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Learning from Experience

Leçons tirées des expériences

Lernen aus Erfahrung

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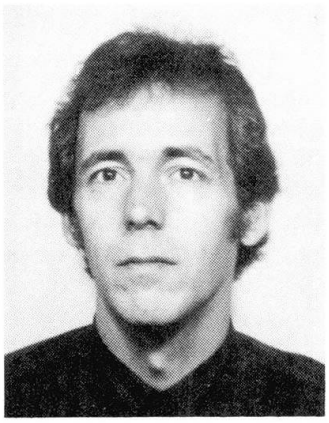

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SUMMARY

The paper offers a simple, common-sense approach to the problem of feedback from the construction phase to the design office, by making the best use of the experience gained from each project. The amendments which have to be made to each contract during its construction are seen as representing, in part, the various ways in which the original documentation has failed. By careful analysis of this «source material», recommendations for improved design procedures are sought. Also included is a review of the effects of amendments made during construction to the final cost and smooth-running of the contract.

RÉSUMÉ

L'article présente une approche simple et logique de l'actualisation de l'information – du chantier à la planche à dessin – en faisant le meilleur usage de l'expérience acquise lors de chaque projet. Les modifications apportées à chaque contrat pendant l'exécution représente différents cas où l'information originale n'était pas suffisante. L'analyse détaillée de cette «information originale» permet d'établir des recommandations pour des procédures de projet améliorées. L'article traite aussi de l'influence des modifications en cours de construction sur le coût final et sur le développement sans accroc du contrat.

ZUSAMMENFASSUNG

Dieser Beitrag zeigt einen einfachen Weg auf für den Rückfluss von Erfahrungen von der Baustelle zum Projektierungsbüro, indem die Erkenntnisse jedes einzelnen Projektes optimal ausgewertet werden. Als Basis dieser Untersuchung werden die Vertragsänderungen und -ergänzungen betrachtet, da sie als Massstab für die Unzulänglichkeiten des ursprünglichen Vertragswerkes betrachtet werden. Die sorgfältige Analyse dieser Unterlagen führt zu Empfehlungen für die Projektierung, die Kostenplanung und allgemein für einen reibungslosen Projektablauf.

1. INTRODUCTION

1.1.1 In civil engineering, site experience is considered to be an essential part of a young engineer's training and a certain amount of relevant site experience is also often seen as an essential requirement for many of the more senior posts within the industry. The engineer on site will need to know, or to find out very quickly, how the contract he is dealing with fits together and how the various documents (viz. drawings, conditions of contract, specifications, methods of measurement and bills of quantities) jointly combine to describe the works to be carried out. He will also quickly realise how difficult is the task of preparing such documents and how contracts sometimes fail to provide the necessary information.

1.1.2 As a senior engineer on the resident engineer's staff for a major roadworks contract, the author was aware of the very valuable experience he was gaining, but realised, some time later, that the knowledge acquired could have been enhanced by a more careful recording of certain aspects of his work as they arose. When the opportunity presented itself at a later stage to carry out a research project it was decided to conduct a detailed study of the amendments to this Contract, in the hope of relearning and sharing that experience. It is argued that such an analysis, if carried out in a systematic manner, has considerable value in providing feedback to future designers and recommended that some such similar study should be undertaken on each contract completed.

1.1.3 Amendments to the contract studied were made initially by site instructions written by the resident engineer and his staff (many written by the author) and followed up where required by variation orders. The site instructions were thus seen as a record of some of the principal ways in which the original contract documents had failed to provide the necessary information to complete the works. It must be stated that a large number of these instructions were unavoidable, as they related to instances which could not possibly have been foreseen at the design stage. Accepting this fact, the analysis therefore concentrated on those amendments resulting from errors or lack of insight in the original documents, in an attempt to find common faults/failings in the current methods of design and contract preparation employed in the design office.

2. THE EFFECT OF AMENDMENTS ON CONTRACT COMPLETION AND COST.

2.1.1 As the aim of this paper is to reduce the number of amendments which will be needed on future contracts, by virtue of the enhanced feedback obtained from previous work, it is considered useful here to analyse some of the problems which arise as a result of these amendments.

