projects. Variations occur in types of soil, terrain, remoteness, weather encountered, etc. that makes each construction project unique. This creates two problems. Firstly, it is difficult to find two identical projects, one carried out by EBM and one by LBM, on which to base a cost comparison. Secondly, contract documents tend to differ between the two technologies, most importantly in the preliminary items. One method that can be used is to examine a project carried out by one method and to hypothesise the cost if it had been carried out by the alternative method. In practice this becomes fraught with difficulties and the multiple assumptions that have to be made for the hypothetical cost tend to undermine confidence in the result.

The third method is based on deriving information based on "averages" over a range of similar projects. This smoothes out the individual characteristics of projects. However, it can be difficult to find two sets of data, one for LBM and one for EBM, that are sufficiently similar on which to base a cost comparison. Despite these difficulties, this method is potentially the most informative for general consideration of the choice of technology to use for a given type of project in a given environment.

Definition of Cost.

Having decided the scale of aggregation on which to base a cost comparison study a further decision is required on how to define "cost". There are three main choices:

1. Financial costs
2. Economic Costs (direct costs only)
3. Economic Costs (including both direct and indirect costs)

Engineering decisions for public sector infrastructure are usually taken on the basis of economic costs and benefits as this gives the most efficient allocation of resources for the national economy. For this reason the choice of technology, i.e. either LBM or EBM, for roadworks should also be based on an economic cost comparison. This requires a certain amount of skill as well as some detailed knowledge and data on the local economic situation.

Where a system of bidding is used to choose between private sector contractors in open competition the choice of bidder, other things being equal, is based on the financial cost. Consequently a financial cost comparison is useful as a guide to how market forces operate.

In labour abundant economies, the use of economic costs usually favours the more labour intensive methods[2]. In this situation one compromise is to carry out a financial cost comparison and, if LBM are cheaper financially, their margin of advantage is assumed to be even greater if economic costs were used.

Where the cost of LBM and EBM are comparable, or LBM are more expensive, an economic cost comparison is necessary. Considering direct costs only, this requires the removal of all taxes and duties and the shadow pricing of costs. For the latter, it is the shadow wage rate that is most significant as this is can typically be less than 50% of the market wage rate.

However, a cost comparison using economic costs for the main resources does not always capture the full economic benefits. Multiplier effects are typically more significant for LBM as more of the costs of a project stay in the local economy. The impact on poverty is more significant where LBM are used through the distributional effects of wages for unskilled labour. For these reasons, a more thorough economic comparison considering wider macro-economic effects is justified.

Thus the nine possible options for cost comparisons can be summarised in a 3 x 3 matrix based on level of aggregation and method of costing as illustrated in Table 1 below. The level of complexity of the cost comparison increase from left to right and top to bottom of the matrix. The most straightforward is number 1 in the matrix. The most thorough is number 9. Illustrations of the use of some of these different cost comparison methodologies are given in the case studies that follow.

Table 1: Cost Comparison Methodology

		Scale of operation		
		Individual operation	Single project	Programme of projects
Costing Method	Financial	1	2	3
	Economic	4	5	6
	Macro-economic	7	8	9

[2] This does depend on the magnitude of tax on equipment purchase and running costs relative to the opportunity cost of labour.

3 CASE STUDY 1: GHANA FEEDER ROADS

Feeder roads in Ghana have been rehabilitated and maintained using both LBM and EBM since the mid 1980's. A particular feature is that private sector contractors have carried out all the work. Equipment-based contractors are well established in Ghana. Labour-based contractors were established from 1986 onwards with the encouragement and support of the Department of Feeder Roads. Over 90 contractors have now been trained in LBM for feeder road rehabilitation. This is a rare example of LBM and EBM used side by side to rehabilitate the same standard of road over an extended period of time.

A financial cost comparison study carried out in the late 1990s used data from completed contracts for about 383 kilometres of road - 226 kilometres EBM and 157 kilometres LBM. Many of the contracts included variations orders. For this reason, final costs and not contract prices were used for the comparison. Based on straight averages for the sample of roads used, LBM were 40% cheaper than EBM (Table 2).

Table 2: Financial Cost Comparison, Ghana Feeder Road Rehabilitation.

