TOWARDS A METHOD OF MEASUREMENT AND COST CONTROL FOR CIVIL ENGINEERING WORK IN THE PETROCHEMICAL INDUSTRY

by

Alan James Davies

in collaboration with

Imperial Chemical Industries

A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of Doctor of Philosophy

University of Northumbria at Newcastle

August 1995

Volume 1 of 2

ACKNOWLEDGEMENTS

It would be ungracious of me not to acknowledge the supervision and forbearance of Cliff Hardcastle and Henry Brown at various stages of this work. Something of them must inevitably have rubbed off onto me. It would be equally ungracious of me to forget the organisational efforts, at the collaborating organisation, of Geoff Solomon and Norman Davies (no relation) whose work and interest in the findings of the research did them great credit. It was also a pleasure to have had the opportunity to work with, and hear the viewpoints of, the other potential users of measurement and cost control models.

I am indebted to John Lowe, my Director of Studies, for managing to guide my work to this outcome. I found his affable approach sufficiently "hands off" to encourage some thinking on my part; which I suppose was the point. I have enjoyed our association, and hope it continues. My thanks also go to Susie for not permitting me to spend our honeymoon writing up this Thesis.

ABSTRACT

This work deals with the formulation of a hypothetical measurement and cost control model for Petrochemical Civil Engineering work. The conventional model used at the collaborating organisation is the conventional general building construction measurement model, adopted without modification. Therefore there is a presumption, rather than proof, that this model is appropriate to Petrochemical Civil Engineering cost data. The lack of theoretical development in the cost modelling field give grounds to suspect that the conventional general building construction measurement and cost control model have little empirical observation to guide their formulation. Thus it will be argued that the reasons to employ any such model in preference to any other are likely to be sociological influences of peer group paradigm practice. These sociological influences have been insufficiently recognised and studied.

This thesis argues for the collection of empirical evidence upon which to build a hypothetical cost model for Petrochemical Civil Engineering work, and that this would constitute a small step towards the theoretical development of cost modelling. To this end a strategy of grounded theory is proposed, devoid of any of the "preconceived truths" characteristic of middle range theory. It shall be argued that, given the lack of strength in the theoretical component of model building epistemology, the first step should be to make the model fit the data rather than to employ a prescriptive model into whose requirements the data must be shaped (this is argued to be an undesirable characteristic of the conventional models).

For the purpose of measurement functions, statistical analyses shall identify significant and insignificant cost centres in the Petrochemical Civil Engineering cost data. A hypothetical Petrochemical Civil Engineering model shall be formulated whose parameters more closely reflect these observations. Validation of this hypothetical model shall be commenced by means of a survey of all of its potential users. The survey solicits their judgement as to whether the model is likely to achieve its objectives in practice. The reluctance of some users to believe the empirical findings will be argued to be symptomatic of the sociological basis upon which alternative cost models and techniques are frequently appraised.

Given the characteristic property of empirical models, that they yield general trends but not precisely identical outcomes, discussion shall be offered of whether truly "standard" models for costs of construction projects are either achievable or, indeed, desirable. The project costs being observed are the outcomes of actions and decisions in the social world, not the outcomes of phenomena of the physical world. Therefore it is necessary to ask whether dissimilarities are being modelled as opposed to similarities, and whether "universal" methods of measurement and cost control could ever fit any individual project to which they might be applied. It should be noted that the aim of this work is to formulate a model for a limited set of situations, not for all construction work; though there are areas of overlap between construction work types in different sectors of the industry.

A test of the hypothetical Petrochemical Civil Engineering model, in the form of a tender produced using tender documents prepared according to the parameters on the hypothetical Petrochemical Civil Engineering model will reveal favourable performance. The ensuing criticisms, by measurer and tenderer, of the hypothetical model shall be shown to be largely of a technical nature, indicating a tendency to appraise models on the basis of their internal consistency rather than on the basis of the epistemological arguments surrounding the formulation of their internal components.

For the purpose of cost analysis and planning functions, unacceptably high variability of cost behaviour shall be found using conventional Elemental cost centres. This will be argued to be inadmissible in a cost model. The need to identify more consistent and significant cost centres will be argued. A potentially useful classification of such cost centres, developed by others, shall be identified. Investigation into their applicability to Petrochemical Civil Engineering modelling shall be recommended as being worthwhile.

It shall be recommended as an area for future work that a single model, at an appropriate level of abstraction, be sought which is capable of simultaneously fulfilling the measurement and cost analysis and planning functions. The conventional measurement and cost planning models are merely differing levels of abstraction of each other, the latter being an over simplified abstraction from the over detailed former. That this abstraction is deemed to necessary at all is argued to be demonstrative of the fact that neither of the conventional levels of abstraction are appropriate.

Contents

Chapter 1: Problem Statement and Structure of Thesis

Chapter 2: Theoretical Underpinning of Models

Chapter 3: The Objectives of a Cost Model for Petrochemical Civil Engineering Work Related to Orthodox Conventions

Chapter 4: Review of Research Methods

Chapter 5: The Formulation of Measurement and Cost Control Models in Related Fields

Chapter 6: Formulation of a Hypothetical Petrochemical Civil Engineering Measurement and Cost Control Model

LIST OF CHARTS, TABLES AND DIAGRAMS

CHAPTER 1:
PROBLEM STATEMENT AND STRUCTURE OF THESIS

1.1 PROBLEM STATEMENT

The problem with which this research work was confronted was clearly prescribed. A collaborating Petrochemical organisation was expending some £157 000 000 per annum on capital construction work at the time this study commenced, for which no specialist measurement and cost control model existed. A suitable set of such conventions needed to be investigated. The organisation possessed geographical divisions in which measurers applied different versions of the conventional Building models, for no other obvious reason than that of familiarity. It was necessary to ascertain which such model, if any, was best suited to the nature of the construction work in question. It soon became apparent that the nature of the construction work in question was that of a curious hybrid blend of what might be termed "classical" Building work and "classical" Civil Engineering work. Parts of the Building model could be applied, or parts of the Civil Engineering model; but neither with outrageous success.

An additional problem was that the buildings and structures being modelled were regarded as being ancillary to, or as supporting, the process plant used to manufacture the organisation's products. Therefore the "building work", if it may be so called, often took a subservient role. Whereas a "building" would normally be deemed to require the provision of supporting infrastructure, in Petrochemical Civil Engineering the building itself could be a supporting infrastructure. Charts 1 and 2 show respectively the scale of capital construction investment at the collaborating organisation, and its turnover by product division, at the time of commencing this study (source: internal papers at that organisation). The costs (and potential savings which might accrue from the development of suitable measurement and cost control techniques) are considerable.

CHART 1: UNITED KINGDOM EXPENDITURE ON CONSTRUCTION AT THE COLLABORATING ORGANISATION

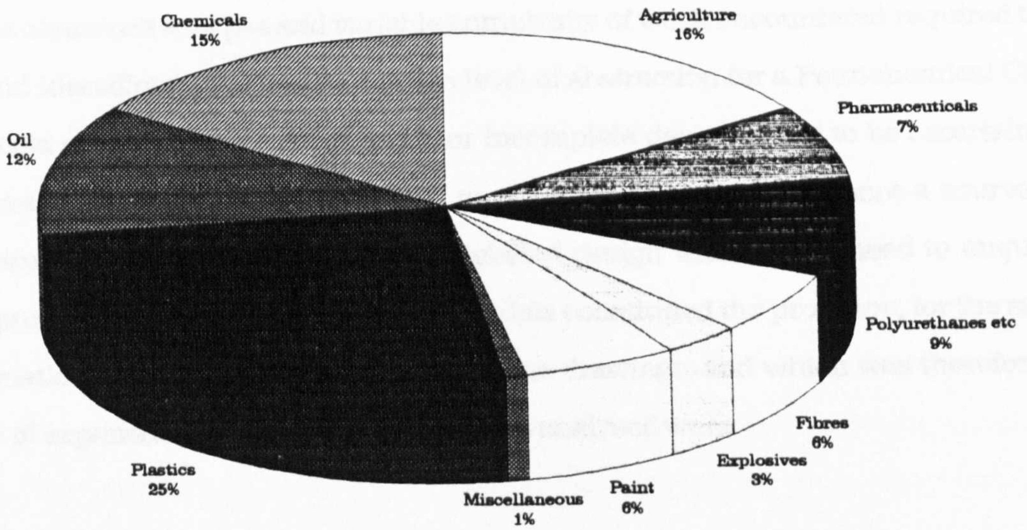
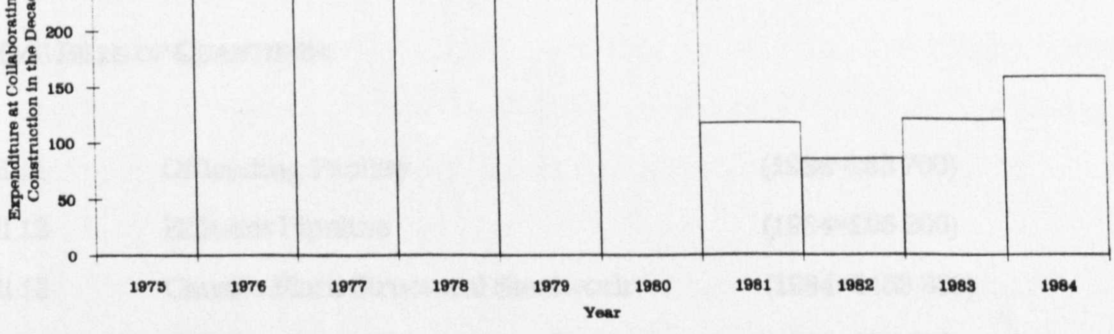


CHART 2: TURNOVER AT THE COLLABORATING ORGANISATION BY PRODUCT DIVISION



As stated, the design of process plant would often receive priority. Contracts for the Petrochemical Civil Engineering work would often be let on the basis of incomplete design.

This is not a situation envisaged by the conventional building models which were being employed at he time. Such models were formulated in the expectation that design would be substantially complete.

The mixture of construction types and variable complexity of work encountered required the exploration and identification of an appropriate level of abstraction for a Petrochemical Civil Engineering cost model. In the case of crude or incomplete design it had to be ascertained whether the detail demanded by conventional models was excessive and hence a source of over administration. In the case of relatively detailed design there was a need to enquire whether the provision of detail in conventional models constituted the provision, for the sake of it, of information which could be gleaned from the drawings, and which was therefore a possible case of expensive redundancy. The projects analysed were:

SMM5 BILLS OF QUANTITIES:

Bill 2	Melinar Plant	(1985=£110 100)
Bill 3	Ethoxylates Plant	(1980=£381 800)
Bill 4	Ammonium Nitrate Plant	(1980=£211 700)
Bill 5	Contol Room Building + Alterations	(1977=£190 900)
Bill 6	Protein Plant Site Development Works	(1977=£301 100)
Bill 7	Control Room Building	(1974=£253 500)
Bill 8	Substations	(1980=£379 400)
Bill 9	Laboratory Extension & Refurb	(1982=£149 300)

SMM6 BILLS OF QUANTITIES:

Bill 11	Offloading Facility	(1984=£83 700)
Bill 12	Effluent Pipeline	(1984=£95 200)
Bill 13	Caustic Plant Structural Steelwork	(1984=£463 800)
Bill 14	HCl Reaction + Compressor Sections	(1985=£77 600)
Bill 15	Bagged Salt Warehouse Extension	(1984=£39 600)
Bill 16	Anhydrous Caustic Plant	(1984=£687 100)
Bill 17	Cool Firing Cement Plant	(1984=£410 800)

Two further projects were subsequently added (Office/Staff Amenities and Plastics Plant containing high quality finishings) in order to supplement the superstructure, fittings and finishings aspect of the data. The comprehensive statistical analyses described here were repeated following the addition of these data. The characteristic results replicated. In order to avoid unnecessary repetition, and to save space, the results reported in Chapter 6 and in the Appendices are those following the repeat analyses.

1.2 CONSIDERATIONS OF PHILOSOPHY AND PRACTICALITY

Fundamental to the consideration of such cost models is the need to question the basis of their formulation and adoption in practice. There was little evidence to suggest that the models used, the building cost models unabridged, had any rational basis upon which to justify their application in practice. They were the "traditional" models, used, presumably, for reasons of "practicality" or "familiarity". This, though, cannot be taken to imply "validity".

The propensity for the construction industry to resist change is well known; the reasons why practitioners tend to support established models and oppose potential rivals has been the subject of rather less exposition. A new, or improved, model was being sought whose underlying principles might be adopted by the collaborating organisation. Therefore the likelihood that potential model users might resist a "theoretical" alternative to the *status quo* (though on what grounds is a matter for considerable debate) had to be anticipated. Therefore part of this research looks into the ways in which theories and models can come to be espoused or rejected and discovers that these reasons are not all scientific. The relationship between what the industry calls "theoretical" and what it calls "practical" is briefly discussed. The word "theory" tends to be misunderstood and misused. It may be that in building economics we have no models worthy of the exalted status of theory.

The mention of the word "theory" can cause practitioners to become sceptical. Phrases like "academics in ivory towers" and "cost models are irrelevant" have been known to appear in the correspondence columns of professional journals. If cost models are irrelevant, then so be it. They are nevertheless used in practice. We employ them in our daily business and purvey their output to our clients. If they are irrelevant, and this has been alleged, then there is a clear need to look at potential alternatives to the irrelevancies, in the interests of rational development. Such alternatives must include the alternatives being developed in the "theoretical" world. Indeed, it is from the "theoretical" world that the "alternatives" are likely to emanate.

In a survey executed by Fletcher *et al* (1972) the viewpoints of practitioners belonging to two influential professional societies were sought regarding the development of conventional Building measurement and cost control models. In the section of the survey entitled "Practice Generally" two of the most populous responses were "criticism comes from the theorists and academics" and "the existing SMM works well". The works of academia seem often to be vilified by the professions. Therefore the basis of such reasoning requires discussion. Criticism is essential to the advancement of knowledge. It must come from somewhere. If it does not come from the industry itself then some academic must offer it.

Fletcher *et al* (1972) had the misfortune to report a response rate to their survey of approximately 0.33 per cent. Out of 49 170 enquiries made to the practitioners concerned, 158 replies were received. The enthusiasm of the professions towards participation in development of the subject (whether it be "theoretical" development or no) may or may not to reflect distrust of development..

It can never be proven beyond doubt that any individual model works; not even the conventional models; we can only select the least defective one from a range of models which have either already been formulated or which, as audacious upstarts, are about to be. Further, if we insist on the upstart models being tested, we must demand at least as much of the conventional ones. In fact we should demand better of conventional models, as they are the ones in widespread use. It cannot be presumed that the models in widespread use are intrinsically better than their rivals, without looking at the potential rivals.

1.3 Structure of Thesis

Chapter 2 discusses the overall philosophy of science concerning theories and models. These aspects of methodology are considered to be subject-independent, but necessary. It will identify which of the overall philosophical approaches are considered to be pertinent to the models being studied and formulated in this work. The Chapter will draw principally on the philosophy of Duhem (1954), Musgrave (1978), Koertge (1978), Popper (1959), Grünbaum (1978), Kuhn (1962), Masterman (1970), Feyerabend (1970, 1975 and 1978), Sen (1970), Post (1978) and Toulmin (1970).

Chapter 3 will discuss the requirements of cost models and criticise the Conventional Petrochemical Civil Engineering Cost Model as an information communication medium. The Chapter will then discuss the requirements of such models and criticise the Conventional Petrochemical Civil Engineering Cost Model in terms of an appropriate level of abstraction of detail. Chapter 2 will then discuss the requirements of such models and criticise the Conventional Petrochemical Civil Engineering Cost Model in terms of its relevance to the design and costs of the building or structure which it purports to represent.

Chapter 3 will criticise the basis of the conventional model's formulation and will draw principally on the work of Ferry and Brandon (1991), Flanagan (1980), Hardcastle (1992), Daly (1981), Barnes (1971 and 1977), Fine (1982), Davies and Greenwood (1994), Stamper (1973), Hardcastle (1992), Hardcastle *et al* (1987a, 1987b and 1988), Heath and Bryant (1992), Drucker (1978), Cirillo (1979), Diederichs and Hepermann (1985), Saket (1986), Emmett (1990), Hooker (1985), Snell (1973), Feyerabend (1975), Brandon (1982), Silverton (1983) and Dirksen (1982).

Chapter 4 will briefly review the overall state of theoretical development in building economics, point out some of its weaknesses and report some recommended agenda for cost modelling research. The Chapter will set out a basic strategy for the research in this thesis and review and criticise the research methods (the data collection tools) used.

Chapter 4 will propose statistical analysis of the data in Conventional Petrochemical Civil Engineering measurement and cost control models in order to obtain empirical observations of cost behaviour. The Chapter will then propose a survey among all likely end-users, inviting their judgement on the hypothetical measurement model so formulated. The interviews will seek to ascertain whether the end-users consider that the hypothetical model would achieve its stated objectives. The survey will also enable the respondents to comment on whether they agree with its stated objectives. The Chapter will then propose an experimental measurement exercise whereby a known historical project will be re measured using the hypothetical model and priced as a *bona fide* tender. This will constitutes the beginning of a hypothetico-deductive phase; that is of model-testing.

Chapter 4 will question whether there need be an overt intention (as the pure and social sciences often presume) to generalise to the whole population (in this case the whole construction industry). An empirical model which follows an individual situation, or a limited number of situations of similar character, is specifically being attempted in the work described here. The Chapter will recommends study of the principles of idiographic models. Chapter 4 will draw principally on the work of Ashworth (1994), Raftery (1991), Newton (1991), Popper (1959), Neale and Liebert (1980), Hogarth (1980), Feyerabend (1975), Katona (1963), Layder (1993), Barnes (1971), Dominowski (1980), Hartman and Hedblom (1979), Sen (1970), Dobson *et al* (1980), (Lukacs (1971) and Flanagan (1980).

Chapter 5 will commence by giving some brief overall treatment of the epistemology of model-building and point out the epistemological requirement for a theoretical basis upon which to found the actual building of models. Without some theoretical basis, the model is vacuous. In the general context there is a need for a more substantial body of theory upon which to base model-building. Without rational consideration of what the "facts" to be modelled ought to be the exercise is no more than one of data collection. This is especially likely if the conventional rules of the measurement model have been formulated more by a process of negotiation between interested parties than by any prior substantial data analysis. Chapter 5 will then question the applicability of conventional standard Element classifications to the Petrochemical Civil Engineering data under study.

Chapter 5 will then briefly review the formulation of, and discusses some methodological issues concerning, models in related fields bearing similar characteristics to the hypothetical model described in this thesis. The models in question will be: the Civil Engineering Cost Model, the Building Cost Model, a Commercial Rival to the Building Model, the Iterative Civil Engineering Model, the Builder's Quantities Model, the International Engineering Construction Model, a Rational Bill of Quantities Model for Civil Engineering Work and Elemental Models.

Chapter 5 will draw principally on the work of Kenny (1979), Hindness (1977), Brandon (1982), Bowen and Edwards (1985), Tong and Lu (1992), Feyerabend (1975), Kenley and Wilson (1986), Barnes (1971), Strotton (1988), Bennett (1983 and 1986), Quier (1992), Moore and Ashworth (1986), Saket (1986), Saket (undated), Horner *et al* (1986), Horner and Saket (1984), Pasquire (1993), Barnes (1971), Singh and Banjoko (1990), De Troyer (1986), Diederichs and Hepermann (1985) and Davies and Greenwood (1994).

Chapter 6 describes the statistical analyses used to formulate (by empirical observation) a hypothetical Petrochemical Civil Engineering model. The "Preliminary Analysis at Bill of Quantities Item Level of Abstraction" section will describe the analysis of historical cost data in Petrochemical Civil Engineering Bills of Quantities by rank order distribution of cost (apportioned by tenderers).

The section "Comprehensive Analysis at Bill of Quantities Item Level of Abstraction" will describe analysis of Petrochemical Civil Engineering cost data following "normalisation". Item values in Bills of Quantities will be standardised by dividing each item value by the mean item value. For each Bill of Quantities descriptive statistics will be produced of mean item value, standard deviation and skewness.

In the sections "Analysis at Trade and Trade Subsection Level of Abstraction" those Trades and Trade Subsections in which cost-insignificant Bill items proliferate will be identified. A cost-insignificant item is defined for the sake of argument as being one of the lowest value Bill Items which collectively aggregate to the last 5% of the Bill Total (when placed in descending rank order of value)

The section "Recommendations regarding Cost-insignificant Parameters and Generic Families of Parameters" will identify those items which permanently reside in the cost-insignificant category previously described. Their omission from the measurement system shall be suggested. Those generic families of items which are similar in nature but conventionally classified in separate measurement rules and identically or similarly priced will be identified. The simplification of their measurement will be suggested, by virtue of reducing the number of measurement categories for such items or by amalgamating such items into composite items. Proposals for an experimental method of measurement shall be set out.

In the section "Analysis at Elemental Level of Abstraction" the historical cost data will be grouped by functional building Element and Elemental cost distributions by project and the incidence of functional Elements across all projects will be computed. Cost significant and cost insignificant Elements shall be identified and discussion offered as to whether data classification using conventional Elements is capable of leading to standardisation. The overt need to standardise shall be questioned. Study of idiographic, as opposed to nomothetic, models will be recommended.

Chapter 6 will classify Elements by the rate at which they generate costs (attract prices from Tenderers). Elements as Major Cost Generators or a Minor Cost Generators will be considered, and proposals made for their treatment within a hypothetical measurement model. Chapter 5 will draw principally on the work of Barnes (1971), Ashworth and Skitmore (1983), Drucker (1978), Gray (1983), Azzaro *et al* (1987), Flanagan (1980), the Building Cost Information Service (1969), Morrison and Stevens (1983), Ferry and Brandon (1991), Brown (1984), De Troyer (1990), Marks *et al* (1990), Diederichs and Hepermann (1985) and Nachmias and Nachmias (1976).

Chapter 7 describes the first steps of the validation of the hypothetical model (which will have been formulated on the basis of the empirical observations in Chapter 5). A survey of all potential model users will be executed in order to solicit the judgement of these experts as to whether the proposed method of measurement would achieve its stated objectives. In Chapter 7 the first test of the hypothetical model will be carried out by re-measuring an existing historical project using the hypothetical model as the method of measurement and having one of an approved panel of contractors price the project again as a *bona fide* Tender. Comment by the Tenderer and the expert user who "re measured" the project on the use of the document for Tendering purposes shall be added.

Chapter 7 will describe two brief tests to compare SMM7, The hypothetical model and "Shorter Bills of Quantities" in terms of their relative compatibility. Chapter 7 will refer broadly to Hughes (1983), Silverton (1983), Saket (1986) and Heath and Bryant (1991).

Chapter 8 will offer overall conclusions and recommendations for further work, and will refer broadly to the work of Saket (1986), Morrison and Stevens (1983) and Diederichs and Hepermann (1985).

1.4 Cross-Referencing of Chapters, Appendices, Tables and Diagrams

Table 1: Index to Tables and Diagrams

Problem Statement	Appendix	Relevant Chapter(s)
Chart 1: Expenditure at the Collaborating Organisation on Capital Construction		Ch 1
Chart 1: Turnover at the Collaborating Organisation by Product Division		Ch 1
Table 1: Index to Charts, Tables and Diagrams		Ch 1

A Preliminary Analysis	Appendix	Relevant Chapter(s)
Table 2 "Least Value" Items In 3 Petrochemical Civil Engineering Bills of Quantities	App 1	Ch 5
Table 3: Small Value Items in 3 Petrochemical Civil Engineering Bills of Quantities	App 1	Ch 5
Table 4: Effect of removing from Petrochemical Civil Engineering Bills of Quantities the "Smallest Value" items which collectively comprise only 5% of the Bill Total (All Items)	App 1	Ch 5
Table 5: Cost distribution in Petrochemical Civil Engineering Bills of Quantities (SMM5)	App 1	Ch 5
Table 6: Cost distribution in Petrochemical Civil Engineering Bills of Quantities (SMM6)	App 1	Ch 5
Table 7: Skewness of distribution of cost data in Petrochemical Civil Engineering Bills of Quantities (all BQ items)	App 1	Ch 5

THE IDENTIFICATION OF COST-SIGNIFICANT AND COST-INSIGNIFICANT PARAMETERS IN THE CONVENTIONAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL (TRADE SUBSECTION LEVEL OF ABSTRACTION)	APPENDIX	RELEVANT CHAPTER(S)
Table 10.1: Cost Distributions In "Lowest Cost" Bands By Trade Subsection (SMM5 BQ)	App 3	Ch 5
Table 10.2: Cost-insignificant Items In "Lowest Cost" Bands By Trade Subsection (SMM6 BQ)	App 3	Ch 5
Table 11.1: Cost-insignificant Items In "Lowest Cost" Bands By Trade Subsection (SMM5 BQ)	App 3	Ch 5
Diagram 4.1: Demolitions + Alterations: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.2: Excavation + Earthwork: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 3: NOT USED		
Diagram 4.3: Piling: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.4: Concrete Work: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.5: Brickwork + Blockwork: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.6: Roofing: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.7: Carpentry: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.8: Joinery: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.9: Structural Steelwork: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.10: Metalwork: SMM5 BQ (See Table 11.1)	App 3	Ch 5

THE IDENTIFICATION OF COST-SIGNIFICANT AND COST-INSIGNIFICANT PARAMETERS IN THE CONVENTIONAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL (TRADE SUBSECTION LEVEL OF ABSTRACTION) (CONTD)	APPENDIX	RELEVANT CHAPTER(S)
Diagram 4.11: Plumbing [Part]: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.12: Plumbing [Part]: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.13: Electrical Installation: SMM5 BQ (See Table 11.1)	App 3	Ch 5
Diagram 4.14: Floor, Wall + Ceiling Finishes: SMM5 BQ (See Table 11.1)	App 3	Ch 5

RESULTS OF ANALYSIS OF ELEMENT COSTS IN THE CONVENTIONAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL	APPENDIX	RELEVANT CHAPTER(S)
Table 16.2: Major and Minor Cost-generating Elements in Petrochemical Civil Engineering projects: All BQ Items: SMM6 BQ	App 5	Ch 5
Table 16.3: Major and Minor Cost-generating Elements in Petrochemical Civil Engineering projects: Measured BQ Items Only: SMM5 BQ	App 5	Ch 5
Table 16.4: Major and Minor Cost-generating Elements in Petrochemical Civil Engineering projects: Measured BQ Items Only: SMM6 BQ	App 5	Ch 5

VALIDATION OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MODEL: RESULTS OF STRUCTURED INTERVIEW SURVEY OF MODEL USERS (STAGE 1)	APPENDIX	RELEVANT CHAPTER(S)
Diagram 6.1: Reduction of Measurable Items Using the Hypothetical Model	App 6	Ch 6
Diagram 6.2: Reduction of Measurement Time Using the Hypothetical Model	App 6	Ch 6
Diagram 6.3: Effect on Measurement Time (Low Cost Items) Using the Hypothetical Model	App 6	Ch 6
Diagram 6.4: Readability of the Hypothetical Model	App 6	Ch 6
Diagram 6.5: Simplicity and Clarity of the Hypothetical Model	App 6	Ch 6
Diagram 6.6: Effect on Working-up Time of the Hypothetical Model	App 6	Ch 6
Diagram 6.7: Reduction of Working-up Time (Low Cost Items) Using the Hypothetical Model	App 6	Ch 6
Diagram 6.8: Appropriateness of Level of Abstraction of Detail of the Hypothetical Model	App 6	Ch 6
Diagram 6.9: Doubt Regarding Items "Deemed to be Included" in the Hypothetical Model	App 6	Ch 6
Diagram 6.10: Clearer Specification Provisions in the Hypothetical Model	App 6	Ch 6

VALIDATION OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MODEL: RESULTS OF STRUCTURED INTERVIEW SURVEY OF MODEL USERS (STAGE 2)	APPENDIX	RELEVANT CHAPTER(S)
Diagram 7.1: Reduction of Measurable Items Using the Hypothetical Model	App 7	Ch 6
Diagram 7.2: Reduction of Measurement Time Using the Hypothetical Model	App 7	Ch 6
Diagram 7.3: Effect on Measurement Time (Low Cost Items) Using the Hypothetical Model	App 7	Ch 6
Diagram 7.4: Readability of the Hypothetical Model	App 7	Ch 6
Diagram 7.5: Simplicity and Clarity of the Hypothetical Model	App 7	Ch 6
Diagram 7.6: Effect on Working-up Time of the Hypothetical Model	App 7	Ch 6
Diagram 7.7: Reduction of Working-up Time (Low Cost Items) Using the Hypothetical Model	App 7	Ch 6
Diagram 7.8: Appropriateness of Level of Abstraction of Detail of the Hypothetical Model	App 7	Ch 6
Diagram 7.9: Doubt Regarding Items "Deemed to be Included" in the Hypothetical Model	App 7	Ch 6
Diagram 7.10: Clearer Specification Provisions in the Hypothetical Model	App 7	Ch 6
Diagram 7.11: Adequacy of Units of Measurement in the Hypothetical Model	App 7	Ch 6
Diagram 7.12: Adequacy for Preparing BQ of the Hypothetical Model	App 7	Ch 6
Diagram 7.13: Adequacy for Preparing Tenders of the Hypothetical Model	App 7	Ch 6
Diagram 7.14: Difficulties Foreseen in Pricing BQ Items Using the Hypothetical Model	App 7	Ch 6
Diagram 7.15: Reduction of Tendering Time Using the Hypothetical Model	App 7	Ch 6
Diagram 7.16: Acceptability of Level of Abstraction of Priceable Detail in the Hypothetical Model	App 7	Ch 6

Table 20: Example of Design Variations to, and the Input of Costs of Factors of Production into a "Lead Position": [Leitposition: 013.21] Beton für Abfüllungen, Fundamente, Böden, Platten, Decken / [Lead Position 013.21] Concrete for Filling, Foundations, Ground Floors, Slabs, Upper Floors	App 8	Ch 2, 5, 7

1.5 Summary Remarks

Much of the literature on models of the type being studied here tends to centre around the internal consistency of the model. Criticisms (if criticisms they are) tend to be of a technical nature, concentrating on the degree of "watertightness", in a legalistic sense, of the individual clauses and conventions. Too little of the literature, though there is some, concentrates on the epistemological issues surrounding the actual formulation of the models. Rather less work in cost modelling (or in building economics as a whole) deals with the sociological influences upon the adoption of models and techniques in practice; the rather subjective assumptions about what we imagine such models actually do (see Ashworth, Raftery and Newton, *infra*).

The reasons why models become accepted in practice are not necessarily scientific in the pure sense of the word. The extent to which a model, in terms of its internal consistency or of its own intrinsic content, works can easily be shown. But this avails us little (Feyerabend, 1975). To accept a model on its (presumed) intrinsic merit is to feed the model with data acceptable to the model; thus the model itself dictates the form the data should take. It is hoped that this thesis can argue the need to establish some rational empirical evidence to aid decisions regarding model formulation and selection; some evidence of cost data behaviour which ought to dictate the form the model should take.

Chapter 2 will discuss the theoretical underpinning of theories and models.

CHAPTER 2:
THEORETICAL UNDERPINNING OF MODELS

2.1 GENERALLY

The problem encountered in this work is that of an organisation using more than one model (of the same generic type) for the measurement and control of capital cost of construction work in the Petrochemical Civil Engineering sector of the construction industry. The organisation was confronted with a problem: which such (or which other) model to adopt for the stated purpose. The problem, therefore, was one of model selection. This warranted the need to seek a rational basis for model selection; whether of conventional models or of alternative models.

The Chapter will first explore the problem in terms of the overall philosophy of science related to models and theories. It will deal with some philosophical approaches to the proof and refutation of theory or model systems. The Chapter will compare theory with practice and explore the possibility that in professional practice ideological (as opposed to logical) reasons could exist for selection or rejection of models. The Chapter will then seek to apply these philosophical considerations to conventional Petrochemical Civil Engineering measurement and cost control models. The status of the conventional models will be established and criticised in terms of the perceived current state of their theoretical development. The Chapter will then seek to argue towards a more rational approach to the formulation and adoption of such models.

2.2 PROOF AND REFUTATION OF THEORIES AND MODELS

It is required of a theory that it possess considerable power to predict the behaviour of those things which it describes, otherwise it is refuted to some extent. Thus what it predicts should be confirmed by experience. The main problems associated with models or theories are those concerned with their verification or falsification. An acute dilemma in regard to refutation is what is known as the *Duhemian Problem*. This is the situation where experience does not support the predicted outcome (Duhem, 1954).