2.1.2 The normal process for making an amendment to a contract under the I.C.E. Conditions of Contract (5th edition)[1] requires the Engineer to issue a variation order fully detailing the extent of the change, together with its financial implications. A number of difficulties exist with this system, not least of which is the process by which revised costs are determined, for which the Engineer has a duty to consult with the Contractor (Cl.52(1)). In practice such problems are often overcome by the Engineer or his representative on site issuing a verbal instruction, followed up by a written 'site instruction' detailing the method by which the difficulty is to be surmounted and the method of payment to be employed. This permits the Contractor to get on with the job with minimum delay and with written instructions, the full implications of which can be analysed at a later stage. If the change requires a variation order to be issued this should be done as soon as possible after the instruction has been written.

2.1.3 The full implications of any change in the original contract are not always easily recognised at the time the change is made, and the effects on the eventual cost of the Works to the Employer may be considerable. Some of the most important of these effects are now discussed under the following sub-headings :

- Direct cost implications
- The problem of delay
- Relationships between Contractor and Engineer
- The cumulative effect of amendments

2.2 Direct cost implications

2.2.1 The method of pricing contracts using a bill of quantities is intended to provide the Engineer with a sound basis for calculating rates for additional work which are in line with the general level of rates used in the main contract. Indeed, this is often seen as one of the main reasons for selecting this particular method. There are, however, difficulties in this system which can lead to higher costs being incurred by the Employer.

2.2.2 Rates included in the bill of quantities which do not properly reflect the work content of the item being priced - this can occur if the Contractor has 'loaded' a rate which he considers has been undermeasured, or where he can foresee that further quantities are likely to be required. The effect of such loadings might be expected to balance out, since if some items are overpriced then presumably others will have been underpriced. Except in cases where rates are obviously loaded, the Engineer is unlikely to know that the rate does not properly relate to the particular item concerned. Thus, when additional quantities of an item are required where the rate is favourable to the Contractor, he will be quite willing to accept the new work at this rate. On the other hand, if the rate is unfavourable, the Contractor is much more likely to look for additional reasons why the particular rate does not apply and to demand that a new rate be calculated.

2.2.3 Where no similar rate in the bill of quantities can be found - in this case, the Engineer or his representative must either order the work to be carried out on a dayworks basis or calculate a new rate for the additional work:

- Dayworks - these rates are often higher than the going 'market rate' and are generally only appropriate to short-term hire situations, where even the best supervision can involve the Employer having to pay for the Contractor's mistakes.
- Calculating a new rate - this should be done on the basis of rate build-ups used in the original contract, but the Contractor is often loath to provide such information as it is the basis of his pricing system and in the wrong hands, i.e. those of a competitor, could be used against him in later competitive tenders. Under present conditions these build-ups may also indicate the low profit margins which the Contractor has had to employ in order to win the contract.

2.2.4 It would seem then that the Employer will often have to pay more for varied work than he would have paid for the same work in a competitive tender situation.

2.3 The Problem of Delay

2.3.1 "The overall effect of any but the smallest amount of daywork will be to disrupt smooth planning and progress of the works and to delay that part of the work affected. Any overall delay effect on the contract completion can only be assessed in relation to the particular circumstances.
....Whatever the detailed examination of the position shows there will always be a general effect due to the diversion of labour and plant from the programmed work"

This extract from "Building and Engineering Claims" by Major and Ranson [3] gives some indication of the consequences which can result from delays caused by additional work. It is perhaps the most serious and costly of all such problems.

2.3.2 Delays can be considered under two distinct headings :

- Delays which affect one part of the works only and have no 'knock-on' effect on the contract completion date.
- Delays to activities on the critical path which may require an extension of the original contract.

2.3.3 In practice, the problem is not so simple. Delays from different sources exist simultaneously, critical paths in the contractor's programme will change as the work progresses and the difficulty of assessing who is liable and for exactly how much can be considerable.

2.4 Relationships between Contractor and Engineer

2.4.1 The difficult financial climate which currently prevails in the construction industry, where work is short and money is tight, has led many to suggest that contracts are being won by contractors submitting lower and lower tenders, squeezing their profit margins to the limit in order to secure future workload. In an article by Gosney [4] two views of the problem of controlling a contract with low profit margins are stated. The first of these is by Oleg Kerensky, of Freeman Fox and Partners :

> "The job is done in an inefficient manner, claims are formulated and the contractor exercises his prerogative to the maximum to obtain money from the client when a mistake is found or anything is changed."

