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Investigating the Range of Estimating Accuracy in Road Projects

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Abstract
Cost estimates forms a key element in the planning and management of project and project staff expend considerable effort preparing them. The ability to produce cost estimates to a reasonable level of accuracy and in a timely fashion to support the efficient planning of a project is influenced by a number of factors. These include the skill levels and numbers of estimators as well as national, industry and project related factors.

For any national construction sector, these factors combine to provide an indication of the capacity to, and constraints in the preparation of accurate estimates. In Ghana, the Ministry of Transportation is responsible for managing the road sector. Three of the Agencies under the Ministry namely, Ghana Highway Authority (GHA), Department of Urban Roads (DUR), and Department of Feeder Roads (DFR) are responsible for developing and maintaining all the road networks of different classes throughout the country. While it is the responsibility of road sector contractors to produce the estimates that they submit for their tenders to undertake any proposed road projects, the roads development process requires a substantial estimating effort on the part of the Agencies to form the basis of a business case that justifies a decision to go ahead with any proposed scheme. The output from the estimates provide relevant data for establishing the national roads budget as well as information to support any application for donor funding or internationally sourced loans to undertake the projects.

The paper presents the results for an analysis of the national estimating capacity for the three Roads sub-sector Agencies as part of a wider research project to improve the estimating accuracy in Ghana. It examines the estimating procedures that exist within the three Agencies as well as establishing *estimating load to staff ratio* to identify current weaknesses and constraints in estimating accurate road project cost. The paper proposed estimating boundaries as guide for estimators in the Road sector in Ghana.

Keywords
Estimates, Estimators, Project, Road, Construction

1. Introduction

The management of construction industry is a controversial issue within the national economic indicators. The industry employs a lot of people and therefore has an impact on the macroeconomic indicators. Thus, the construction industry is responsible for large percentage of the gross domestic product. In Ghana for example, the road sector alone accounted for nine percent (9%) of Ghana's gross domestic product (NTPG, 2005). Accurate forecasting of cost of future events is vital for the realisation of accurate estimates on projects. Business executives in both private and public sectors of any economy depend heavily on these estimates in making their business decisions. Cost estimates therefore form a key element in the planning and management of the project, and project staffs expend considerable effort preparing them. The ability to produce cost estimates to a reasonable level of accuracy and in a timely fashion to support the efficient planning of a project is influenced by a number of factors. These include the skill levels and numbers of estimators, national, industry and project related factors. For example, Harris *et al*., (2006) considered many of the factors that influence estimating accuracy, and associate availability of information with greater accuracy. Other writers on the subject, including, Touran and Lopez (2006), Skitmore and Thomas (2002), Tas and Yaman (2005), Williams (2003), Wong and Hui (2006), and Edwards and Bowen (1998; 2005) among others, concur with the role information plays for establishing accurate estimates and subscribe to the information school of taught. The implication from the greater information school is that all other external factors being equal, two estimators will arrive at the same project cost. While the assertion of the information school is predominantly true, it ignores the influences of internal factors such as the behaviour and decision orientations of estimators in their operational environment. The influence of these internal factors in assessing risk in estimating contributes to the differences in the estimates produced with the same information by two estimators. Therefore, the forecast of any event will have the upper limit and the lower limit. Ahuja *et al*., (1994) define range estimating as a simulation modelling process performed after an estimate is made. Many researchers and authors investigate on range estimation based on the data available. However, the accuracy of the data alone will not provide accurate estimate. The factors that the estimators have influence on impact significantly on the accuracy of estimates. The paper reveals that range estimating will address the problems associated with both the data and the estimator's behaviour in the assessment of uncertainties.

2. Estimating Procedures in Road Sector of Ghana

In Ghana, costs of road projects are estimated from the first principle. This is done by determining the direct cost .and indirect cost on the work activity being estimated for. Direct cost is obtain from the output standards of plant and machinery, all-in rates of labour, quantity standards for materials and the prices of other inputs from the market. In addition, percentages are applied to the above to cover for indirect cost and profit. The procedures adopted in the determination of the direct and indirect cost in Ghana are discussed in the subsequent sections.

2.1 Direct Cost

Direct cost is cost of constructional inputs that are directly incorporated in the work activity. These costs are obtained from a number of sources. These sources are discussed in detail in the subsequent section of the paper.