Systems can be defined of the form $(T \cdot A) \Rightarrow e$, where T is the predictive theory or model, A is one of the set of auxiliary hypotheses necessary to deduce the prediction and e is the implied prediction (see, for example, Koertge, 1978). In other words theories or models are general statements containing, or founded upon, less general hypothetical statements, which purport to explain how things behave. The possible outcomes of any test of such a system are $(T \cdot A) \rightarrow e$ (experience confirms the prediction made by the system) and $(T \cdot A) \rightarrow \sim e$ (prediction failure or anomaly occurs).

The difficulty which the Duhemian Problem presents is the difficulty in defining what to do about $(T \cdot A) \rightarrow \sim e$, that is, what to do when the prediction, e is not confirmed: and whether to modify such parts or reject and replace them. Which part of the system is to blame; the theory or model, its auxiliary hypotheses, or both?

The *extent* to which a theory or model can in any event be proven or refuted will be addressed later. First, possible solutions to the Duhemian problem will be identified individually. What can be done if the evidence does not conform to the predictions of the theory or model?

2.3 POSSIBLE SOLUTIONS TO THE DUHEMIAN PROBLEM

According to Musgrave (1978), "prediction failure" means that a theoretical system containing a hypothesis fails if that particular hypothesis fails. Thus Musgrave seemed inclined to blame the hypothesis. The potentially damaging nature of prediction failure is illustrated by the fact that a particular hypothesis, A could be contained in more than one theoretical system, T. The implication from this is that the failure of some theoretical system S' can induce the failure of some other theoretical systems, S'', S''', S'''' (and so on) which contain the same refuted "supposition" or "hypothesis" as system S'. Thus an entire family of models all formulated on the basis of the same faulty underlying principle can be discredited by virtue of the fact that one model in that family possessing that refuted principle has not performed well in the light of experience.

The principal reactions or solutions to this potentially alarming failure or anomaly are listed below. The list structure is that suggested by Koertge (1978). It is not an exhaustive list, but its exclusions are relatively trivial:

(i) Reserve judgement (which does not really constitute a solution unless aspects of the Feyerabend's account can be shown to apply, though that would require some imaginative interpretation: this interpretation is not Feyerabend's),

(ii) Reject the process of Induction (show that the derivation of the implication was not correct)

(iii) Reject T (the Popperian account),

(iv) Reject A (the Lakatosian account),

(v) Reject T and A (the Popperian account or certain combinations of other accounts),

(v) Ignore the contradiction (the Kuhnian or Sociological account),

(vi) Do not adopt a standard solution which risks contradicting or ignoring the factual evidence (Koertge's account), or

(vii) Reject the research tools used (show that the experiment purporting to show ~e was unreliable). This is not of immediate philosophical concern in this Chapter, though it is obviously necessary later to recognise that no research method is perfect. Criticism of the research *tools* as opposed to the research *philosophy* are offered elsewhere (*vide infra*).

Rejection of T may or may not necessarily imply the rejection of A (and *vice versa*), thus illustrating the difficult nature of the philosophical problem. The various solutions are now discussed in further detail.

2.4 INDUCTION

This method relies on the use of observations to argue towards the probability that a theory or model, T and any of its auxiliary hypotheses, A are true. Any prediction success, e, constitutes confirmation. Any prediction failure, ~e, is deemed to be outside the purview of either T or A.

Such models, in fact, rely on inference. The inference is said to be an inductive inference if it passes, *via* some principle of inductive logic, from singular or particular statements such as results of individual observations, experiments or experiences to more universal statements, such as hypotheses or theories, which say that because the singular observations, experiments or experiences yielded certain results then all such observations, experiments or experiences will definitely or probably yield such results.

Such methods have their critics: "Now it is far from obvious, from a logical point of view, that we are justified in inferring universal statements from singular ones, no matter how numerous; for any conclusion drawn in this way may always turn out to be false: no matter how many instances of white swans we may have observed, this does not justify the conclusion that all swans are white" (Popper, 1959).

Therefore inductive methods appear to possess the weakness that they lead not to universality of causation, but to degrees of reliability or probability: there is a probability of a swan being white, but no absolute certainty. Some scientific validity can, in fact, be ascribed to a model which is not absolutely accurate: "We have described the principle of induction as the means whereby science decides upon truth. To be more exact, we should say that it serves to decide upon probability. For it is not given to science to reach either truth or falsity... but scientific statements can only attain continuous degrees of probability whose unattainable upper and lower limits are truth and falsity" (Reichenbach, 1930, *cit* in Popper, 1959). This is not to say, though, that statements of likelihood or probability would be insufficient to satisfy the basic needs of professional practice.

However to the Popperian this is inadequate: if the universal statement or theory has to be taken as probable rather than true then, by virtue of the inductive relationship, the principle of induction (the logic relating observation to theory) and even the observations themselves must be taken as probable rather than true. Hence, as it produces neither absolute truth nor absolute falsehood, the entire inductive process will inevitably require modification from its original state. Inductive methods, therefore, have been said to be regressive. Induction is selective. Being dedicated to arriving at a theoretical position they discard data which do not support the position sought.

If it is the purpose of science to put forward and test theories or hypotheses, it is evident that there can be two stages of reasoning involved: the stage during which the theory or hypothesis is *formulated* and the stage during which the theory or hypothesis is *tested*. The inductive method demands a rational reconstruction of the steps leading to the formulation of the theory. This may or may not consist of a set of empirical facts, but nevertheless follows an *inductive* course in that it attempts to build up a theory rather than break it down. Conversely, the school of *the logic of knowledge* believes not in questions of fact pertaining to the *formulation* of a theory *(quid facti)* but in questions of the *justification and validity* of the theory itself *(quid juris)* (originally attributable to Kant, but cited from Popper (1959)). This leads to considerations of deductive research methods.

2.5 THE POPPERIAN (HYPOTHETICO-DEDUCTIVE) ACCOUNT

This method will not admit an irrefutable theory or model, T. It relies on *falsification* of T and/or A by "severe testing" and replacement with testable alternatives, T' and A' (Popper, 1959). It has been argued (Koertge, 1978) that this method prefers to reject the theory, T rather than its auxiliary hypothesis, A. This invites a criticism: either T or A, or *both T and A* could be wrong. In order to falsify T, an unproblematic auxiliary hypothesis would be required to bring about the falsification of T as opposed to the falsification of A. As unproblematic auxiliary hypotheses can prove to be difficult to come by this solution cannot give any strong advice as to whether it is T or A which needs to be replaced (Koertge, 1978).

This method has been called "counter-intuitive": the severity of testing cannot be maintained. Popper claimed that the execution of a series of tests led to the diminishing severity of each successive test owing to the increase in background knowledge, and hence the increased probability of soundness which accrues from each successive test. Grünbaum (1978) was sceptical about what constituted "severity of testing" and argued that if there is no reason at the time to doubt a test there is no reason to repeat it. What is more, Grünbaum argued that Popper was contradicting himself. Diminishing refutational returns from successive tests and the consequent increased "certainty" of the theory amount to nothing more than the inductive approach, which Popper and others originally viewed with disdain. It is suggested here that the fact of diminishing marginal returns from tests indicates an inability to completely falsify.

The hypothetico-deductive models start with the assertion that "no observation, which might be used inductively to lead to the formulation of a hypothesis, can be unbiased; therefore the starting point of the induction must be false" (Popper, 1959). The way in which our senses interpret the raw information which we see, hear, or feel is clouded or conditioned by prior experience. Thus there is a degree of expectation as to the likely outcome of such hypotheses, or as to the meaning of such observations. One is likely to classify observations as being relevant or irrelevant and select or discard one or other methodology considered unlikely to produce the desired outcome. "Induction is ampliative in nature. It expands our knowledge, or at all events our pretensions to knowledge. This is all very well, but... it cannot ... lead us with certainty to the truth (Medawar, 1982).

The hypothetico-deductivists argue that the best thing to do with ideas is to *test* them, irrespective of method of formulation. They should be tested until they no longer withstand the tests; that is, to *destruction*. Popperian thinking is that a hypothesis or theory must be capable being refuted, otherwise there is no worth in having the theory and no point in having a science incapable of admitting that its guiding tenets could be false. By contrast, inductive approaches try to justify the truth of statements as opposed to their falsehood. There is no reason to suppose, though, that any deductive process will perforce proceed any more systematically and inevitably than would any inductive process. It is just as likely that "guesswork" and "inspiration" will feature in deductive processes as they will in inductive processes.

The inspiration behind an idea is as likely to be intuitive or irrational as it is to be logical. Thus hypothetico-deductivists say that the only sensible thing to rationally construct is the second stage; the tests to which the idea can be put. There is no reason to justify the *derivation* of a theory as it may have been arrived at by casual, as opposed to causal, observation or even by act of blind faith. It matters little. The sole purpose of the *hypothetico-deductive* method is to test the idea.

But if inductive styles are questionable in terms of "logic of process" and deductive styles can *resemble* them in terms of "logic of execution" what makes them *different?* It would seem that the hypothetico-deductive model is no less immune to criticism than is the inductive approach: "There is no logic of 'discovery' - in that sense, there is no logic of 'testing', either; all the formal algorithms proposed for testing... are, to speak impolitely, ridiculous... There are maxims for discovery and maxims for testing: the idea that correct ideas come from the sky, while the methods for testing them are highly rigid and predetermined is one of the worst legacies of the Vienna Circle" (Putnam, 1991).

The hypothetico-deductive approach suggests that the *correctness* of an idea cannot be inferred from close observation of the world being studied (Popper, 1959); only the theory *itself* can be so inferred. The mere fact that it has been *formulated* does not vouch for its validity. Its *correctness* can only be judged by applying the theory and seeing whether it *works*. Thus, it has been argued, the more correct a theory proves to be, the more successful it will become. The theory could become the dominating theory in its field and its community of adherents become sufficiently populous to turn the theory into a paradigm (*vide infra*).

In the long run an idea could become relatively successful not necessarily by virtue of its *correctness*, but by virtue of attracting a school of adherents who happen to *believe* it, regardless of any inductive reasoning, deductive test or contrary evidence. In fact it may be that they have neither the time nor the inclination to *question* the theory. The fact of *acceptance* of a theory does not necessarily imply its scientific *validity*. Lengthier discussion of the influence of belief, that is, of psychological considerations, is offered later. First it is necessary to consider the nature of the established theories themselves; that is, of paradigmatic models; the Kuhnian Account.

2.6 THE KUHNIAN ACCOUNT

Kuhn's account describes the act of ignoring the prediction failures, at least until they overwhelm the prediction successes. The method basically consists of ignoring anomalies and persevering with further development and application of the theory or model, T (and, presumably, of its contributory hypotheses, A). Only a large number of anomalies will bring about its replacement by an alternative, and even that is debatable. This approach is said to be characterised by periods of "normal science".

The influential concept of a "paradigm" was first expressed by Kuhn (1962). A theory is a paradigm if it is accepted by its "disciples" as the dominating theory in its field, until such time as a better one replaces it. Once the paradigm is accepted there follows discipline, or a period of what Kuhn referred to as "normal scientific activity", during which the adherents to the paradigm seek to develop it further and find more situations to which it could apply. Thus "normal scientific activity" seeks to establish and widen the truth of the paradigm rather than to replace it with something else, or with something better.

The fact that such normal scientific activity is founded on the broad acceptance of the paradigm as the best available explanation of things is suggestive of a position of relative conservatism. Normal scientific activity seeks not to bring theories into disrepute; rather the opposite. In seeking to practice paradigms rather than depose them we impute to them some degree of immunity to refutation. What creates the pressure to embrace a new paradigm is the phenomenon of anomaly, that is, the occasions when things do not behave in the way predicted by the theory. A single anomaly, or several anomalies, would be ignored and the theory still retained as a paradigm. Therefore our paradigm theories do not cater for isolated anomalous results. In disciplines in which research is well-developed paradigms are likely to be accepted as "laws" for a long time. Newton's theories, for example, were paradigms for many years until they were upstaged by, *inter alia*, Einstein and his Relativity.

Kuhn (1972) referred to the conflict between predicted outcome and anomaly as the "essential tension'. A single anomaly would be ignored. Several would constitute a crisis. It is still not clear, though, how many anomalies would constitute 'several', or what kind of anomalies they would have to be.

However it is only when the anomalies become *significant in number* that the adherents to a paradigm would perceive a "Kuhnian paradigm crisis" to exist and consider replacing one with another (this replacement being known as "paradigm shift"). It is argued here that there it is difficult to conceive of a moment when there would be sufficient grounds (prediction failures) to produce sufficient "crisis" to *justify* the adoption or replacement of a paradigm. What, in any event, would be a suitable definition of "crisis"? In what definable circumstances would a "scientific revolution" take place?

In the case of a political revolution, to which Kuhn compares scientific revolutions, there can be competing ideas, but what, short of armed insurrection, actually *foments* the revolution? What is the analogical "breaking- point" in the process of "normal science"? Toulmin (1970) enquired, in similar fashion: "How extensive do the conceptual incongruities between the ideas of one scientific generation and the next have to be, if the transition between them is to constitute a 'scientific revolution' on Kuhn's present account?"

Feyerabend (1970) alluded to Kuhn's argument for *tenacity,* which would cause a paradigm to be embraced even if the evidence against embracing it were strong. "Having adopted tenacity we can no longer use recalcitrant facts for removing a theory, T, even if the facts should happen to be as plain and straight-forward as daylight itself. But we can use other theories, T, T', T", etc. which accentuate the difficulties of T while at the same time promising means for their solution. In this case elimination of T is urged by the principle of tenacity itself... Kuhn's argument for tenacity (need for a rational background for argument) is not violated either as the better theory will of course provide better standards of rationality and excellence".

Therefore proliferation of theories with stronger rational arguments could lead to the deposition of the paradigm. The fact that the alternative theories or models have stronger rational argument can cause deposition of an existing paradigm even though the paradigm itself had a tenacious rational background argument. Proliferation (as espoused by Feyerabend *et al*) is further discussed later.

Masterman (1970) claimed that Kuhn never attributed the downfall of a paradigm theory to its *falsification*. Rather the over-development of the theory merely *exhausts* it; anomalies are induced which do not refute it, but which produce only marginal advances in its development comparative to the effort of undertaking the exercise: "His essential point is that an anomaly is an untruth, or a should-be-soluble-but-is-insoluble problem, or a germane but unwelcome result, or a contradiction, or an awkward fact, which Kuhn correctly characterises as an 'irritant'... Putting it more generally, it is not only the case that a fully-extended paradigm, or theory, reaches a point where further extensions of it produce diminishing marginal returns... The situation is worse. The paradigm goes bad on you, if it is stretched too far, producing conceptual inconsistency, absurdity, misexpectation, disorder, complexity and confusion, in exactly the same way as a crude analogy does...".

Thus paradigms may deteriorate owing to the occurrence of anomalies produced by analogies beyond their original scope; they are not necessarily refuted owing to their internal inconsistencies, but by external factors beyond their scope. This is by virtue of the fact that the paradigms *themselves* define the limits of their own predictions. When applied to matters outside their original purview they of course fail. Thus normal paradigm activity tends to be inductive in character. A great deal of "mainstream research", and this is true of cost modelling, is devoted either to the defence, justification, formulation or further application of models, not to their destruction, despite the rather frequent misuse of the word "test". A "test" which produces what was expected, or which produces encouraging results, is not a test. One does not test an idea by collecting information which agrees with it.

Induction had a similar criticism. Masterman (1970) stated: "No philosopher of science before Kuhn had described this deterioration. All had blamed the gradual collapse of various scientific theories on the fact that they were eventually falsified in experience by, say, the emergence of new facts ; *i.e.* on the non-co-operation, as it were, of nature. None had blamed it on the fact that theories, since they have to have concrete analogical paradigms at the heart of them to define their basic commitments, and since the effect of these paradigms is to drastically restrict their fields, collapse, when extended too far, by their own make-up; without any necessary accentuating irritation from nature at all".

Feyerabend (1970) considered that "...it is quite imaginable that scientists abandon a paradigm out of frustration and not because they have arguments against it. (Killing the representatives of the status quo would be another way of breaking up a paradigm)." Thus religious or political doctrines can be likewise replaced.

Toulmin (1970) argued that the anomalies which might depose a paradigm are not as 'drastic and inexplicable' as might first be thought to be necessary. Indeed, Toulmin argued that the more such 'catastrophes' are studied the less catastrophic they turn out to be: "the conceptual incongruities between the ideas held by the scientific generations separated by Kuhn's 'paradigm shift' are not profound; they are caused not by revolution, but by 'degrees of variation' between theories". The opponent theorists subsequently, if gradually, concede that because these profound contradictions were never really profound their theoretical positions were in fact much closer together than they would first admit.

Thus, argued Toulmin: " ...The occurrence of a 'scientific revolution' no longer amounts to a dramatic interruption in the 'normal' continuous consolidation of science: instead it becomes a mere 'unit of variation' within that very process of scientific change... the very basis for distinguishing between 'normal' and 'revolutionary' change in science which was the very heart and core of Kuhn's theory, collapses... ".

2.7 The Lakatosian Account

Put simplistically, this method consists of rejecting the auxiliary hypotheses, A, as being weak and retaining the theory, T, as being a strong, "hard core" part of the (T·A) system. Lakatos called this approach a "Methodology of Scientific Research Programmes (MSRP)". The Kuhnian model was a forerunner to this; Lakatos was suggesting a modification thereto.

The Lakatosian recommendation was to consider the theory or model, T as being acceptable *enough* and to let it go largely unchallenged by retaining it as the underpinning agent of a research programme. Such programmes would involve rejection or refinement of the individual hypotheses. New hypotheses should be adopted which are inspired by the *positive heuristic* of the programme, that is, which are consistent with the power of the theory or model to create evidential support *for* them. Theory or model validity is viewed as a function of the historical fact that it has been the subject of such a programme. Study of the historical development of science (or rather of research programmes) would thus determine which theory or model was strongest. Lakatos also considered model proliferation to be necessary in order to bring about paradigm shift, but disagreed with the basic Kuhnian requirement for *successive* periods of tenacity and proliferation, that is profound distinctions between one period of normal science and the next.

Feyerabend (1970) held that proliferation and tenacity do not belong to *successive* periods of the history of science, but are always *copresent*. They can immediately precede revolutions, but are, to be more accurate, *always there*. "Science as we know it is not a temporal succession of normal periods and periods of proliferation; it is their *juxtaposition*".

Abandonment of a research programme is possible due to its failure to yield fruit, but does not necessarily lessen its validity. There may be reasons for abandonment totally unconnected with the theory or model itself. A programme may be discontinued due to the need to pursue some other activity, lack of funds, or even overt political pressure. Therefore old ideas are not necessarily bad (or dead). There may have been perfectly innocuous reasons for having at some time discontinued the research programme in question.

Lakatos had a degree of support: "There is no idea, however ancient or absurd that is not capable of improving our knowledge... Nor is political interference rejected. It may be needed to overcome the chauvinism of science that resists alternatives to the *status quo*" (Feyerabend, 1975). Feyerabend therefore agreed with much of Lakatos' thinking, but strongly championed competition between entire theoretical systems, as opposed to the mere refinement of auxiliary hypothetical components, as a means of comparison. This leads to consideration of the Feyerabendian solution.

2.8 THE FEYERABENDIAN ACCOUNT

To say that this involves reserving judgement would be a very loose interpretation of Feyerabend's philosophy. It is not Feyerabend's. Feyerabend's approach championed the proliferation of theories and models in healthy competition with one another. Feyerabend argued that scientists should lose their obsession with pursuing an accepted "one true method" and should compare numerous approaches to the same problem.

Feyerabend's approach envisages numerous competing models and demands the toleration of supposedly "heretical" models as the only effective way to increase knowledge. Paradigm adherents lose touch with reality; whereas the "heretics" are trying to provide competing models in order to increase the amount of knowledge through which the truth might be better approached. Feyerabend (1975) alleged that departure from reality can (and *does*) result from group adherence to the *status quo*. "It will seem that the truth has at last been arrived at. At the same time, it is evident that all contact with the world has been lost and that the stability achieved, the semblance of absolute truth, *is nothing but the result of an absolute conformism*". The Feyerabendian approach has been variously criticised as being anarchic, though Feyerabend vehemently denied this.

2.9 Koertge's Account

Koertge's suggested addition to the list of possible solutions presented above was an attempt at developing a mechanism to enable the scientist to assess the *relative* plausibility of removing T or A following prediction failure. It tried to define certain conditions in which it would be better to reject T or A (Koertge, 1978).

The method recommended a "common-sense" approach as opposed to a *sociological* approach. A sociological approach, as defined by Koertge, means rejecting either T or A according to some convention of accepted peer group practice (*vide infra*) which *protects* one or other part of the (T·A) system, by acting, as it were, as a rigid "handbook" of problems and remedies. Koertge suggested a flexible approach: check on the most probable sources of trouble and check on the most accessible ones first, without resting on some sociological explanation that one or other of T and A has priority. This approach had a basic requirement, however, that no "hard and fast" rule for solution be adopted which might *contradict the available factual evidence* pertaining to the situation at hand.

Koertge's solution may provide advice on which of the other authors' "standard" solutions to adopt under given appropriate sets of circumstances; though Koertge required some urgent clarification of certain detail in the other solution models. Koertge suggested (and claimed not to be speaking in a facetious manner in so suggesting) that a good first point of reference would be the novel "Zen and the Art of Motor Cycle Maintenance" which, Koertge alleged, constituted a "common-sense", "non-standardising", "flexible", "prioritising" "repair manual", and a good place for an aspiring scientist to seek preliminary guidance on research methods.

2.10 Selection of Theories and Models

Consideration having been given to the possible methods of dealing with proof or refutation of theories or models and their constituent hypotheses, it is deemed appropriate now to turn to questions of how the theory, model or hypotheses actually came to be adopted. As it has already been stated that a theory must (largely) explain phenomena it is considered pertinent to discuss the relationship between paradigm and true theory, the ways in which they can be compared and the extent to which they are compared in practice.

Professional practice tends to distrust "theory" as a concept. The mention of the word "theory", history tells us, can cause practitioners to experience paroxysms of rage. Phrases like "academics in ivory towers" and "cost models are irrelevant" have appeared in the correspondence columns of professional journals. If cost models are irrelevant, then so be it; they are nevertheless used in practice. We employ them in our daily business and purvey their output to our clients. If such models as exist *are* irrelevant, and this *has* been alleged, then their very irrelevance provides the need to look at potential alternatives, including those being developed in the "theoretical" world, for it is from the "theoretical" world that potential "alternatives" are most likely to emanate. What is the relationship between the "theoretical" and the "practical"? What do "theoretical" and "practical" actually *signify*? Of these two, which is the weakest?

Social or professional peer groups tend to embrace and practice, as groups, accepted theories, rules, models, techniques and norms. These socially accepted norms, *inter alia*, were described by Kuhn (1962) as being *paradigms*. A *paradigm*, basically, is something which a group, rightly or wrongly, *practises*. A paradigm can dominate the thinking and practice of a group for a long time until it is deposed by another, which the group then embraces. Kuhn referred to this as *scientific revolution*, culminating in *paradigm shift*, whereby a model is discarded for some reason in favour of another. Such revolutions are no different to social, political or religious revolutions. "Social", "political" and "religious" are key words in this context; accepted group norms (paradigms) are not *necessarily* adopted or deposed on the basis of rational appraisal. It is worth discussing, therefore, whether a "theoretical" model formulated on the basis of rational appraisal is any better worse than a "practical" model which might *not* have been formulated on such a basis.

When somebody says "I have a theory that..." what they really mean is that they have a *hypothesis* which has not formally been investigated. Until the investigation occurs it remains a supposition, not a theory. A hypothesis which survives tests (attempts to *refute* it) can become an explanatory theory. Every time it survives a test it acquires greater immunity to refutation. However, whether a hypothesis has been formulated following rigorous or informal observation, or whether it came in a dream, matters little to the hypothetico-deductivist. It is a hypothesis to be tested. It could have been formulated out of mere *belief*, which makes it not a *logical* phenomenon, but a *sociological or psychological* one. It may even be a *myth*. It is insufficient merely to suppose, assume or imagine that one model works better than another.

Indeed, if conventional models "do not explain things" it becomes of importance to explore how they could come to be practised at the expense of their potentially "explanatory" or "theoretical" rivals. Therefore it must be determined whether there are grounds other than "scientific" validity for model acceptance.

2.11 The Sociological (or Ideological) Paradigm Account

Kuhn (1962) gave no fewer than 21 definitions of phenomena which could be characterised as being paradigms. Masterman (1970), following Kuhn's (1962), classified these into three broad categories: metaphysical paradigms (metaparadigms), artefact (or construct) paradigms and sociological paradigms.

The metaphysical paradigms include: a set of beliefs, a myth, a successful metaphysical speculation, a standard, a new way of seeing, an organising principle governing perception, a map, or something which determines an area of reality. They reflect the world view of scientists.

The artefact, or construct, paradigms include: a textbook or classic work, a supplier of tools, a piece of instrumentation, a grammatical paradigm, an analogy, a gestalt-figure, or an anomalous pack of cards. They reflect the tools and methods used to investigate or solve problems.

The sociological paradigms include: a universally recognised scientific achievement, a concrete scientific achievement, a set of political institutions, or an accepted judicial decision. They signify what is accepted by some social or peer group.

It is evident (Masterman, 1970) that Kuhn used the word 'paradigm' rather than the word 'theory' because paradigms can be defined as tangible, definable pieces of accepted social or professional practice or commitment capable of existing *prior to the existence of a theory*. A theory is but one of 21 phenomena which could be classed as paradigms (following Kuhn's account). But paradigms can function which are not theories. Masterman (1970) argued: "...at least it is made clear that, for Kuhn, something sociologically describable, and above all, concrete, already exists in actual science, at the early stages, when the theory is not there".

Masterman (1970) contrasted this to (for example) Feyerabend, who studied Kuhn's work more than any other contemporary philosopher of science, but who always presupposed the existence of at least one theory. Kuhn, on the other hand, made no such supposition: theories can be preceded by paradigms, that is, arise out of them. Kuhn, notwithstanding the foregoing, implied quite clearly that paradigm activity is not necessarily scientific activity.

Therefore a paradox arises: extension or development may be sought of a "paradigm" which is sufficiently undeveloped to warrant the title "explanatory theory". If a paradigm is embraced which has not been seen to possess these explanatory powers then how does it come to be hy is it embraced in preference to some equally worthy (or equally unworthy) rival? This can perhaps be explained by considering the ways in which people might deal with the evidence, or the lack it, which might justify, or not justify, any decision to accept the theory or model.

Lack of evidence to support a model will not necessarily deter a person from deciding to use it and then behaving as if the decision were correct. Lewin (1951) suggested that the mere fact that a decision has been made exerts a stabilising influence. A person will behave according to that decision even were it difficult so to do. Lewin described the housewife who selects an expensive piece of meat when she could have selected cheaper alternatives. Having deemed it to be attractive she will make sure that it reaches the table and is eaten. Thus someone who deems a given model to be desirable (for *whatever* reason) will try to ensure that people use it, though there may be no more proof of its efficacy than of the efficacy of any alternative. The model may be of material or commercial value to the people who champion its use; this could be a strong factor in establishing its attractiveness to a sponsor.

Were a model to be seen to possess defects, that is, features of it which could not be used to justify any decision to use it, it would not necessarily follow that the decision to use it would change. Each decision, once made, creates a greater or lesser degree of dissonance or discordance. This could crudely be described as the degree of anguish which follows the decision itself. There will always be reasons not to decide to use a given model as well as reasons why such a model should be used. These contradictions are known as the "pre-decision conflict".

A key point in this context is that the decision-makers might not *regard* the situation as being one of conflict. They may be unaware of, or palpably ignore, the reasons not to use a model. The decision to use the model having been made, the reasons not to use it still remain and cause the dissonance. There will be a greater or lesser compulsion to justify the decision depending upon the amount of dissonance.

Festinger's Theory of Cognitive Dissonance (1957) held that the amount of dissonance existing after a decision has been made is a direct function of the number of things the person knows are inconsistent with that decision. When the consonant information, that is, the information which would support a decision, is outweighed by the dissonant information, that is, the information which would not support the decision, there is no guarantee that the decision will be based on the consonant information. This assumes, of course, that all such information is available, which is not necessarily the case. This point is elaborated below.

A parallel can therefore be seen between the psychological or sociological reasons to accept or reject an alternative and the scientific reasons to embrace or unseat a paradigm. It is argued here that however "scientific" or "unscientific" the method of model selection, the "need to justify" tends to create paradigm practice.

Why would somebody, confronted with two or more equally-attractive (or unattractive) alternative models, decide to select one or other of them? They will be equally attractive if, for each, there is an equal amount (or lack) of information to support them. The information may exist, but the person may be unaware of it, *or choose to ignore it*. Known models may be chosen due to familiarity, but choices made purely on that basis can hardly be described as rational. Familiarity with a model does not justify its superiority over another, about which nothing might be known. Fear of the unknown effect of using an alternative might exist, but there may be no greater empirical proof of themodel so accepted than of any rejected alternative.

It is clear that a model, theory or paradigm can be accepted or rejected without recourse to "the facts". In this sense Kuhn, Masterman *et al* are correct in identifying social or ideological grounds for acceptance or rejection. Feyerabend (1970) put it succinctly: "The most important point is however this: it is hardly ever the case that theories are directly compared with 'the facts', or with 'the evidence'." Thus the most salient characteristic of the paradigm idea is that it deals with *group* acceptance. Scientific or professional, it matters little; the paradigm, in the context of this study, is a sociological phenomenon.

Sen (1970), in considering choice of economic models, suggested that a model may be selected not on the basis that any gain would ensue from using it, but on the basis of conformity; that is, commitment to a set of social or peer group ideals: "Every economic system has, therefore, tended to rely on the existence of attitudes to work which supersedes the calculation of net gain from each unit of exertion. Social conditioning plays an extremely important part here... and one reason why economists seem to have little to contribute in this area is the neglect in the traditional economic theory of the whole issue of commitment and the social relations surrounding it".

An individual might select a model not out of personal (informed) preference, but out of loyalty, or fealty to some group of associates, peers or rulers. Sen stressed the importance of Harsanyi's (1955) distinction between 'ethical' and 'subjective' preferences. The former relates to preferences which the individual would *rather* express (were it left to the individual) and the latter relates to preferences which he or she actually expresses (implying or requiring that something or somebody *influences* the choice, for whatever reason). This is, in effect, another way of suggesting that man is an irrational creature. However, by adopting a stance of commitment to a group, the individual's choice of model will at least be consistent, which suggests a measure of rationality, albeit a rationality displayed by the group rather than by the individual. But what type of rationality is it? Sen (1970) concluded: "In the sense of consistency of choice, there is, of course, no reason to think that admitting commitment must imply any departure from rationality. This is, however, a very weak sense of rationality."

It can be seen, therefore, that adherence to a paradigm model due to social, religious, political or peer group commitment reasons could occur at the expense of adherence brought about by taking recourse to the 'facts', whatever they might be. It is equally probable that model rejection could be brought about by the same pressures. Scientific treatment of a model, theory or paradigm can be given if it is "stripped of its sociological environment" (Masterman, 1970).

2.12 THE OBJECTIVIST OR EMPIRICAL (POSTIAN) ACCOUNT

Post (1978) argued for an objectivist solution to the problem of theory or model selection. Post argued for a "normative" programme; an approach which excludes "positivistic sociological" definitions of what constitutes "success". Explanations like "we use this model because it works" are fatuous without empirical evidence that such a model works. The model cannot be considered in isolation on the basis of some assumed (or even demonstrable) intrinsic merit. Consideration of "intrinsic" merit (which can be real or imagined) is not a rational solution unless it is compared with the "intrinsic" merit of other models. Here Feyerabend (1978) supported Post: "... it does not suffice to consider its 'intrinsic' merits for this just amounts to comparing the idea with itself".

Further, definitions of what constitutes "success" depend a great deal upon who has a vested interest in promoting the model: "The mere fact that a certain procedure is followed in practice does not render that practice acceptable to an objective methodology of appraisal. Indeed even the fact that a practice following certain criteria generally leads to 'success' does not justify those criteria in an objective programme" (Post, 1978). Post's implication would appear to be that models deliberately designed so as to be incapable of being unsuccessful must be dubious. They could be formulated so as to exclude potential falsifiers.