... and the second by a spokesman for the Federation of Civil Engineering Contractors :

> "When money is tight, the client is less likely to say that you have done a good job and we are aware of your problems - there is a definite lack of enthusiasm to make 'ex-gratia' payments."

2.4.2 If variations could be priced and agreed before the work is carried out this would go a long way towards easing the situation. It is, however, exactly in these instances where the viewpoints of the engineer and contractor are polarised to such an extent that early negotiations and subsequent agreements are unlikely to occur.

2.4.3 It seems then, that when survival is at stake, aggression comes to the fore and relationships between agents and resident engineers will deteriorate, resulting in a good deal of misdirected effort which can only have a detrimental effect on the job as a whole.

2.5 The Cumulative Effect of Amendments

2.5.1 If the variations to a contract are so numerous or complex that the general site productivity and efficiency suffers, then a contractor's inability to perform to his original programme might justly be laid at the employer's door. Even where this is not a true reflection of the facts, the contractor's agent is likely to exploit such a situation to explain away his own inefficiencies in any dialogue with his Head Office, and this will only result in increased friction between engineer and contractor.

2.5.2 The question eventually arises as to the position where the cumulative effect of a number of instructions is so drastic as to change the basis of the contract. It is suggested, however, that in view of the detailed provisions for dealing with variations incorporated in the contract forms, the changes would have to be of a very substantial nature to establish the contention of a revised basis.

2.5.3 It is fairly clear then, that any reduction in the number of site instructions/V.O's issued is going to be of benefit and will certainly make for better relations between the contractor's agent and the engineer's representative on site. The agent who is continually having to reprogramme his works due to a steady flow of amendments, some of which could have been avoided, is likely to have a less tolerant approach in his negotiations with the engineer's representative.

3. SCOPE AND LIMITATIONS

3.1.1 The detailed knowledge required of individual site instructions and the background leading up to them being written, has meant that it has only been possible to analyse the one contract. Indeed, it is suggested that the kind of study undertaken here could only sensibly be conducted by an engineer who has been intimately involved with the contract throughout its entire duration. On other contracts, such studies might possibly be carried out alongside the 'as-built' records by an engineer who retains responsibility for the contract during the maintenance period. Alternatively, some classification could be undertaken as the works progress.

3.1.2 The approach is thus totally retrospective, and as such has the advantage of analysing problems which in hindsight may sometimes appear obvious, and their elimination or diminution at the contract preparation stage a simple matter. It should be acknowledged, however, that the difficulties involved in preparing documents for a large road works contract are considerable, and the sudden rush to produce these documents which so often happens just before a contract goes out to tender, may make picking up mistakes or rectifying errors a secondary goal. If particular areas which lead to these 'errors' can be pinpointed and checking concentrated on them, it is hoped that fewer 'latent variations' will slip through the net in future contracts.

3.1.3 The remaining sections of the paper cover the particular contract studied, the method of analysis adopted and the lessons learnt from this contract. It is clear that anything deduced from such an exercise will be, in part, specific to the particular contract studied and to the particular design organisation concerned, but it is hoped that some of the insight gained will be of a more general use to those engineers' departments and consultants carrying out a similar type of work. The main aim is to illustrate the procedure adopted and to recommend such a procedure as a means of optimising the experience from each contract undertaken.

4. THE CONTRACT STUDIED

4.1.1 The contract consisted of 8 kilometres of dual carriageway constructed as a by-pass, with three interchanges and four side-roads diverted across the new road. Seven bridges, a box-section underpass and a number of culverts were also included but the study encompassed only those instructions relating to roadworks and not to structures.

4.1.2 Main roadworks quantities :

Total excavation	:	870,000 m^3
Imported fill	:	165,000 m^3
Total length of drainage	:	30,000 lin m
Sub-base	:	150,000 tonnes
Road base	:	92,000 tonnes
Flexible surfacing	:	55,000 tonnes

5. METHOD OF ANALYSIS

5.1.1 Each site instruction was classified under two distinct headings :

- By MMRBW (Method of Measurement for Road and Bridge Works)[5] section
- Within one of the following categories :-
  (a) Error in contract documents
  (b) Could have been foreseen - instructions falling within this group range from those where a greater insight could have avoided any instruction/variation, to instructions where a more detailed study might have lessened the impact of any amendment.
  (c) Could not have been foreseen.