2.1.1 Plant and machinery cost

Equipment and tools are required to install the materials in road construction. The equipment usage relationship with the materials could be obtained from database. The relevance of this data base however depends on the frequency of review of the data base. Equipment may be estimated on the duration of the

project or on activity bases. Road construction is equipment intensive and in Ghana equipment is estimated on activity bases. In countries where the equipments for road construction are not manufactured within, the users of these machines depend on the specifications in the manufactures manual. The use of the out put standards in the manufacturer's manual in most cases does not give the true representation of the real situation. This is because the geographical terrain upon which the study is conducted for the machine will differ from region to region. Furthermore, most of these equipments are slightly used and therefore the efficiency of these equipments reduces with age. In the absence of no alternative, these output standards are sometimes use in estimating project cost.

In the 1975 work study was conducted in Ghana on the basic equipments for road construction. The results of that study have since been used for estimating cost of road projects in Ghana. The use of this information in recent time's impact significantly on the accuracy of road cost estimates in Ghana. This is due to the fact that improvement in technology in recent times has significantly improved the efficiency of the constructional plant and equipments. It is therefore expected that the output standards of these plant and equipments will increase when compared with the output standards from the 1975 studies. Furthermore, the improvement in the fuel usage of these pieces of equipment will improve with the technological advancement. In developing economics most contractors owned used equipments from the developed economies. This is due to their low turnover which does not permit them to acquire new pieces of equipment. Again, these contractors find it difficult to obtain loans from the banks for their business. The use of output standards from either the manufacturers manual or the data from 1975 studies do not depict the present conditions of the equipments that are use in the road sector of Ghana. Most of the equipment existing in 1975 when the study was conducted has been taken out from production. It means basis of the data in 1975 have been changed since equipment with different technology is being use in recent times for road construction in Ghana. These differences are some of factors that contribute to inaccurate cost estimates in Ghana. It should however be noted that there are other factors such as error in design, estimator behaviour etc. also causes inaccurate estimates on projects. Figure 1 shows the behaviour of the cost estimate as the result of the differences in the data as against the actual that the equipment produces at the project site.

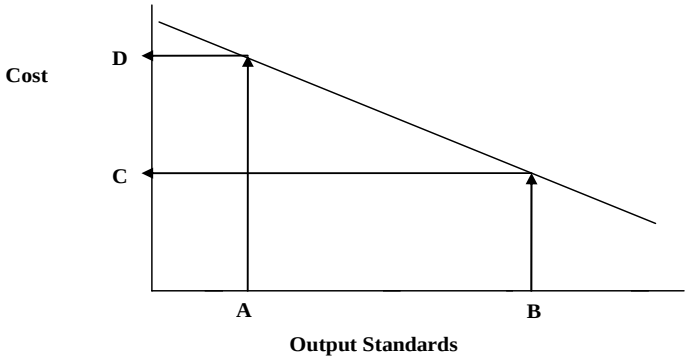

Figure 1: Cost versus Output Standards in Road Sector of Ghana

From Figure 1, output standard B produces cost estimate C, whiles output standard A produces cost estimate D. Figure 1 shows the real situation in Ghana. Efficiency of the equipment improves with technological advancement. Logically therefore, cost estimates should be lower with the use of more efficient equipment than lesser efficient equipment. From Figure 1 output standard A represents the data form 1975 studies and B represent data from advance technology. Output standard A produce cost estimate D which is higher than cost estimate C produce from output standard B assuming all other factors are the same. If this is the case, then the cost estimates on road projects can be said to be on the higher side in Ghana. However, cost overruns are still being experienced on most road projects. The overruns are the result of inadequacies in the original estimate. These inadequacies in the original

estimate apart from the differences in the output standards as explained above can also be due to other factors such as error in design and estimator behaviour among others. This paper is concern about how estimator behaviour in decision making orientations could lead to differences in cost estimates on the same project and how range estimating can be use to address these shortcomings in cost estimating in Ghana.

2.1.2 Material cost

The material cost is the cost the contractor will pay for the material and does not include any mark up for handling by the contractor. At the job site, fright is however included in the material cost. Cost of materials is obtained from market surveys. This cost is readily available and reflects the true prices that pertain in the open market at any given time. Also, the quantity standards for materials are computed for each work activity. Cost of material component in any activity is therefore obtained with accuracy. The arbitrary increase in cost of material in the open market is however the source of worry to contractors. These increase are however, compensated with an adjustment to the cost of the material by the use of Price Adjustment Factors.