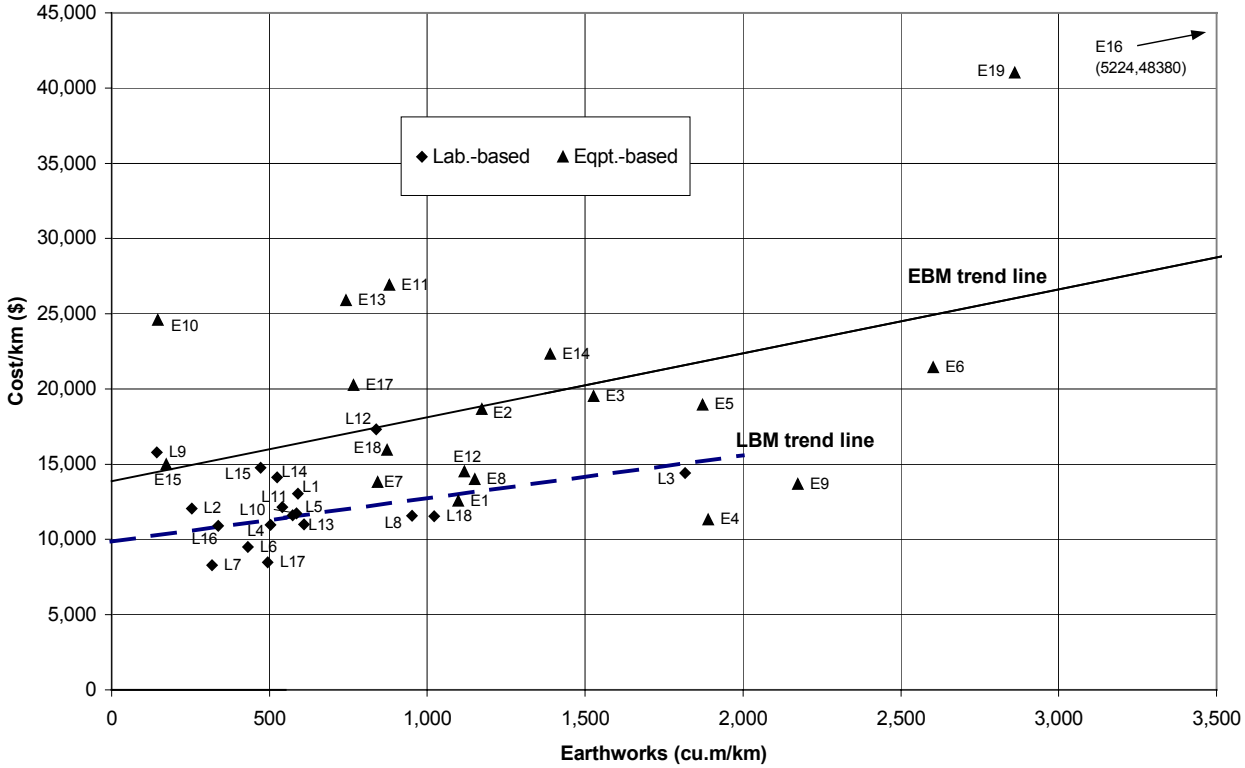
Technology	Total Sample Length km	Average Contract Length km	Contract cost US$ per km	Cost Advantage
LBM	156.85	8.71	11,441	41%
EBM	226.78	11.94	19,311	-69%

The problem with this comparison was that the Department of Feeder roads tended to favour the use of EB contractors where the necessary earthworks were large or where the haulage of gravel for surfacing was particularly long. Thus, it was expected that the average quantities for the EB contracts were higher than for the LB contracts. For this reason the analysis also extended the cost comparison to see whether the relative cost advantage changed with work quantities, for example, increased earthworks (see figure 1). Although there was some narrowing of the cost difference, the surprising result was that LBM were financially cheaper than EBM over the whole range of quantities (haulage, earthworks, etc.) in the sample contracts. Thus, the conclusion was drawn that the average cost of the contracts using LBM was about 30% cheaper financially than those using EBM.

A further problem with the comparison, and one that raises important questions over the market, is that the labour-based contractors had not bid in open competition with equipment-based contractors. Instead they had either worked on negotiated rates, thereby saving bidding costs entirely, or only bid against each other. This raises two important and related questions. Would the bidding costs required in open competition have narrowed the cost comparison sufficiently to make LBM costs the same or higher than EBM? Also, if the financial costs of LBM were lower than EBM, why were existing contractors not adopting more labour intensive methods?