5.1.2 Certain instructions did not fit easily into any of the MMRBW sections and these were listed under a 'GENERAL' category (as indicated in fig. 2).

5.1.3 By considering the instructions, initially under MMRBW section and within each of these sections, separating out those due to errors, those which could have been foreseen and those which could not have been foreseen, it was possible to determine instances where the same kinds of problems were being repeated. The general 'findings' detailed in the next section were thus derived from this procedure (see fig. 1).

6. LESSONS LEARNT

6.1.1 This section contains the main conclusions/findings of this particular study and is sub-divided into two categories :

- General - includes suggestions which do not relate to any one particular section of MMRBW but which have arisen from problems usually found in more than one of these sections and which are considered to have a general bearing on contract preparation.
- Specific - problems which are clearly specific to one MMRBW section and which have arisen sufficiently often to make their inclusion, hopefully, of some value.

6.2 General

6.2.1 It is common when producing drawings for a large roadworks contract to produce separate drawings for main line, interchanges and side-roads, and, because of the large amount of information to be presented, a number of copies of each stretch of main line, or

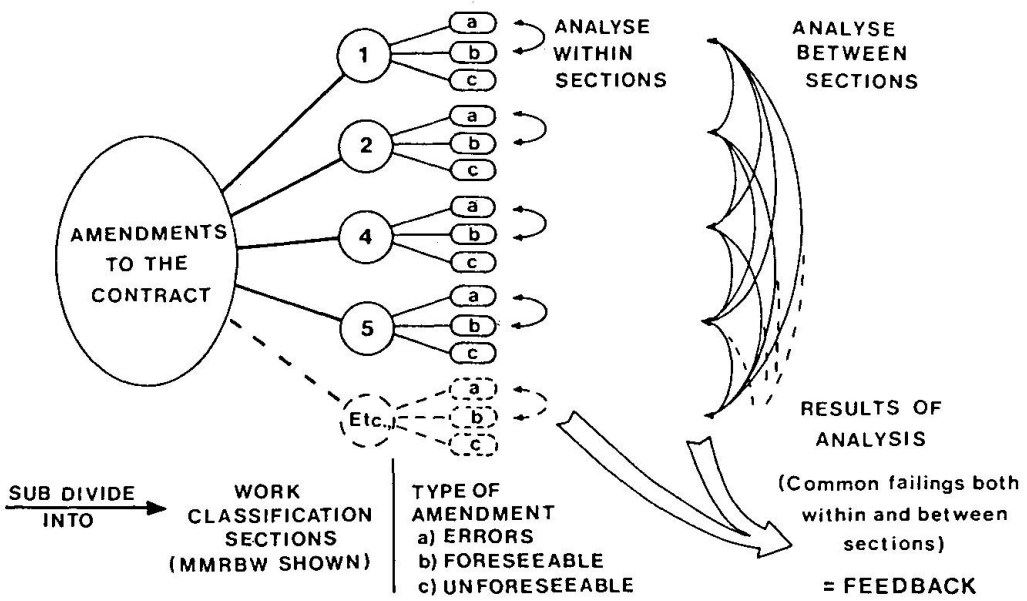

Fig. 1 Diagram Illustrating Method of Analysis

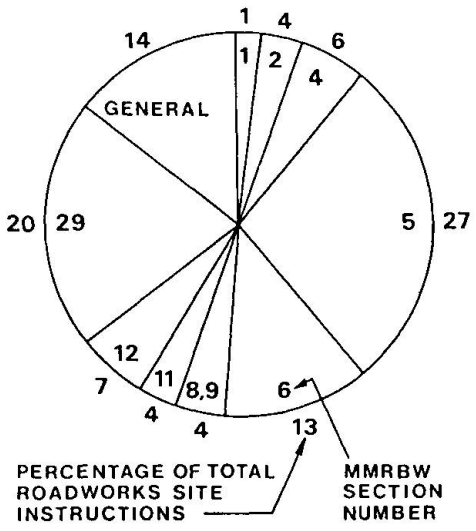

Fig. 2 Distribution of Site Instructions

interchange/side-road may be used to separately illustrate the following aspects :

- main layout including drainage and general roadworks
- site clearance and land availability
- setting out details
- signs and roadmarkings
- statutory undertakers plant and diversions.