The Postian Problem was straightforward. Given two theories, T_1 and T_2, by what criteria can and should we decide to prefer T_2 over T_1? The solution was straightforward. If the empirical parts of a theory, that is those parts which have withstood some testing, are represented as E_1 and E_2 respectively, then the criterion for selection is $\Delta E>0$; that is where one theory has more "test-survival" than the other. T_1 is better than T_2 if, in moving from T_2 to T_1, $\Delta E>0$ is induced. T_2 is better than T_1 if, in moving from T_1 to T_2, $\Delta E>0$ is induced. Post's qualification was, of course, that no such tests should have led to refutation.

2.13 The Petrochemical Civil Engineering Measurement and Cost Control Model

Cost modellers in the field of Petrochemical Civil Engineering would not be dismayed by the suggestion that approximations to the truth are the best obtainable results. Models stating some criterion as being "general" on the basis that, for example, only 95% of the cases observed actually satisfied that criterion would merely express statements of high probability, but ought consequently to be highly acceptable in practice. Such probabilities would lie within the tolerances of accuracy usually permitted by conventions of commercial practice. The Petrochemical Civil Engineering cost data themselves are somewhat crude and do not completely represent their imagined associated construction costs in any event (*vide infra*). A solution is sought which is accurate enough, but not so accurate that the commercial benefits which it brings are outweighed by the incremental effort of obtaining higher degrees of accuracy (see also Sen, 1970).

In Building cost modelling, it is argued, there are too few well-developed theories capable so far of dominating the thinking of its associated practising community. In fact it is debatable whether, in the field of Petrochemical Civil Engineering cost modelling, there are any true theories. Consistent with Masterman's (1970) interpretation of Kuhn (1962), it is argued that in Petrochemical Civil Engineering measurement and cost control there are many paradigms existing prior to theory which do domininate the thinking of the associated community. These paradigms do not constitute theories as they do not adequately explain the cost behaviour which they purport to represent. Whence do these Petrochemical Civil Engineering paradigms arise?

In practice the paradigmatic models in Petrochemical Civil Engineering have been adopted analogically from the paradigm models of the wider, general domain of Building cost modelling. It is argued that these "parent" models from other closely related fields are no more justifiable in the "scientific" sense of the word than the analogical Petrochemical Civil Engineering models adopted therefrom.

Following Musgrave (1978) (*supra*): if the Petrochemical Civil Engineering models can be found to be based on some faulty underlying principle or principles also contained by the general Building cost models from which they are adapted then the entire family of such Building cost models can be similarly discredited.

Too seldom have established building cost techniques been subject to tests of validity or formulated by processes other than of negotiation between interested parties. Conventional models may be based on untested assumptions that their constituent parameters bear relationship to the prices which tenderers might, or might not, apportion thereto. Seldom, also, have practitioners trusted alternative models about which they might know little. Often have they persevered with established models about whose 'factual' performance they might know less.

The absence of 'factual' reasoning behind the model is consistent with a sociological paradigm. Hence Petrochemical Civil Engineering cost modellers adhere to paradigm practice, adopted analogically from the general set of models described above, but are practising *prior to theory*. Scorn of the term "theory" constitutes a misuse of the meaning of the word. Current models are adopted for more for sociological reasons, as classified by Masterman (1970). Specifically, these models are espoused out of commitment to a peer group as suggested by Sen (1970) or by virtue of it being in a person's job interest so to do, as suggested by Toulmin (1970).

It is relatively less likely that such models have been formulated on the basis of rigorous observation of the cost behaviour of their constituent data. Therefore such observation should be attempted. A hypothetical model could be proposed, without logical formulation, which could appear, *prima facie*, to be a ridiculous model. For the researcher the joy would be in seeing whether it worked. The practitioner might refuse to contemplate such a model because it had not been *shown* to work. The contradiction is that the *established* model might not have been shown to work either. It could, in truth, be as "ridiculous" and unjustifiable as any competing model. But the practitioner might preferentially use the established one, as if the fact that it were officially endorsed, or were in widespread use, somehow bore testimony to its validity.

Thus, it is argued, Petrochemical Civil Engineering cost models exist in the "pre-theory" state described by Kuhn *et al.* There are sets of global, uniting beliefs in the domain of professional practice. However there is a danger if this belief turns out to be more *de facto* than *informed*. To speak impolitely, the established building cost models of the "real world" are less likely to be in the "real world" than the explanatory theories which "academic" world has not yet fully developed, but which, strangely, have already been fully castigated by professional practice.

It is argued that the "scientific" development of Petrochemical Civil Engineering and Building cost models is sufficiently infantile that there are not yet any theories capable of having strong explanatory powers, or capable of surviving the "severe testing to destruction" demanded by the hypothetico-deductivists. A relatively crude set of analyses should suffice to show that insufficient *empirical* consonant or dissonant information has, as yet, been identified which would assist any cost model selection decision.

Further, it is argued, the "model or method proliferation" suggested by Feyerabend (1970) will contribute towards the development of a stronger explanatory theory for Petrochemical Civil Engineering measurement and cost control by providing more such information. Only competition can facilitate this process. Any strengthening or weakening of conventional Petrochemical Civil Engineering measurement and cost control models will contribute to the strengthening or weakening of the general Building sociological paradigms, whose underlying principles they assume.

If this work does not serve to provide logical reasons to adopt a new model or change an existing one, then perhaps it might provide sociological reasons. It might "persuade" or "convert" people regarding model selection, as if by way of a religious or spiritual mission, rather than by exposition of empirical "facts": "such a change of position could have come about only as a result of a 'conversion' - the sort of mind-change which a man would have to describe by saying, 'I can no longer see nature as I did before...' - or alternatively as the outcome of 'causes' rather than 'reasons' - 'Einstein was very persuasive...', or 'I found myself changing without knowing why...'. or 'It was as much as my job was worth...'." (Toulmin, 1970). If Toulmin's reasons for "conversion" were good enough reasons for conversion to the *established* models (and there is much evidence to support such an argument) then (by the same token) they *must* constitute good enough reasons for considering "conversion" to potential alternatives.

A possible approach to the treatment of the established Building model (which was very like the establishment approach to heresy) was attempted by Skoyles (1986), who was extolling the virtues of serious research to an assembly of practitioners: 'To demonstrate that QSs (*sic*) should have a rethink about the principles of measurement, I vigorously tore up a copy of the SMM. Unfortunately the pieces flew into the face of the evening's guests [sic] - the President of the QS Division. I shall long remember [... 's] kind acceptance of my blurted apology -'Remember Ted, the SMM works' ". At £20 per copy for the SMM, was this a wasteful "research technique" on Skoyles' part, and was the (then) President of the Quantity

Surveying Division of the Royal Institution of Chartered Surveyors an adherent to a sociological paradigm? Time, and the work which follows here, might tell.

2.14 SUMMARY

It is the contention of this thesis that:

(1) There is a lack of theoretical development in building economics, which is characterised by the practice of group paradigms prior to theory formulation.

(2) There is a consequent paucity of rational scientific evidence to justify the adoption of conventional Building cost models. These models are too often presumed to possess intrinsic merit.

(3) The conventional Petrochemical Civil Engineering Measurement and Cost Control Model, being no more than the general Building cost model adopted in its entirety, is a sociological paradigm with even less claim to have been founded on the basis of rational evidence.

Chapter 3 will discuss the use, content, requirements and objectives of a measurement and cost control model for Petrochemical Civil Engineering and, by implication, for building work in general.

CHAPTER 3:
THE OBJECTIVES OF A COST MODEL FOR PETROCHEMICAL CIVIL ENGINEERING WORK RELATED TO ORTHODOX CONVENTIONS

3.1 THE CONVENTIONAL PETROCHEMICAL CIVIL ENGINEERING COST MODELS AS INFORMATION COMMUNICATION MEDIA

The communication of measurement and cost control information within the design team and between the design and production teams in Building, Civil Engineering and Petrochemical Civil Engineering has traditionally, and widely, been *via* the Bill of Quantities. This document contains a basic list of parameters which represent recognisable physical design features of a completed building or structure, against which successful tenderers are invited to assign prices for payment by the building owner. This document is produced by transforming pictorial design information into sets of quantitative and qualitative phraseology which purport to represent the work which the contractor is expected to carry out. These data are measured and described according to sets of rules, known as Standard Methods of Measurement, which prescribe the features which shall be measured and the phraseology which shall be used to describe them.

There has been much debate about what the document communicates or ought to communicate to its users, and about how efficacious it is for facilitating its perceived cost control functions. "It is evident that if the building is split up into its constituent parts and the cost of each part can be estimated, an estimate can be compiled of the whole work. It has been found in practice that a schedule can be made setting out the quantity of each type of work in recognised units of measurement, and that estimated prices can be built up for the labour and material involved in each unit. This schedule is the Bill of Quantities, the prices in which can be added up to arrive at a total sum" (Willis and Newman, 1988).

Willis and Newman omitted to mention that there are also plant and equipment costs, but offered a useful starting definition. The process by which a Bill of Quantities is produced is easily described: "1) Taking off' in which dimensions are scaled and read from drawings and entered in a recognised form on specially ruled paper... ; and 2) Working up' which comprises squaring the dimensions,... transferring the resultant lengths, arranged in a convenient order for billing and reduced to the recognised units of measurement; and finally the billing operation, where the various items of work making up the complete project are listed in full, with the quantities involved in a suitable order under work section or elemental headings" (Seeley, 1988). Seeley overlooked the existence of areas, volumes and masses, but adequately summarised the process of information transformation; from pictorial form into words and numbers which purport to represent the way in which construction costs are generated.

It is unlikely, though, that these documents truly represent the way in which construction costs are incurred by the builder. Indeed it is not construction work which is measured by the design team. "There has been an attempt in recent revisions of the rules for measuring Bills of Quantities... to orientate the measurement of the building to the way costs are incurred on site. However, the vast majority of items are still largely measured 'in-place', that is to say they are measured as fixed in the building with no allowance for waste and no identification of the plant and tools required to install them. This is to avoid the possible situation arising where the quantity surveyor tells the contractor how to 'do his job' or makes assumptions as to his efficiency" (Ferry and Brandon, 1991).

Flanagan (1980) stressed the importance of recognising the resources and activities which give rise to construction costs, which conventional models ignore. Though this is a potential weakness, much depends upon the particular purpose for which the model is designed, and for whose benefit the model exists. It must be determine whether it was ever *intended* that the particular model should recognise such cost determinants. There can be no firm expectation that the main purpose of models such as the Bill of Quantities *is* to represent construction costs. It would be appropriate, therefore, to consider what the functions of such models are, or should be.

Ferry and Brandon (1991) correctly asserted that the Bill of Quantities is a "Cost Model", defining a "Cost Model" as "the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its cost", but harboured doubts as to whether this model adequately represents, or ought to represent, the true costs of construction.

Hardcastle (1992) argued that there may be confusion over the definition of the main purposes of the Bill of Quantities, but that other auxiliary uses can be identified. This argument is not supported here. The main function of the Bill of Quantities is clear, as will be argued below. Hardcastle nevertheless alluded to an interesting scenario, if it existed; a scenario where the *main* use of a document cannot be defined, but where *incidental* uses thereof can be described at length. A strange situation, indeed. Hardcastle correctly stated, though, that these incidental uses are only *potential* uses. Skinner (1979) identified 14 procedures for which the Bill of Quantities is an information source.

Daly (1981) identified 21 cases of potential utility, to contractors, of Bills of Quantities. All of these potential uses were invoked at some time or other, but *not consistently*. There was a tendency for Bills *not to be used* in four cases and *only occasionally to be used* in six cases. Of the eleven cases of *extensive* use, only two related to resource and project planning (the true cost determinants in the domain of the builder). Six cases of "extensive use" related to interim and variation payments (the domain, by prescription in building contracts, of the design team). Therefore the document acts as an accountancy tool, not a spectacularly useful tool for planning or prediction. Unfortunately Daly's results did not clarify the situation regarding use in preparation of tenders.

The Bill of Quantities is clearly a vehicle for communicating information. Daly, however, admirably demonstrated the severe limitations to its actual utility, as opposed to its possible utility, other than as a vehicle for payment to the appointed contractor. It would be pertinent to investigate the significance and validity of the information contained in such documents in terms of *cost-importance*.

That the Bill of Quantities, or any model which uses "lowest cost" as a contractor selection criterion, is not an entirely suitable vehicle for actually comparison of contractors can be inferred from Ng and Skitmore (1994) and Holt *et al* (1994). They argued, variously, that contractor selection should be based on numerous desirable attributes of contractors, not solely on level of tender bid. It could be contended that any tender sum so accepted will change in any event owing to disruptions, not all of which are attributable to contractor performance . Potential contractor performance is not considered in any formal, objective manner by "bid only" models of contractor selection. The argument that the tender sum, represented by the sum of the prices assigned to the Bill of Quantities, should not be the sole selection criterion suggests that the Bill of Quantities is not as important a tendering instrument as might be first thought. This effectively restricts the area of application of the Bill of Quantities to that of cost evaluation of design change brought about by the design team. It is design alone which the conventional Bill of Quantities is intended to represent; and even that is debatable (*vide infra*).

It should be understood, that the principal function of the Bill of Quantities is to provide prices for valuing variations to the work (or rather to the *design*) portrayed therein. Its benefit to the tenderer is imagined to be significant but is, in practice, limited. It provides information about the proposed project which may or may not be actively used by the builder. It exists for the benefit of the design team, as a tool to aid their cost control and prediction. By its use the design team dictate the way in which the tenderer is expected to present prices. Indeed Bills of Quantities contain "disclaimer" clauses instructing tenderers not to rely upon them for various construction management purposes.

In Civil Engineering it has been argued that "the first purpose of a Bill of Quantities is to facilitate the estimating of cost of work by a contractor when tendering" (Barnes, 1977). It is argued here that conventional Bills of Quantities are not intended for that purpose. They may be useful in that context, but not necessarily efficacious (see also Skinner, 1979).

The Chartered Institute of Building (1982) held that the purpose of a Standard Method of Measurement should be to lead to the production of Bills of Quantities able to provide unambiguous information needed by contractors' estimators to establish, *inter alia*, the cost of building. All other uses of Bills should be regarded as subsidiary. A modification is suggested here: all uses of the Bill other than the valuation of variations should be regarded as subsidiary. It could never provide all information required to compile a tender and a tender can be compiled without it. Is sufficient that the information therein does not *hinder* the tendering process. Were there ever an unworshipful company of paradigm adherents it would be the one obsessed with the idea that Bills of Quantities are, or should be, a key instrument in the builder's estimating process. They are not, it is contended, and could never be.

In reality the Bill of Quantities purports to reflect a state of design (a finished product) and not the construction methods selected or the factors which influence their costs. There is some argument that it *should* reflect those methods. However, with certain exceptions, the methods are not for the design team to dictate. Therefore there is no perceived need for the Bill to describe the *work*, because the builder decides what that work, and its resource inputs, shall *be*. The builder's estimator finds it difficult enough to predict performance on site (see Fine, 1982); the Bill of Quantities should never attempt so to do. Though it models a unique design, the Bill can never model unique construction methods and prices. The best it hopes to achieve is *an approximation of a unique situation by using a general set of standard parameters* of description. Even this aspiration is somewhat dubious (see 'nomothetic models', *infra*).

The builder can approximate by inserting standard prices against these standard parameters. The builder can forecast a set of resource requirements, but not very accurately: achieved output on construction projects varies between 50 and 200% of the output allowed in such an estimate. The weakness of the prices assigned by the tenderer to these resource units is that they tend to be "standard" prices computed from estimated "mean" output allowances, which could never bear true relationship to achieved output (Fine, 1982).

Given that all building cost information originates from builders, the picture still cannot be clear; the builder cannot predict perfectly and is not supplying true building costs in any event. The Bill requires that the tender be broken down and apportioned to the design features described therein. Its priced contents cannot represent, or dictate, the way in which a tender has been, or should be, compiled. Thus it cannot represent true building costs: 'We know that the rates in the Bill of Quantities are not true costs, but they are not even true prices in the sense of a price on the supermarket shelf. The contractor is not offering to 'sell' brickwork at so many pounds per square metre, his accepted offer is for constructing a whole building and the rates are simply a notional breakdown of his total price for commercial and administrative purposes. There is thus no reason why any individual rate should be justifiable in relation to either cost or competition" (Ferry and Brandon, 1991).

The Bill of Quantities has one express function only (for that is why it was invented): to serve as a tender analysis in a format specified by the design team so it can be used to approximate costs of design changes in the pre contract or post contract period. Davies and Greenwood (1994) argued that there is no difference, in design terms, between pre contract design change and post contract design change: "both mechanisms are basically the same; they merely occur at different times".

This is to say that if the preferred mechanism of valuing such variations is to take recourse solely to the price information in the model (and it is often so preferred) then there cannot be a difference between the design changes at these different times *as far as the cost model is concerned*. Any design change which so changes the scope of the project that it no longer remotely resembles the contents of the model does not affect the workings or the contents of the model; it merely means that the contents of the model can no longer be used and that other solutions must be found. This is evidence that the conventional model is very weak as a predictive, inductive and theoretical model. That which it fails to predict is considered to be completely outside its purview.

Davies and Greenwood (1994) argued for a level of abstraction of information which could be used in both the design and production phases. The conventional model exists at an unsuitably low level of abstraction for that purpose. Its use by the production team to execute numerous estimating or planning tasks can be envisaged, but these are only *possible* uses and there is no expectation that its use in such situations will be particularly efficacious.

Thus the use of the conventional cost model is not intended to be synonymous with its possible use by the production team. The separation in the construction industry of design and production matters is notorious. It is argued here that the conventional measurement and cost planning models cannot fulfil both roles simultaneously. For any attempt to bridge this gulf to succeed the model should exist at an appropriate *level of abstraction*.

3.2 Level Of Abstraction Of The Model

Level of abstraction is a key issue in this regard. Information which exists at a low level of abstraction exists at a high level of detail and information which exists at a high level of abstraction exists at a low level of detail. In neither case is the amount of detail necessarily synonymous with significance (either to cost or design). The significance of information can only be ascertained by viewing the information in an appropriate context.

An appropriate context to consider is that surrounding the initial formulation of the model; for if the inductive process of its formulation was of a psychological, as opposed to logical, nature little can be said of its resultant content. The circumstances determining cost behaviour may not have been the circumstances reflected in the formulation of the model which is supposed to represent those costs. Hence the parameters which the model contains may be inappropriate to its intended use. Certain (or all) of its constituent detail may be redundant in terms of what it is the model is supposed to actually communicate.

This, it is contended, is because the parameters of such models were not formulated as a function of cost significance; they were formulated as a function of design significance using known determinants of physical appearance, not known determinants of cost. Thus their derivation may be out of context with their intended use; that of representation of significant cost features. If such models contain insignificant or redundant cost centres they will do so regardless of their level of abstraction, because no matter what the level of abstraction, it is "design centres" which are being abstracted.

The most significant feature of the conventional measurement model is the quantity of the detail itself. Models could be out of context in that they might, as a result of their manner of formulation, *dictate* cost behaviour rather than *represent* it. If so, the model is prescriptive, not descriptive; it does not identify in its structure which parameters are relatively cost important and which are not. "Information which says what must or ought to be done is very different from information which conveys facts, or information which passes judgements, but it relies on both of these other kinds of information. Typical prescriptive information includes orders and instructions, rules and regulations, recommendations and advice. To justify prescriptive information one must appeal to the consequences of acting upon it" (Stamper, 1973). An effort should therefore be made to make the model more descriptive. This implies empirical observation of data prior to formulation.

This invites the suggestion that the paradigm models of practice (see Kuhn and Masterman) are not theories; they do not explain anything very well. Rather, by virtue of not categorising or reflecting the relative importance of those things which can be observed they could falsely depict the situation which they were intended to describe. It is suggested at this juncture that if parameters of a model are formulated which are not a function of the behaviour which it is intended the model represent then the level of signification of the information in the model will not vary as a function of its quantity. In fact the level of signification of the information will remain constant, because there is no functional relationship between the conditions of the model's formulation the relevance of what it is modelling. As the constituent parameters of a model may not have been formulated to actually follow cost-significance (see Davies and Greenwood, 1994) it is important that the nature of cost-significance in the models should be investigated.

Tender cost analyses, usually in Elemental format, are produced mainly by abstraction from priced Bills of Quantities (see, for example, Ogunlana, 1979). It is suggested here that the fact that such a process of abstraction must occur at all suggests that the level of abstraction of the Bill of Quantities must have been to some extent inappropriate for facilitating cost control functions in the first place. Flanagan (1980) stated that "for the purpose of cost planning, the building price is analysed into functional elemental categories, but these are of little help in the identification of factors affecting prices". Flanagan argued for greater study of construction activities as cost determinants.

Davies and Greenwood (1994) argued that not only do conventional Bills exist at an inappropriate level of detail, but so also do the elemental cost analyses derived therefrom. The analyses in fact over-compensate for the excessive detail of the Bills by manifesting themselves as gross oversimplifications. Therefore the two models are mutually contradictory. The parameters contained by the cost analyses are too insensitive to reflect, to an appropriate degree of definition, the effects of design variations. The parameters contained by the Bill of Quantities contain much detail which is inappropriate for *any* potential use. Such information is, as was said by Hardcastle (1992), *redundant*. The most appropriate level of abstraction, it is argued here, lies between that of Bill of Quantities and Elemental Cost Analysis.

A cultural change is required, it is argued. A suitable set of model parameters must be identified exist at a lower level of abstraction than that of the Bill of Quantities, much of which is redundant by virtue of being a bath filled to overflowing (see, for example, Barnes, (1971) and Hardcastle *et al* (1987a, 1987b and 1988)). It should also exist at a higher level of abstraction than that of the conventional Elemental Cost Analysis, much of which is vague by virtue of having "thrown the baby out with the bath water". A model is needed which fulfils both roles simultaneously and avoids unnecessary duplication of effort (Davies and Greenwood, 1994).

Attempts at Element standardisation should be treated *cum grano salis*; the paradigm of adopting a single set of standard rules for variable behaviour induce a reduction of grip on the *reality* of variable behaviour. This is evident: cursory inspection shows that conventional Elemental classifications have been founded, curiously, on a general set of design features (somehow expected to be exhibited by all buildings, regardless of their structure) rather than on prior analysis of cost behaviour. Yet the very Element costs displayed by these models are *highly variable* from building to building *within the same Element*. The *fact* of this high variability *must* be evidence that conventional Element classifications obscure, or do not recognise, the significant cost determinants. This has to be inadmissible in a cost model.

Thus it becomes necessary to discuss data identifiable in the conventional Petrochemical Civil Engineering cost data commensurate (or not commensurate) with the level of definition described above. It should also be determined whether there are levels of detail which, owing to the manner in which the the model has been formulated are, to speak impolitely, spurious. In order so to do it is proposed here to examine the parameters which contribute (variously) cost significance or mere detail in the conventional model.

Viewing conventional (or any) cost models as information systems, it can be postulated that such systems possesses the property of equifinality (Heath and Bryant, 1992). That is, they are each capable of achieving the stated goal, whatever that goal might be, but by different means. Given that each system has this capability it would seem reasonable to embrace the system which possessed the least complexity. This implies that it contains less information, *in toto*, than the other systems. If it is capable of containing less information and still achieving the goal what can be said of the "surplus" information possessed by the others? Can a model containing less information than other models be a better model?

Classical cost modelling "theory", to misuse the word, holds that the more the design of the building or structure has evolved, and hence the more information contained in the cost model, the better the model becomes. This is naive. The concept of entropy must be considered. Entropy is the degree of uncertainty which results from randomness, or lack of predictability, in a situation or information message. When certainty or predictability is present in a situation then no additional information is needed, and no entropy exists (Heath and Bryant, 1992). Once a model or system achieves an acceptable degree of certainty or predictability the addition to it of further information merely creates entropy; the uncertainty and confusion. The idea that equal, or equivalent, certainty can be obtained by the provision of less information than is usually "expected" is alien to conventional thinking regarding conventional cost models.

An extension to the basic argument is now offered. The entropic content of the model can be reduced by removing it from the model. If the entropic information has *not* been removed, it is argued that it is not surplus in the sense of merely being benign. It is not information which just happens to be there, and which has no effect. It could have a detrimental effect. Heath and Bryant (1992), building on work by Shannon and Weaver (1949), discussed the concept of information in a communicating system being distorted during transmission. The transmission device itself can cause distortion of otherwise clear information. For example, though the person speaking into a telephone may be speaking clearly and lucidly, there may be problems associated with the "mechanics" or "electronics" of the telephone system itself (the transmission device) which cause the recipient to hear just "noise". "Noise" thus induced will increase uncertainty. Much of what is heard, though never intended by the sender, will nevertheless be heard.

However the person receiving may have no way of knowing that the transmission device is distorting the message. The noise may be taken at face value as being intended, necessary and usefu. The recipient may *act* upon the information; it may not be *perceived* as being "noise". It is attributable by Heath and Bryant (1992) to Shannon and Weaver that if noise is introduced, then the received message contains distortions, errors and extraneous material which would lead one to say that the received message exhibits, as a result, increased uncertainty. It has increased the total quantity of information, but it may sound to the recipient as if it were all beneficial.

Considering the Petrochemical Civil Engineering cost model as such a communicating device there may be noise and uncertainty produced by the structure and workings of the model which flow from the measurement conventions governing its formulation. These conventions may prescribe to the sender the inclusion of extraneous information in the model which portrays distortions of the information which the sender might otherwise have communicated. The recipient, though, of the Bill of Quantities, or the user of an Elemental Cost Analysis abstracted therefrom, might do no less than assume that the information contained (received) was all relevant. It might not occur to the recipient that it is possible for the model itself to induce distortion. It is argued that the encoding device, the conventional method of measurement, induces such distortions. The "noise" is induced by the conventions which determine the model's content.

3.3 The Relationship to Cost of the Conventional Petrochemical Civil Engineering Model

Bias in cost distributions is known to be a feature of Bills of Quantities. They behave according to the principles expounded by the economist Pareto, who found that 80% of the income in a country is earned by 20% of its income earners. Such distributions of cost have been suggested of Bill of Quantities items by, for example, Barnes (1971), the Property Services Agency (1983), Hardcastle *et al* (1987a), Hardcastle *et al* (1987b) and Hardcastle *et al* (1988). This principle has been seen to apply in numerous situations, such as quality control of manufactured products (Wadsworth *et al*, 1990).

Horner and Saket (1984) and Horner *et al* (1986) described a method of estimating for tenderers, using data from Civil Engineering projects, which they alleged achieves the same results as conventional models by only using 30% of the items which would form a Bill of Quantities. That the "Pareto" distribution applies to many situations is widely accepted by those who have studied the phenomenon. Thus it may be alleged that 80%-90% of the items in a Bill of Quantities can aggregate to only 10%-20% of its cost total. Barnes's (1971) work in Civil Engineering is the most salient recent related modelling work related to measurement and cost control.

Drucker (1978) contended that this type of distribution is a feature of all data arising from commercial activity: 'What exists is likely to be misallocated. Business is not a phenomenon of nature but one of society. In a social situation... events are not distributed according to the 'normal distribution' of a natural universe. In a social situation... a very small number of events - the first 10 to 20% at the most - account for 90% of all results; whereas the great majority of events account for 10% of the results." Drucker (1978) also contended that "A second implication is that resources and efforts will normally allocate themselves to the 90% of events that produce practically no results. They will allocate themselves to the number of events rather than to the results. In fact, the most expensive and potentially most productive resources (i.e. highly-trained people) will misallocate themselves the worst. For the pressure exerted by the bulk of transactions is fortified by the individual's pride in doing the difficult - whether productive or not. This has been proved by every study".

Goldratt (1990) held that the "80/20" distribution was a considerable underestimate when dealing with variables in the world of "throughput of costs": "In the throughput world, even the Pareto principle must be understood in a totally different manner. It is no longer the 20-80 rule. It is much closer to the 0.1-99.9 rule. A tiny fraction (0.1 percent) determines 99.9 percent of the result... attention is spread much too thin, on too many seemingly equally important problems". Therefore it should be determined whether all the data, or information, in the conventional models cost model have the equal importance ascribed to them (by omission) by the conventional measurement conventions. That these phenomena are phenomena of the economic world, or of the commercial world, as Drucker put it, is important to remember.

Cirillo (1979) explained that the "Pareto" distribution is an empirical law, based on observations of what actually happens. Though Pareto's distribution curve is of the same general shape for all populations studied, the exact distributions differ from population to population. The "law" predicts a general phenomenon, but not the precise outcome. Cirillo (1979) elaborated by asserting that such distributions do not occur by chance. They are not observations of phenomena of the natural world, and so the distributions are not normal; *not the result of random error*. A complexity of sociological, political and commercial conditions are determining the outcomes. Much literature related to building economics depicts and discusses normal distributions as if the entities being observed are features of a world of physical, as opposed to social, science. This is an erroneous assumption. There is the risk, therefore, that economists (including building economists) pay insufficient attention to the sociological foundations of their models and theories.

Effort is expended measuring those things which it is believed (but is not necessarily known) affect costs. Effort should not be expended measuring those things which contribute little (if any) cost. Such things are of no use if they appear in a document which is primarily concerned with costs. It should be ascertained, therefore, what is cost-significant and what is not. Further, our data classifications and measurement techniques should be selected such that they follow criteria of cost-significance rather than some other (arbitrary?) criteria.

Measurement can be technically difficult and very time-consuming. Then, as if in defiance of the beliefs of the design team, the builder appears to consider much of the product of systematic measurement to be relatively unimportant. It is difficult to make a case, therefore, for including items of little cost-importance in a document with a highly-restricted cost planning function. As will be shown later tenderers frequently attach no costs whatever to extensive tracts of the cost document. Items which were of no importance to the builder at the time of tendering can by logical inference be equally as unimportant to the builder for the purpose of valuing changes to the contents of the document.

It has been suggested of the Bill of Quantities that "considered as a model, it should therefore comprise a list of carefully described parameters on which the cost of the work done can be expected to depend. Clearly these parameters should include the quantities of the work to be done in the course of the main construction operations. There is no point in listing those parameters whose influence on the total cost of the work is so small as to be masked by uncertainty in the forecasting of the cost of the major operations" (Barnes, 1977).

It has also been suggested that the failure of Bills of Quantities items to take into account the uncertainty affecting costs of building operations renders them dubious in terms of reliability: "Simulations of repetitive processes show that costs are largely generated by the interferences and uncertainties that exist, and that simple additive models like the BoQ [*sic*] seriously under-estimate costs. It is the failure of these simple additive models that produces much of the drama in our industry" (Fine, 1982). This is to assume, of course, that it is intended that the model *should* represent the way in which construction activity occurs on the construction site. No such contention is made here. The document was never intended to cater for the ways in which the builder incurs costs, but was intended always to provide a convenient, if crude, way of effecting payment to the builder in certain situations.

Fine clearly did not follow the thinking of Willis and Newman and was even less complimentary to the Bill of Quantities when he compared the "science" of the ingredients in a chemical reaction with the ingredients in the Bill. He showed that were the quantities of the chemical ingredients altered a different result would be obtained, but were the quantities and prices of Bill of Quantities items to be redistributed at random and the tender sum recalculated there would be no appreciable difference between the original and recalculated totals.

There appears to be a polarisation of opinion. One school of thought believes that the items measured represent the work done. One school of thought believes otherwise. One school of thought believes that simple item addition, as it were "grocery lists", produce correct totals. The other school of thought suggests that such lists ignore the occurrences and uncertainties which most markedly affect building costs. Certain items, therefore, the *measurement* of which is costly, may have no cost significance to the person who *prices* them - the builder.

There appears to be little reason to disagree with the suggestion that the prices in such documents need bear no resemblance to reality (Ferry and Brandon, 1991). They are merely rates at which the builder is happy to be paid; they are therefore prone to abuse. An opportunist builder might 'load' the prices in the Bills; not to alter its total, but to ensure favourable rates of payment. There is little, really, that can be done about this. The tender has been accepted. Any suggestion that the prices inserted by the builder are inappropriate, even though they might be, would probably not be based on factual knowledge. The problem is in not knowing how the prices were built up or for what particular reasons the prices were so apportioned to the measured Bill items. Arguably, the design team cannot *know* whether a price or rate is correct. Therefore the design team is not in a strong position to question the individual item costs in Bills of Quantities, to the extent that such item costs exhibit subtle variations when like items are compared across ranges of construction projects.

What is far more meaningful, therefore, is the relative cost of these items; what value should an item have before it significantly contributes to total cost? Which items are relatively unimportant in cost terms? Which items have an aggregate value so small that if they were removed from the measurement system altogether the overall tender sum would not discernibly alter? There seems to be misallocation of effort measuring things which the tenderer considers to be unimportant and which, far as prices for valuing variations are concerned, are redundant (though the design team, curiously, think otherwise).