2.1.3 Labour cost

In developed economies publications are` made that provide the labour hours required for a task. In some instances however, adequate experience may give the estimator more accurate base for determining labour hours required for an activity. In Ghana, labour hours required for an activity in the road sector are obtained from the publication as the result of a study conducted in 1975. This publication has two important factors that will affect the accuracy of cost estimates. First, the data is based on national average hence the cost obtain from such a publication will not reflect the real situation of the project. This is where the decision orientation of the estimator will have an influence on the assumptions should the estimator decides to use data different from the publication which is deemed by the estimator to be more accurate. Secondly, in recent times, the technological advancement in the areas of health and construction methods will produce labour hours that will vary from the 1975 studies for any activity. The effects of these factors are exhibited in the final cost of the project. To address this problem, a range has to be determined where estimates could be said to be reasonably accurate. This therefore calls for range estimating in the road sector for budgeting and comparing the estimates produce by the estimators.

2.1.4 Subcontractor quotations

In the road sector of Ghana, subcontractors are either nominated or domestic. In the public sector, the estimator relies on the quotations from subcontractors in specialised works like pilling and in relocation of services among others. In some instances, contractors' estimators rely on subcontractors quotations for items of work which they intend to subcontract. In both cases, the quotation of the subcontractor contains labour, material, equipment and tools, indirect cost and profit.

2.2 Indirect Cost

Indirect cost consists of cost of labour, material equipment and tools items required to support the whole project. Thus, indirect cost could be classified as indirect cost to the client and indirect cost to the contractor. In any case, it is the client who will pay all indirect costs since the contractor will spread its indirect cost on the total estimate for the project. In preparing engineer's estimate in the public sector, provisions are made for indirect cost to cover both the cost to the client and the contractor due to the reasons discussed above. Indirect cost to the client consists of land acquisition cost, legal fees, administration costs, and sometimes design fees. In major projects, design fees are separated from the project estimate. In that case, the indirect cost will not include the design fees. In Ghana, indirect cost is either price separately as a bill item or incorporated in the unit rates as a percentage. Usually, fifteen (15) percent is provided on the unit rates for indirect cost. This figure was based on the 1975 studies. This figure might not be realistic in these recent times. Again in determining the indirect cost, the estimator's decision making orientation influences the judgement the estimator makes. This explains why indirect

cost differ from estimator to estimator on the same project hence differences in the cost estimate of the same project both estimators produce. Managers and decision makers should therefore have a range within which cost is acceptable due to this human element. This again calls for range estimating in the road sector to guide managers in comparing cost estimates and to address the problems associated to estimator behaviour in decision making orientation.

2.3 Profit

Profit is allowed as a percentage on the unit rates of the work activities. In the public sector of Ghana, ten (10) percent is usually allowed on the unit rate for profit. This percentage if based on 1975's studies which again might not be relevant in recent times.

3. Workload to Staff Ratio in Road Sector of Ghana

The estimating procedure in the road sector of Ghana requires reasonable number of experienced estimators. However the sector lacks adequate number of estimators. Table 1 shows the number of estimators and the average number of projects that estimates are prepare per year in the various Agencies.

Table 1: Estimating Load to Staff Ratio in Road Sector of Ghana

No.	Name of Agency	No. of Estimators	Average No. of Projects per year	Estimating load to staff ratio
1	Ghana Highway Authority	9	180	20
2	Department of Urban Roads	6	300	50
3	Department of Feeder Roads	3	550	183.33
	Total	18	1030	57.2

(Source: GHA, DUR, and DFR of Ghana)