There will also usually be separate drawings produced for :

- typical construction details
- longitudinal sections
- cross-sections
- headwall details
- structures

Checking of drawings is usually carried out by studying each completed drawing as it is produced, to ensure that all the details shown are correct. A number of the amendments on the contract studied arose from discrepancies either between drawings showing adjacent lengths of road or between drawings detailing different aspects of the work. If such amendments are to be avoided, a secondary check for continuity is recommended.

6.2.2 Tie-ins, particularly of side-road diversions to existing carriageways, contributed considerably to the number of site instructions issued. It is considered that this may be due to the finer level of detail which has to be dealt with in order to properly provide the necessary information for these areas. An engineer who has been working on the design of a section of main-line roadworks is relying on typical construction drawings to provide much of the detail which needs to be specified, whereas at tie-ins, typical details tend to be of little value and each aspect of the road cross-section needs to be considered to ensure that a sensible solution is obtained. It could be argued that side-roads should be designed by a separate team from those involved with the main-line, or at least that one engineer be made responsible for checking all tie-ins.

6.2.3 It is normal practice when accepting a contractor's alternative to include within the letter of acceptance some phrase such as 'subject to no additional cost to the employer.' This is clearly a sensible procedure, for it has already been mentioned that the full effects of any change are not always properly understood at the time the change is made. However, it is possible that the change which the contractor wishes to make might reduce the cost of other parts of the works to the employer and, where these can be foreseen, it is suggested that the letter of acceptance should make it clear who is to benefit from this.

Example :The contractor had made arrangements with a landowner to tip spoil on a section of land adjacent to a new side road embankment and requested that he be allowed to fill up against the new batters. It was possible to delete from the contract a considerable length of french drain as a result of this work and the contractor at a later stage claimed some benefit from this.

Whether the claim was valid or not, it could have been 'nipped in the bud' by covering it in the original agreement.

6.2.4 The wording of site instructions/variation orders can be very important and it is recommended that all such documents should be written so as to be clearly understood by any person, even though he may never have seen the site or been at all involved with it. Sketch plans are very helpful here.

Example :The words 'resite' or 're-erect' were used on a number of instructions to direct the contractor that he should not position signs as shown on the original drawings but as detailed within the instruction. In negotiations with the contractor's quantity surveyor at a much later stage, claims were made for the additional cost of taking the signs down and re-erecting them.

Clearly the contractor's quantity surveyor was merely wanting to ensure that any additional works were properly paid for and, in instances where both parties agree that work was carried out but no records are available, it is sensible to agree a reasonable cost. The engineer must, however, be careful. The author's experience of receiving fully detailed records of men, plant and materials for work which although instructed, had not yet been carried out underlines this fact.

6.2.5 Drainage, service ducts and statutory undertakers plant and diversions consist of complex networks within the area of the new works and great care is needed if all are to be accommodated acceptably within the limited space available. Although this is generally well understood, a number of cases still occurred where drainage lines or service ducts were to be laid at the same level as existing/diverted services at intersections.

6.3 Specific

6.3.1 Drainage

- Invert levels and drain and manhole/catchpit types are often quoted both on drawings and within drainage schedules, and these two sets of information must be consistent if difficulties are to be avoided.
- A decision not to provide drainage in a marginal area may reduce the tender price for the works, but can cause considerable headaches if it is found to be necessary at a late stage in the construction of the contract.
- Service ducts are usually specified together with a marker block to be constructed in the roadside verge to indicate their position. However, when the ducts are actually laid, verges are unlikely to be made up, and it is important that either a temporary marker be used, or that the position of the duct laid be very carefully marked on a drawing.

6.3.2 Roadworks - The regulating and scarification of existing roads, where these are to be overlaid, is often shown in two separate ways on contract drawings (see Fig. 3):

- By a system of cross-hatching on the existing road surface to illustrate the construction required for different areas
- By use of a typical longitudinal section showing the acceptable construction materials as the new alignment falls to meet existing levels.