Currently certain contracts continue to be ring-fenced for labour-based contractors in Ghana. The main reason for this is an agreement by the Department of Feeder Roads to provide a guaranteed workload until such time as the labour-based contractors have paid off their equipment loans with a commercial bank. Labour-based contractors have a strong preference for the status quo, which gives them a protective shelter. The few that have bid for road rehabilitation contracts in open competition with equipment-based contractors have not been particularly successful. The reasons for this have not been established but are believed to include the packaging and bidding procedures for the open tenders. In general, this example undermines the theory that if LBM are financially cheaper, then the market will ensure their success.

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



4 CASE STUDY 2: MOZAMBIQUE

A comparison of labour based and equipment based road work contracts carried out between 1997 and 2002 in four provinces of Mozambique was conducted to determine the financial and economic factors to assist planners with technology choice. The study looked at a total of 87 contracts covering some 4,255 kilometres of roads. The contracts were categorised into full rehabilitation, periodic maintenance and routine maintenance interventions and then into equipment based or labour based technology according to the contract title. An initial review of the data collected showed that only 60% was suitable for consideration in the study. The average per kilometre costs for the projects undertaken, after adjusting the raw data for inflation, are shown in table 3 below.

While these figures seemed on the surface to form the basis of a fair comparison, it was clear that they were very low in all respects for full rehabilitation of a 6m wide gravel road built to proper engineering standards and also for periodic maintenance involving re-gravelling of the same. On the other hand the costs for routine maintenance appeared high, leading to the conclusion that the costs did not match the supposed intervention level. This fits with figures

collected from other countries where rehabilitation averages out at $8,000 per kilometre (Uganda) and $14,000/kilometres (ILO- worldwide analysis)[3].

A closer examination of the projects showed that there was a great range and variance of activities being undertaken in the separate contracts classified under the same intervention. Some rehabilitation contracts contained little more than heavy grading operations and some routine maintenance contracts contained significant lengths of gravelling work. Parastatal contractors, using subsidised government grant-aided equipment, carried out most of the projects for which data was available. In order to fully adjust both labour based and equipment based contracts to a fully comparable level, the field unit costs and calculated ownership and operations costs of equipment were used to calculate a standard cost for each intervention for both technologies. This standardised theoretical analysis using unit costs and productivities from field data and eliminating differences from variance of profit and overheads gave a very different result for financial cost (Table 3).

These adjusted financial figures were then subjected to a thorough economic re-working in order to find the economic cost of carrying out the same work. This involved applying a standard conversion factor for the data of import, export, duties and subsidies. Applying shadow pricing for skilled and unskilled labour, fuel, equipment and materials. This process allowed for the discounting for taxes on all items in the costs analysis. This gave the economic cost shown in Table 3. These economic cost figures show that the high tax and duty levels on equipment in Mozambique has a bigger effect on EBM relative to LBM than in other countries. Still the economic advantage of LBM is similar to other countries at about 50%.

Table 3: Cost Comparison Data, 6m Gravel Roads, Mozambique.

Analysis	Intervention	EBM $	LBM $	LB cost advantage %
Raw Data	Rehabilitation	2,114	2,945	-28%
	Periodic Maintenance	973	626	55%
	Routine Maintenance	829	758	9%
Adjusted Financial Cost	Rehabilitation	15,618	10,114	54%
	Periodic Maintenance	10,852	6,635	64%
	Routine Maintenance	516	362	43%
Economic Cost	Rehabilitation	9,656	6,401	51%
	Periodic Maintenance	6,640	4,198	58%
	Routine Maintenance	322	245	31%

This detailed collection of financial data and analysis enabled the authors to go further and examine some other economic indicators. The break even wage rate was calculated to be $4.12 for rehabilitation and $3.80 for periodic maintenance. These rates are in line with those determined for other countries. The whole life cost (road rehabilitation followed by routine maintenance and periodic maintenance) was then calculated. The evaluation was done for an 8 year period on a 48 kilometre long gravel road with existing roughness (IRI) 15 and discount rate of 12%. The salient figures for the full cost of rehabilitation and subsequent maintenance are shown in Table 4 and indicate the advantage of LBM:

Table 4: Whole Life Costs, Mozambique.

