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# Effects of Indequate Design by Specialist Consultants in Construction Projects

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**Abstract:** Inadequate design by specialist consultants can cause differences to the initial contract sums of proposed projects. This study presents a review of the effects on Initial Contract Sums of variations caused by specialist consultants and the Adjustment of Prime cost sums. Adequacy of design could be affected by deficiencies in detailing, specification, legislation and building of drawings and inaccuracies in the build-up of Prime cost sums prepared for the Bills of Quantities. Five completed projects in a selected domain of projects and analysed in order to illustrate the effects of inadequate specialist consultants' Designs on the Initial contract sums of construction projects. Differences to the initial contract sums were encountered on all the five projects, ranging from 3.36-43.40%. It is recommended that clients should present their brief in details and specialist consultants should spend time, with forethought in the preparation of contract documents.

**Key words:** Inadequate design, specialist consultants, initial contract sums, variations, prime cost sums

## INTRODUCTION

The specialist consultants undertake design for specialist components of the building project such as engineering installations. The designs for these specialist components are prepared separately from the design of the main building; which is usually undertaken by the architect. The adequacy of such design would be reflected in the variation between the original cost of the specialist components envisaged and the final cost of the components as installed in the building.

This study investigates the causes of inadequate design by specialist consultants in construction projects and assesses the magnitudes of financial consequences of such design inadequacies. A selected domain of projects is utilized as a case study to illustrate the behaviuor of the risk factor of inadequate design by specialist consultants.

**Aim:** The aim of the study is to examine the effect of inadequate design by specialists consultants.

**Objectives:**

- To articulate from literature relevant information to the area of study.
- To establish the effect of variations due to inadequate specialist consultants design on construction projects.
- To establish the effect of adjustments to Prime Cost sums (PC sums) due to inadequate design details.

Design in its broadest definition is the meaningful and imaginative allocation of physical processes (Worthington, 1994). The role of the designer is to understand the client's needs and expectations and match these to the most appropriate design solutions. 'Design' is also taken to embrace obtaining any outstanding planning permission, specifying and such interlocking activities (Turner, 1995).

The contract conditions preempt the occurrence of shortcomings in the design and offers options to provide appropriate solutions should such shortcomings occur. Clause 1(2) of the JCT 1963 edition requires the contractor to notify the architect if he finds any discrepancy in or divergence between parts of any one of the following documents or between documents of the same description, namely:

- The contract drawings
- The contract bills
- Any instruction issued by the architect under these conditions.
- Any drawings or documents issued by the architect under clauses 3(3), 3(4) and 5 of the conditions.

Clause 12 (2) states that any error in description or quantity or omission of items from the contract bills shall not vitiate this contract but shall be corrected and deemed to be a variation required by the architect.

Clause 11(4) requires that all variations required by the architect shall be measured and valued by the quantity surveyor and clause 11(5) stipulates that effect

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shall be given to the measurement and valuations of variations in interim certificates and by the adjustment of the contract sum.

Thus clause 1(2) identifies the likelihood of the occurrence of errors in the contract documents and clause 12(2) verifies that errors in contract bills shall be corrected and deemed to be a variation requested by the architect whilst clause 11(4) provides for the payment of sum variations and the consequent adjustment of the contract sum. In addition, clause 11(6) provides that any loss or expense incurred by the contractor as a result of variations raised by the architect shall be compensated for or reimbursed to the contractor. It is pertinent to note that instructions emanating from design consultants such as the structural Engineer, the Mechanical Engineer, the Electrical Engineer must routed through the architect to the contractor and therefore, they are in effect; architects' instructions. Those architect instructions that seek to rectify design errors could be broadly categorized as consultants' instructions.

Discrepancies could occur between documents in the provision of design details. For example; wrong size of beams could be shown on the architect's drawings.

Discrepancies between documents could be corrected by either amending the documents in which case there would be no claim or if the documents containing the discrepancies are to stand then the bill of quantities will require amendment by evaluating the difference and adjusting the contract sum accordingly.

Hughes (1981) mentioned that errors in the bill of quantities are of four kinds.

The errors in contract documents could be attributed to improper design. Thus improper design is a source of risk. Cooper *et al.* (1985) have pointed out that this risk arises as a result of inadequacies in the design, which could lead to shortcomings in the project output. The result of improper design is that once construction is underway, variations involving substitution, omission or additional work might be necessary in order to rectify the shortcomings. Thus improper design is a source of risk, which could lead to variations involving substitution, omission, or additional works.