In general, the cross-hatching is intended to give an overall picture of the amount of this kind of work to be carried out, and the longitudinal

section depicts the actual points at which construction materials shall change. If this is the intention, then it should be clearly stated that the cross-hatching is merely an aid to measurement and that actual materials used shall be as defined by the longitudinal section. Should a tie-in have to be redesigned vertically, the hatching is of course immediately rendered invalid over the length where levels have been changed. It is normal to permit the contractor to chose from a number of alternative pavement constructions, and where all or any of these are to be permitted in overlay situations, the above mentioned details must take this into account. Notably, the cross-hatching should be specified for a particular selection and depth of construction materials.

6.3.3 Accommodation Works - The procedure for arriving at an agreed list of accommodation works for each landowner on a scheme can be a long and protracted affair. There are usually a number of parties involved (viz, design engineer, valuer, land agent and landowner) and, as the level of accommodation works can affect any compensation, there will often be a considerable amount of discussion. Typically, the design engineer puts forward an initial set of proposals which forms the basis of negotiation between the valuer and the landowner, or his agent. In formulating the original set of accommodation works, the design engineer must first consider what effect the road scheme has had on the landowner in question and try to assess the minimum amount of works which will, where possible, provide the same accesses and facilities as were enjoyed previously. Preliminary consultations with the landowner/agent may highlight points which had not been fully covered and, if accepted, these should be taken into account before the accommodation works (subject to negotiation) are determined. At this stage the design engineer's involvement is concluded and the amount of agreement which has been reached in these initial discussions will often dictate the amount of detail which can be included within the main contract. This, of course, assumes that the final negotiations between valuer and agent will not be completed before the contract is put out to tender - a situation which often occurs. The responsibility for ensuring that all points have been fully covered in these initial stages, and that the maximum amount of detail is included on the drawings (albeit provisionally), rests mainly with the design engineer, for the landowner's agent will know that anything which has been overlooked will have to be rectified later (i.e. by instruction on site). A number of such instructions were necessary on the contract studied and the recommendation contained in the N.E.D.O. report 'Efficiency in Road Construction' [6] that certain accommodation works need not be in the form of works, but could be offered as a cash payment to the landowner concerned would seem a sensible improvement.

6.3.4 Works for Statutory Bodies

- When Statutory Undertakers' equipment is diverted within the area of the roadworks, consideration should be given to the equipment which has been abandoned as a result. Old manholes, pipes and ducts may need to be broken up, removed or filled in to ensure that the new works are not adversely affected.
- The resident engineer's staff will be required to provide line and level for Statutory Undertakers diversions within the works and it is considered essential that frequent checks be made to ensure that the new service

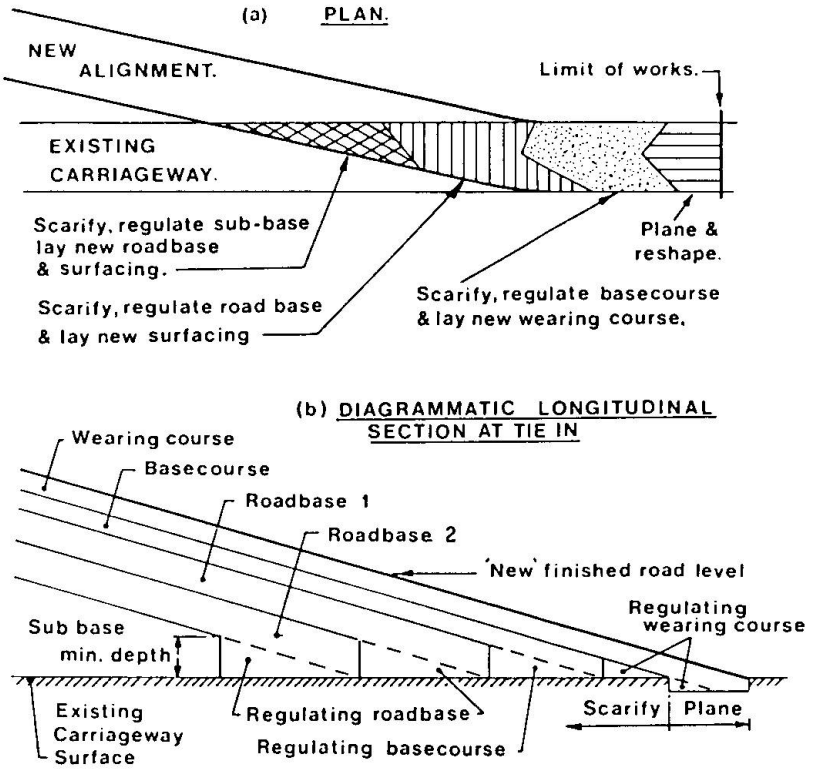

Fig. 3 Methods of Detailing Scarification & Regulating.