Technology	EIRR	NPV (US$ mill)	NPV/Cost
LBM	34%	0.324	0.36

[3] Edmonds & de Veen "Technology choice for construction and maintenance of roads" ILO- 1991

EBM	17%	0.104	0.09

EIRR=Economic Internal Rate of Return; NPV = Net Present Value.

The Poverty Impact Ratio (PIR) of these investments was also calculated for different proportions of user benefits to the poor and proportions of government spending on the poor. Across the full range of these figures LBM gave a PIR at least 20% higher than EBM.

The inconsistent description of interventions and technology choice in contract documentation caused problems with data collation. Despite this it was clear from the study that in the case of Mozambique there was a high potential for market forces to render a significant advantage to labour based contractors over their equipment based competitors.

5 CASE STUDY 3 – UGANDA FEEDER ROADS

A study carried out in 1998-99 examined the relative cost of feeder road improvement in Uganda by LBM and EBM in the period 1993 to 1997. Although over 11,000 kilometres of feeder road improvement had been carried out, reasonably complete cost data only existed for some 133 kilometres of labour-based improvement and 92 kilometres of equipment based improvement. This formed the core data for the cost comparison study with the remaining data used for partial validation purposes. A feature of this study was a three-step approach whereby a financial cost comparison of the two alternative methods was followed by a comparison of direct economic costs and finally a comparison of macro-economic effects.

Financially LBM were found to be 18% cheaper than EBM for full feeder road rehabilitation. The margin of advantage of LBM increased to 38% when economic costs were used. This was mainly due to the effect of shadow pricing labour[4]. This outweighed the relative advantage to EBM of removing taxes and import duties. Sensitivity tests showed that the result was fairly robust over a wide range of change in major factor prices. The breakeven wage rate was calculated at slightly over US$4 per day, which compared with an actual wage rate of US$1.15 per day.

One of the most interesting parts of this study was the attempt to include secondary effects[5] in the comparison between LBM and EBM. A simple macro-economic model of an input/output type was used. Key factors and coefficients applicable to rural Uganda were derived. Based on this model, the indirect effects were found to be higher than the direct effects for both LBM and EBM. Investment using LBM resulted in a significantly higher effect than EBM for all the parameters studied.

Considering both direct and indirect effects, LBM were calculated to generate three times as many jobs as EBM. For every one job created on the project it was calculated that LBM generated 1.6 jobs in the wider economy due to multiplier effects[6].

LBM were calculated to generate about 1.8 times more Gross Domestic Product (GDP) than LBM considering both the direct and indirect effects. A comparison of the main components of GDP, i.e. household income, consumption and private investment, showed a similar difference in magnitude for each component.

Direct public revenues, i.e. tax and duties generated using LBM were smaller than for EBM. This was due the relative significance of taxes and import duties on heavy construction equipment, spare parts and fuels in projects using EBM. However, interestingly, the

[4] An accounting ratio of 0.54 was used to shadow price labour based on the average labour productivity in rural small-scale and household enterprises, both agricultural and non-agricultural.

[5] Secondary or indirect effects (multiplier effects) are due to the effect of project expenditure on the wider economy e.g. wage income may be spent on local products generating secondary benefits to shopkeepers and local producers.

[6] A similar calculation for a study in Madagascar gave over two jobs in the wider economy for every one job on the project.

revenues generated indirectly using LBM were estimated to be about two times higher than those indirectly generated using EBM. This was due to the effect of more retention in the local economy of funds spent on LB roadworks. The net effect on the fiscal accounts was a smaller fiscal deficit if LBM were used.

As expected, LBM were calculated to have a smaller negative effect on the trade balance due to their lower requirement for imports compared to EBM. Indirect effects on the trade balance were similar in magnitude for both methods.

The conclusion was drawn that, if the wider macro-economic effects were considered, the advantage of using LBM compared to EBM was greater than that calculated based on a direct economic cost comparison.