## ANALYSIS OF VARIATIONS

Having deduced that variations could be consequences of the risk of improper design, the next important step is to assess the possibility of the occurrence of such events in a project being executed under the JCT 1963 edition standard form of building contract.

Variation involving substitution could arise when an item of work is redesigned as a result of error on the part of the design consultant; or when alternative materials are ordered to be used as a result of non-availability of the initial option.

Similarly, variation orders involving omissions could be given by consultants to effect the removal of an item from the works.

The occurrence of design errors that could warrant substitution of works by consultants would not be so substantial as to cause some significant effect on the contract sum. This is because consultants have an expressed and an implied professional duty of care to their clients. Where a consultant gives incorrect advice, they may be sued for damages under the tort of negligence. Claims arising as a result of improper measurement rarely arise in building construction (Hughes, 1981). Hence, the effects of variations involving substitution on the contract sum could be ignored for the purpose of risk management since the effects would not have high impact even though the occurrence could be frequent (Smith *et al.*, 1999).

Similarly, the omission of works by consultants that would be so substantial as to cause some significant effect on the contract sum could lay the consultants open to charges of professional negligence. Thus, this type of variation event will not have a high impact on the contract sum even though its occurrence could be frequent. Consequently; could also be disregarded in the evaluation of risks that are significant. Jaafari and Schub (1990) have challenged the commonly held view that design omissions and errors are the primary cause of disturbances in projects' performance.

Additional works that are directly attributable to consultants will arise as a result of incomplete design scope. Drawing; ideally, should show the nature and scope of the work to be carried-out under the contract. They are to be detailed and comprehensive enough to assist the quantity surveyor in the preparation of the bill of quantities. They are also to assist the contractor to accurately price and carryout the works satisfactorily. These contract drawings will include the Architect's drawings, Structural and Services Engineering drawings. However, architects tend not to confirm the full scope of design required before the contract is signed. This is because the variation clause permits architects to alter their decisions after the contract is signed. Consequently, estimation inadequacies could arise due to the fact that drawings might not be accurate or comprehensive enough for detailed take-off.

According to Kolawole and Adenuji (1990), a poor soil condition that goes undetected before commencement of construction is a source of risk in that it does not only affect the progress of construction work, but it might render the completed building inhabitable.

However, it devolves upon the project consultants to endeavour to ascertain underground soil conditions and consequently design the structural component of the building in order to reflect the bearing capacity of the soil. Where this is not done, this type of situation, which connotes improper design, could give rise to an unstable building.

Another source of additional works is unforeseen site conditions. As Halligan *et al.* (1987) have noted, contractors routinely encounter unexpected geologic and structural conditions during the course of construction. For instance, the actual location and quantity of ground water and other geologic features; as well as conditions of existing utilities, are frequently unforeseeable and consequently, contribute to problems with project costs and schedules. Consultants might have to alter their designs in order to accommodate the unexpected site conditions that could develop. As such, unforeseen site conditions are sources of risk that could give rise to variations involving additional works.

There could be much uncertainty as to the occurrence of additional work due to unforeseen site conditions. However, the provision of reports by project consultants on the site geologic and structural conditions can serve to alert contractors to conditions about which a large degree of uncertainty exists or that may be critical to some aspect of the project.

The Aqua group (1982) set the following sequence for the development of design in order to facilitate the design process:

- Sketch plans and elevations (to a scale, say, 1:100) which, after receiving the client's approval,, are sent to all consultants who will then prepare their draft schemes.
- Whilst (1) is in progress, any services for which the architect may be responsible (e.g. plumbing, drainage, e.t.c.) must be worked-out in detail.
- Concurrently with (1) and (2) the design must be considered in detail and drafts of construction details prepared. It is important at this stage that finishes and materials should finally be decided as these can affect dimensions critical to the primary elements of the structure and subsequently the work of other consultants.
- When the consultants' drawings are accepted and not before, the assembly details, which have been drafted in outline, can be completed.
- Only now that all the detailed information has been assembled and coordinated can the final overall picture be completed with accuracy.
- Layout and site plans and sections are finally completed, incorporating information on all external services and the setting-out of the building.

The most important rule is to complete all drawings before the stage is reached when others require them. The Aqua group (1980) has also emphasized that to prepare drawings in a sequence other than that suggested above is to invite trouble in the form of a badly detailed building, constructional delays, a long list of claims for extras and finally a dissatisfied client.