Major cost determinants are relatively few in number (see, for example, Diederichs and Hepermann, 1985). Were this seen to be the case in Petrochemical Civil Engineering Bills of Quantities data then it could be argued that too much of the effort and administration devoted to producing the level of detail so displayed in the conventional models is misdirected effort. Further confirmation of the cost distributions discussed above was presented for Civil Engineering data by Saket (1986) and Saket (undated), and for Petrochemical Civil Engineering cost data by Hardcastle *et al* (1987a, 1987b and 1988). Ashworth and Skitmore (1983) suggested that the removal of minor items from Bills of Quantities might go some way towards improving the accuracy of the remaining cost-important items; thus making the whole process more realistic. Their justification appeared to be the fact that cost-insignificant items are seldom estimated using normal estimating procedures, but rather are priced on an *ad hoc* basis. They did not comment on how the costs of these items would be estimated once they were no longer *expressly* identified, but it is contended here that the problem is not insurmountable given that such data are cost-insignificant.

Horner and Saket (1984) recognised this and alleged that these lists of items are longer than is necessary to achieve an acceptable level of accuracy. It is not clear what an acceptable level of accuracy ought to be, however, but practitioners frequently allege +/- 5% at Bill of

Quantities stage. This claim though, is not based on any substantial evidence. Serious attempts at analysis in this and related fields, for example by Keating (1977), Fine and Hackemar (1970), Gates (1967) and Barnes (1977) revealed figures ranging from 5 to 25%.

Accuracy of cost predictionis a vague concept in the case of the types of model under discussion, nor could it ever be precisely achieved. Therefore it is deemed appropriate to consider attributes of such information which may be relevant in terms other than those of cost. As it has already been argued that the model primarily exists as a tool to aid the design team rather than the production team it is deemed pertinent also to consider what relevance this information has to the design itself. If the document represents neither true construction costs nor the true design then its use is so limited as to question the justifiability of its obsession with detail.

3.4 The Relevance to Design of the Conventional Petrochemical Civil Engineering Model

It is a commonly-held view that whereas the existence of a measured item might not directly have a cost implication to a Tenderer, its existence conveys indirectly to the tenderer some notion of the complexity and scope of the proposed design. This may, or may not, be true. It can be difficult, *prima facie*, to ascertain whether the data can be actually attributable to design sources. The measured items reflect the design, but the prices placed against them represent the commercial tactics of the successful tenderer.

It is debatable, also, whether large amounts of such measurement information are really necessary: "Having too much information may be just as bad as having too little, sometimes it is worse because one may become confused. Possibly less, more accurate information would be more beneficial" (Hardcastle, 1992). This however must perforce be contingent upon ascertaining what level of accuracy and definition it is reasonable to require.

It is here, it is argued, where sociological considerations enter the debate. The notion that better accuracy can only be achieved *via* the acquisition of physical quantity of detail is likely to be founded belief rather than sure knowledge. Hardcastle's (1992) argument is supported here; were better accuracy the goal then it could only be achieved *via* the acquisition of more *appropriate* information.

This is to assume, obviously, that accuracy is a paramount requirement of a Bill of Quantities. It is argued that it is not. The term "accuracy" in the given context is a largely irrelevant term. The Bill itself models neither true building costs nor a true tender build up. The builder produces such a build up but does not necessarily incorporate it in the Bill. If the information in such a document is inappropriate either to the design or the work intended then arguments concerning its accuracy as a cost estimate are fatuous. If it does not represent what it is supposed to represent then it is a model of a well-defined, but fictitious, situation.

Discussion of the influence of *prescription* cannot be avoided here. As a method of measurement prescribes what shall be measured, and how, it is logical to infer that the method of measurement itself may create some level or amount of detail which cannot be inferred from the actual design. Measurement rules, by virtue of the way they are written, may suggest complexity which the design itself does not. Such rules may be so absurdly simple that they give the impression that a complex building is, in fact, not complex. The converse could also apply. This might mislead a tenderer. Much depends upon whether the detail of the Method of Measurement is appropriate to the type of construction work involved, or to *any* type of construction work.

It is argued that the detail of conventional Bill of Quantities models is not a function of significance, but of mere existence; the measurement conventions dictating how the information should be prepared and presented can only specify that what exists should be measured if no prior analysis has determined what is important. "BQs [sic] prepared under previous standard Methods of Measurement lack flexibility and can contain an unnecessary amount of detail and superfluous information" (Emmett, 1990, arguing for a simpler set of measurement rules). A simpler set of measurement rules, Emmett contended, will not prejudice accuracy. Besides, extreme accuracy is not the prime objective of the model. "Fewer items does not mean less accuracy, but it does mean less intricacy" (Emmett, 1990).

The detailed treatment demanded by detailed measurement rules was admirably demonstrated by Baccarini (1984 and 1984a), who showed the profuse amount of technical detail which must accompany an item description of even a simple design feature of a building. It is frequently the measurement rules themselves which are complex; not the features which they describe. The cost behaviour is flowing from the artificial parameters of the model; the design feature is simple, but complex rules have been devised for dealing with it. A case for simplicity, therefore, could well be argued.

Smith (1987) favoured using different levels of measurement detail for different levels of design detail, suggesting the use of SMM6 where the design is incomplete and the use of SMM7 in the "Utopian" situation where the project is fully designed. It is difficult to agree with this reasoning, given that SMM6 prescribes more detailed measurement than does SMM7. Its application to incomplete design, which might not reveal any detail, would appear rather misplaced. Nevertheless, Smith raises the important point that methods of measurement intended for complete design are frequently used on incomplete design.

Hooker (1985). a member of the Standard Method of Measurement Development Unit which drafted SMM7, related some of the Unit's findings: "Quantity Surveyors thought that the present level of detail of the [SMM] rules was frequently more elaborate than was merited by the standard of information provided by architects and engineers. For their part, estimators suggested that in view of the frequently high incidence of variations, stemming from the inadequacy of the pretender design documentation, the method of measuring work should reflect more closely the construction process and serve to highlight the disruptive effect of variations". Detailed rules of measurement, then, are inconsistent with incomplete design.

As to whether the items measured reflect the construction *process*, it is contended that even if they did it would matter little if tenderers nevertheless accorded them "zero" or "negligible" cost importance Hooker (1985) further elaborated, commenting on contributors to the development of SMM7 who were neither surveyors nor estimators: "These contributors to the inquiry concentrated upon the discussion of methods of ensuring that the maximum benefit be obtained from the pre-contract measurement process so that the need for subsequent remeasurement for any reason can be drastically reduced, if not 'removed'". At this point it might be permissible to assert that if it can be contrived that substantial pre contract re-measurement need not occur then a strong case exists for reducing the effort involved in pre contract measurement.

Given that methods of measurement will perforce expect some level of detail commensurate with completeness of design, how does the surveyor *arrive* at the required detail in the case of an incomplete (or missing) piece of design? Perhaps by resorting to the "witchcraft" described by Fine (1982). There are, clearly, situations in which it is difficult to attribute the detail in the Bill of Quantities either to the design *or* to the method of measurement: "The cautious surveyor in preparing the Bill will sometimes measure abnormal foundations, often unnecessary, another even more cautious, will throw in expensive retaining walls, and for good weight, concrete *ad lib* in his drainage section" (Snell, 1973).

In other words, if some design information is missing (or incomplete) there is still the desire to ensure that there is enough content in the Bill to cover, or into which to subsume, any (ill-defined) contingencies. The design can be resolved later. The measurer will tend to create detail even though it might be unavailable in the design and/or not required by the Method of Measurement, in the belief that the existence of some (any) detail provides a form of insurance against some future (undefinable) contingency. It is argued that in so doing the measurer creates a problem by incorporating variations at the outset.

Thus the measurer "invents" items in order to cover overall cost rather than the costs of known features of design. Therefore not only do Bills frequently not represent the building *costs* but also frequently do not even represent the intended *design*. Thus the builder is confronted with variations even if the finalised design does not change and even if the work done on site never altered from what was actually intended: "Irritation arises when the total sum of a priced out Bill of Quantities differs greatly from the actual value of the work, even when the rates remain unaltered and the actual work remains unaltered too" (Snell, 1973).

It would appear, *prima facie*, to be a ludicrous situation whereby parts of the cost model can be fictitious (the content does not represent anything in particular; it merely attracts prices). Yet measurement conventions can permit, even demand, laborious treatment of such fiction. Subsequent analysis will reveal that large tracts of "fiction" did in fact exist in the data studied. It is further contended that if the paramount desire is to represent, for cost control purposes, a sum of money in the aggregate and that if a large proportion of the items measured represent neither a significant sum of money nor even what it is *intended* then there is nothing to fear if the measurement of unrepresentative items is discontinued or simplified. Their costs can be subsumed elsewhere, because their costs are derisory.

It is difficult to state with certainty that the measured items truly reflect the complexity of the design. Complexity can be a function of the measurement rules as much a function of the building. Notions regarding complexity can be gleaned elsewhere: from the drawings, for example. It has been asserted (Smith, 1979) that if the drawings do not show the complexity of the design then the Bill of Quantities ought to. This argument cannot be supported: if the drawings from which the measurements were prepared do not show the complexity then the measurer can only contrive to produce such complexity due to some express requirement of the measurement rules *themselves* or by some desire to *invent* detail as a form of "contingency" allowance against some unforeseen event. The irony is that if some subjective allowance has been made for them, then these events cannot have been unforeseen. Some subjective allowance would be less time-consuming, no less accurate and no less problematic than treatment by some complex set of measurement conventions.

Detail created by these conventions is a systematic misrepresentation of the state of reality and, hence, spurious. The eventual design will not change; it merely has not evolved yet. However the contents of the cost model will have to; because the design had not evolved at the time the model was produced its original contents amounted to a myth (see Masterman, 1970). Thus such practice, perversely, can actually *constitute* the problem with which the practice itself was intended to deal.

It has been suggested (Hughes, 1983a and 1983b) that if a method of measurement causes the problem, that is, is the source of misrepresentation, then it cannot provide the solution to the problem. "The contract documents of which the BQ [but not the SMM] is a part must reflect the total situation obtaining at the time of tender. If the design is incomplete and items have to be 'invented' [to whatever degree] then the contract, not the method of measurement, must provide for the consequences". This should be compared with Feyerabend's (1975) assertion that a model cannot be tested according to the facts if it has itself discarded any facts which might constitute a test.

Paradoxically, should design ever be complete then measurement would not be necessary, as there would be no variations. Should design be grossly incomplete then measurement, perhaps, is not the solution. A method of measurement, therefore, should be used when appropriate, but when used should be appropriate to the situation. Measurement should not be done out of a desire merely to conform to some accepted paradigm practice. "Wildly incomplete design renders [BQ] quantities an improper basis for contracting; and the quantity surveyor should not hesitate to say so. A defence of 'I did what [the] SMM - in which I have no confidence - told me' is not calculated to inspire the client in the independence and judgement of his professional adviser" (Silverton, 1983).

It is evident that much of the detail sought by measurers, or, more correctly, demanded by ruling conventions, because the measurers are merely obeying the conventions, is of dubious worth in terms of tendering and calculating the cost of change. A model for measurement and cost control in Petrochemical Civil Engineering work should not exhibit the properties of existing models. It should contain sufficient detail only to achieve reasonable efficacy, which is all that could ever be achieved anyway, but not enough detail to render it unnecessarily cumbersome. It should not be stifled by convention which is so formulated as to require detail for the sake of acquiring it; detail which, in some cases, can be neither inferred, used nor believed; which may have been distorted or contrived for the sole purpose of satisfying the demands of the model itself.

It is, perhaps, that we are blinded by the light of our own conventions; we fail to see what we need to see. The term "model-blindness" in relation to cost models is Brandon's (1982). Its essential meaning is that we can become so accustomed to using certain techniques that we forget why we use them, or whether they ever did what we end up imagining they do. As a practising group we lose, or never possessed, the inclination to rationally justify their efficacy, or to examine possible better alternatives. Thus manifestations of paradigm practice arise; sociological, or even ideological, as opposed to logical.

Dirksen (1982), an independent observer of the activities of construction cost modellers, whilst appreciating that Bills of Quantities do perform some useful work, gave a word of caution: "Mentioning the likelihood of inaccuracies does not imply that the quantity surveyor does slap-dash work. But there is a danger: accuracy can turn into pedantry over detail, care into slowness, correctness into inflexibility". It is obsession with the dubious notion that all information must be intrinsically useful simply because it exists which causes us to create too much of it. Dirksen concluded: "The fact that quantity surveyors live with figures and love them can cause too many to be produced, and then not even the right ones".

It is clear that there are problems associated with the content and relevance of conventional Petrochemical Civil Engineering cost models. Much argument has been presented towards the thesis that it is possible for such models, as presently structured, to tell "fairy tales" rather than provide a reasoned account of what has happened, or will probably happen. The paradigm of institutional acceptance remains and must, in the interests of furthering our knowledge, be challenged.

Feyerabend (1975) alleged that departure from reality can (and *does*) result from group adherence to the *status quo*. "It will seem that the truth has at last been arrived at. At the same time, it is evident that all contact with the world has been lost and that the stability achieved, the semblance of absolute truth, *is nothing but the result of an absolute conformism*". A measure of non-conformism should therefore be introduced: the validity of the conventional cost models should be challenged. The possibility of rational improvement of such models should be entertained.

3.5 SUMMARY

It is contended in this thesis that:

(1) Conventional measurement and cost planning models do not recognise the true determinants of building cost. Though this is a weakeness, it is not inconsistent with the intention that the models are for the use of the design team for the purpose of approximating the cost not of changes to the methods of production, but to changes in design (proposed in the pre contract - the cost planning model, or actual in the post contract - the measurement model).

(2) Ease of use of the conventional models is synonymous with ease of abuse. Much of the content of this model carries little cost importance and is often fictional in any event. A newly-formulated model should be characterised by a reduction in the amount of redundant or entropic information which contained by the conventional model.

(3) The conventional measurement and cost planning models are prescriptive, not representative, of cost behaviour. Their underlying measurement conventions are capable of producing "noise" for the sake of having it. Due to the way in which they have been formulated their constituent parameters make no attempt to reflect the relative importance of cost centres. A model should be formulated on the basis of prior empirical observation of cost behaviour in the appropriate data; the model should be made to fit the facts, not create them. This will not undermine the paradigm, but attempt to provide a rational, rather than sociological, step towards the development of measurement and cost planning theory.

(4) The paradigm practice of abstracting an over-simplified cost planning model from an over-detailed measurement model is an unnecessary duplication of effort and produces two inappropriate models at inappropriate levels of abstraction. The identification of consistent cost centres should be attempted which exist at a suitable level of abstraction for use in both models, or in a single model which performs both functions simultaneously.

(5) The paradigm practice of the conventional model being a tool of the design team will not disappear quickly. Therefore a newly-formulated model should be capable of being input into the broadly-recognised conventional format of the paradigm model. Therefore the consistent cost centres so identified should be capable of being expressed in terms of design parameters, but the facility to input costs of the factors of production if desired. These cost centres should therefore take the form of a "neutral" language capable of being commutative between these two domains.

Chapter 4 will briefly review some pressing issues for cost modelling research and will review and criticise the research methods by which the objectives stated above will be attempted.

Chapter 4:
Review Of Research Methods

4.1 Generally

This Chapter will review the research methods, that is the tools for data collection and interpretation, employed in this work. The strategic philosophical aim has already been considered (*vide supra*). Criticism shall be offered of the methods as data collection tools. The Chapter will also deal with problems of proof and refutation attributable to these tools. Problems of proof and refutation were identified in terms of overall philosophy, but not discussed with reference to the tools of data collection, in Chapter 2.

4.2 The General State of Cost Modelling Research in the United Kingdom Construction Industry

The general position of cost research in the United Kingdom construction industry was summarised (Ashworth, 1994) as follows:

1) Little attempt has been made to verify current practice,

2) Understanding is limited to experience and intuition,

3) Current practice may be unsoundly based, and thus there are disadvantages of continuing along this route as a priority,

4) Future investigations should build on a factual basis, and not on the possibility of false assumptions,

5) The profession should be convinced of the necessity of getting [*sic*] the fundamental principles authenticated, since these are often not properly understood and

6) Opinions alone may be biased and therefore unreliable.

These discouraging signs have implications for the development of cost modelling research and, it is contended, strongly underpin the philosophical statements expressed in Chapter 2. The requirement to deal, as far as possible, with facts rather than opinions and the necessity to try to distinguish "fact" from "opinion" has implications for the possible methods of data collection which a piece of research could utilise. Though the understanding of research methodology "is important, it can sometimes be overemphasised. It should be regarded as nothing more than the tools of the trade. It is important to be aware of the range of research methods available and to appreciate their relevance to the work being studied... it may be necessary to combine some of the... methods during the carrying out of research projects" (Ashworth, 1994). Raftery (1991) suggested an agenda for research into models for building cost and prediction. The principal suggestions were as follows:

1) The need to disentangle the modelling of costs from the forecasting of market prices,

2) The need for empirical work on the comparative robustness and reliability of statistical methods compared with the naive "cost planning" (in place) methods currently in use, and

3) The need for research on the nature (reliability, rationality) of human expertise.

In this thesis the word "cost" is used to indicate the price(s) provided by the builder which are therefore present in the models, and which the client must therefore pay. The cost to the builder is not necessarily the price inserted by the builder into the model. Raftery is correct in asserting that the conventional cost planning models, having been formulated on the basis of design parameters as opposed to true "cost" parameters, are naive. This point will be developed (*vide infra*).

Raftery clearly held that reasons for embracing techniques or models such as "expertise" can be ill-defined, potentially subjective and potentially irrationally expressed This is to classify the conventional Petrochemical Civil Engineering measurement and cost model, and the Building model as a sociological, psychological or ideological paradigm.. Therefore it is to the social sciences which this thesis (and much other research in building economics) should in part look for ideas and criticisms. Building Economics is not in a "pure science".

Newton (1991), in a review of the state of cost modelling, held that it was important for modellers to begin to focus on the inherent or implicit assumptions conventionally built into cost models and also to focus on the inherent assumptions made about the validity of them. Newton's argument is supported here to the extent that there appears to be an underlying assumption regarding the conventional Petrochemical Civil Engineering cost model. This assumption is that its constituent design-based parameters are all important and, hence, relevant. The structure of the conventional model, it is argued, does not adequately reflect the relative cost importance of design parameters as it has not been formulated following prior empirical observation of the cost behaviour of those parameters. Indeed, as they are borrowed, unaltered, from outside the field of Petrochemical Civil Engineering, it is unlikely that such empirical observation took place, highly likely that the model does not represent the observable facts and likely that the facts have to be made to fit the model. The assumption that a model's parameters are important solely because the model demands their inclusion is a weak basis for model validation. The rules of measurement themselves, in respect of conventional models, are not truly empirical in nature, having been formulated more by a process of negotiation between interested parties than by prior data analysis .

4.3 INDUCTIVE, DEDUCTIVE AND EMPIRICAL STRATEGY OF THIS THESIS

Given the (apparently) contrasting characteristics of inductive and deductive methods it is considered that the approach in this work will be primarily inductive. Observations of behaviour of cost data in the conventional Petrochemical Civil Engineering measurement and cost control model will be used to attempt to formulate a *hypothetical* measurement and cost control model for Petrochemical Civil Engineering work. The establishment of an empirical basis for model formulation will serve to compete against conventional models in this and other fields, the basis for whose formulation and adoption in practice has largely been on a sociological basis. This is seen also to be consistent with Ashworth's requirement to verify or challenge existing practice. On the basis of these findings, the cost behaviour observed will be used to formulate a hypothetical model for Petrochemical Civil Engineering work.

Though testing of the conventional model is not an express direct aim, the analysis of conventional data could (arguably) constitute such a test, to the extent that it may or may not be a destructive treatment of it (see Popper, 1959). The analyses executed on the data from the conventional model will be used to attempt to show that its cost parameters do not necessarily behave in the way assumed by the designers (and users) of the conventional model. It is debatable, in fact, whether its designers had any notion of how these cost parameters might behave, given the lack of theoretical development in cost modelling.

Thus the work will attempt to show the conventional models to possess the status of "paradigm prior to theory". The conventional cost model does not explain cost behaviour very well. The *overall* approach of this work will be inductive as, in working towards a hypothetical model, it will effectively arrive at (culminate in) a hypothesis. However there will be some deductive content following formulation of the hypothetical model in the form of validation with its potential users and a "field test".

It is true that a hypothetical model such as is proposed here could have been formulated intuitively, without the use of prior observation to justify its formulation, and the work devoted *entirely* to testing it. However it is considered that to first demonstrate actual, as opposed to assumed or imagined, cost behaviour of data in the conventional models might overcome any sociological or ideological resistance to alternative models. This would be a rational step as it would increase the amount of consonant or dissonant information which would aid a model-selection decision (see Festinger). It would be a step towards a more rational formulation for the sociological paradigm, which is empirically weak. The paradigm is not being tested as such. The work is operating within the overall framework of the paradigm, but is arguing for more rational criteria for its validation (see Post, 1978).

The relative conservatism of the practitioners as a peer group and their possible distaste for what they would regard as "theoretical" models must be borne in mind. Potential misunderstanding of the meaning of the word "theory" was discussed earlier (*Chapter 2*). It was considered better first to attempt to expose the shortcomings of the existing models in order to try to reduce scepticism regarding "simpler" models. Detailed models are often regarded in practice as desirable precisely because they are detailed; as if the presence of profuse (but relatively untested) detail were a guarantee of accuracy, of reliability, of true relevance to the costs of construction or of some (psychological?) feeling of well-being.

In terms of theoretical development, the field of cost modelling is relatively poverty stricken. Though there are numerous techniques available for cost modelling, the conventional techniques are often viewed as ends in themselves. There have been few attempts in the "establishment" to link these techniques to some predetermined (genuine) theoretical framework. Therefore in the absence of a strong theoretical background (no theories precedent to the model building process), an empirical approach to model-building is argued for. This permits a degree of objectivity which did not necessarily surround the formulation of the conventional models or theories, if there are any. "Empirical research, the foundation of the scientific approach, refers to any activity that systematically attempts to gather evidence through observations and procedures that can be repeated and verified by others" (Neale and Liebert, 1980).

A rational scientific approach requires that everything, no matter how obvious or trivial looking, must be proved or refuted on the basis of evidence. That something seems obvious, appears sensible, or "must be right" is no basis upon which to accept a proposition. Arguments such as "this model is better because it is practical" have no scientific worth whatsoever. Belief and ignorance have no place in the rational appraisal of models. "The apparently sensible statements that brushing one's teeth will reduce cavities, that cigarette smoking may be a health hazard, or that children will be psychologically better off if they are loved than if they are treated harshly are only propositions. They may be totally correct, totally incorrect, or correct under some circumstances. But in any case the basis of acceptance will be systematic, public exploration of each proposition rather than belief, good sense or precedent. It is this demand for publicly observable evidence that hallmarks the objective nature of empirical work (Neale and Liebert, 1980).

Appraisal of models based on "professional judgement" are weak, as definitions of what professional judgement actually is are vague. But to question professional judgement is to "touch a live wire". The paradigms of professional practice are subject-based; research methods are appraised independent of subject. "Professional people have been trained in their subject knowledge, but not in the use of conceptual skills or in the intuitive processes used to manipulate knowledge. Judgement, intuition and flair are, it seems, sacrosanct. Questioning their 'judgement' is like an attack on their moral or professional character" (Hogarth, 1980).

Acquisition of "academic" or "professional" knowledge of one's subject is one thing; the means by which to appraise the objective worth of what one has learned is another. " ...one thing must be avoided at all costs: the special standards which define special subjects and special professions must not be allowed to permeate *general* education and they must not be made the defining property of a 'well-educated man'. General education should prepare a citizen to *choose between* the standards, or to find his way in a society that contains groups committed to various standards *but it must under no condition bend his mind so that it conforms to the standards of one particular group*" (Feyerabend, 1975). Research, in this context, is not vocational. It is subject independent.

What, exactly, is the rational basis by which "practicality" could superseding "rationality"? In anticipation of arguments such as "we need practical models; this model works because it is *practical* (in other words, it is the model which we happen to *use*?)" it is necessary to look for a definition of a practical model. A brief definition has already been offered of "theory". Theories explain. What does "practical" mean? What does it explain? The Concise Oxford English Dictionary (1975) offers the following definitions of "practical":

1) *Of, concerned with, shown in, practice (cf. theoretical).* This tells us nothing. It is what our discussion is about.

2) *Available, useful in practice.* This is a good definition to use. We need a *useful* practical model. But the argument has to centre around what constitutes "useful". Useful to the practitioner, useful to the sponsor, or useful as a cost model?

3) *Engaged in practice, practising.* This is not disputed. People who practice. But what do they practice?

4) *Inclined to action rather than speculation.* This does not imply *correctness.* A person inclined to action could be *speculating* during such action. It merely means that that person is doing something, not that what is being done is correct.

We must reconcile ourselves to clear meanings. Nowhere is there a definition that the word "practical" means "right". It merely means "is used". These statements should not be scorned as being exercises in semantics. It is quite clear that there can be no possible implication that a "practical" cost model is *necessarily useful*, in the sense of *describing* cost behaviour, just because it is *being* used for that purpose. There can be *no possible implication* that the sole reason that the model *works* is the fact that it is the one used in practice.

Given a rational need for observable evidence it is inevitable that discussion will occur concerning what, exactly, constitutes rational and observable evidence. For this reason it is necessary to review the various research methods (tools of data collection) in order to ascertain the extent to which they are able to provide the rational evidence required. Once the method has been selected the it is the method which is being imperfect. It is important, then, to consider these methods and the ways in which they could facilitate comparison and appraisal of models and alternative approaches. It is consideration of different approaches which helps us to advance our knowledge.

Merely to revise the conventional model without questioning the fundamental basis of its formulation is merely to "reshuffle the same deck of cards"; it amounts to accepting without question that its basis is in fact: "When at a cross-roads and faced with a new problem, sometimes we just act in the same way as we have always acted, without making new decisions and without considering the advantages and disadvantages of our actions" (Katona, 1963).

4.4 STRATEGY OF GROUNDED THEORY AND MIDDLE RANGE THEORY

Central to research approach to is the decision about whether to use the "grounded theory" and "middle-range" theory approaches. This decision is contingent upon the state of theoretical development of the material being studied. Middle range theory is used mainly to test hypotheses, theories or propositions. Such propositions are made and data are collected and analysed, and the results fed back, in order to confirm, reject or modify the initial proposition. This implies that a testable proposition, hypothesis or theory has already been formulated. "In essence, MRT encourages research which is led by a clear theoretical idea formulated prior to the research" (Layder, 1993). Thus middle range theory is characteristic of the deductive method.

Lack of theoretical development in the field of Petrochemical Civil Engineering cost modelling (and, to a considerable extent, the general Building cost modelling field from which its paradigm models are drawn) implies rejection of a strategy of middle range theory. An approach is needed which caters for this lack of theoretical development. A grounded theory approach is thus recommended., which encourages research without preconceived theoretical ideas regarding the topic being studied (though in practice it is difficult to avoid preconceived notions). Thus, using this approach, theories can develop as the research unfolds. It enables the researcher to be flexible interpretation of the findings as there are no preconceived theoretical "truths" or requirements to influence the researcher's thoughts or, indeed, to influence decisions about what should be observed.

There is a danger with the middle range theory approach; preconceived 'accepted' ideas may lead to bias in the collection of data: "...the researcher should adopt theoretical ideas which fit the data collected during the research rather than collecting data that fit a preconceived hypothesis or theoretical idea" (Layder, 1993). Grounded theory promises the former, not the latter. It is more characteristic of the general inductive approach adopted here. Criticisms of the data collection methods employed in this Thesis are now offered.

4.5 Statistical Analysis of Conventional Petrochemical Civil Engineering Measurement and Cost Control Models and Their Cost Distributions

Statistical analysis, strictly speaking, is not a research method so much as a tool to aid the research method selected. It requires that data already exist, that some method, already selected, has been used to collect the data. The so-called "statistical method" merely interprets the data thus gathered.

One purpose of statistical analysis is to contribute to theory by investigating the supposition that the conventional measurement models produce misapplication of effort by generating profuse cost-insignificant, unnecessary and redundant item detail. In order so to do statistics will be produced describing the cost distributions in Bills of Quantities at the hierarchical levels of Elements, Trades, Trade Subsections, Generic Families of Bill Items and Individual Bill Items. This is considered justifiable in that it (a) extends existing knowledge of cost distributions to a data set in a field not previously studied for such a purpose and (b) will, though a true destructive test was not the direct aim of this research, show the extent to which conventional models do or do not work. The technique also facilitates comparison of data behaviour with that of data previously observed in other fields, principally in Civil Engineering proper (see Barnes, 1971). Thus it is capable, *mutatis mutandis*, of replication.

A second and ultimate purpose is to use the results so obtained, the cost centres so identified, to formulate a possible improved model for measurement and cost control of Petrochemical Civil Engineering work. It is contended that this hypothetical measurement model, once formulated, will aim to simplify the pre contract and post contract measurement and cost control procedures without unduly impairing their efficacy. This act of formulation will constitute an inductive phase of the work.

This technique will be used to identify actual Bill of Quantities cost centres, at differing levels of abstraction, which are populous but which tenderers consider to be relatively unimportant for valuing variations to the design which the model purports to represent. Should it be demonstrated that such detail is of little consequence to the tenderer, that is, is redundant, this would afford some evidence that conventional models exist for the benefit of the design team (as ideological models) and do not exist as theories (or logical models) which actually *explain or predict* cost behaviour.

4.6 Criticism Of The Statistical Method

This infers criticism of the validity of the results, as the statistical techniques are mere processing tools which show what the results are. The results themselves cannot be presented and be deemed to "stand alone", it is true, but there is a paradoxical problem in trying to extend the significance of the results beyond "stand alone" status. This is the problem of the process of induction; the problem of using singular statements (observations) to proceed *via* an inductive argument to a more general or universal set of statements (hypotheses or theories) (see Popper, 1959). The problem is one of justifying whether it is possible to generalise from a single observation or small sample thereof. It must be understood, though, that this is contingent upon whether generalisation is *intended, or even desirable* (see "idiographic models", *infra*). "Experimenters are usually interested primarily in the internal validity of their results.. with the issue of generality of secondary concern (Dominowski, 1980).

A principal criticism is that there is a possibility that the results were freak results. Were the techniques to be applied time and time again and the results replicated exactly, then the results would not be freak results. Therefore it must be determined whether the results were a singular, chance phenomenon, by considering the size and nature of the sample. A key consideration is that of "finite series". A finite series of observations will not necessarily yield the same outcomes as an infinite series. Popper's (1959) illustration of the problem is now offered.

We know that the probability of an unbiased tossed coin coming down "heads" is 0.5. We know that if we toss it 1 000 times we will obtain a data series containing 1 000 terms. Experience tells us that, as near as makes no difference, 500 of the terms in the series will possess the property of being "heads". Experience also tells us that no matter how many times the coin comes down "heads" the probability of it being "heads" next time is still 0.5. Suppose, though, that the observer's power to interpret observations is *not clouded by such prior experience* (see Popper, 1959); the observer has no prior knowledge of such probabilities, or expectations as to the likely outcomes of coin tosses. The observer tosses the coin 1 000 times and it comes down "heads" every single time. The observer will quite reasonably conclude, based on a large sample of 1000 observations, that on the next (or any) toss it will always come down "heads" and never come down "tails". The naive observer cannot conceive, given the results of that particular set of observations, that an infinite series, or even another 1 000 throws, would even out the balance. The data problem is such that we cannot observe, or always imagine, an infinite series. Thus results from a limited data series could produce conclusions and probabilities which are entirely reasonable under the circumstances, but which are quite erroneous (Popper, 1959).

In the context of observing Petrochemical Civil Engineering cost data it is necessary to establish whether the finite data sample used could be considered to be representative. Detailed Bills of Quantities data from an eventual total of 20 Petrochemical Civil Engineering projects will be analysed. These data constituted the entire workload of the collaborating organisation at the time of analysis. Defining a Bill of Quantities item as being a statistical case, it is considered that a sample size of some tens of thousands of cases is sufficiently large to permit reasonable reliance upon the results yielded.