6 CONCLUSIONS

A number of studies have been carried out in various developing countries to compare the cost of LBM and EBM of road construction and maintenance. In the 1980s these studies were mostly used for internal monitoring of force account operations and compared the costs of equipment use with labour use on individual activities, or between brigades[7]. Studies during the 1990s started to look into the economic effects of the choice of technology and began to build economic models for the direct effects[8]. More recently studies have further developed the economic models and placed emphasis on the indirect effects through macro-economic analyses (Madagascar[9] and Uganda). A summary of some of these studies is given in Table 5.

Table 5: Summary of Selected Cost Comparison Studies

Study country	Number of projects considered	Financial advantage	Economic advantage	Macro-economic multiplier difference[10]
Benin	3	25%	-	-
Rwanda	By activity	Varied	-	-
Madagascar	8	10%-65%*	50%	0.37
Lesotho	By activity	Varied	-	-
Ghana	37	30%	-	-
Uganda	4	18%	38%	0.40
Namibia	3	42%	-	-
Mozambique	87	54%	51%	PIR advantage 20%

The various cost comparison studies carried out so far have used different methods of analysis that makes it difficult to draw broad conclusions. There is a need to elaborate a basic methodology to be followed and define the data to be collected in carrying out this type of study in the future. It is hoped that governments and financing agencies would see the benefit in supporting such a proposal.

A common fact is that conducting even the simplest cost comparison study has proved difficult. The problems with availability and comparability of data are numerous. The number of comparable projects or contracts in any similar area of a country over a reasonable time period tends to be few making the comparisons statistically insecure. Perhaps surprisingly, it is the costing of EBM that has proved most problematic. The mobilisation

[7] G. Taylor. "Cost of LCU constructed Gravel roads 19777-1986" LCU 1987- Lesotho. SWK. "Comparative assessment of Construction brigades" 1982–Benin.
[8] Bertin Marten. "Étude comparée de l'efficacité Économique des HIMO et HIEQ" 1991-Rwanda.
[9] Razafindrakoto & Roubaud. "L'approche à HIMO" 1997- Madagascar.
[10] Based on impact to GDP (change in GDP for unit change in public investment spending)

and ownership costs[11] of equipment are not well documented and, for force account and donor-supported programmes, are often ignored in the reported data.

The move over the last decade from directly employed labour to the use of contractors for roadworks might have been expected to clarify the cost comparison and hence technology choice situation. This has so far not proved to be the case. Even in countries where LBM appear financially cheaper, EBM continue to predominate. This suggests that there are considerable barriers to entry into the market for labour-based contractors - an area warranting further investigation.

Based on studies so far, the scale of operation appears important. The smaller the piece of work, the greater is the advantage of using LBM. Thus, small and scattered projects can show a significant cost advantage for LBM over EBM. This is significant because, as many countries increasingly decentralise the management of their rural road networks, there is a tendency to a larger number of such projects. This suggests that LBM should often be the technology of choice for local (road) authorities.

An important point is that LBM have tended to be promoted where wider economic benefits have been sought. When economic efficiency and return on investment is needed to justify the choice of technology, then the direct economic benefits need to be included in any cost comparison analysis through shadow pricing of all items.

If, as in many cases, the purpose of choosing a more labour-intensive method of construction is to contribute to a higher level socio-economic developmental goal such as poverty alleviation, conservation of foreign exchange, job creation or democratisation, this can only be captured if a full macro-economic analysis is carried out. Where such a comparison shows a clear advantage towards the utilisation of LBM for any programme of investments in roadworks, the client organisations and financing agencies need to consider how to deal with this. If the "market" is to be used there has to be a system that enables a portion of that advantage to be used as an incentive for the private sector to prefer the chosen technology. Not by the application of penalties for non-compliance, but through direct financial incentives built into the contract process or broader fiscal measures that favour the adoption of the technology that gives the greatest socio-economic benefits to the country.

Unfortunately this is not so simple. LBM and EBM are fundamentally different approaches. EBM are characterised by high fixed costs and low variable costs. Once an investment is made in capital equipment, the cost is "sunk". Any cost comparison where the marginal cost of using equipment (i.e. running costs only) is used will usually show a clear cost advantage for EBM. This is the principal reason that a sustained and high-level political commitment is required if LBM are to become established in the market as an available technology choice for construction works.

[11] This includes purchase costs, equipment life, utilisation rates and interest rates.

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