According to Worthington (1994), "... spending time at the early stages of a project design identifying needs and assessing options, is time well-spent. This is a small expenditure compared with the budget at risk once contractors are on site. Changes of mind at the implementation stage can result in heavy cost penalties."

Any inadequacy or non-availability of the drawings could likely result into an ill-defined scope. Griffith (1990) has also attributed the problems to design:

- Detailing-inaccurate or inadequate detail of design concepts
- Specification-incorrectly specified or misused materials and components
- Legislation-inadequate knowledge or disregard of compulsory legislation or advisory documents.
- Buildability-lack of design empathy. Buildability is the extent to which a building design facilitates ease of construction (BCA, 2000).

Therefore, adequacy of design could be affected by deficiencies in detailing, specification, legislation and buildability.

Ideally, the architect ought to have made firm and complete decisions on the design and specifications before tenders are invited. However, architects tend to abuse the variation clause by not confirming the full scope of design required before the contract is signed (Wainwright and Wood, 1981). Consequently, incomplete design scope, errors and omissions and inadequate specifications will result.

## ANALYSIS OF PRIME COST SUMS

Prime cost sums (P.C. sums), as defined in clause A (8) of the SMM6, are sums provided in the contract bills for work to be executed by nominated sub-contractors, a statutory authority or public undertaking. The costs of materials or goods to be obtained from nominated

suppliers are also provided for by P. C. sums. The reason why P. C. sums are provided for certain works is that it is necessary to employ on the works specialists for such works as electrical installation, heating and hot water services, etc as the main contractor may not himself carry out such work efficiently. P. C. sums are also provided for the supply of certain materials like sanitary fittings, ironmongery and fittings and fixtures because their details are not considered at the early stage when tenders are being obtained.

For the purpose of inclusion in the contract bills, P. C. sums are normally obtained by approximate estimating. This may involve estimating all plant, material and labour requirements of the work item and then building up an estimate using the current labour rates and unit prices of materials. Alternatively, quotations may be requested form specialist firms if the work is of a complex nature. In the case of supply of materials, the considerations when estimating are the prices of the materials, freight charges, excise duties and insurance costs.

During the progress of the works, the nominated subcontractors and suppliers are requested by the Architect to submit the estimates or quotations for the work, which they are to undertake. These estimates, if approved by the Architect, represent the actual prime costs of the work to be undertaken and they would, therefore be set against the sums provided in the bills of quantities. The P. C. Sums in the bills are approximate sums and their adjustment to the actual costs incurred may cause a variation in the contract sum. The procedure for the adjustment of P. C. sums in accordance with clause 30 (5) (c) of the JCT form of contract involves obtaining any difference between the estimate submitted by the subcontractor and the relevant P. C. sum in the contract bills and then adding or deducting it from the contract sum. The rate of profit stated in the bills of quantities is also adjusted pro rata to the amount payable. If the amount is paid within the discount period, then 2½ % of this sum representing the cash discount would be carried to the final summary as a deduction from the contract sum in the computation of the final account.

On account of having obtained a reasonable estimate in the building-up of a P. C. sum, the subsequent subcontractor's claim may be expected to be the same as or to differ little from the P. C. sum allotted for his work. Consequently, the pro-rata adjustment of the main contractor's profit may also not vary much from the initial sum. Hence, the total of net differences should be insignificant in comparison to the contract sum.

In a typical bill of quantities, the appropriate consultants; that are the electrical engineer or the mechanical engineer as the case may be usually prepare the sections for the electrical, plumbing and mechanical installations. Where this is the case, the final values of the prime costs on adjustment usually differ little or none at all from the initial values; as the initial values are actually good estimates of the prime costs.

Where, however; the estimates are not sound; then it could be expected that the difference between the initial and final values of prime costs would be significant. This could occur if persons other than the specialist consultants prepared the estimates; as it often happens when the main bills of quantities are prepared before the specialist consultants are appointed; or when the contract is awarded before the consultants' drawings are ready. Since these services are specialist items, the specialist consultants are in the best position to prepare their estimates. Once these estimates have been prepared by persons other than specialist consultants, then it is likely that the prime costs will have to be adjusted significantly at the final account stage; in order to reflect the true status of theses values.