However the data set used does not constitute a complete set of data for all Petrochemical Civil Engineering work, nor for Building work in general. Thus the sample cannot be termed a random sample from the Petrochemical Civil Engineering population, more a "sample of convenience", using what is available. "A researcher interested in studying, say, psychotic patients is most likely to make use of psychotic patients who are located in some nearby facility. Clearly no population has been defined from which the subjects have been randomly selected, except for the possibility of defining the population as 'psychotic patients in this facility'. Consequently one does not know whether the findings might be generalised to 'all psychotic patients'. Similar remarks can be made about research employing various patient groups or other noticeable segments of the general population" (Dominowski, 1980). The data used in this research comprised the entire workload of current and recent construction projects available at the time of the study.

Cost distributions identified in other "segments" of the construction industry are discussed elsewhere. Subsequent Chapters will compare the behaviour of the Petrochemical Civil Engineering cost data to the findings of such related work. It will be shown that certain extensive analyses were repeated following addition of cost data for further Petrochemical Civil Engineering projects which became available after the work commenced. This constitutes a measure of "result-replication", which is argued to marginally increase the validity of the results.

4.7 Survey Method: Drafting An Experimental Measurement and Cost Control Model for Petrochemical Civil Engineering Work

The term *survey* has been defined as "the systematic collection of data from a group (sample) of respondents using a standardised (the same) questionnaire. A survey as such is not a research design... data collection techniques do not define the level of research to be adopted" (Hartman and Hedblom, 1979). In this study the technique employed used questionnaires as the basis of a structured interview; questions were asked of the respondents to determine whether certain objectives would be reached, but ample opportunity existed for the respondents to comment on whether they agreed with its objectives, and why.

The survey invited all likely end-users to comment on a hypothetical measurement model whose parameters were formulated so as to represent, (that is, explain?) the actual cost behaviour identified by the prior observations. The interviews themselves will sought to ascertain whether the end-users considered that the hypothetical model would achieve its stated objectives. Also, drafting suggestions by the users are obviously considered useful. These interviews constitute a survey. As to whether the sample could be considered to be representative, the reader is referred to the discussion of "psychotic patients" (*vide supra*) (Dominowski, 1980).

Inviting the respondents' own comments in the interviews may also go some way towards establishing whether they embrace as individuals the conventional model which they embrace as peer group members (see, for example, Sen, 1970). "If, in a given situation, a person is part of a group, he may be motivated by the interests of his group. His motives may be centred around the welfare of his family, his business associates, or his country, and what would be best for his own welfare may be secondary or may not even enter into consideration" (Katona, 1963). There is the possibility, though, that if the individual accepts the established model at face value he or she may not even be serving the long-term interests of the group.

No less importantly, it may be possible to determine whether they consider that the hypothetical position would be tenable "in practice". Though there are relatively few respondents in absolute terms, the sample is considered to be a highly-representative sample; all potential users at the collaborating organisation will be consulted. One aspect of this technique was clearly inductive in character. As the survey demonstrates whether the users consider the hypothetical model might be justified in terms of its aims or thesis it contains an element of inductive inference. Information is being sought to support a hypothetical alternative to an existing set of conventions.

It has been said of interviewer-administered questionnaires that the interviewer can exercise better control and thus achieve better quality results. The method possesses the advantages of "obtaining better quality responses to open-ended questions. This follows since the interviewer can probe and insure [*sic*] complete responses... the quality of the data are better, and some control has been obtained by the interviewer reading the questions" (Hartman and Hedblom, 1979). However the issue of "control" must be taken *cum grano salis*. If too much control is exercised by the interviewer the question arises of whether the observations are being unduly guided and, hence, biased (*vide supra*). Lack of exerted control would seem to imply lack of inherent bias on the part of the observer.

As to whether the survey is inductive or deductive in character, a fortunate paradox would appear to arise. As it seeks verification by its likely users of the extent to which a hypothetical model might perform (or fail to perform) in practice it may be argued that it thereby constitutes the first test of the validity of a set of hypothetical statements. This is not an overwhelmingly strong argument, though. The inductive method does not seek refutation of the hypothetical model; it seeks not overtly to test; it culminates at worst in the refinement of the original hypothetical statements. Interviews are a good technique for such refinement.

The "fortunate paradox" is this: any survey observations which could be potential falsifiers of the hypothetical model, though not directly admitted by the inductive process leading to its formulation, could constitute an *inductive counterargument* in favour of the conventional model which the hypothetical model aims to supersede. Thus the worst outcome of the survey is that if the inductive process fails there would be a body of inductive counter-evidence, supporting the *status quo*, which did not previously exist in terms of formal expression. It may be that the hypothetical model is not proven, but this does not make things bad; the important point is that the survey permits an element of rational discussion, as opposed to "institutionalised" irrational discussion.

The survey carried out in this work, then, is designed to be honest. The hypothetical model can be criticised just as the conventional model can. Potential weaknesses of the hypothetical model, as opposed to protected. The survey is a healthy one; though it seeks to develop a certain argument it admits criticism of it. It admits counter-argument; the champions of the *status quo* might show less propensity to admit possible weaknesses of *the status quo*. It is preferable to risk a rational rejection of an alternative model than to preserve an existing model based on the dubious reasoning that 'it is a practical model, therefore it is better than the theoretical one and criticism is unnecessary' (unattributed quotation).

The hypothetical model and the established model should be judged by the same people against the same criteria; one should not be protected against the other: "... rational discussion consists in the attempt to criticise, and not in the attempt to prove or make probable. Every step that protects a view from criticism, that makes it safe or 'well-founded', is a step away from rationality. Every step that makes it more vulnerable is welcome. In addition, it is recommended to abandon ideas which have been found wanting and it is forbidden to retain them in the face of strong and successful criticism unless one can present suitable counter-arguments" (Feyerabend, 1975).

4.8 Criticism of the Survey Method

The survey method is a highly useful way of gathering data, but can pose difficulties as it lies somewhere between psychometric testing and observation by sampling (Dobson *et al*, 1980). If it consists of a highly-structured set of questions then it might resemble a psychometric test, but the key difference is that in the research described here it was not the subjects themselves who were being tested. They were merely being asked to express their views about something; in this case about the likely performance of a hypothetical measurement model.

The actual construction and phrasing of the questions becomes important: the more structured the questions become, the greater are the imposed limitations to the set of data so collected. Because the questions are structured to address some end objective the questions to which the subjects must respond are being *prescribed*. The motives of the interviewer may or may not be revealed to the subjects by the manner in which the questions are phrased. In effect, the respondents are being told what to observe (see Popper, 1959). In defence of the survey carried out here, the questions related to all conceivable functions of a measurement model and its resultant measurement model; therefore there was no *overt* attempt to delimit the possible responses.

Conversely, in a pure sampling exercise the process is more open-ended. The questions themselves become rather less important than the desire simply to ensure that a suitable representative sample of the population is taken. The interviewer has no particular vested interest and merely wants responses; nothing and no-one is being tested. In an opinion poll conducted at the time of an election, for example, there is frequently only one question asked (Dobson *et al*, 1980).

A criticism of the survey is that it concentrates on verbal reports, not on actual behaviour (Dobson et al, 1980). The subjects could respond untruthfully, or in ways which does not represent their true points of view. What people say is not always what they do. When using questionnaires or structured interviews problems of subjectivity arise. The respondents could harbour preconceived notions or be inherently biased. People cannot always articulate why they do things or why they hold certain viewpoints; they may merely consider that they *ought* to be thinking these things. "We construct reasons for our actions, reasons that are acceptable to society and that put us in a good light; we even believe that these are our reasons; but the true reasons are different, they are repressed, covered up, and unknown to us" (Katona, 1963).

Therefore the respondents, being members of social or professional peer groups, could be capable of providing what is often referred to as the "team answer" to the questions or tasks which they have been set, regardless of their personal preferences or beliefs. Thus the influence of group adherence to a paradigm (though it might not be favoured by the *individual* group members) might be mirrored in the attitudes and responses expressed in the survey: "[the worker] finds the work process pre-existing when he enters production: it is not a process that he is able to shape or determine in any way. 'He has to conform whether he likes it or not' " (Lukacs, 1971; in McDonough, 1978).

A possible weakness of the survey is the possibility that it may be unable to *find* the truth. Even when the subjects are answering truthfully, truth distortions can be brought about. In the survey of the potential users of the hypothetical measurement model such truth distortions could manifest themselves in numerous ways. A subject might not understand, or might misunderstand, a question or questions, or may place different definitions on the words used. The subject, in trying to impress the interviewer, might not respond in the way that he or she would *naturally* respond (Dobson *et al*, 1980). The interviewer might, by his or her presence, or "body language", exert a subtle influence on the subjects; though in the survey carried out at the collaborating organisation this bias was partly cured, or at least made consistent, by having only one interviewer. A subject might give an exaggerated, or amplified, response because he or she happens to be extremely enthusiastic about, or is vehemently opposed to, what is being proposed.

In the survey carried out in this study, opponents of the hypothetical measurement model *in principle* held the conviction that detail was *safe* in principle and simplicity was *dangerous* in principle. Despite the empirical evidence of the prior analyses opponents of the hypothetical model retained the belief that existing conventions of measurement must be more trustworthy because they demand the inclusion of everything rather than the exclusion of the significant or the redundant. Some respondents, though addressing the objectives as stated, made it clear that they did not necessarily agree with those objectives. The fact that a highly-structured set of questions makes the subjects address the objectives desired by the researcher is seen to be an advantage in that it ensures that the objectives of the researcher are addressed. However, a paradox of objectivity arises; it inevitably becomes pre-structured and directed (Popper, 1959).

Popper once attempted to demonstrate the impossibility of pure, unbiased observation by asking a group of students to look around them and write down what they observed; whereupon they asked him to tell them what they were supposed to be observing. The survey technique is very much the same: with a question or set of questions being posed by the interviewer, the subjects are being told what to write or talk about.

It would be unwise, therefore, to take the results of the survey at the collaborating organisation as being concrete proof of the validity of the experimental model. Rather, its evidence should be taken as persuasive. There was, though, a perceived benefit in carrying out the survey. In consideration of the relatively conservative attitude of the surveying profession, it was deemed desirable to confide in the respondents as to the nature and purpose of the work; to consult with them rather than impose a system upon them. Thus, it was perceived, a co-operative, if cautious, approach would ensue.

4.9 Experimental Method: A Test Of The Experimental Model

This phase of the research was definable as experimental as it conformed to the "one variable" principle. Any difference in the outcome of the experimental exercise could be attributed to the sole difference between the conditions of "normality" and the conditions in the experiment). A measurement exercise was being carried out, using a previously-completed Petrochemical Civil Engineering project, in the same fashion as the original project. The only differing condition or variable was the document containing the rules for measurement of the work. The sole difference in conditions was a single altered variable; the differing Bill of Quantities provided to the tenderer as a result of using a different Method of Measurement. Thus only the introduction of that convention could cause a different result. "This is the only logical conclusion because the two conditions are identical, and are treated identically, in all respects except for one solitary difference. Hence any differences in outcome must be directly attributed to the sole difference in the conditions" (Dobson *et al*, 1980).

A salient feature of the experiment was that it was not designed to *numerically* measure differences in the processes or product of measurement and tendering using a new measurement convention. Owing to the nature of measurement and tendering processes this would be difficult to achieve. Surveyors have different idiosyncratic approaches, even when they are all using the same basic measurement rules. Such a course of action could not be adopted, for practical reasons. Some of the users were seconded to the collaborating organisation from consultant firms. Measurement of the physical resources consumed by measurement and tender documentation tasks was not permitted on the grounds of commercial sensitivity. These outside firms were not themselves collaborators in the research.

It is accepted that Methods of Measurement define minimum amounts of information which should be provided. Different measurers spend greater or lesser amounts of time interpreting and providing information over and above the minimum requirements, according to their interpretation of the particular circumstances prevailing on individual projects. Similar considerations apply to the tendering process. The tenderers all possess identical information upon which to base their tenders. What an experiment cannot do, however, is dictate how a tenderer goes about preparing a tender.

In reality the tenderer cannot be compelled to actively use the Bill of Quantities for preparing a tender (see Daly, 1981). Its principal role is that of allowing the tenderer to notionally break down a tender rather than to compile one. It would seem inevitable that the tenderer would strategically, or tactically, load the *price* structure, as the tenderer cannot alter the *model* structure. Neither can the available information always communicate to the tenderer the degree of risk or uncertainty surrounding certain aspects of projects, interpretations of which are, conventionally, somewhat subjective. Risk to tenderers can be categorised as external or internal.

External risk is that risk which is imposed upon the tenderers from external sources. It is the risk associated with the quality of the information with which they are provided. The fact that, e.g., a Bill of Quantities exists will have the effect of minimising some risk, by virtue of containing quantitative information relating to a proposed project. Importantly, this risk is equal for all tenderers, as all tenderers possess exactly the same information. However, no amount of information a Bill of Quantities can perfectly describe everything; there is always an amount of interpretation of the things which the Bill cannot communicate.

Internal risk is self-imposed by the tenderers; by the way in which they interpret identical information, by simple errors, or even by unfamiliarity with the conditions described by such information. Whereas the measurement document can and should attempt to minimise the external risk imposed upon tenderers it could never influence the internally-imposed risk caused by the different ways in which tenderers may interpret the identical sets of information with which they are provided.

The type of external risk allegedly reduced by providing copious measurement detail may in fact increase. If the measurement detail is contrived to compensate for incomplete design, then such detail imposes risk upon the tenderer by virtue of being a misrepresentation of what the tenderer actually has to provide.

4.10 Criticism Of The Experimental Method

There are such criticisms. The subject, that is, the tenderer, will usually know that it is an experiment. When using an experimental measurement convention for Petrochemical Civil Engineering work it would be difficult to disguise the fact. When tendering involves a Bill of Quantities it is necessary for the tenderer to have a copy of the chosen Method of Measurement (in this case a hypothetical Method).

Also, a Method of Measurement expressly identifies the individual items to which such prices are expected to be assigned, though this expectation is not always realised. Once in possession of an experimental method of measurement and experimental Bill of Quantities the tenderer could only come to one conclusion: it was an experiment. The tenderer's behaviour might be affected by this knowledge. We must look to Social Sciences for explanations of people's behaviour in these, or in analogical, conditions.

The major criticism of experimental methods of research is that of "distortion of behaviour". "Psychologists have attempted to squeeze the study of human life into a laboratory situation where it becomes unrecognisably different from its naturally occurring form" (Heather, 1976). The same considerations were found to apply to the observation of the behaviour of animals in (artificial) zoos. This led to the development, in the 1940s of ethology, which involves studying animals in their natural habitat. Some psychologists of the day argued that ethological principles should be extended into human psychology, but it is only recently that natural studies of people's behaviour have been attempted. "The setting in which behaviour occurs is *not* a natural one but one that has been specially created. Consequently there is the question of the extent to which the behaviour in laboratory settings is representative of behaviour in other (natural) settings. In addition, the human subject is aware of being a participant in a research study, and this raises some of the questions that apply to survey research. Finally, most...experiments involve 'samples of convenience', making statistical generalisations somewhat questionable. Overall, ...experiments... are strong with respect to internal validity but weak with respect to external validity or generality" (Dominowski, 1980). Again, it has to be considered whether generalisation is intended or desirable. A model for a particular segment of a population is being sought. It is contended that the different population segments have different characteristics. Models of a "general" type may be inappropriate (see "idiographic" models, *infra*).

The analogical defence of "ethology" is the best defence which can be made of the experiment carried out here. True, the tenderer knew that this was an experimental model, but it is argued that this knowledge would have had no influence on the tenderer's behaviour as the knowledge was not "dangerous" in the given context. This is easily demonstrated by simple reference to the use of "established" models. Being anxious to secure work, tenderers are used to complying with whatever documentation is specified. They are experienced in such situations. This would not be the first time that the tenderer had been confronted with "new" measurement document. SMM5, SMM6 and CESMM (and its successors) were all "new" at one time or other.

Problems attributable to unfamiliarity with an experimental method would be like those associated with *any* new method of measurement. The fact that it was a new method would not in any way affect the ability of the tenderer to practice his or her "stock in trade". Tender documentation varies from day to day, from project to project and from client to client. Tenderers are often faced with new or unfamiliar information; the tenderer *was* working in natural conditions. Further, the subject's behaviour was not being observed; only the fruits of his or her labours. The aim was to make observations about the product of this labour and to acquire feedback about the tenderer's views regarding this product.

Another criticism of the method centres around "expectancy effects". It can be alleged that the expectations and vested interests of the experimenter can influence the subject and make the subject want to please the experimenter and produce the results which the experimenter seeks. A defence to this criticism can be offered. The measurer (at the collaborating organisation) and the tenderer were both given the experimental method of measurement and technical notes regarding its contents. The measurer may have had expectations as to the behaviour of the model, being one of the participants in the prior user survey, and the experimenter clearly had such expectations, being the person trying to justify the model. However, neither the measurer nor the experimenter communicated these expectations to the tenderer, as neither were present when the tender was being prepared.

4.11 The Case Study

Though the case study is not a technique directly employed here, there are some underlying principles pertaining thereto of importance to construction project data. This concerns whether the "classical" criticisms of the case study are actually, in the context of construction projects, criticisms at all. The philosophy centres around whether a model is being formulated for all possible situations, or only for an individual situation (or a limited number of similar situations).

4.12 Criticisms of the Case Study

The case study is generally regarded as being inappropriate for proceeding from singular observations to general statements such as theories. It is *idiographic* as opposed to *nomothetic*, that is, it deals with individual cases, not groups of individuals. "Therefore unlike other methods it does not lead to statistical analysis" (Dobson *et al*, 1980). By this Dobson *et al* imply that it would be comparatively useless to analyse a single case and hope to draw a universal inference therefrom. In the context of Petrochemical Civil Engineering models it would be of little avail to speculate on the basis of observing the characteristics of (say) only one item in a Bill of Quantities. The results of a single case study, though interesting, cannot be generalised to others, therefore this approach is unlikely to lead to, or disprove, general theoretical statements. Its "biographical" or "narrative" nature leads to subjectivity. Due to deep involvement with the single subject under study it is unlikely that the researcher can remain dispassionate about it (Dobson *et al*, 1980).

In this study there is no overt intention to generalise to the whole "construction" industry population. Techniques for measurement and cost control are being sought which represent the particular characteristics of a particular set of cases in a particular segment of the industry. The more a model generalises, the less it is likely to fit any of the individual cases to which it is supposed to apply. It may even be better not to generalise. Perhaps, when it comes to consideration of the construction industry as a whole, standardisation is neither achievable nor inappropriate Given that the industry's first guiding principle is that "every project is different", the hapless learner might wonder why its second guiding principle is the development of standard, universal models which can only serve to mask the individual characteristics of these individual projects.

In fact Flanagan (1980) found what he termed "mutual exclusivity" of conventional Trade and Elemental cost centres. He encountered difficulty in satisfactorily modelling the costs of a single project using Trade and Elemental values from a large variety of projects. Only with "homogenised" data, that is, projects with relatively similar unique characteristics, did his results improve. This seems to question the fundamental basis that a general model could be developed, using "averages" from the whole population, which would satisfactorily fit individual projects. Therefore an empirical model (one which follows the individual situation, or a limited number of situations of similar character, rather than one which vainly misrepresents some abstract "average" situation) may be preferable. Some study of the principles of idiographic models is recommended. Further discussion of this idea is offered later (See Kenley *et al*, 1991).

4.13 SUMMARY

1) In respect of models of the type discussed in this thesis: little attempt has been made to verify current practice, understanding is limited to experience and intuition, current

practice may be not soundly based, and future investigations should build on a factual basis, not on the possibility of false assumptions (Ashworth, 1994).

2) There is a need for empirical work on the naive "cost planning" (in place) methods currently in use, and a need for research on the nature, reliability and rationality of the "human expertise" which forms a rather vague or subjective reasoning behind the conventional models (Raftery, 1991). The conventional rules of measurement are not truly empirical in nature, these rules having been formulated more by a process of negotiation between interested parties than on the basis of prior substantial data analysis (*vide infra*).

3) There is a need to focus on the inherent or implicit assumptions conventionally built into cost models and also to focus on the inherent assumptions made about the validity of them (Newton, 1991).

4) The approach in this work will be primarily (but not exclusively) inductive. The main objective is to use observations of behaviour of cost data in the *conventional* Petrochemical Civil Engineering measurement and cost control model to formulate a *hypothetical* model. This is considered to be a step towards a more rational formulation for the sociological paradigm, which is empirically weak, and will bring it a little nearer true "theoretical" status.. The paradigm is not being tested as such. In fact this work is operating within the overall framework of the paradigm model, but is arguing for a shift in the basis of its formulation and validation.

5) Owing to a lack of theoretical development in the field of Petrochemical Civil Engineering cost modelling and the general Building cost modelling field from which it is drawn the strategy of middle range theory is rejected. An emphasis on a grounded theory approach is recommended. This approach encourages research without preconceived theoretical ideas and enables the researcher to be flexible about interpretation of the findings as there are no preconceived theoretical "truths" involved.

6) Statistical Analysis of the data in Conventional Petrochemical Civil Engineering measurement and cost control models shall be executed in order to obtain empirical

observations of cost behaviour. Statistical analysis is the research method, but a tool to aid the research.

7) A survey will be conducted among all likely end-users, inviting their judgement on the hypothetical measurement model so formulated. The interviews will seek to ascertain whether the end-users consider that the hypothetical model would achieve its stated objectives. The survey will also enable the respondents to comment on whether they agree with its stated objectives, given that its hypothetical statements have been formulated following empirical observation. Also, drafting suggestions by the users are obviously considered useful.

8) An experimental measurement exercise will be carried out and priced as a *bona fide* tender, using a previously-completed Petrochemical Civil Engineering project, and using the hypothetical measurement model. The sole difference in conditions as far as the tenderer is concerned will be an experimental Bill of quantities resulting from the use of the hypothetical measurement model. The pricing of tender documents based on various methods of measurement is a natural part of the work of the tenderer's estimator.

9) In this study there is no overt intention to generalise to the whole "construction" industry population. Techniques for measurement and cost control are being sought which represent the particular characteristics of a particular set of cases in a particular segment of the industry. Therefore an empirical model which follows an individual situation, or a limited number of situations of similar character, is sought. In the circumstances some further discussion of the relative desirability of idiographic and nomothetic models will be offered. Some study of the principles of idiographic models is recommended.

Chapter 5 will describe the formulation of models, in related fields, which bear similar characteristics to the hypothetical Petrochemical Civil Engineering model. The Chapter will also give some treatment of their epistemology and methodology and will culminate by outlining the steps to be undertaken in the statistical analysis of the conventional model data and the formulation of the hypothetical Petrochemical Civil Engineering model itself.

CHAPTER 5:
THE FORMULATION OF COST MODELS IN RELATED FIELDS

5.1 THE EPISTEMOLOGY OF MODEL-BUILDING

In order to interpret data two sets of assumptions are required. There must be a reasonable set of assumptions about how the data were generated (the model) and a set of reasonable assumptions about how the data can be summarised (the statistical methods) (Kenny, 1979). We attempt to prove or disprove hypotheses by drawing inferences from the model, the data and the statistical summaries. That the hypothesis in question has been proved or disproved cannot be implied in any way from the data or any inference drawn from them. Statistical evaluation of the data can only produce probabilities of proof or refutation. The model, and the assumptions on it is based, are always open to question.

Thus in cost modelling the absolute truth cannot be attained. "Modern epistemology tells us that proof is a goal that is never achieved by social scientists or any scientist for that matter. As the ancient Hebrews felt about their God, the scientist should never speak the words truth or proof but always keep them in mind" (Kenny, 1979). Therefore a model, though a useful tool, cannot on its own come up with truth or falsity. It is necessary first for the theory or hypothesis to have undergone some formulation in the mind or imagination of the researcher; the model can only help to prove or falsify statements already formulated by some logical, psychological or ideological theoretical activity.

The model itself is not the centre of attention; that it is efficient, or produces interesting results, or whatever, is helpful, but it is only a tool. used to pursue a higher ideal. "Very often a statistical model can elegantly and simply summarise the data. Although the fit of the statistical model may satisfy the curiosity of the statistician, it only whets the curiosity of the social scientist since most social scientists gather data to test substantive theory. They invest their egos and reputations in theory, not in statistical models... the formation of scientific hypotheses is guided by theory and not by a statistical model" (Kenny, 1979).

In the context of cost modelling, Kenny's foregoing statement is useful. Firstly, it is debatable whether most cost modelling research is devoted to testing; there is not an overwhelming amount of evidence of this, apart from the test of "social acceptability" (*vide supra*), if such tests can be called tests. Secondly, it is debatable whether there is a substantial amount of cost modelling research activity directly dedicated to theory, whether to testing or establishing it. However Kenny is right to point out the dangers of viewing the model itself as a solution, or as an end in itself, and is right to point out that model-building relies on assumptions to which careful attention should be paid. Such assumptions are open to question, and should be questioned.

As to whether a model should be based on assumptions or on facts it is, of course, more desirable that it should be based on facts if at all possible. Assumptions and facts, though, are bound together; it can prove difficult to tell them apart; they can cause problems for modellers. "Models are reconstructions of the order of facts; the validity of the model is determined by its 'fitting' the order of the facts" (Hindness, 1977). However this depends upon the modeller being able to define what constitutes "fact".

Hindness perceived that the epistemology of model-building comprises two distinct phases; the "theoretical" (the actual building of the model, using some language of synthesis) and the "non-theoretical" (the act of observation itself, using some language of analysis). The act of observation involves no theoretical preconceptions regarding which facts are more important than others. The facts are merely observed. Hindness could not defend this position, denying the possibility of divorcing the synthetic language of the "governing science or theory" from the analytical language of "fact-collection". Without an underlying theoretical structure the discerning modeller would be left wondering what the facts to be collected ought to be, or what the facts so collected actually represent. Alternatively the less discerning modeller might accept as *given* that the "facts" collected were appropriate, as the model itself so accepts. Without some "theoretical" framework the observations are arbitrary and relatively meaningless... "in the epistemology of model-building an essential arbitrariness in the selection of facts to be modelled is further compounded by an arbitrary relation of 'resemblance' between the model and the facts it is supposed to represent. We shall see that such doctrines merely add a dogmatic and speculative dimension to a conception that is already so vague and imprecise as to be almost vacuous" (Hindness, 1977).

It is argued that the conventional Petrochemical Civil Engineering cost control model possesses certain such weaknesses. That there is a lack, or at least a dearth, of theoretical development in the field has already been argued. Given this lack, it is contended that conventional model-building in this field consists *solely* of the fact-collecting phase. There is no true strong explanatory powers Worse, given no true theoretical structure, the user of the conventional model can only presume that the "facts" demanded by the model and which, therefore, flow from it, are true facts. There are implicit assumptions that the model actually models what it ought to model. Thus there exists a rather arbitrary relationship between the conventional model and the facts which it is *imagined* to represent. As stated (*supra*), the rather arbitrary "costs" which it models tend not to be based on the true determinants of cost. The most important "facts", that is, the most important cost centres, have not been determined prior to the building of the model. The model is not structured on that basis; it does not even go so far as to "speculate", as Hindness put it. This testifies to the lack of theoretical content.

It is clear that though there are limitations to what can be generalised from the process of observation of finite sets of data, and hence limitations to the models so produced, "the research and data must be grounded in a solid foundation of careful observation" (Kenny, 1979). But only the modeller can theorise about what is to be observed.

5.2 The Theoretical Development of Building Cost Models

In the general context of cost modelling, Brandon (1982) argued that there was a definite need for a more substantial body of theory upon which to base cost modelling practice. Brandon's solution, though, was to call for a shift away from current models rather than the development of improved theoretical structures for the purpose of better relating the existing models to the facts which they are supposed to represent. Whether a "drift away from" is any different to "modifying" is, of course, a matter for semantic debate.

Bowen and Edwards (1985) alleged the strength of the conventional building model to be that it paralleled the design process and was therefore relatively easy to use. It has been suggested here, though, that the conventional Petrochemical Civil Engineering cost model is, by the same token, relatively easy to abuse. Lack of theoretical or scientific consideration of its formulation renders the model incapable of preventing the user from entering information into it which bears no relationship whatever to the design and, therefore, to any current or eventual facts. Further, "ease of use", though welcome, hardly constitutes "scientific" justification for the use of a model.

"Ease of use", "systematic structure" and the like are desirable features of a model, but it must be borne in mind that the fact that the model undeniably possesses some intrinsic merit, based on its structure alone, is insufficient to guarantee that what it models is necessarily what ought to be modelled. Without rational consideration of what the "facts" to be modelled ought to be, and this might affect the model's structure, the situation arises whereby in interpreting the model the user can do no better than take such "facts" at face value. Thus, conventionally, the exercise risks remaining purely an act of data collection; it can only be presumed that the "true facts" are being modelled.

Tong and Lu (1992) recognised that the "client-provided quantities" model, as they termed it, possessed the properties of being prone to variation and prone to abuse. However they dealt rather with the ways in which the tenderer might so abuse the model and exploit the potential variations rather than with the causes of such properties, to wit the content of the model, brought about by its manner of formulation.

5.3 Weaknesses in Existing Cost modelling Theory: The Myth of Standardisation

The idea of standard Elements, and of standardisation of cost behaviour for cost analysis, is weak as long as conventional definitions of Elements are retained. Using conventional Elemental cost classifications, it is argued, Element costs are inherently *variable* to some degree. Standardisation of what is inherently variable to some degree must therefore be an unnatural practice. Standardisation, then, can only remain *justifiable* to a certain degree. This statement requires some elaboration. Let us make two working propositions:

Proposition 1: Any standard model ascribing standard traits of cost behaviour to something which is *variable* can *never* fit any individual observable situation to which it might be applied. It will *always* distort or misrepresent this behaviour. The degree of misrepresentation is proportional to the degree of variability of the behaviour misrepresented, and

Proposition 2: For the model to adequately represent a characteristic set of cost behaviour its constituent parameters need to be defined *following* empirical observation of that cost behaviour. Otherwise the model is nothing but a figment of the imagination. Worse; parameters *not* defined following empirical observation will compound the induced distortion in Proposition 1. In effect the model will compel the user to structure and format the *data* so as to fit the *model* (an *ideological* model) rather than the model fit the observed behaviour (a logical model).

The conventional model, therefore, is very much like the *Procrastian Bed* of Greek Mythology (see Graves, 1959). Procrastes would offer accommodation to passing travellers. He bade his guests sleep on a certain bed in his house. The bed was of a certain size. Little did his guests know how Procrastes would exact payment for the hospitality. If they were too long for the bed he cut off. their feet If they were too short he would stretch them on a rack until they acquired the required length. He insisted on them fitting the bed exactly. Thus "the facts shall fit the model".

It follows that the data could be made to obey the artificial parameters of an ideological model instead of the data dictating the parameters which a logical model ought to possess. This is consistent with lack of theoretical grounding. In using such an ideological model we will lose some meaningful context of cost behaviour which the model was not designed to recognise. It seems plain that the ideological model cannot be *tested* against salient facts if it was not formulated on the *basis* of, or its designer merely *ignored*, salient facts. "Such ideology is 'successful' not because it agrees so well with the facts; it is successful because no facts have been specified which could constitute a test, and because some such facts have been removed. Its 'success' is *entirely man-made*" (Feyerabend, 1975).

Do any conventional models exhibit the properties in Propositions 1 and 2? Yes, it is argued. It is not disputed in the literature, or in practice, that conventional Elements were formulated to represent design features. No bones are made about the fact. However design bears but a weak functional relationship to construction cost. The factors of production bear a strong relationship, but design team models tend not to recognise them.

The sublime contradiction is that models which attempted to, such as Operational Bills of Quantities (see, for example, Skoyles and Fletcher, 1964 and 1970) gained little acceptance in practice, largely because they had the infuriating property of being *structured* according to those cost determinants. Such practice is regarded as less reprehensible when it comes to certain logistics of Civil Engineering work, though the cost determinants are no different in that field: they just manifest themselves in different *proportions* than in conventional building work.

Thus the parameters of conventional building models represent what the building looks like, not what the cost behaviour looks like. Cost is incidental to the conventional Elemental structure (it flows out of it artificially), not a condition precedent to its formulation (it does not flow into the model, naturally, according to observed behaviour). This illustrates Turner's brilliant concept of "the secret of the sausage": we do not know what its ingredients are, but we still eat it! A myth, and hence a paradigm, if there ever was one. What are its ingredients; how did it come to possess them; what should its ingredients be? We take risks eating what the model (the sausage machine) produces if we never took the trouble to look at what flowed into it in the first place. The ingredients matter, always. The mechanism does not matter, until the point is reached where the mechanism in some way begins to pervert the ingredients, in the manner of the Procrastian Bed.