Table 1 shows that on average estimators prepare cost estimates on 57.2 projects in a year. This implies that estimates are prepared on 4.8 projects in a month by each estimator in the road sector of Ghana. The implication of this is excessive workload on the estimator. This type of condition in the work environment will influence the estimators' behaviour in the level of details that is assess before making a decision and thus have negative impact on the accuracy of estimates. The work environment with inadequate number of estimators causes stress on the estimators. The earlier researchers concur to this assessment. For example, Mei-Yung *et al*., (2005) researched into factors that affect accuracy of cost estimates and concluded that stress on estimators' impact negatively on the accuracy of cost estimates. The researcher identified that some of the critical stressors such as excessive workload, role conflict, job ambiguity, and work environment among others have influence on the decisions of the estimator. An estimator who is stressful due to workload will not be analytical in performing its duties. The decisions that such estimator takes are not based on detail assessment of the information due to high workload. This situation affects the estimators' ability in making sound and logical judgement. The estimator has very little time in analyzing information .thoroughly before making decisions under such work environment. Therefore, the behaviour of the estimator in the road sector of Ghana is greatly influenced by stressors identified by Mei-Yung *et al*., (2005). The resultant effect is cost overruns experienced on most road projects in Ghana. It should however be noted that stressors identified by Mei-Yung *et al*., (2005) are some of the many factors that impact negatively on the accuracy of cost estimates.

4. The Way Forward

A project estimate is an estimate on future event. In other words, it is an informed assessment of the likely cost of the project. The word likely means there are a number of probable outcomes that could be derived depending on how the uncertainties that are inherent on the project are assessed. A decision maker must estimate the probable outcomes of his actions in terms of future events and make his decisions based on these estimates. Thus, estimating procedures may be subjective such as the manager evaluating his control measures for future period, designing operation system or through the use of quantitative techniques. In both cases, the accuracy of the estimator's decision in the operational environment would have direct effect on the estimate that would be produced. This position was emphasised by Adams and Swanson (1976), and Archilbald and Villoria (1967). Abernathy, (1971) conducted investigations and concluded that estimates improves as the estimator gains experience. The estimators' ability in assessing risk therefore influences the estimates. Some estimators are risk prone and other risk averse. These personal characteristics of estimators account for the differences in estimates that two estimators produce with the same data in the same work environment. Figure 2 illustrates the single estimates produce by the two estimators for a project.