The basic condition that will precipitate the likelihood of significant adjustment of prime costs at the final account stage is inaccurate estimation of their prime costs. This could happen in two instances, namely:

- If the contract is awarded before specialist consultants are appointed
- The contract is awarded, the specialists consultants are appointed; but the specialist designs are not detailed or well-specified.

## PRESENTATION AND ANALYSIS OF DATA

Some 5 projects that have been executed by a particular client would be considered in order to illustrate the effects of inadequate design. The restriction to a single client would circumscribe the investigation of the effects of inadequate design by the specialist consultants to a particular domain.

Table 1 shows the percentage increases over the initial contract sums of the projects caused by inadequate specialist consultants' designs.

Each project would now be considered in detail in order to articulate the manner in which inadequate design affects the initial contract sums of projects.

Table 1: Percentage difference to the initial contract sum in project caused by inadequate specialist consultants designs

| Project | Percentage difference to the initial contract sum in project (%) |
|---|---|
| Project I | +43.40 |
| Project II | +3.36 |
| Project III | +6.61 |
| Project IV | +3.39 |
| Project V | +3.46 |

Table 2: Percentage difference to the contract sum caused by adjustment of prime cost sums in Project I

| S/No. | Description | Percentage difference over initial amount of P.C. sum in bills of quantities (%) | Percentage difference in contract sum caused by P.C. sum adjustment (%) |
|---|---|---|---|
| 1. | Electrical installations | +230 | +19.19 |
| 2. | Supply and installation of theatre seats | +370 | +22.14 |
| 3. | Supply and installation of venetian blinds | -100 | -0.37 |
| | | Net difference caused by adjustment of P.C. sums | +40.95 |

**Project I:** The largest percentage increase in the contract sum of Project I was caused by the adjustment of prime cost sums (+40.95%). The final account showed that electrical installations had increased by +230% over the original amount allocated for electrical installations in the bills of quantities (Table 2).

Electrical installations had increased by 230% over its initial amount allocated for electrical installations in the bills of quantities and this caused a 19% increase over the initial contract sum. The supply and installation of theatre seats had increased by 370% over the initial amount allocated for the job in the bills of quantities and this addition caused a 22% increase over the initial contract sum. Venetian blinds; on the other hand, were completely omitted and this resulted into a 0.37% decrease on the initial contract sum.

The increase over the initial amounts allocated in the bills of quantities appeared to be inordinate; i.e., disproportionate. For the purpose of inclusion in the bills of quantities, prime cost sums are normally obtained by approximate estimating or are derived from quotations obtained from specialist firms. On account of having obtained a reasonable estimate in the building-up of a P.C. sum, the subsequent subcontractor's claim might be expected to be the same or to differ little from the initial P.C. allocate for the work. However, in this project, the adjustment for electrical installations and the supply and installation of theatre seats had been gross (230 and 370% respectively).

This observation warrants the conclusion that the estimates for electrical installation and theatre seats had not been adequate; that was why at the final adjustment stage, the P.C. sums had reached high levels. Whilst tracing the design stage of this project, it could be observed that the design was done by an architect in the in-house section of the client organization. This architect solely designed this structure; without any significant design inputs from the services' engineers. At the time of the contract, only the architectural and structural drawings were ready. There were no mechanical and electrical drawings.

The specialized nature of the fittings and fixtures in the project required inputs at the design stage of a fittings specialist. This was not available. Consequently, the quantity surveyor was not in a good position to provide sound estimates for the P.C. sums in the bills of quantities thus it was not surprising that the P.C. sums had to be grossly adjusted in the final account of this project.

The client in this project had sought to reduce costs by avoiding the use of consultants. The client decided to use his in-house architect and engineers; some of whom were not appointed in good time. This constraint had led to incomplete design.

"Other adjustment" in the final account represented a set of items of work that were initially placed in the bills of quantities but their actual quantities varied upon completion. Subsequently, remeasurement had to be done to decide upon their actual quantities. In project I, the net effect of such remeasurements were to increase the initial contract sum by 2.45%. The item remeasured ranged from work in lintel (concrete, reinforcement and formwork) to ironmongery, plumbing and finishings. The variation in quantities could be traced to error in measurement by the quantity surveyor. Therefore, inadequate specialist consultants' design caused an increase over the initial contract sum of Project I by 43.40% (+40.95%+(+2.45%)= 43.40%).