Models, for various purposes, but exhibiting similar characteristics to the work attempted here have been independently formulated contemporary with, and since, this work commenced. The success (or otherwise) of such work shall be used to help establish, *mutatis mutandis*, the usefulness and applicability (or otherwise) of this work.

5.4 FORMULATION OF IDIOGRAPHIC MODELS FOR CONSTRUCTION PROJECTS

Kenley and Wilson (1986) argued in favour of an idiographic approach to modelling on construction projects. Their principal claim was that specific "laws" should be sought pertinent to specific "situations". Nomothetic approaches, that is, "ideal" models based on "averages" of grouped project data, which seek "general" laws for all projects, are inappropriate and potentially meaningless. The underlying, questionable assumption (see Newton, 1991) behind nomothetic models is that individual project variations from the "mean" or "ideal" of all projects analysed are the result of random error, and that this "mean" or "ideal" is consequently an entity of some reliability or significance is erroneous.

Random error results from observation of the natural physical world; the phenomena being observed are ontologically alike; they have the same properties. The phenomena being observed on construction projects are not the phenomena of the natural world (belonging to natural science); they are phenomena resulting from deliberate decisions made in the commercial world of construction management (belonging to social science). This supports earlier arguments, for example Cirillo (1979) and Drucker (1978).

Such phenomena, therefore, are ontologically *dissimilar*, the "errors" around the dubious "mean" are *not* occurrences wholly of chance. Such errors are *systematic* errors, which Kenley and Wilson (1986) argued to be "the result of the individual ontology of each project - systematic error - rather than random error from an ideal". Kenley and Wilson further argued that even if a nomothetic approach were conceptually and functionally feasible it would be difficult to extrapolate from an "ideal" nomothetic model. This is taken to be support of an earlier argument (*vide supra*) that whilst it is difficult to generalise from singularities (the idiographic approach) it must therefore be equally as difficult to singularise from a generality (the nomothetic approach). Therefore there exists the possibility that truly "standard" models and techniques have less in their favour than would first appear.

Criticisms of the idiographic approach have the potential to founder on two rocks. Firstly, if we cannot extrapolate from idiographic models then, by the same token, we cannot extrapolate from nomothetic models. Secondly, the proponents of the nomothetic models, who point out the difficulty of generalising from singularities, assume that there is necessarily an intention to *generalise*. This is not really the case on construction projects. It is beyond dispute that current modelling practice on construction projects is unashamedly dedicated to singularising from generalities. Conventionally, the modeller starts with "general" cost planning models, which are vague and of dubious theoretical worth (*vide supra*) and attempts to develop models which become more and more unique to the project in question (or, at worst, to a fairly discreet and limited set of projects) as further design information becomes available. This contravennes the so-called scientific approach which starts with the unique and atempts to generalise. See Ferry and Brandonon (1991), who illustrate the dubious (in scientific terms) transition from generality models to uniqueness during the design period.

There is a well-hackneyed phrase used in the construction industry that "every project is unique". This does not explain the industry's baffling propensity immediately to seek "standard" and "general" techniques for dealing with such projects. Therefore, it is argued, it might be better to seek models unique to individual projects, or to small sets of projects with similar ontological properties, at the outset. Instead of modelling projects in the early design period on the basis of over-simplified abstraction from the detailed data of individual projects which already exist in abundance (see Davies and Greenwood, 1994), a better approach might be to commence with the detailed project data at the start, by finding an individual project which fits best. The subsequent cost planning effort of trying to adjust for perceived differences between projects would be significantly reduced had the perceived differences not been deliberately introduced into the model in the first place.

Though Kenley and Wilson's work dealt primarily with modelling of cash flow and expenditure on construction projects the principles which they discussed have implications for the search for a measurement and cost control technique for Petrochemical Civil Engineering work. A nomothetic approach is not necessarily the answer; a narrower, idiosyncratic approach, together with the model proliferation which it would bring is potentially healthy. It is not the intention to generalise beyond a limited set of Petrochemical Civil Engineering projects which possess an ontological make-up of their own. Systematic error is eliminated, or at any rate reduced, by idiographic approaches. The concept of a single, universal method of measurement would accentuate the number and scale of the systematic errors brought about by an increased range of ontological dissimilarities in the individual project data used. The greater idiosyncratic content would tend to produce a model which was "splendidly average" and "patently unrepresentative" of any individual situation which it was likely to encounter. At least singularities actually *fit* something.

One way to produce a single, universal method of measurement for construction work would be to concatenate the truly idiographic content of measurement models and amalgamate their truly nomothetic content. How many such idiographic models would be involved, though, is a matter of conjecture. There would be idiographic and nomothetic content: the respective contents of conventional measurement models overlap with each other (*vide infra*). Kenley and Wilson (1986) provided suitable remarks with which to sum up: "The nomothetic approach assumes that there are consistent similarities between projects and the proponents of this approach then produce what are viewed as non-transient industry averages for groups of projects, discounting their significance as random (hence implying unimportant) error... if the above assumptions are violated, nomothetic prediction is invalid and probably meaningless.. it is contended that the conditions required... are not fulfilled".

5.5 Formulation of the Civil Engineering Cost Model

Barnes (1971) developed, for Civil Engineering Work, a "Method-Related" Bill of Quantities model which recognised that cost determinants such as the construction operations themselves (and the associated deployment of plant and equipment) could have a significant cost effect independent of the measured quantities of finished work characteristic of conventional models. Barnes' work was the basis for the formulation of the Civil Engineering Standard Method of Measurement (1976), the Civil Engineering Standard Method of Measurement 2nd Edition (1985) and the Civil Engineering Standard Method of Measurement 3rd Edition (1991). It was noteworthy in that it highlighted the tendency for most of the cost of a construction project to be attributable to a relatively small proportion of the measured parameters in the conventional Civil Engineering cost model.

It is worth noting that the character of the construction work in this study was somewhat of a "hybrid" blend of "classical" Civil Engineering and "classical" Building Construction.

Unfortunately the data available for this study were produced by the application of the conventional "building" model. Detailed comparisons with Barnes' work, therefore, were impossible to achieve, though the basic principle of establishing rank order distributions of cost could be adopted.

Barnes' main criticisms of his own work were centred around the difficulties posed by his methodology, together with the attitudes of model users. His programme of application of the formulated model, on a number of live projects, proved time-consuming and very expensive and required an inordinately large amount of co-operation from industrial collaborators. This problem was compounded by scepticism; what Barnes termed "the inertia attached to current practice", which is, it is argued, typical of the paradigms of professional practice and which was discussed earlier.

5.6 Formulation of the Building Cost Model

The Standard Method of Measurement of Building Works, Seventh Edition (1988) started development concurrently with the early stages of this work. It took 10 years to develop and was expensive to produce. It concentrated on redefinition of traditional work sections by way of a Common Arrangement shared with the drawings and specification. It adopted a tabular format resembling that of the Civil Engineering Standard Method of Measurement (1971), the Civil Engineering Standard Method of Measurement, 2nd Edition (1985) and the Civil Engineering Standard Method of Measurement, 3rd Edition (1991). It is alleged that its aim was to reduce the number of measured Bill of Quantities items by up to 50%. SMM7 has by no means been universally adopted in the construction industry despite official endorsement by its sponsoring professional bodies. There has also been criticism of its aims; indeed, there has been criticism of whether its aims have actually been achieved.

Strotton (1988), in an early review of SMM7, observed drafting problems associated therewith (mainly doubts as to which unmeasured items are deemed to be included with which unmeasured items). Strotton doubted its suitability, given that most projects do not go to Tender on the basis of complete design: "There appears to be a conflict between general rule 2-11 and the normally understood meaning of the phrase 'deemed to be included' ...

having given the materials in the description surely there is no need to state in the rules that they are deemed included...". Strotton continued: "The building industry today is being required to provide completed buildings in very short design/building programmes. I can see very little reason to believe that SMM7 will assist in achieving these reduced times. BQs [*sic*] might be marginally smaller and QSs may have to measure fewer labours but I do not believe the saving in time and volume will be significant".

Strotton doubted, therefore, whether sufficient time and volume savings had been effected by SMM7 and doubted its suitability for the majority of construction projects, those for which the design is incomplete at time of Tender: "If the SMM7 rules and the other common arrangement documents are followed strictly as intended then fully detailed drawings and a complete specification is necessary before the BQs can be completed and the Tenders invited". It is curious that Strotton bewailed the necessity to provide a complete specification, without which the tenderer has no realistic hope of pricing the work properly. Such bewilderment was found among potential users during validation of the hypothetical Petrochemical civil engineering measurement model (*vide infra*) and is, frankly, baffling. An inadequate specification would render the contract document into greater works of fiction than they already were.

SMM7, then, appears not to have gone far enough down the road to simplification. Strotton concluded: "In conclusion I believe that SMM7 goes some way along the path which the brief of the development unit sent them but the end of that path has not yet been reached". Bennett (1986) asked whether the complexity of Bills of Quantities reflects a desire to have Bills of Quantities *per se* rather than a desire to have them represent something meaningful. Thus, in terms of epistemology, the conventional building model has obviously been subjected to a model-building phase, but its modellers may be displaying the tendency criticised by Hindness (1978) of being somewhat arbitrary in their selection of the facts with which it deals.

Bennett (1986) expressed doubt as to the facts to which the SMM7 could actually *prove* to be applicable: "...inevitably, the use of Bills is increasingly questioned as the industry's methods change ever more rapidly and so inhibit the emergence of any widespread established form of construction. Bills have become over-complicated in the face of this change in an attempt to retain their use. Indeed, the SMM development unit's original terms of reference required the production of different levels of measurement in an attempt to cope with the fundamentally changed nature of the industry's work. In the absence of any clear and well-informed decision on the type of projects to which SMM7 is intended to apply, the new method will inevitably remain an awkward compromise". The attempt to retain the use of a model for the sole purpose of retaining its use would seem to be an example of the "model-blindness" criticised by Brandon (1982). Curiously, Bennett (1983) had earlier argued that SMM was, in its development, "moving in the right direction" and appears, therefore, to have revised his view over time.

Benham and Capon (1983) were dissatisfied with the philosophy behind the proposed SMM7. It seemed to be designed for a "Utopian" situation and therefore seemed relatively pointless: "As all practising quantity surveyors know, no building is fully designed at tender stage, (at least not in our combined 60 years of experience). Although a desirable objective, this is, and will remain, unobtainable. The method of measurement that a quantity surveyor requires should cover the prevailing situation where buildings are not fully designed at Tender stage. This is the document that has been called for as a second stage of SMM7, whereas we believe it should have been given first priority. We are aware, of course, that to achieve this goal an initial approach must be to assume the first option, namely that a building is a complete design, but more emphasis must be given to the second stage of the discussion. We do not want to end up with two SMMs, or the one for use with a fully-designed building will never be used". Whether more than one method of measurement, or a single method, is needed has already been discussed (*vide supra*).

However it seems clear enough: methods of measurement expecting measurement in extreme detail based on some extreme detail of design appear seldom to be applicable, as the design is seldom truly complete at the times when the application of the detailed conventional model is expected to be applied. Simpler versions (the only ones possible if design is lacking) are therefore likely to be more applicable in most cases. Mower (1982) said of the proposed SMM7: "The... brief was primarily to produce proposals which would (a) consider the problems which arise where design information is not complete at Tender stage and (b) satisfy the demand for simpler and less detailed Bills". SMM7, it seems, addressed (b), at least to some extent, but not (a).

Mower continued: "The assumption that a change in the rules of measurement can help overcome the problems arising from incomplete design is quite erroneous. Problems arise under building contracts, not because of shortcomings on the part of earlier editions of the SMM, but because of short-comings on the part of professional consultants on the one hand and of contract managers on the other". Thus, if Mower was correct, changes to measurement rules which simplify the product of measurement will not cause subsequent problems, because changes to measurement rules do not cause problems. Measurement cannot be blamed for certain problems whose causes lie outside the measurement domain and in any event cannot be a substitute, with rules set in stone, for professional judgement and competence. It cannot be hid behind, by insistence on the pedantic, religious devotion to, and purveyance of, its rigidity.

It should be desirable that changes to measurement rules (for whatever reason) do not produce unnecessary complexity. If neither changes which simplify nor changes which complicate are problematic then at least what is simpler must be easier and cheaper. If the simple model and the complex model both possess equifinality (*vide supra*) then it would make sense to use the simple one. Mower concluded: "I would suggest that all that is needed to improve the current situation is a sensible editing of SMM6, primarily to eliminate measurement of items which have little significance. All the other matters dealt with by the *DU* (the SMM7 development unit) are questions of professional practice and, while they may be of importance, they have no place in considering the rules of measurement" (this author's italics and parentheses). Interestingly, the hypothetical Petrochemical Civil Engineering model described here was obtained principally by eliminating the apparently insignificant from SMM6 baed data, using prior analysis of cost data behaviour.

SMM7 appears to be part of the answer, but appears not to restrict its attention to pure measurement considerations. It also appears to be designed for use on projects which seldom, if ever, occur - projects which are completely designed and which are less likely to experience post contract variations. such projects are rare in Petrochemical Civil Engineering. The valuation of these variations is the main function of the Bill of Quantities; the document produced (until now) by detailed measurement. The need even for the amount of detail in SMM7, therefore, must be challenged.

5.7 FORMULATION OF A COMMERCIAL RIVAL TO THE BUILDING MODEL

"Shorter Bills of Quantities" (1986) was formulated using similar philosophy to the Petrochemical Civil Engineering Model proposed here; that of effecting large percentage reductions in measurable (but redundant and insignificant) "cost centres". At first it was targeted at international markets where conventional measurement models characterised by "traditional" levels of detail are not so well-favoured, doubtless for cultural (sociological) reasons. To this end, "Shorter Bills" was made available with a version of phraseology couched according to the principles of the Principles of Measurement (International) For Works of Construction, which is recognised by practitioners in various continents.

A salient feature of "Shorter Bills of Quantities" is that its standard phraseology for item descriptions simultaneously acts as a simplified method of measurement for building work. It dictates what to measure and how to measure it in a different way to the "mainstream" methods of measurement. That it was formulated intuitively without extensive recourse to the type of analysis undertaken here was made known by one of its authors during interview with this author (Quier, 1992). The following additional information was obtained during said interview:

1) Although no substantial empirical analysis was undertaken, some market research into the likely demand for the product was carried out. The methodology behind its formulation was largely intuitive. However, upon hearing the findings of Hardcastle *et al* (1987a, 1987b and 1988) one of its authors enquired whether these findings might conceivably have provided certain empirical evidence which the "Shorter Bills of Quantities" model lacked. Some consultation with contractors and subcontractors was undertaken. Thus if it resembled the hypothetical model for Petrochemical Civil Engineering it may provide inductive support for it.

2) The publication has many subscribers: the publishing company ceased recording sales after more than 100 customers purchased it.

3) Subcontractors frequently purchase individual specialist work sections rather than the entire package.

4) Numerous surveying practices are avid users of "Shorter Bills" and will use it in preference to other measurement systems unless there is some overriding reason not to.

5) The model has been used on projects of varying values and degrees of complexity (even as complex as hospitals worth £8 million) with no significant problems.

6) No undue complaints have been received from contractors regarding its use save from one contractor who, aggrieved at its parent company for not awarding it a contract without competition, was lodging every possible objection to the contractual arrangements for the project.

7) The model has apparently operated with no undue problems on projects using minor amendments to the forms of contract which refer to "Shorter Bills of Quantities" rather than to some other method of measurement.

Two other of its authors, Moore and Ashworth (1986), claimed that item reductions of up to 50% can be achieved using the system. They assert that "Shorter Bills" can benefit commercial clients interested in rapid procurement of buildings. Petrochemical companies are such clients. Praise for "Shorter Bills of Quantities" is not restricted to its authors. Emmett (1990) bore testimony to its efficacy: "after some initial reluctance from trade subcontractors, who were unfamiliar with the contents and requirements of shorter bills, we have not experienced any negative response. The method of measurement is logical and quickly understood by the BQ preparer and recipient estimator. Nor have we found that the use of SBQ has detrimentally influenced the settlement of final accounts and we welcome the opportunity to use SBQ on future projects".

Thus Emmett supported "Shorter Bills of Quantities",. More importantly, Emmett found that the use of a simpler measurement model does not appear unduly to impair the ability of the Bill of Quantities to perform its principal functions. Were the hypothetical model described here no simpler than "Shorter Bills of Quantities" there is good reason to conclude that it will be able to operate in practice with reasonable success.

5.8 FORMULATION OF THE ITERATIVE CIVIL ENGINEERING MODEL

Saket (1986), Saket (undated), Horner *et al* (1986) and Horner and Saket (1984) described the development of an approach to contractors' tender estimating called "iterative estimating", based on the principle of pricing a small proportion of items (the most cost-significant items) which would otherwise constitute a conventional Bill of Quantities. Effectively only 30% of the items (by rank order distribution by cost) would be priced. Saket discovered cost distributions in Civil Engineering Bills of Quantities to be similar to those discussed here. The Property Services Agency (1983) found, in Bills excluding Civil Engineering Work, that such distributions existed in individual work sections within Bills of Quantities (that is, in subsets of the data samples). This was also found in the data used here (*vide infra*). Saket's iterative estimating approach has been tested on 6 live projects and is claimed to have achieved:

1) Tenders on average 0.7 % lower than those prepared by conventional methods,

2) More consistent tenders and

3) A minimum saving of 50% in the time taken to price tenders.

These results could be used to further underpin the argument that the Tendering process will not be unduly hampered by the use of a measurement system which embodies simplicity; if anything they could, in the long term, make things better.

Saket considered the application of iterative estimating to the valuation of variations and settlement of Final Accounts. It is argued here, though, that to use an estimating tool (that is, a predictive tool) to actually settle a Final Account would be relatively pointless; a prediction tool is not needed for a set of events which have already occurred and which, therefore, do not need to be predicted. However, if the accountancy information is somehow fed into the predictive model in order to improve the qualities of the original estimate, then Saket's point becomes valid. The Bill of Quantities, though, remains an accounting tool whose effective contribution to predictive models is possible, but limited. Saket has shown, however, is that obsession with detail is perhaps unnecessary; this is taken as further support for the approach adopted in this work.

5.9 FORMULATION OF THE BUILDER'S QUANTITIES MODEL

Pasquire (1993) introduced the "Builder's Quantities" model, which stood as a method of measurement for small- to medium-sized contractors to use in the preparation of tenders. It classified sub-sections and work groups which more closely represented the sequence of construction operations on site than the "trade" divisions of conventional models. This model bore some similarities to (for example) Barnes' (1971) model for Civil Engineering in that it recognised, in certain cases, the need to consider items of plant and equipment as separately-identifiable determinants of cost.

A fundamental tenet of Pasquire's philosophy (and of that of the contractors involved) was that clients should not impose a model structured to reflect the preferences of clients. Pasquire's model, therefore, was purely intended for the *internal* needs of contractors whilst preparing tenders. Thus it is not a tender document; it performs a dissimilar function to the conventional Petrochemical Civil Engineering and Building models, which require contractors to break those prices down into a format dictated by the preferences of the design team.

Pasquire's methodology of formulation consisted of studying builder's quantities data and their usefulness to the various internal management functions of the collaborating contractors. By the author's own admission the data so collected were qualitative in character and thus potentially subjective. Therefore some validation was undertaken by means of triangulation; that is, of verification by potential expert users outside the participating organisations.

Were it Pasquire's intention to formulate a nomothetic model the technique of verification at other organisations other than those at which the original data were collected possesses some virtue. Pasquire has perhaps collected evidence that generalisation may be possible, *mutatis mutandis*, from the results of the studies at the individual organisation. Further benefit may have accrued from verification at the original organisation in order to ascertain whether the model could have served as a idiographic model.

5.10 Formulation of the International Engineering Construction Model

The Standard Method of Measurement for International Engineering Construction (1984) was formulated "to contribute to the framework of project documentation, and in particular to provide measurement principles for the estimating, tendering, contract management and cost control aspects of industrial engineering construction" (*verbatim* from said document). Thus, like other conventional measurement models, it is in fact idiographic in character, despite its title of "Standard". It seeks to apply to an individual, "special" situation. It is not a "general, universal" model. Like other conventional measurement models it contains specific recommendations to use other models in other situations.

Curiously, it is typical of other conventional models of its type in that it covers certain construction work also covered by other methods of measurement. It illustrates a typical property of conventional models; they are not truly idiographic in character (their respective contents are not mutually-exclusive). Neither are they truly nomothetic. Their authors take pains to point out the limitations of the model's potential application; as if they (or at any rate, the bodies formulating them) were not convinced that they were truly standard or "general" models. The more limitations a theory or model puts upon itself the less explanatory it becomes.

In the method of formulation (quoted *verbatim* from the Standard Method of Measurement for International Engineering Construction, 1984) "particular attention was directed towards consultation with trade association [*sic*], contractors, client organisations and professional bodies" (this author's italics and parentheses). Though it is not made entirely clear what the methodology was it is evident that "consultative documents" were sent to various of these parties and that 55 bodies responded. It is also clear that various Members, Consultancies and Regional Committees of the Sponsoring Bodies (the Association of Cost Engineers and the Royal Institution of Chartered Surveyors) contributed "technical advice and practice guidance". Owing to lack of evidence as to the nature of this advice and guidance it can only be speculated as to whether the document was formulated within some implied, accepted tenets of paradigm practice.

5.11 FORMULATION OF A RATIONAL BILL OF QUANTITIES MODEL FOR CIVIL ENGINEERING WORK

Singh and Banjoko (1990) criticised the shortcomings of conventional Bill of Quantities models. That such criticisms have often been voiced, but seemingly to little effect, was brought into context by Singh and Banjoko by virtue of their assertion that the Method-related model developed by Barnes (1971) has not superseded the use of its conventional forerunners.

In like manner to the Building model (SMM7, 1988) the sociological inertia of professional practice has prevailed despite the official endorsement of the respective professional societies, whose presumed vested interest it is to see their models purchased and used. The strength of Barnes' model lies in the fact that some rational theoretical and analytical treatment preceded its formulation. However it would seem from Singh and Banjoko's that the question of whether the officially sponsored model, or any model, was formulated on a rational basis would appear to matter little and that the question of whether the sponsoring bodies are actually using "rational approach" as a reason for so sponsoring them would appear to matter less.

The practitioners, collectively, appear unwilling to sponsor's influence, or to consider as a prerequisite for selecting a model the fact that some rational means of formulation might have been attempted. Likewise, they appear unwilling to consider lack of rational approach to formulation as a prerequisite for the deselection of the "conventional forerunner". Singh and Banjoko (1990) was based on Banjoko (1985). Central to its methodology was the "worth evaluation" of different forms of Bills of Quantities; of measures of their suitability to satisfy financial control and estimating requirements of clients and contractors. By determining the deviation of the "perceived worth" to users of a given Bill of Quantities from the "mean perceived worth" of all of the Bills studied Banjoko determined whether any given Bill of Quantities format was biased towards the requirements of one or other of the users.

Banjoko established that Barnes' (1971) Method-related model performed better overall than traditional Civil Engineering models. However in attempting to overcome the problem of conventional design-based models being dictated by, and hence biased towards, the design team, they overcompensated in respect of the requirements of the production team. A set of criteria for a rational form of Bills of Quantities for Civil Engineering was recommended.

Though Banjoko's work treated measured quantities of finished work and factors of production as potentially significant determinants of cost its main purpose was to deal with Bill of Quantities format rather than directly attack conventional methods of measurement. Therefore this work has limited applicability to the study undertaken here.

5.12 FORMULATION OF ELEMENTAL MODELS

It can be said that conventional definitions of building Elements have been arrived at regardless of the materials used, let alone the methods of construction (De Troyer, 1986). Accepting de Troyer's account, it would appear bizarre that the parameters of an Elemental cost model are defined irrespective of how they are built and the components from which they are made. This is tantamount to saying that a cost model should not recognise cost determinants and cost behaviour'.

Difficulties associated with "standard" sets of Elements were encountered on Civil Engineering projects by Marks *et al* (1986). The inherent variability of these types of construction makes the derivation of a single set of standard Elements a daunting task. It is argued that a better approach for Petrochemical Civil Engineering would be to establish individual, idiographic sets of predictable cost centres appropriate to individual types of building or structure rather than force the cost data to conform to a nomothetic, ideal, predetermined set of parameters which may be inappropriate to any types of building or structure encountered.

In other words we should consider changing our sets of Elements, or abolishing them and replacing them with something else, which amounts to much the same thing. A solution is needed with identification of significant cost determinants *as a condition precedent to model* *formulation. The model must flow from logical costs; costs must not flow from an ideological model.* Such is the predicament of the conventional Elemental model; Elements were invented without prior cost investigation and inconsistent cost behaviour was observed to flow casually (not causally) from its invented parameters.

Diederichs and Hepermann (1985), in the domain of housing and administrative buildings, identified some 45 key cost parameters which they allege exist practically independent of the type of structure. These parameters are claimed to be prone only to marginal variation in cost behaviour and to be predictable to relatively high degrees of accuracy. Pertinently, these key cost parameters are not Elements in the sense that they are "classically" -defined in United Kingdom practice. However they can be apportioned to Elements (factors of design) or to labour, plant and materials (factors of production) if desired. Thus this model claims to bridge the "gap of definition" between the design team model and the building team model. Additionally, it permits input by the builder during design and planning, if desired. The true resource-based cost determinants *must* come from the production team; they *cannot* come from the design team. It has long been held that there is a highly-distinct separation between design and production in the construction industry. The *Diederichs-Hepermann* model, or one similar, promises to be an interface between the two.

An endearing feature of the Diederichs-Hepermann model is that it does what the "heretics" knew it should. It refuses to conform. It will not admit that Elements (as conventionally defined) have a part to play in identifying significant cost centres. *Elements do not determine costs; they purport to represent them, and they do it badly.* This model refuses to standardise *a posteriori*; it standardises *a priori*, that is by deduction from prior observations of cost behaviour. Thus it reduces the "Proposition 1" and "Proposition 2" distortions discussed *supra*. It follows cost behaviour. It exists at what is argued to be a more appropriate level of abstraction; that between Bill of Quantities and Elemental cost analysis.

Further, its key cost parameters can be replicated by equivalent United Kingdom parameters which already exist, but which are not as yet used in cost planning. These cost centres are not the conventional Elements, but are features ontologically-akin to, and at the equivalent level of abstraction of, the Coordinated Project Information Work Sections or of the old NEDO Work Categories (which, incidentally, can be easily expressed in terms of inputs of the factors of production). It seems ironic that the factors of production can be seen to be important in a model for settling Final Accounts, but not in a pre contract model. Nothing, therefore, needs to be invented; we can use what we already have. It is only necessary to change the bad habit of not analysing cost behaviour *first*.

Southgate (1988a, 1988b) suggested an alternative set of design-based building elements which claimed better to relate structural form to the manner, sequence and phasing of construction operations. This work, however, constituted a mere regrouping of existing elements and did not propose any ideal, or optimal, level of abstraction of the component cost parameters of the Elements it espoused.

The Diederichs-Hepermann model (1985) identified a level of abstraction of building cost data consistent with the above requirement and identified in the data a relatively small, but highly predictable, set of significant cost centres, which they called "Lead Positions". Thus the model embodies the principle that it is not the pursuit of *quantity* of detail, but pursuit of an appropriate *level* of detail which is desirable. Further, the costs in the model can be expressed in terms of resource inputs, thus affording the facility to commute expressions of cost between the domains of design-based parameter and production-based parameter, if desired. Diederichs and Hepermann (1985) essentially provided a "dictionary" *via* which the translations between the design and production terminologies can be made. It is argued here that such a language need not be *truly* common as conventional Bills of Quantities do not seek, nor could they achieve, a truly "Common Speech". A simple device of translation is needed, but it must be based upon an appropriate level of detail and be capable of being commutable between the design and production domains.

The fact that significant cost determinants can belong to more than one building Element (like, for example, Coordinated Project Information Work Sections or NEDO Work Categories) and the fact that a building Element can possess more than one such cost determinant "serves to illustrate the rather arbitrary nature of conventional Element classifications. Building costs are not determined by the way in which we *classify* cost information. Therefore we should expect such classifications to follow cost and not *vice versa*" (Davies and Greenwood, 1994).

5.13 Proposals for the Formulation of a Hypothetical Petrochemical Civil Engineering Model

An approach to the formulation of a hypothetical Petrochemical Civil Engineering Cost model should consider the following requirements:

1) The model must have some theoretical basis upon which to decide which are the important facts to collect. Otherwise we have a model-building phase and nothing else: what flows through the model is arbitrary and meaningless.

2) A better theoretical body must be developed in order to have the existing types of model better represent the facts which they are supposed to represent. However, improvement of the existing type of model is suggested, as it is not clear what the recommended alternative departures from the basic model type are.

3) It is difficult to standardise what is inherently variable, so the hypothetical model should not attempt to become a "general, universal standard". Standard models are ideological; they cannot fit any individual observable situation. In obeying a standard model we must distort the observations so as to fit the model. Model proliferation is desirable. A move towards a completely nomothetic approach, that is, an attempt to over-generalise, as was partly attempted during the formulation of the Builder's Quantities model, should be resisted at this stage, at least until the idiosyncratic behaviour of the Petrochemical Civil Engineering data is better understood. A nomothetic model may not be appropriate.

4) Individual models based on prior empirical observation, though they have limitations, are more logical. They do not place their own limitations outside the boundaries of the area to which they intend to apply in any event. Over-stretching has caused theories and paradigms to fail. The problem with conventional models is that they are neither nomothetic nor idiographic models; there is unnecessary overlap. The features of the hypothetical Petrochemical Civil Engineering model should obey empirical observation of the cost behaviour of the data. It should not be an ideological model.

5) Rank order distributions of cost of the type characterised by the Method-Related Civil Engineering model and the Iterative Civil Engineering Model should be identified in the Petrochemical Civil Engineering data and used to define the guiding parameters of a hypothetical model for Petrochemical Civil Engineering.

6) A move towards greater simplification of detail should be sought than was achieved by the Building Cost Model (SMM7), which has been criticised as having fallen short of the objective of simplification (among other objectives).

7) Behaviour of costs of Elements should be observed in the data, with a view to redefining, or finding alternatives to, conventional Element classifications. Cost planning and measurement data could eventually be subsumed into a single model, at an appropriate level of abstraction between that of the over-complicated Bill of Quantities and the over-simplified conventional Elemental Cost Analysis. That the industry seeks "standard, general models", yet structures its conventions such that models start as "general" models and develop into "unique" models (singularities) is a contradiction.

8) The most detailed of these unique models (the Bill of Quantities model and its surrounding conventions of measurement) is a partly entropic information system. Much of its detail constitutes mere noise, liable to distort the intended message. The detailed requirements of the measurement conventions demand facts to fit the model, as opposed to a model to fit the facts.

5.14 Summary Remarks

It is evident that much detail sought by measurers and often demanded by existing measurement conventions is indeed superfluous in terms of worth to the Tendering and Final Account processes. There is evidence that the "craving" for detail is not necessarily founded on the certain knowledge that such detail is the right detail, constitutes "the facts", or is of significant benefit to the process or to the user, though the user might deem the information received to be intrinsically correct, necessary and beneficial, being unaware of possible distortions brought about by the model itself, being a device for transmitting information. There is the suggestion that, conventionally, all is geared towards having the user satisfy the requirements of the model rather than having the model satisfy the needs of the user.

Chapter 6 will deal with the formulation of the hypothetical Petrochemical Civil Engineering model. Results of the statistical analyses of the data in the conventional model will be presented, results of the "experimental test" will be presented and discussed, and comparisons of performance shall be made between with the hypothetical model and similar "rivals", in pursuance of healthy debate (see Feyerabend and Lakatos).

CHAPTER 6:
THE FORMULATION OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL

6.1 LEVEL OF ABSTRACTION: INDIVIDUAL BILL OF QUANTITIES ITEMS: PRELIMINARY ANALYSIS (APPENDIX A1.1)

Whilst further data were being collected 3 Bills of Quantities for Petrochemical Civil Engineering projects were analysed to ascertain the general distribution of their costs among "small value" and "least value" items, as defined by Barnes (1971). "Least Value Items" were defined as those which collectively amounted to less that 20% of the Tender Sum. "Small Value Items" were defined as that 40% of all the items in the Bill which had the lowest individual values. Barnes ascertained that such items contributed between 0.3% and 3% of their respective Tender Sums.