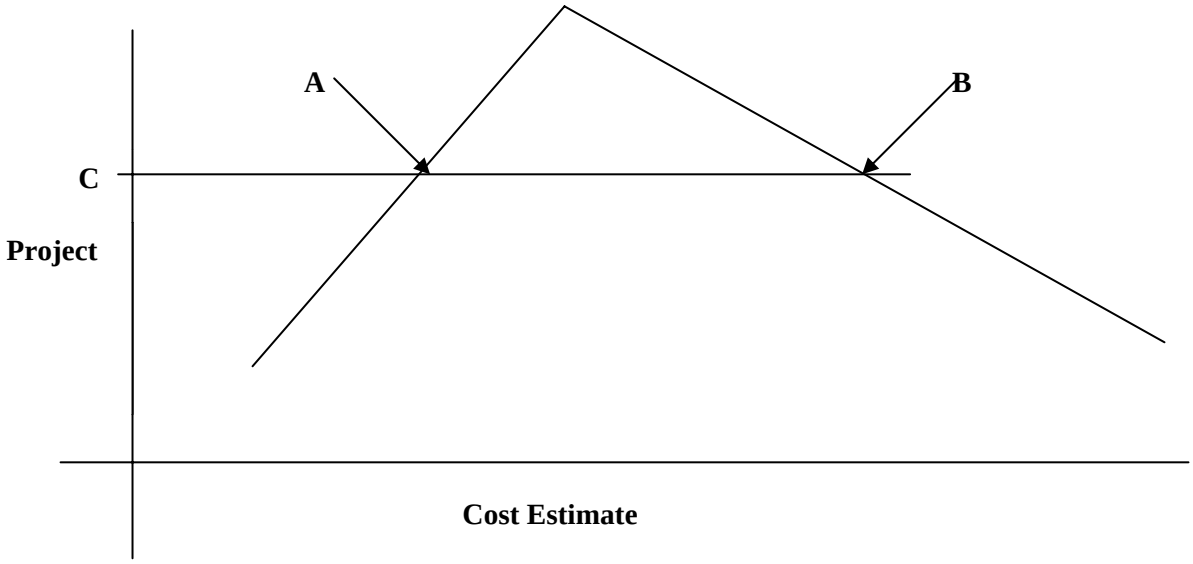

Figure 2: Single Estimate by two Estimators

Figure 2 is a typical graph showing how the factors within the control of the estimator significantly affect the accuracy of estimates. This situation depicts the situation that exists in the construction industry hence the deductions from Figure 2 can be apply in addressing cost estimating problems in Ghana. From Figure 2, one estimator produce estimate **A** and the other produce estimate **B** on the same project. Both estimate **A** and **B** are equally likely. However, there is far grater chance that **A** will be exceeded due to the fact that very little time is use in analysing information before taking decision. Estimate **B** on the other hand has grater chance of being overestimated again due to the decision making orientation of the estimator. The issue is which of the two estimates can be said to be an accurate estimate for the project C. It is logical that the mean of the two estimates could be said to be best estimate for project C. The boundary from **A** to **B** therefore constitutes a range within which the estimate is deemed accurate. This is where range estimating is vital to both the estimator and the project manager. This type of estimating is useful for managers in taking decisions on the reasonableness of estimate produce by estimators. It also serves as a guide to estimators and practitioners in the construction industry.

Range estimating has been the focus of most researchers and authors in recent times. Different tools have been used in range estimation. The most common is Monte Carlo simulation. Monte Carlo simulation has

gain increasing popularity in addressing uncertainty and risk in construction. Some of the researchers and authors that apply Monte Carlo simulation in addressing uncertainty and risk in construction management include Touran and Lopez (2006), Shen and Wu (2005), Liu and Frangopol (2005), Tung (2008), and Ahmed *et al*., (2007). In Ghana, data on previous projects is not readily available. Furthermore, the studies done in 1975 which form the basis of quantity standards in estimating do not depict the present day situation due to advancement in technology. Assumptions made therefore depend on the individual estimator's personal characteristic in assessing risk. With the presence of these uncertainties, it is difficult for two estimators to give definite estimate on a project since each estimator has their own beliefs on the estimate. To address these problem, Monte Carlo simulation could be use to model these uncertainties to produce a range of possible outcomes.

In Monte Carlo simulation, the total project cost is the sum of several random variables. Variability of a limited number of components contributes to the total cost variability (Curran, 1989). Most of the cost variation in road sector of Ghana is due to variability of limited number of components. These components are put together as contingencies on the project. The amount allowed for these components in cost estimates depends on the estimator's decision making orientation with respect to the uncertainties on the project. Assume contingency allowed on the project is represented by variable A then by applying Monte Carlo simulation, the final cost of the project will be the sum of several random variables and the fixed cost. This is presented mathematically in Eqn. (1).

$$CT = CF + \sum_{1}^{n} A \qquad (1)$$

The previous section elaborated on the type of data available in the road sector and its effect on the accuracy of cost estimates. An allowance is therefore made in the estimate to accommodate this effect and other uncertainties discussed in the earlier sections that influence negatively on the accuracy of estimates. The basis of the amount allowed for the contingency again depends on the experience of the estimator but not on any scientific basis. By the use of Monte Carlo simulation, 1000's of Eqn. (1) will be generated for each value of CT to form a distribution upon which a range of possible values of CT will be determine. The practical demonstration of the use of Monte Carlo simulation for range estimating using data from real completed projects in the road sector of Ghana will be discuss in detail in another paper as part of wider research project in improving estimating accuracy in the road sector of Ghana.

5. Recommendation and Conclusion

The paper reveals that high estimating load to staff ratio exist in the road sector of Ghana. The relevance of the data used in estimating road projects in Ghana in these present times with the advancement in technology has been emphasised in the paper with its negative impact on the accuracy of estimates. Also very important is the decision making orientations of the estimators with respect to the uncertainties on the project and their impact on the accuracy of estimates has been addressed within the paper. The estimates produce for the same data by risk prone estimator differ from that of risk adverse estimator. The estimate of risk prone estimator is highly likely to be exceeded due to the fact that detail analysis of information is not done and risk adverse estimator takes long time in analysing details and hence the relevance of the estimate will be loss due to time. The estimate that lies within the boundary of the two estimates is therefore ideal.

This is where Monte Carlo estimating has found useful for the establishment of range of estimates in the road sector of Ghana. The range estimating will be very beneficial for estimators, project managers and other practitioners in the industry. The lessons leant in Ghana could be utilise in any developing economy since literature has reveal that the factors of inadequate estimating are similar in all developing economies.

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