**Project II:** The adjustment of P.C. sums in project II caused a decrease of –3.55% to the initial contract sum. If it is assumed that the consultants had verified and confirmed their designs before contract award, there ought not be any adjustment of the P. C. sum at the post-contract stage. Therefore; inadequate consultants' design had precipitated the change in P.C. sum. This had decreased the initial contract um by -3.55%.

**Project III:** In Project III, adjustment of provisional sums caused an increase of +5.75% over the initial contract sum. The sum initially inserted in the bills of quantities was supposed to cover for mechanical and plumbing work. There is a point that needs elucidation here. Was it really appropriate to use a provisional sum to cover work in mechanical and plumbing installations?

A provisional sum is supposed to be provided for costs that cannot be easily foreseen, defined or detailed at the time tendering documents are issued. Mechanical and plumbing works for this particular project could have been foreseen, defined and detailed at the time of tendering. Thus, the prime cost sum should have been used to cover for such works. The use of a provisional sum to cover for such work was inappropriate in this regard and this practice connotes inadequate consultants' design. This in fact what happened in project III. The client in project III had sought to reduce costs by avoiding the use of independent consultants. The client decided to use his in house architect and engineers.

These in-house consultants had prepared the contract documents and had allowed for the provisional sums in the bills of quantities.

During the progress of the Works, the contractor requested that the nature and scope of the mechanical and plumbing works covered by the provisional sum should be elaborated by the preparation of a detailed bills of quantities for mechanical engineering installations. The bills of quantities for the mechanical engineering installations were prepared by the consultants and were then given to the contractor to price. The contractor's submission was in fact higher than the in-house quantity surveyor's estimate. However, the quantity surveyor's estimate was chosen even though it represented an increase of 289% over the figure of the provisional sum allowed initially in the bills of quantities. The inadequacy of the initial provisional sum and the recourse to the preparation of a detailed bills of quantities for the mechanical and plumbing installations after contract award; all speak of inadequate consultants' designs. Therefore, the factor responsible for the adjustment of this 'provisional sum' is inadequate specialist consultants' design (+5.75%).

Increasing the height of columns caused an increase of 0.86% to the initial contract sum. This research developed after a site inspection revealed a discrepancy in storey heights between the architectural and structural design drawings. The architectural drawing gave a figure of 2.65m while that of the structural drawing was 3.30m. The factor for this event is inadequate specialist consultants' design. This gives the total effect of the factor of inadequate specialist consultants' design as being +6.61% (+5.75% +0.86% = +6.61%)

**Project IV:** The adjustment of P.C. sums in project IV had increased the initial contract sum by +3.39%. This increase was wholly caused by the adjustment of the P.C. sum allocated for electrical installations. If it assumed that the consultants had verified and confirmed heir designs before contract award, there ought not be any adjustment of the P.C. sum at the post contract stage. Therefore, inadequate specialist consultants' designs is indicated in this respect and it had precipitated a 3.39% increase over the initial contract sum.

**Project V:** The adjustment of prime cost sums in project V caused an increase of +3.46% to the initial contract sum. If it is assumed that the consultants had verified and confirmed their designs before contract award, there ought not be any adjustment of the prime cost sums at the post contract stage. To understand this notion further, it would be appropriate to recall what transpired during the site meeting of 30/3/94; when the electrical subcontractor had complained that the quantities in the bills of quantities were actually less than what was required in the works. This was discovered when the first hostel was constructed. At that time, the additional fixtures had to be valued and this had led to some increase over the initial prime cost sums provided in the bills of quantities. For project V, the adjustment of prime cost sums had led to a 60% increase over the initial prime cost sums provided in the bills of quantities. This kind of development typically illustrates the effects of inadequate design of work by consultants.

## CONCLUSION

Inadequate design could result into differences between initial and final contract sums of construction projects. Inadequate design could stem from deficiencies in detailing, specification, legislation and buildability of contract drawings and or inaccuracies in the build-up prime cost sums inserted in the Bills of quantities prepared at the pre-contract stage. The financial effect on the initial contract sums of such deficiencies in drawings and inaccuracies in the build-up of Prime Cost sums could vary; depending upon the level of inadequacy of the drawing or Prime cost sum.

## RECOMMENDATIONS

- Clients should endeavour to present their briefs to specialist consultants with finest as possible details.
- Specialist consultants should endeavour to spend time on their designs, with forethought, so that final working drawings on presented in the finest details as this will enable preparation of accurate estimates.

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