6.2 LEVEL OF ABSTRACTION: INDIVIDUAL BILL OF QUANTITIES ITEMS: RESULTS OF PRELIMINARY ANALYSIS (APPENDIX A1.1)

The preliminary analysis revealed that between 77% and 87% of measured items and between 80% and 88% of all items in the contract studied contributed only 20% of the total value of the contract (See Table 2). There can be items in Bills of Quantities which are not quantified, but which are presumed worthy of cost consideration. Clearly, though, the majority of unmeasured and measured items were relatively cost-unimportant. The comparison with Barnes' findings, in respect of "Small Value Items", was reasonably favourable. The 40% of "Small Value Items" in the contracts under study ranged between 2.18 and 4.93% of the contract sum; a miniscule contribution in cost terms considering their contribution to the overall population of items (See Table 3).

The initial evidence appeared to suggest that considerable effort is being expended processing items which have little to contribute in cost terms, either for initial tendering considerations or for use in valuing subsequent variations. Contract 01 was based on

CESMM (1976), contract 02 was based on SMM5 (1968) and contract 13 was based on SMM6 (1981). All three methods of measurement appeared to have similar behaviour with respect to the preliminary analysis described above.

6.3 LEVEL OF ABSTRACTION: INDIVIDUAL BILL OF QUANTITIES ITEMS: COMPREHENSIVE ANALYSIS (APPENDIX A1.2)

Data from 15 Petrochemical Civil Engineering Bills of Quantities, were collected and statistically analysed. Eight Bills were originally measured using SMM5 and seven using SMM6. Comments are offered regarding the quantity, adequacy and suitability of the data and the constraints surrounding such data, in Appendix 1.

For each of the 15 Bills of Quantities the items in the Bill were ranked in order of value (highest first) and cumulative totals computed for each item as follows:

1) Percentage of items generated as each item was added and

2) Percentage of total value generated as each item was added.

Taking the figure of ±5% "accuracy" (if such a word can be regarded as appropriate) in construction price forecasting to which practitioners aspire, but which certain commentators, including Ashworth and Skitmore (1983), view with scepticism, the smallest value items amounting only to 5% of the total project cost were isolated. The following calculations were made for each Bill:

1) The number of items so removed and

2) The percentage of the total of all Bill items so removed.

6.4 Level of Abstraction: Bill of Quantities Items: Results of Comprehensive Analysis (Appendix A1.3)

The results are presented in full in Table 5 and are summarised as follows:

1) The ranked order distribution results showed that in all of the 15 Bills of Quantities studied, costs were generated extremely rapidly by a low percentage of high value items. There were high proportions of "zero value" (i.e. unpriced) items, both measured and unmeasured. The results indicated that SMM5 Bills generated a greater proportion of low-value items than SMM6 Bills, but in both cases the proportion was high. The generally accepted "80/20" distribution were frequently exceeded; in some cases Drucker's (1978) "90/10" distribution were observed.

2) The analysis involving "removal" of those items which collectively amounted to only 5% of their respective Bill totals revealed the following:

a) The minimum proportion of items so removed from any contract was 52.86%.

b) The maximum proportion of items so removed was 84.25%.

c) The range for SMM5 Bills was 52.86% to 84.25%.

d) The mean for SMM5 Bills was 70.70%.

e) The range for SMM6 Bills was 57.70% to 78.85%.

f) The mean for SMM6 Bills was 66.80%.

It appears that SMM6 has produced simplification, but only marginally. Across all projects analysed high proportions of items are considered by Tenderers to be of little importance in cost terms. This result was observed vividly and consistently. On the basis of these results, a large proportion of effort appeared to be expended on a large proportion of items which contribute little of importance to the overall cost. If such items attract little cost-significance in tendering they attract (by definition) little cost-significance in the process of valuation of variations. Indeed, there were high proportions of unpriced items (zero value).

The results suggested that the bulk of cost was consistently generated by a small proportion of high-value items. The results suggested, also, that SMM5 Bills generate a greater proportion of cost-insignificant items than do SMM6 Bills. In the data analysed, however, this proportion appeared to be marginally greater. For both SMM5 and SMM6 Bills the proportion of such items was very high. On the basis of such results it was recommended that further analysis be carried out to identify such cost-insignificant items in detail with a view to investigating whether such items can be removed from the measurement system altogether; the justification being that they have little to contribute to overall costs.

Cognisance should be taken, however, of the argument that whilst a large number of items might be considered by the Tenderer to be unworthy of pricing, the nature and extent of their proliferation communicates to the Tenderer an indication of the detail or intricacy of the intended work. Whilst this is, *prima facie*, a sensible argument, it is rejected for the following reasons:

1) If the detail of the items truly reflects the detail of the drawings then it should be sufficient (except for the major cost items) to refer to the drawings.

2) During data collection, large numbers of instances were observed where not only were the quantities fictitious, but also the items of "work" themselves;they were merely inserted to attract "usable" rates and not necessarily to represent the state of the design.

The argument in (2) could be extended further given the apparently wild excesses of "abuse of Bills of Quantities" (*vide supra*). There was at least one example in the data analysed of the entire Plumbing Trade in a Bill of Quantities being priced as "included elsewhere". There was no indication of exactly "where". As this particular section contained sanitary fittings and pipework which were, by visual inspection, clearly worth several thousand pounds, it could be wondered what "cost-significant" really meant. Eradication from the measurement conventions of items such as that, though, would be reckless behaviour on the measurer's part (to say nothing of the apparent recklessness of the Tenderer).

6.5 "NORMALISING" THE DATA (APPENDIX A1.4)

Data for all 15 Petrochemical Civil Engineering Bills of Quantities, representing thousands of items were analysed in order to produce the following statistics representative of the nature of their cost distribution within their respective Bills of Quantities (*Tables 6 and 8*):

1) Frequencies,

2) Mean values (normalised for ease of reference),

3) Standard Deviations,

4) Skewness of Distribution and

5) Maximum values.

These statistics were then reproduced following the removal of unmeasured items from the data sample, in order to gain indications of the effect upon the results of so doing. The results were tabulated (*Tables 7 and 9*). Comments are offered in respect of the data and their validity in Appendix 1. The results were of great interest. Clear differences could be seen between Bills produced using SMM5 and Bills produced using SMM6. The results are summarised as follows:

1) The statistical analyses showed that the item cost distributions in the Bills are not normal, but very highly skewed such that the vast majority of items have values considerably lower that their respective Bill means. This may surprise observers who assume such distributions to be normal, as if observation of the physical world were taking place. Drucker's (1978) comments, that we are not observing the natural world but observing the effects of social or commercial activity, appear to be vindicated.

2) The impression conveyed by inspection of the typical distributions is actually distorted by the fact that the monetary value (or the bulk of it) is contained in a few very high

value items which lie in the long tail of the distribution. Such items have a very low frequency, but a very high proportional contribution to the total value of any given Bill.

3) The skewness (an indicator of such a long-tailed distribution) is in no Bill less than 4.47 (for all items of the Bill) and is in no Bill less than 3.71 (for measured items only in the Bill). For a distribution reasonably approaching normal a skewness measure of nearer +1 or -1 would be expected, depending upon which side of the mean the bulk of the items lie. For a true normal distribution the proportion of items on each side of the mean would be more or less equal. This is most certainly not the case for the data studied here.

4) The maximum item value (an indicator of the length of the tail of the distribution) is in no Bill less than 27.65 times the mean for all items in the Bill and is in no Bill less than 14.3 times the mean for measured items in the Bill. This result is perhaps seen in better context if it is realised that for this analysis the minimum value is 0 and the mean value for each Bill is 1.

5) By removing unmeasured items from SMM5 Bills (Contracts 2, 3, 4, 5, 6, 7, 8, 9) the mean standard deviation, skewness and maximum value are, without exception, all reduced. This is probably explained by the fact that, in SMM5 Bills, there are a larger proportion of high value unmeasured items; indeed, the highest value item in every Bill is unmeasured.

6) By removing unmeasured items from SMM6 Bills (Contracts 11, 12,13, 14, 15, 16, 17) the results were somewhat different:

a) In 4 Bills (Contracts 11, 14, 16, 17), the mean and standard deviation were reduced and the maximum value reduced. In 3 Bills (Contracts 12, 13, 15), the mean and standard deviation were increased and the maximum value unchanged. This, it suggested, is due to the fact that measured items in Contracts 12, 13 and 15 tend to have relatively high values and that in those contracts the highest value item in the entire Bill is a measured item.

b) A different result occurred in contracts 14 and 17, whose skewness increased upon removal of unmeasured items from the analysis (similar Bills, ie

Contracts 11 and 16, had their skewness decreased). In all such contracts it is clear that the highest value item in the Bill was unmeasured. It is suggested that in contracts 11 and 16 there were a greater preponderance of low-value unmeasured items than existed in Contracts 14 and 17. Removal of high-value items would tend to reduce skewness. This is not a definitive statement, however.

7) The descriptive statistics (for all items in the Bills of Quantities) are given in Table 6.

Investigation of, for example, the value of the second or third highest item, would, on the face of these results, appear to be unnecessary given that it has already been demonstrated, *vide supra*, that 15.75% of the items in a Bill of Quantities can provide 95% of its total value. What is more, some of those 15.75% were not measured items in any event. The descriptive statistics (for measured items only) are given in Table 7.

The results showed only marginally less spectacularly the properties shown in Table 6 (for all Bill items). What was clearly noticeable was that SMM6 Bills appeared to produce higher value measured items than did SMM5 Bills. This would appear to indicate that SMM6 did, to some extent, achieve the simplification and eradication of spurious detail which it is alleged it sought. Further discussion of these results (in general and of nuances) is offered later. The general conclusions to be drawn from comparing the descriptive statistics for the SMM5 and SMM6 Bills under study are:

1) SMM6 Bills had a higher mean for measured items indicating a greater preponderance of influential high value measured items;

2) SMM6 Bills had a greater standard deviation of measured item value from the mean.

3) SMM6 Bills had marginally less skewness, not withstanding the previous statement.

4) SMM6 Bills had higher maximum item values, inferring again that they have a tendency to have large value measured items and fewer large value unmeasured items,

indicating, perhaps, that their desired simplification of detail has to some extent been achieved.

The overriding consideration was, however, that in both SMM5 and SMM6 Bills the vast majority of items were of very low value and did not contribute more than marginally towards the total cost generated. The frequency of the lowest value item (ie zero value) in some examples exceeded 100. It was recommended, therefore, that some measure be attempted of the costs of production of Bills of Quantities items to ascertain whether disproportionate effort is expended on the majority of low value items. This recommendation was not acted upon at the time because of (a) practical time constraints and (b) the possibility of offending the sensitivity of employees by such an investigation and breaching the confidentiality of the records of surveyors involved, a large proportion of whom were not employed "in-house". It was recommended at this stage that further analyses of the relative significance of items and groups of items (i.e. sub-populations of the data and their relative behaviour) be undertaken.

That many measured items are of no real monetary worth, for the purpose of tendering and for the purpose of valuing variations, is further and clearly demonstrated by the analysis in this chapter. This appears to be the case regardless of which method of measurement is used. The fact that SMM6 would, from the analysis in this chapter, appear to produce less cost-insignificant detail would appear to have demonstrated that it has, at least in part, satisfied certain of its original objectives regarding simplification. It does not necessarily follow, though, that the scope and level of detail demanded by that (or any) set of measurement rules necessarily reflects the scope of the work to which it is being applied (*vide supra*). What certainly could *not* be said at this stage is that SMM6 is perfectly suited to the type of construction work under study, although it would certainly be more appropriate than CESMM in many respects.

What appeared to be somewhat less consistent than the general trend of "highly skewed" behaviour and the vaguely discernible tendency for SMM5 Bills to produce more highly priced unmeasured items was the behaviour of unmeasured items in SMM6 Bills. It would be beneficial here to discuss the effect of unmeasured items in general and to try to apply such principles to the data in question.

Description is offered (*vide infra*) of the definition of an "unmeasured item" and argument has already been offered (*vide supra*) regarding the use and abuse of items in Bills of Quantities. These notions, in the case of unmeasured items, require elaboration. Even though the remit of this work was to concentrate upon that what is measured there is no doubt that the pricing of unmeasured items could have an effect upon the pricing of measured items (and *vice versa*) if the overall Tender figure is considered immutable.

It is commonly held that unmeasured items can take the following forms:

1) Preliminary Items (items which are required for the general execution of the work but, by virtue of the fact that they are not uniquely attributable to any given section or element of the design, cannot be so quantified).

2) Prime Cost Sums for specialist work (based on consultant's pretender estimates for specialist work such as Mechanical and Electrical Installation). Strictly speaking these are measurable as they are frequently based on separate Bills of Quantities for specialist work.

3) Provisional Sums for work which it is known will be required, but the exact nature and extent of which cannot be effectively measured at the time of Tender.

4) Dayworks (a "Prime Cost" allowance for work not yet envisaged and which, if it occurs, will be of such a nature that it will be difficult to physically measure).

Thus it can be seen that items of major cost importance can be unmeasured (by deliberate choice or force of circumstance). It is further commonly held that the choice of whether work should be priced as "measured" or "unmeasured" is frequently the Tenderer's. Where the Tenderer is given the opportunity to price some Preliminary Item, such as "Water for the Works", the Tenderer might price it as a lump sum in the Preliminaries section. Alternatively it could be inserted as percentages of all (or certain) prices in the measured sections of the Bills., thereby risking that if the quantity of such work varied the payment for the general preliminaries item would also vary. Such is the risk; items can be priced as Preliminaries pursuant to some policy or strategy or be subsumed in sections of measured work and payment be foregone should such sections be found to be "fictional".

It is ubiquitously argued that Bills can be "strategically loaded" or "abused" by Tenderers to facilitate their cash flow. This can be applied to unmeasured items as well as to measured ones. The tenderer could allow for certain costs in the "unmeasured" or the "measured" sectins of the Bills. What is not too clear from this (or any) analysis is the extent to which this occurs. Tenderers were ever reluctant to disclose their Tendering policies and (*vide supra*) the surveyor has no precise notion in any event of whether the prices so included are realistic.

It is contended that due to the phenomena just described, serious attempts at Elemental (or equivalent) analysis of unmeasured items are more difficult to achieve than such analyses for measured items. The approach to pricing unmeasured items is less able to be standardised and less consistent. This comparative inconsistency, though, nevertheless does not prevent the general cost behaviour of unmeasured items from being different in nature to that of measured items. Gray (1983) recognised that in certain situations 90% of the Preliminaries cost can be found in the six largest such items priced. This is a noteworthy given that a Bill of Quantities is capable of possessing more than 200 items of "general" or "Preliminaries" work.

Difficult though it may be to understand the detail behind the pricing of such items (owing to our inherent vagueness regarding the Tenderers' policy decisions involved) it could not be but valuable to acquire greater knowledge thereof. Azzaro *et al* (1987) argued thus: "a much better understanding is needed of the most sensitive aspect of tendering - the preliminaries estimate".

The inherent variability of unmeasured item content is illustrated by the fact that Flanagan (1980) found Preliminaries to range between 12.6 to 64.4% of project cost. The Building Cost Information Service (1969) found that surveyors, when estimating, usually append percentage additions of between 10 and 15% of the value of the measured items. As it is not immediately apparent that Preliminaries allowances made by practitioners are based rigorously on empirical analysis of historical data it is suggested that surveyors' perceptions regarding the detailed behaviour of unmeasured items are not too clear.

6.6 Cost-Insignificant Parameters and Generic Families of Parameters

It was the purpose at this stage to identify those Trades in which cost-insignificant items (see working definition, *supra*) proliferated. The data tended to be grouped in Trades (not necessarily in Elements; Element codes frequently had to be added to the data). This was with a view to experimenting with reduction of the number of items generated by the measurement system, by:

1) Investigation of those items which, by virtue of being of low value, might feasibly be considered for elimination from the measurement conventions and

2) Investigation of "generic families" of items of similar character which, by virtue of attracting similar or equal prices and rates, could be grouped together, have their measurement rules simplified or have the number of their measurement categories reduced.

6.7 Level of Abstraction: Trade: Analysis of Cost-Insignificant parameters

The data were split by Trade and tabulations produced showing:

1) what percentage of all items belonged to each Trade,

2) what percentage of items in the lowest 20% value band resided in each Trade,

3) what percentage of items in the lowest 15% value band resided in each Trade,

4) what percentage of items in the lowest 10% value band resided in each Trade and

5) what percentage of items in the lowest 5% value band resided in each Trade.

Thus, for example, if an item resided in, say, the lowest 15% value band that item was one of those items which collectively amounted to only 15% of their respective Bill Total, based on the technique of "ranked order" distribution, lowest first.

6.8 LEVEL OF ABSTRACTION: TRADE: RESULTS OF ANALYSIS OF COST-INSIGNIFICANT PARAMETERS (APPENDIX 2)

The results are presented in Tables 9.1 and 9.2, Diagrams 1.1-1.3 and Diagrams2.1-2.3. The most noticeable result was that behaviour across Trades was remarkably consistent. The "percentage of all items" results show that certain Trades predominate, but marginally. What was interesting was that the relative percentages in each Trade did not significantly vary from cost band to cost band. Thus, generally, any given Trade retained its "share" of the total number of small items and large items. For example, Brickwork and Blockwork in SMM5 possesses about 7% of *all* items and about 7% of *low value* items. Metalwork in SMM6 possessed about 4% of *all* items and about 4% of *low value* items.

Whilst, on the basis of earlier evidence, it is true that all Trades have a preponderance of low value items, there are very few Trades which appear to have a considerably greater proportion of them than other Trades. Trades where the percentage of items rises as the percentage cost band falls will presumably exhibit the property of having relatively more small value items. Trades where the percentage of items falls as the percentage cost band falls will presumably exhibit the property of having relatively fewer small value items. It is apparent that, with one or two exceptions, the percentage rises and percentage falls are marginal. The following results can be reported, however:

Trades with a preponderance of small value items (% rises) (marginally) were:

SMM5 BILLS OF QUANTITIES: Brickwork and Blockwork / Carpentry and Joinery / Structural Steelwork / Electrical Installation / Glazing / Drainage

SMM6 BILLS OF QUANTITIES: Excavation and Earthwork / Brickwork and Blockwork / Woodwork / Structural Steelwork / Electrical Installation / Glazing / Painting and Decorating / Finishings

Trades with a preponderance of small value items (% rises) (discernibly) were:

SMM5 BILLS OF QUANTITIES: Plumbing / Painting and Decorating

SMM6 BILLS OF QUANTITIES: Plumbing / Painting and Decorating

Trades where item spread appeared even (no discernible % change) were:

SMM5 BILLS OF QUANTITIES: Piling / Metalwork / Fencing / Finishings

SMM6 BILLS OF QUANTITIES: Piling / Asphalt Work (not encountered in SMM5 data studied) / Roofing / Metalwork

Trades with a preponderance of larger value items (% falls) (marginally) were:

SMM5 BILLS OF QUANTITIES: Excavation and Earthwork / Metalwork / Roofing

SMM6 BILLS OF QUANTITIES: Demolitions / Fencing

Trades with a preponderance of larger value items (% falls) (discernibly) were:

SMM5 BILLS OF QUANTITIES: Concrete Work / Fencing

The above observations, it must be noted, were not *spectacular* observations; rather they were *marginal* trends. All Trades possessed large numbers of small items and the percentage variations between cost bands were generally slight. It was noticeable, however, that in all Bills studied, Plumbing and certain Finishing Trades clearly showed percentage shifts towards the "low cost" bands and Concrete Work showed a clear tendency towards "larger" items. Further analysis (*vide infra*) will reveal that, for the Petrochemical Civil

Engineering data studied, Preliminaries vary between 3.35 and 17.81% of the contract total. Proposals for better understanding of the behaviour of such subpopulations of the data will be offered in that Chapter.

6.9 LEVEL OF ABSTRACTION: TRADE SUBSECTIONS: ANALYSIS OF COST-INSIGNIFICANT PARAMETERS

The data were further split by Trade subsection within each Trade and tabulations of the same cost band percentages as in Appendix 2 were produced. The tabulations so produced are provided in Tables 10.1, 10.2, 11.1 and 11.2 and in Diagrams 4.1-4.18 and Diagrams 5.1-5.18.

6.10 LEVEL OF ABSTRACTION: TRADE SUBSECTIONS: RESULTS OF ANALYSIS OF COST-INSIGNIFICANT PARAMETERS (APPENDIX 2)

Based on these more detailed tabulations the following results can be reported:

1) The results revealed that the tendency for the vast bulk of items to reside in the category "cost-insignificant" is true even for subsections within Trades. The figure in parentheses after each "subsection" heading gives the percentage of items in that subsection which reside in the "bottom 5% of cost" band. There are some extremely high percentages.

2) As the analysis further breaks down the data into smaller and smaller subpopulations of previous data subpopulations, one would expect presence of, say, one large item in such a subpopulation will have a greater overall effect on that subpopulation. Were such a large item removed therefrom, a greater "percentage change" than previously observed at overall Trade level would be expected. This indeed happened. However, though te tendency of the Trade subsections towards "smaller" or "larger" items was indeed evident, it must be borne in mind that the expressions "smaller " and "larger" are *relative*. In all trades costs are dominated by a small proportion of high-value items. In this context a "larger" item is one which resides in the "lowest 20%" cost band.

6.11 Recommended measurement Conventions for Cost-significant and Cost-insignificant parameters of a Hypothetical Petrochemical Civil engineering Measurement and Cost control model

These recommendations are based on the empirical cost behaviour observed following analysis of the data in the conventional model (see Appendix 4). It should be noted that the analyses upon which these recommendations were based were executed twice; once upon the project Bills identified in Appendix 2 and once with the addition of 3 further project Bills. The second analysis replicated extremely closely the characteristics of the first (though obviously there were differences in minute detail). In order to avoid unnecessary repetition, the recommendations shown here are those based upon the second analysis.

6.12 Level of Abstraction: Element: A Comprehensive Analysis

It was suggested earlier that there may be scope for extending the principle of non-measurement of cost-insignificant matters to entire functional Elements of building work. Each such Element will contain a sub-population of items, ie of the data, and it may be that an entire Element could be of sufficiently low cost-significance to warrant the suggestion that its costs be dealt with other than by detailed physical measurement.

An "Element" is invariably defined as that part of a building or structure which always performs the same function regardless of its constituent materials, method of construction, size, shape, form or physical appearance. Thus "structural frame", "substructures" and "roof" are Elements by definition. This definition, it was argued earlier, is a weak one. It disregards potentially important cost determinants. It is widely held that buildings of different function will exhibit different Elemental characteristics and, hence, characteristic balances of cost distribution by Element. From this it may be posited that certain types of building or structure will show a tendency to possess consistently cost-insignificant Elements which could be dealt with as suggested above, as their very insignificance might not justify the attention.

Data for all 15 projects were analysed to detect the behaviour of Elements across all such construction projects. The Element classifications used were those devised control purposes by the Bill users and were largely adpted from the conventional "Building" classifications. Comments about the suitability of the Element classifications themselves are added later, using the benefit of hindsight. It was suspected, however, that classifications such as those of the Building Cost Information Service (1969) did not wholly reflect Petrochemical Civil Engineering work.

The data were split by contract Bill and aggregate statistics computed to arrive at total values for each Bill. The data were then split by Elements within each Bill and for each such Element the proportion of its value as a percentage of its own Bill total was computed (Diagrams 3 Refer). Tabulations were then produced which showed the incidence of Elements across all Bills and which showed the distributions of cost in the Elements (Tables 13.1-13.3).

6.13 Level of Abstraction: Element: Results of Comprehensive Analysis (Appendix 5.1)

The results were inconclusive for establishing predictability of costs using conventional Element classifications. The results were highly conclusive for establishing inconsistency of costs using conventional Element classifications. This may support the assertion that the conventional classifications are unsuitable for their purpose and that a more representative set of cost centres should be identified. The following could be discerned:

1) Element incidence was inconsistent, though this would seem obvious for buildings or structures of different function. The initial suggestion was that buildings of different function would behave differently. For example, a Roads and Pavings contract would show different Elements to an Effluent Pipeline contract. Were data available for, say, 15 Effluent Pipeline Contracts then the likelihood is that strong patterns would emerge which were peculiar to that type of structure; thus cost-insignificant Elements would be more readily identifiable.

2) Element behaviour as a proportion of total cost was almost as inconsistent across projects, but it was of interest to note that the following Elements never attained as much as 5% of their respective Bill totals:

Site Preparation (maximum 0.76%) / Chimneys and Cooling Towers (maximum 0.97%) / Onplot Stairs (maximum 2.29%) / Onplot Stairs, Lifts (maximum 2.36%) / Onplot Fittings (maximum 4.02%) / Onplot BWIC Mechanical (maximum 3.55%) / Onplot BWIC Electrical (maximum 0.64%) / Bridges (maximum 1.93%)

6.14 Conclusions and Recommendations

It was recommended on the basis of these results that the data were of insufficient quantity for any conclusive evidence to be discerned and that a greater number ofprojects be analysed by Element. Stronger patterns would patterns would then be expected to emerge. emerge. The compilation of a matrix of Project types and Element types, as an aid to prediction of Element incidence and Element cost, was recommended. This would clearly be a medium to long-term strategy, as construction projects of the type under study did not come "on stream" in vast numbers simultaneously. Analyses of less recent historical data were suggested for this reason.

It is clear from inspection of the results shown (Tables 15.1-15.4) that Morrison and Stevens' (1983) "principle of controlled flexibility", that an Element should have a relatively low coefficient of variance in order to be retained as a reliable cost centre in its own right, has been violated almost without exception. It is recommended, therefore, that constituent components of Elements be sought which are more predictable, or that a set of reliable, significant cost centres be established which are not founded on conventional definitions of Element structure. It would seem contradictory to have defined "standard" Elements for a cost model whose cost behaviour are by no means standard. Consistent with the establishment of a matrix structure of Elements or cost centres would be the need to establish functional relationships between Elements.

If the behaviour of one element varies as a function of the behaviour of another related Element then it would seem sensible to pair them together rather than to categorise them separately. As they would not be independent of one another there could be no logical reason to classify them as though they were mutually-exclusive.

Worthington's (1995) account of commutative and non-commutative relationships between Elements is worthy of scrutiny. Commutative relationships were defined by Worthington as being of the following character: where 2 elements, E_1 and E_2, are related a commutative relationship is defined by the expression $\Delta E_1 \rightarrow \Delta E_2 \Rightarrow \Delta E_2 \rightarrow \Delta E_1$. Non-commutative relationships were defined as being of the following character: where 2 elements, E_1 and E_2, are related a non-commutative relationship is defined by the expression $\Delta E_1 \rightarrow \Delta E_2 \sim\Rightarrow \Delta E_2 \rightarrow \Delta E_1$. Thus in a commutative relationship an Element or cost centre can affect another and be affected by it. In a non-commutative relationship an Element or cost centre could affect another but not be affected by it. By way of a simple example, consider the Elements Internal Walls and Partitions and Internal Finishings. The Wall Finishings could be heavily influenced by the type of wall construction selected, but the However the cost of the Internal Walls and Partitions in no way influenced by the Wall Finishings selected.

An interesting further feature of Worthington's work was the partial identification of unexpected relationships between Elements. Worthington was able to observe design consultants clearly indicating that (for example) certain superstructure Elements were dependent upon the substructure selected. Classically, an inverse relationship is supposed; that the substructures are designed to be dependent upon the superstructure selected; that is, that is, to do no other than ensure that the designed building can be held in position.

6.15 Further Discussion

It is interesting to note that the Bill users at the time of the investigation could not see any merit in establishing a matrix of building types and Element types, arguing that patterns would not replicate if, say, the next building analysed was not the same type of building as the previous one. It could only be stressed to the users that a project of a different type would be *expected* to have different Elemental make -up; the ability to *actually predict* the incidence and cost-significance of Elements of buildings of differing function would be of great use in deciding what to measure in detail and what not to measure in detail, depending upon the expected cost - significance of the Elements in question.

Ferry and Brandon (1991) offered useful comments about Elemental Cost analysis: "Meticulous allocation of trivial sums of money... should be avoided. If there is no time to prepare a full analysis an outline analysis will be better than nothing and may take less than an hour to prepare". Ferry and Brandon continued: "The information should be in a standard form and should also be in a suitable form for use; costs which require measurement of details in order to apply them to an estimate will not be very helpful at cost plan stage". These comments are endorsed to the extent that for some Elements it may not be necessary to measure anything at all; their costs may prove to be easily predictable and so insignificant that allowance could be made for them by other means. The argument for standardisation, however, is difficult to support (*vide supra*).

6.16 IDENTIFICATION OF COST-GENERATING ELEMENTS IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES

On the basis of the fact that when Bill items in general were analysed some patterns of "major" and "minor" cost generation were discernible, it was decided cautiously to extend this principle to Elements and examine the rate at which Elements (ie subpopulations of items) generated costs relative to each other.

It had already been established to a certain extent that certain Elements and, hence, entire subpopulations of the data contributed little to the overall cost. Slavish acceptance of this based on what (for the purpose of *Elemental* analysis) was suspected to be an inadequate quantity of data sole would have been unwise, however. Further investigation of some description was clearly necessary, but there was little prospect of being able to gather more such data for reasons discussed earlier.

6.17 "NORMALISED" RATE OF COST GENERATION BY ELEMENT IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES

The data were split by contract Bill and aggregate functions were computed for mean Bill item values. Each item was divided by the mean item value for that Bill as absolute values were not required; the purpose being to study behaviour relative to some "bench-mark". The data were then split further by Element within each Bill and a mean item value was computed for each such Element.

The mean Element item value was taken to represent the mean rate at which that Element generated costs. The mean item value for the entire Bill was taken to represent the mean rate at which the Bill as a whole generated costs. Any Element which generated mean costs more rapidly than did the Bill as a whole was termed, for the purpose of the exercise, a "Major Cost Generator". Any Element which generated mean costs more slowly than did the Bill as a whole was termed, for the purpose of the exercise, a "Minor Cost Generator". These relative values were tabulated and compared (*Tables 16.1-16.4*). Comments are offered regarding the data and the analysis in Appendix 5.

6.18 RESULTS OF ANALYSIS OF COST GENERATION BY ELEMENT IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES (APPENDIX 5.2)

It would be spurious to claim that the results of this analysis could be any more conclusive than were the results of the previous analysis (*vide supra*) but it was discernible that certain Elements did generate costs at a slower rate than did the Bill as a whole (and vice-versa). Based on the results of the analysis for all items in Bills, Minor Cost Generators were perceived to be:

> **Demolitions / Excavations / Foundations / Reservoirs and Tanks / External Services / Drainage / Chimneys and Cooling Towers / Onplot External Walls / Onplot Internal Walls / Onplot Stairs / Onplot Windows and Doors / Onplot Stairs and Lifts / Onplot Internal Finishings / Onplot Fittings / Onplot BWIC Plumbing / External Works / Bridges / Dayworks**

At this point a limitation of the data is recognised. Unmeasured items are frequently of high value and will possibly distort the results. Bearing in mind that approaches to measured items was the objective, the analysis was performed with measured items removed. Based on the results of the same analysis for measured items only, Minor Cost Generators were perceived to be:

> Demolitions / Reservoirs and Tanks / External Services / Drainage / Chimneys and Cooling Towers / Onplot Frame / Onplot Roof / Onplot Stairs / Onplot Windows and Doors / Onplot Stairs and Lifts / Onplot Internal Finishings / Onplot Fittings / Onplot BWIC Mechanical / Onplot BWIC Electrical / Onplot BWIC Plumbing / Bridges

It is interesting to note that the two lists are very similar. It is more interesting to select certain of the above Elements in the context of earlier comments *(see Chapter 2)* regarding "fictional" items in Bills of Quantities. It was observed, during data collection, that there appeared to be large tracts of "fiction" in the Elements. In Builder's Work in Connection with Mechanical, Electrical and Plumbing Installation, for example, it was possible to encounter (for example) some 60 consecutive Bill items with identical numerical quantities. This invited suspicion that this section of the Bill of Quantities was inserted for the purpose of:

1) Representing some desired sum of money for "budget" purposes and

2) Attracting "sample" prices and rates for valuing such variations as will inevitably have been caused by the fact that the measurements do not represent the intended (or any) design.

That Tenderers choose not to price some of these items anyway would seem to be evidence that the exercise of "inventing" of such items (if undertaken for serious reasons) is, to a considerable extent, futile. More discussion of this point shall be offered following the conclusions and recommendations for this section. Without further analysis of specific individual detail the results are consistent with those of the previous Elemental analysis - they offered no strong patterns of behaviour. Certain observations could, however, be made. For example:

1) Drainage and External Services (work types which are similar in character) generate costs slowly per item except where the project consists entirely of that Element (eg project 11 - Methanol Offloading Plant) - which seems obvious, perhaps.