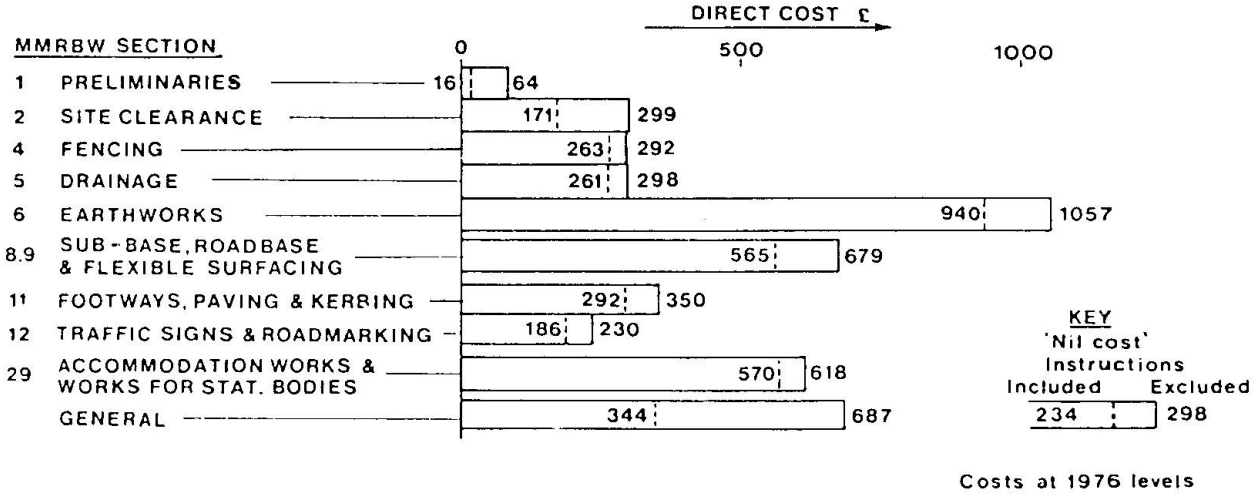

Fig. 4 Average Cost of Site Instructions.

is being properly located. Although the Statutory Undertakers are effectively working directly for the employer, the difficulty of controlling their operations is seen as cause for concern (echoed in "Efficiency in Road Construction"[6]).

7. COST IMPLICATIONS

7.1.1 Fig. 4 shows the direct cost to the employer of an average site instruction within each MMRBW section for this contract. Not all instructions involved payment to the contractor and thus the diagram shows two averages, one including instructions with nil cost and one excluding such instructions.

7.1.2 It must be stressed that these figures are direct costs and do not include any amount of delay or disruption but it is also important to note that in some instances, had the instruction been avoided and full details included within the original documents, certain elements of these costs would still have been incurred.

7.1.3 It is not intended to suggest that these figures have any meaning beyond the contract studied, but the costs were available and have been included for completeness.

8. CONCLUSIONS

8.1.1 In all practical disciplines, the need to learn from experience is an essential part of the process by which improvements are made to the quality of the end product and as we can see from chapter 2, the penalties for producing a low quality set of contract documents can be considerable. The paper recommends a procedure which, it is believed, will help to maximise the experience from each project constructed and thus provide information to enable the quality of future designs and documents to be improved. Feedback of information from the construction stage to the design stage has often been quoted as one of the important ways in which greater efficiency leading to improved 'value for money' can be achieved in civil engineering contracts. This suggestion tends to lead on to a recommendation that contractors should be more involved in the design stage of a project. Although this would clearly have certain advantages, it is believed that improved methods of feeding back information within the Engineer's organisation can also have considerable benefits. In cataloguing previous failings and making this information available to design staff (of whom some will not have done this type of work before) we will clearly make the best use of experience gained.

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