2) Elements such as BWIC Mechanical and External works show the property of generating costs slowly per item when subjected to measurement. When they are the subject of Prime Cost or Provisional Sums (ie not measured) however, they frequently have major cost importance as entire Elements (see projects 7, 8, 9 and 16). The suggestion made here is that, whereas an insignificant Element could be dealt with by "non-measurement", even significant Elements can appear to have insignificant items in them when subjected to existing measurement rules.

3) There are clearly times when individual Elements become important and times when they do not. Therefore a model for predicting the incidence of Elements and their variability of importance would appear to be a useful technique to develop.

6.19 Conclusions and Recommendations

On the basis of the foregoing results it was concluded that it had not been possible (with the given data sample) to establish conclusively a reliable measure of the incidence and importance of Elements across projects.

The incidence of Elements at this stage of the work could not be seen as a function of any given Method of Measurement except in terms of incidence of their constituent items; rather it was seen as a function of a given design. It was concluded that the data were insufficient for such a specific purpose but was recognised that there had to be correlation between function of building and Element make-up. It was recommended, therefore, that further work be undertaken involving more detailed correlation analysis to attempt to establish what relationships exist between:

1) Elements and Design/Building Function,

2) Element "make-up" and Method of Measurement used and

3) Elements and other Elements (mutual co-existence).

It was recommended that rather than exclude Elements *en bloc* at this stage on the basis of inconclusive (but persuasive) results, steps be taken to develop a Design / Measurement Work Type Matrix which will attempt to standardise Elements by Plant or Design type. By compiling Elemental cost analyses of a greater number of Petrochemical Civil Engineering projects than the 15 studied so far, it should prove possible to identify patterns of Elemental behaviour and make, with confidence, predictions of their relative cost importance and consistency. Therefore if the construction of a certain Plant or Building of recognised function is contemplated, it should be possible to predict with certainty that some Elements will have minuscule cost input; in such cases the following options could be chosen as the basis for experiment:

1) Elimination of such Elements from detailed design and measurement considerations at such stage(s) and inserting notional (but predictable) provisional sums where design is incomplete, or

2) Inviting Tenderers to insert their own prices for predefined minor sections and/or components where design is complete, but the predicted cost thereof is low enough not to justify the effort of detailed measurement.

This work can be undertaken to develop a flexible system whereby if an Element is predicted to be "important" its important detail can be dealt with appropriately. If an Element is predicted to be "unimportant", consideration of detail is less likely to be such a stringent requirement.

6.20 FURTHER DISCUSSION

Although no conclusive proofs can be drawn from the analysis in this Chapter it is plain that function should dictate form and that form should dictate cost. It is plain, also, that comprehensive Elemental analysis of projects will reveal much. The important question to ask is "if Elements are to be used to analyse costs, what Elements should we have?" If Elements are to be used to model costs they need to reflect construction costs rather than physical design appearance; otherwise there was can be no justification in having selected the Elements.

Although earlier argument as to the suitability of Element classifications was muted to permit analysis of what existed to take place, some persuasive points from that analysis suggest that it ought to be asked when an Element not an Element. This would, admittedly, appear to be a somewhat ridiculous question but there is sufficient evidence to suggest that if an Element has inconsistent cost behaviour then an Element, by definition, it cannot be. Classical argument would say that there already exists a definition of what an Element is; therefore anything which satisfies such a definition must be an Element and anything which does not, is not. But is the *definition* correct?

It is submitted that there are times when it is necessary to look not at Elements, but at constituent parts of Elements (let them be called "sub-Elements") in order to truly ascertain what is important or not important about the costs of buildings or structures. It is apparent from the (albeit exploratory) analysis in this chapter that Elements are present in greater or lesser magnitude (or greater or lesser cost) across projects. That a particular Element is of greater or lesser cost importance in one building compared with another is due to the fact that

1) The Element itself is greater or smaller in physical magnitude, or

2) Elements of equal physical magnitude have different specifications of quality (conventional Elemental Cost Analyses are inadequate for the purpose of measuring specification effects as the Elements are defined regardless of what the specification might be), or

3) Some constituent part or parts of an Element exist in one building but not in another (even if the Element itself always exists in some form).

Thus an Element could exist in every project but differences between projects could be caused by the presence or absence of various sub-Elements of that Element. It is postulated that existing Element classifications, whilst rightly recognising the existence of functional Elements in the "cost make-up" of buildings or structures, are not sensitive enough (if at all) to the way in which the behaviour of constituent sub-Elements affect the cost patterns of buildings. Existing Elemental classifications do not recognise (or reflect) cost behaviour patterns which are functions of the mere existence (or otherwise) of constituent sub-Elements. These sub-Elements, if they do exist, might themselves be immutable even if the Element, as a whole, is not. It might be possible (indeed, fruitful) either to:

1) Universally identify and represent Elements in terms of recognisable sub-Elements or constituent parts which are less inherently variable or

2) Redefine what should be Elements: defining parts of buildings which are more immutable (and whose costs, consequently, are more predictable).

Consistent with earlier recommendations, it must prove possible to identify constituent parts of buildings which, if they exist, will exist in some predictable form. By inference, if this level of predictability exists, decisions can be better made as to what effort to expend on detailed measurement of Elements. Likewise, constituent parts of buildings which can be predicted not to exist can be dealt with accordingly. This argument builds on an earlier notion that considering Elements as a whole might be misleading and that truer cost behaviour is discovered by sub-dividing the Elements themselves. Work by Brown (1984), relating specifically to the Element of Building Services, would seem to suggest that the existence of a sub-Element is a function of the existence of "sub-Functions" of buildings. In other words, the fact that a building's function is (say) "a Hospital" can only give indicative information as to the broad range of likely costs for the Building Services Element of such a building.

However, were one to ask "what type of Hospital is it?" then one is dealing with sub-functions of buildings and one can be more confident about accuracy and likely ranges of "Element" costs or costs of "Constituent parts of Elements" in such a context. For example, "Psychiatric" Hospitals will exhibit characteristic cost patterns somewhat different to, say, "Dental" Hospitals. Thus we have a less nebulous arrangement than "general Elements" and "general functions" of buildings.

Indeed, in cost planning in the health sector, "Capricode", long recognised "functional" distinctions and would allocate "Departmental" costs, that is different unit costs to different areas of the same building which produce slightly different types of medical or health provision. There is no reason to suppose that the above arguments cannot be investigated in respect of "petrochemical" buildings and plant which, although they offer "petrochemical" provision, perform slightly different "sub-functions" of "petrochemical" provision.

De Troyer (1990) recognised the significance of building cost breakdown, by means of "macro Element" and "sub-Element", as a tool to aid design. De Troyer observed, with some dismay, that conventional Element classifications can be standardised completely regardless of the phenomena which give rise to their costs. Marks *et al* (1990) have striven to establish, by means of research at a (then) public utility company, a system of Elemental analysis for civil engineering construction with the aim of improving cost prediction and control.

Diederichs and Hepermann (1985) claimed to have identified between 40 and 50 key cost parameters which exist for all construction work specifications which are practically independent of the kind of building structure. They claim that these key parameters are subject only to marginal variation and that the costs of such variation can be predicted to high degrees of accuracy. Their work assigns costs of labour, plant and materials rather than design parameters.

Indeed, it is based on *DIN 276* [6], an Elemental Cost Analysis used in the Federal Republic of Germany which is very similar to those used in the UK. In fact, Diederichs and Hepermann do not pay detailed attention to any building Element which does not comprise > 1% of total cost. The use of factors of production appears, effectively, to link designers" and producers" cost models at all design stages and could well prove to be an improvement to UK practice if tested in UK conditions.

Elements can be subdivided, and should be when the circumstances warrant it. It is contended here that the circumstances always warrant it. Morrison and Stevens (1983) introduced the concept of "controlled flexibility" when dealing with Element costs as they, too, found that conventional Element classifications gave rise to inconsistent element cost behaviour. They advocated that Elements contributing less than 1.5% of the project total, or for which no further Subelement classifications exist, should not be "finely" estimated. This implies that they need not be measured in detail according to conventional rules. Further, Morrison and Stevens (1981) suggested that cost centres whose coefficient of variation exceed 36% should be restructured so as to be more predictable. Elements are just such cost centres; in the data analysed here there are Elements which satisfy such criteria.

Morrison and Stevens did not directly address the the idiographic properties of projects; that is, that the Elements which satisfied such "standard" criteria could vary from project to project, but they were correct to criticise the extreme cost variability arising from conventional cost planning models. They were also right to recognise the the importance of identifying Elements as significant or insignificant cost centres. This must be done empirically; it cannot arise from a non-isomorphic design-based model. An isomorphic model (Nachmias and Nachmias, 1976) is one where the structure or shape of the data is similar to the structure or shape of the "reality" which the model is purporting to describe. It is argued that the conventional cost planning model is *not* isomorphic; although it is called a cost model it structures the data independent of the factors which give rise to the costs.

The phenomenon dominating these concluding discussions is the unpredictability, in terms of conventional Elemental analysis, of the projects studied, characterised by the heterogeneous nature of the data sample (see, again, Flanagan, 1980). The Petrochemical Civil Engineering projects studied are characterised by dissimilarity, not by similarity. Therefore it is debatable whether a single classification of Elements (in the conventional sense) could be made to apply. Further consideration of Kenley and Wilson's (1986) argument for idiographic studies. of projects is urged. The nature of projects of these types suggests that a homogeneous sample is unlikely to be obtainable.

Chapter 7 describes the commencement of the testing and validation of the hypothetical Petrochemical Civil Engineering measurement and cost control model.

CHAPTER 7:
VALIDATION OF THE HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL

7.1 GENERALLY

It was established that the work sections which appeared most prominently to display cost-insignificant items and "generic families" of items attracting like prices were:

> Excavation and Earthwork / Concrete Work / Builder's Work in Connection with Services (which included External Service Mains etc) / Finishings.

Accordingly, draft measurement rules were drawn up for those sections based on these (Annex 1). It was proposed at first to test whether the draft measurement rules appeared to satisfy the stated objectives (simplification and eradication of cost-insignificance) by interview based on a structured questionnaire with key expert personnel involved in preparing Petrochemical Civil Engineering Bills of Quantities.

7.2 SURVEY OF USER ATTITUDES TO HYPOTHETICAL MEASUREMENT MODEL (STAGE 1)

The original plan was to interview 7 users in the North-West of England and 6 in the North-East. Staff commitments resulted in only the North-West users being available to comment at this stage.. Comments are offered regarding the survey in Appendix 6.

7.3 SUMMARY OF RESULTS OF SURVEY OF USER ATTITUDES TO HYPOTHETICAL MEASUREMENT MODEL (STAGE 1) (APPENDIX 6)

The results are presented in Diagrams 6.1-6.23 The respondents felt very strongly that the draft measurement rules would achieve the following stated objectives (compared with SMM6):

a) Fewer items to measure (q1)

b) Reduced measurement time (q2) (q3)

c) Hypothetical model was easier to read (q4)

d) Rules were simpler and clearer (q5)

e) Reduced working-up time (q6) (q7)

It can be cconcluded that the respondents, in the main, considered them to have been realised. It should be noted, however, that the respondents did not all necessarily agree with the objectives as stated..

The respondents were, by and large, happy to see no more or less detail than produced by the proposed rules (q8). This is perhaps understandable given the conservative nature of the industry; neither was there any desire other than to proceed cautiously in the development of the experimental model; "step by step".

Most respondents had doubts about where the costs of previously measurable items were deemed to be included (q10): confusion reigned as to whether such costs were defined in some preamble or explanatory note, or with the costs of measured items. Although the hypothetical model contained numerous such explanatory notes, it was clear that more attention needed to be paid to the drafting of the document. Most respondents felt that the proposals regarding specifications were clearer (q12).

7.4 Survey of User Attitudes to Hypothetical Measurement Model (Stage 2)

As stated earlier it was originally planned that the Draft Measurement Proposals for Excavation and Earthwork, Concrete Work, Builder's Work in Connection with Services and Finishings would first be presented to user personnel in the North West and then to user personnel in the North East. Problems of staff availability arose at this time, however, and it became apparent that these staff would have no time available to deal with a limited number of Draft Sections and then undergo the same process upon production of a complete set of measurement rules, as was the original intention.

It was agreed, therefore, that the process be "fast-tracked", i.e. that as complete a set of measurement rules as possible be drafted and presented to North East user personnel. Action would be taken on behalf of the entire organisation based on the results of the "detailed" survey carried out in the North East. To lend weight to the results the "detailed" North East survey would be participated in by 3 staff members in the North West who were available. The number of respondents, therefore, would be 9. This represented all key staff likely to use such a measurement document. Thus as comprehensive a set hypothetical measurement rules as possible was drawn up using the same principles as had already been established. The sets of rules, corresponding to the two survey stages, are Appended (Annex 1for Stage 1 and Annex 2 for Stage 2).

7.5 SUMMARY OF RESULTS FROM USER SURVEY (STAGE 2) (APPENDIX 7)

The results are presented in Digrams 7.1-7.23. The respondents felt strongly that the hypothetical model would achieve the following stated objectives:

1) Fewer items to measure (ql)

2) Reduced measurement time altogether (q2)

3) Reduced measurement time on small items (q3)

4) Reduced working-up time overall (q6)

5) Reduced working-up time on "small" items (q7)

6) Adequate units of measurement (ql3)

7) Reduced time in preparing Tenders (q20)

8) A more acceptable level of detail (q21)

9) No foreseeable problems in pricing Bills of Quantities (q28)

10) About the right level of detail (q8)

The respondents were reasonably or slightly of the view that the following stated objectives would be achieved:

1) A simpler and clearer document (q5)

2) Provision for specifications was clearer (q12)

3) Information for tendering purposes was no more or less adequate (q16) (q26)

4) Reduced time valuing variations (q31)

5) Slightly less time preparing interim valuations (q35)

There were mixed feelings as to whether the following stated objectives would be achieved:

1) A more readable document (q4)
(this appears to contrast with the response to: (q5)

2) Adequacy of the document for the purpose of assigning prices to Bills of Quantities (q18)
(this appears to contradict the response to: (q28))

The respondents harboured doubts, however, regarding the following stated objectives:

1) Where the costs of previously-measureable items were included (q10)

2) Problems foreseen with Bill of Quantities preparation (q14)
(notwithstanding the responses to: (q1) (q2)
(q3) (q6)
and (q7)

These last two points gave most cause for concern. Many of the doubts expressed were about "lack of familiarity", "learning curve" and the likelihood of inconsistency, given that it is debatable whether the experimental method would ever be universally adopted. Specific discussion has been offered elsewhere. It is refreshing to note, though, that some respondents tempered these doubts with expressions to the effect that their fears were sometimes based on not really knowing what would happen until the experimental measurement model was actually tested. Such a test is described later.

As a result of this stage of the research, has been made clear that the measurement document contains drafting deficiencies which have induced feelings of lack of clarity in the minds of the respondents. The commercial and time pressure on Bill users led to the agreement and recommendation that the model be nevertheless tested, "warts and all". All in all, it was felt that the proposals were not reviled by the respondents; in fact, they certainly supported the exercise and in many cases agreed with the objectives,which was encouraging. In the long run it may prove fruitful to experiment with Tenderers assigning labour, plant and materials costs to the ost cenres identified in the model. Thus costs of labour items previously measureable might be somewhat easier to locate.

7.6 Experimental Method: A Test of the Hypothetical Model

The hypothetical measurement model, having been drafted for as many trades / work sections as possible, was used to measure a historical project at the collaborating organisation, using the original Tender Drawings for that project. An experimental Bill of Quantities was thus produced and sent to one of the collaborating organisation's panel of approved Tendering contractors.

The contractor's estimator was to use the experimental Bill of Quantities in the normal manner as an aid to preparing a Tender for the project. The Tender was to be submitted to the collaborating organisation as a *bona fide* Tender. The test project was a warehouse building incorporating roads, pavings. drainage and external services installation. Its value was some £180 000. Allowing for time differences and the like the "new" Tender submitted was within £400 of the original. To claim success on the basis of one test would be ludicrous; not all swans are white (see Popper, 1959), but the following can be said:

1) The simplified approach to measurement, i.e. the omission of much detail which some measurers claim the Tenderer needs, did not prevent the Tenderer from arriving at a figure which was within one quarter of one percent of the total arrived at using a more detailed method of measurement.

2) This is more evidence, however tentative, to support the notion that the effort spent on said detail is an act of over-administration. The absence of said detail did not appear to have any material detrimental effect, "learning curve" problems apart.

3) What is clear is that the amount of detail which, collaboratively, adds up to little money, need not be communicated to the Tenderer purely for cost reasons. The proximity of the Tender total in the "experiment" to the original Tender total suggests, also, that the Tenderer lost little in scope definition as a result of the absence of some previously measured items.

7.7 Critique

A disappointment at this stage of the research was an inability to make prolonged contact with the Tenderer involved. Communication was handled by the Bill users, who tended to be somewhat secretive about the handling and disclosure of information. Some detailed enquiry among Tenderers would have been beneficial but, alas, it was not to be. The surveyor who measured the experimental Bill of Quantities and the Tenderer's estimator, however, offered some comments on their first use of said hypothetical model (*vide infra*).

7.8 Some Results from the Experiment: Feedback from Measurer and Estimator

The feedback from measurer and tenderer was largely of a technical nature, illustrating the conventional tendency in practice to judge models on the basis of their internal consistency rather than the external factors surrounding their formulation. The collective comments received were as follows:

Excavation & Earthwork

1) "Working space (single allowance) is too generous for (e.g.) simple strip foundations".

2) "Excavation for pits (e.g. through hardcore; not from reduced level): provide for a statement for where the dig commences. No need for an individual datum level for each pit".

3) "Excavating alongside services: do we specify precautions in detail or leave it up to the contractor? Probably not a measurement problem".

Concrete Work

4) "Treating surfaces: confirm that each type of treatment is separately identified".

5) "Agreed after discussion that although formwork to plain and reinforced concrete is not separately identified this need not be a problem as you can tell by the concrete feature what would be reinforced and what would not be".

6) "No need to give a width for formwork over 500 wide - just give it all m2".

7) "Better to state Nr of bases for grouting and give thickness. Some grouts are expensive. You cannot always tell how many bases as steelwork is often a separate contract".

8) "Perhaps reinforcement categories can be grouped together according to fixing location rather than strictly following the concrete categories".

9) "State Nr of decimal places for tonnes of reinforcement as a General Rule at the front. We prefer 2 d.p".

DRAINAGE

10) "It is better to give beds and surrounds as a composite item with the pipe rather than with the drain trench. Some drains are above OGL and require no excavation. They are all on standard details anyway".

11) "Pipes in branches: enumerating them causes confusion as to what to include. The simple answer is to measure as other drains (do not separately classify branches)".

12) "Fittings should be extra over".

13) "Manholes: Keep covers and frames and manhole channels as separate items, otherwise every manhole description is different".

GENERALLY

14) "What is deemed to be included is not always clear; *e.g.* is bedding and pointing deemed included with copings? Some people might imply this, but some people might argue. Tighten these rules up".

15) "Insert a General Item stating that rates for each type of excavation should include for all water disposal and for working below water table level. And insert an item for "extra; excavating below water table". What if the quantity of such work doubles in the postcontract?"

16) "The measurement system is not dissimilar from SMM5. The general principles are the same".

17) "Drainage should prove simpler".

18) "Excavation, Concrete, Brickwork and Drainage threw up most items in the take-off. No item saving could be immediately discerned in Excavation and Concrete".

7.9 DISCUSSION OF FEEDBACK FROM MEASURER AND ESTIMATOR

ITEMS (1), (2), (4), (7), (8), (9), (10), (13), (14) AND (15) are useful suggestions for how to "tighten up" the drafting of the experimental measurement model. It is interesting to observe the phenomenon of the conventional model causing the user to make the data fit the model. In ITEM (13) the respondent is suggesting that the use of different descriptions for things which are different is not a good idea; that the use of the same description for things which are not the same is perhaps better.

ITEMS (6) AND (11) are useful suggestions for how to achieve further simplification without detrimental effect, or so may it be interpreted.

ITEM (16), as a general comment, was interesting, given that the experimental measurement model was derived by simplification of SMM6, not SMM5 or SMM7. It was interesting to not the user comment that the general principles of measurement have not been forsaken, despite simplification.

ITEM (17) is taken as a sign that the stated objective of simplification has been achieved in respect of Drainage Work.

ITEM (18) is taken as an indication that in Excavation and Concrete Work there is still scope to achieve simplification.

It ought to be stated at this point that the Tenderer's estimator opined that overall the experimental model seemed to "make more work". To what extent this was due to unfamiliarity was not made plain.

It can be seen that most of the comments were technical in nature, that is to say they were concerned with the internal coherence of the hypothetical model as opposed to its philosophical standpoint. The need for the model to be internally consistent and unambiguous is recognised. The surveyor (as measurer) is trained to scrutinise such detail and the comments were welcomed as aids to future drafting refinement. However the internal consistency of the model is not necessarily a sign that it represents what it ought to represent. What was interesting to note, however, is that no comments were received to the effect that the experimental measurement system prevented either measurer or estimator from doing their work, i.e.:

1) Preparing a document which purports to represent some finished design, as a possible aid to tendering and as a source of prices for valuing subsequent design changes

and

2) Preparing a tender for the project thus described.

Whilst "one swallow doth not a summer make" it must be stated that on the basis of this test alone, the absence of large amounts of previously measurable detail did not substantially affect the end result. Indeed, so close was the "experimental" Tender Sum to the one quoted in practice that the temptation must be resisted to speculate that the detail required by the conventional model and not contained in the hypothetical model made no material difference to the Tendering process.

7.10 CONCLUSIONS

The test executed presented no major difficulties to the participants. The experimental measurement document did not prevent the Tenderer from submitting a Tender quotation so close to the original figure as to be easily attributable to the inherent inaccuracies which exist in estimating. Omission of large amounts of measurement detail appeared not to render the contractor unable to furnish a "realistic" and *bona fide* Tender.

It was concluded also that sufficient evidence was revealed that imperfections in drafting would tend to pose problems in the postcontract as such imperfections would cause debate about definition, clarity and the like. It was considered, however, that drafting was not a model validity problem. In fact, it is believed that better drafting would more clearly demonstrate that the proposition that "conventional Standard Method of Measurement based Bills of Quantities... are a cause of over-administration" is a good one.

7.11 FURTHER DISCUSSION

It is difficult to see how any particular measurement method can materially affect an estimator's ability to prepare a Tender. If design is incomplete, or there are no measurements at all, one can still tender; the proportion of "risk" pricing will alter. Problems will occur in the postcontract only if variations to the original scheme occur and the original scheme was, somehow, not reasonably defined. It is contended that the omission of some cost-insignificant items does not constitute bad definition of a scheme, as this could constitute the elimination of "noise distortion" (*vide supra*), which itself could constitute bad definition of a scheme. Bills of Quantities alone will never be the sole definition of a scheme, let alone the Method of Measurement.

Hughes (1983) assisted in this respect: "The contract documents of which the BQ (but not the SMM) is a part must reflect the total situation obtaining at the time if tender. If the design is incomplete and items have to be "invented" (to whatever degree) then the contract, not the method of measurement, must provide for the consequences". At this point it must be repeated that if such "invention" is to take place then it need not occur so as to conform with the requirements of a model too detailed to be applicable to a state of incomplete design. Further, inventing measurements which represent nothing in particular is likely to make the post-contract problems more technically and legalistically complex than would the use of a simpler (but approximate enough) model.

What is evident from the user responses regarding the hypothetical model is that it is not the items measured which are likely to cause problems, but the definitions of what those items represent; either in their descriptions, by virtue of what they are deemed to include, or in the specifications to which they refer. Hughes (1983) continued:

"If the design is not complete we cannot measure in detail, at least not with any certainty. On the matter of simpler and less detailed Bills of Quantities, it must not be overlooked that however the work set out in the Bills is itemised , the items must *in total reflect the total work required. If the number of individual items is reduced* ... then the content of those items ... must be made clear in the descriptions. That is not to advocate that BQ items must develop into verbose essays (though a specification would help reduce the pressure). Unless it is clearly understood what must be said expressly and how little can be safely implied, however, more problems will have been created than solved". Hence the need for further drafting work on the hypothetical model.

It should be noted that "incomplete design" does not mean, in this context, "next to no design", otherwise it would be wrongful to give a tenderer to understand that the measurements represent what is not known. What is argued here is that in a situation where a reasonable amount of design has occurred a reasonable (but not excessive) amount of measurement detail would be *quantum sufficit* for practical purposes. Anything more detailed would be spurious and would have an inherent tendency to create over-administration by virtue of possessing "built-in" variations.

Paradoxically, it could be argued that should the design ever be complete, we need not measure it at all. There will be no variations. Silverton (1983) lent weight to this point: "Wildly incomplete design renders (BQ) quantities an improper basis for contracting, and the quantity surveyor should not hesitate to say so. A defence of 'I did what [the] SMM - in which I have no confidence - told me' is not calculated to inspire the client in the independence and judgement of his professional adviser".

It should be recognised that measurement can all too easily become a thing driven by procedure. Existing procedures can be unnecessarily detailed. The SMM should be the slave to the surveyor, not *vice versa*. If it can be accepted hypothetically that a method of measurement can be devised which places unfounded reliance upon the detail it contains then it can be accepted hypothetically that measurements can be created for the sole purpose of satisfying the provisions of an unsuitable method of measurement rather than for some valid purpose.

It is debatable whether simple measurements can disable the Tendering process. The one test carried out on the experimental model for Petrochemical Civil Engineering did not do so and many construction projects are successfully concluded in the absence of detailed Bills of Quantities. It is equally debatable whether simple measurements can disable the post-contract process either, provided that what is measured is so drafted as to be adequately defined and understandable.

7.12 A Comparison of SMM7, The Hypothetical Model and "Shorter Bills of Quantities"

In order to effect a brief comparison of these three measurement models in terms of relative simplification, this having been a principal aim of all three, Bills of Quantities for 2 projects in the Petrochemical/Civil Engineering field were analysed. Both Bills were originally produced using SMM7. The items in the Bills were "re-processed" to represent what would or would not have been measured using the hypothetical model and "Shorter Bills of Quantities" respectively. The projects were a Paint Manufacture Amenities Building and an Accommodation Building for Sewage Operatives. They were acquired from sources outside the original collaborating organisation. The results are shown in *Tables 14.*

7.13 Results of Comparison of SMM7, The Hypothetical Model and "Shorter Bills of Quantities"

Overall

The hypothetical model performed similarly to "Shorter Bills of Quantities" (SBQ).

Amenities Building

"SBQ" had 34% fewer items than SMM7. The hypothetical model had 36% fewer. (*Table 14.1* refers).

OPERATIVES' ACCOMMODATION

"SBQ" had 22% fewer items than SMM7. The hypothetical model had 25% fewer (*Table 14.2* refers).

Behaviour across all Trades or work sections was more variable. "Shorter Bills of Quantities" tended to outstrip the hypothetical model in all Trades except Cladding/Coverings, Glazing and Drainage which, in the hypothetical model, were considerably more simplified. It has proved very difficult to simplify the Woodwork section: timber components have different sizes: it is difficult to conceive of how to describe than other than by size of crosssection. In the Operatives' Accommodation project it appeared at first surprising that very little simplification was achieved in the Concrete Work section. In truth the foundations for this building were extremely simple in construction style; simpler measurement could not have been attained. Had the foundations displayed anything other than gross simplicity of design then measurement reductions would have resulted (*cf.* Amenities Building).

7.14 CONCLUSIONS FROM COMPARISON

On the basis of the 2 tests described "Shorter Bills of Quantities" had simplified the measurement conventions to a greater extent than had the hypothetical model. Overall, the Experimental Model had fewer items due to massive savings in one or two Trades. It is suggested, therefore, that the hypothetical model would operate satisfactorily in practice on the basis that "Shorter Bills of Quantities" can be utilised for the same purposes without causing discernible problems in the processes of estimating, tendering, valuing variations and final accounts.

It appears demonstrable that certain detailed measurement demanded by some existing measurement systems is, indeed, a cause of overadministration: the "disappearance" of the detail does not hamper the processes to which conventional measurement is dedicated. The experimental model, having been based on simplification of SMM6, is simpler than SMM7. SMM7 appears not to have achieved simplification on the scale which its users had been given to anticipate.

TABLE 14.1: COMPARISON OF SMM7, THE HYPOTHETICAL MODEL AND "SHORTER BILLS OF QUANTITIES"

ACCOMMODATION FOR SEWAGE OPERATIVES	SMM7: NR OF ITEMS	"SBQ": NR OF ITEMS	% OF ITEMS SAVED	HYP. MODEL: NR OF ITEMS	% OF ITEMS SAVED	REMARKS
Total	400	263	-34	255	-36	Excludes *
Excavation + Earthwork	45	35	-22	30	-33	Incl. underpinning
Concrete Work	87	56	-36	64	-26	
Masonry	32	26	-19	29	-9	
Structural Steelwork	32	11	-67	n/a	n/a	*
Woodwork (excl. ironmongery)	46	42	-9	43	-7	Mainly fittings
Cladding/Coverings	9	7	-22	7	-22	
Asphalt Work	5	4	-20	n/a	n/a	*
Finishings	24	15	-37	19	-21	
Metalwork	5	5	-0	5	-0	
Glazing	8	4	-50	0	-100	+
Painting +Decorating	19	12	-37	12	-37	
Plumbing +Mechanical Installn	37	22	-41	28	-24	
Drainage	51	39	-24	18	-65	

* = Not analysed

+ = In hypothetical model was given with associated joinery components

TABLE 14.2: COMPARISON OF SMM7, THE HYPOTHETICAL MODEL AND "SHORTER BILLS OF QUANITIES"

AMENITIES BUILDING FOR PAINT MANUFACTURE	SMM7: NR OF ITEMS	"SBQ": NR OF ITEMS	% OF ITEMS SAVED	HYP. MODEL: NR OF ITEMS	% OF ITEMS SAVED	REMARKS
Total	482	377	-22	360	-25	Excludes *
Excavation +Earthwork	47	31	-34	38	-23	Incl. Underpinning
Demolition + Alteration	5	2	-60	4	-20	
Concrete Work	55	55	-0	51	-7	
Masonry	72	46	-36	57	21	
Structural Steelwork	-	-	-	-	-	*
Woodwork (excl. ironmongery	78	70	-10	24	-6	Mainly fittings
Cladding/Covering	40	30	-25	26	-35	
Asphalt Work	-	-	-	-	-	*
Finishings	23	16	-30	16	-30	
Metalwork	7	7	-7	-0		
Glazing	2	2	-0	0	-100	+
Painting + Decorating	25	15	-40	17	-32	
Plumbing + Mechanical Installn	22	17	-23	21	-5	
External Services	16	13	-19	14	-13	
Drainage	90	75	-17	36	-60	

* = Not analysed

+ = In Experimental Model was given with associated joinery components

7.15 SUMMARY

(1) SMM7, not in universal use, and CESMM (and its successors) have become the Methods of Measurement sponsored by the relevant professional societies in the field of measurement. There is evidence to suggest, however, that the simplification of measurement which was intended by the issue of SMM7 in its present form is possibly inappropriate in the majority of cases, that is when design detail is incomplete. Therefore it could be argued that much of the detail required by SMM7 cannot be derived from the design of most construction projects.

(2) The Hypothetical Model derived for Petrochemical Civil Engineering has attained greater simplification than has SMM7 and, if fully developed and tested, seems likely to be usable without undue hindrance to the process of Tendering and valuing variations.

(3) "Shorter Bills of Quantities", developed as a commercial package, using intuition rather than the type of analysis described here, appears to be operating satisfactorily in practice, apparently with very little complaint from measurers and contractors (initial trepidation apart). Given that the brief comparisons (vide supra) reveal that in most work sections "SBQ" is simpler than the Experimental Model, there appear to be grounds for optimism. A fully - developed Experimental Model seems likely to perform no worse than does "SBQ" (which has subscribers in "triple figures").

(4) The "iterative estimating" model (Sakst, 1986), using much the same principles as the Experimental Model described here, appears to have performed reasonably well in that it can produce Tenders more quickly than, and very close to, those produced by conventional methods. This would appear to lend support to the argument behind the Experimental Model, certainly as far as the Tendering process is concerned.

It appears that much detail sought by measurers and often demanded by existing measurement conventions is superfluous in terms of worth to the Tendering and Final Account processes. There is evidence that the "craving " for detail is not necessarily founded on the certain knowledge that such detail is desirable, or, indeed, of significant benefit to the process or to the user. Much of it appears to constitute "noise" (see Heath and Bryant (1991)).

There remains, though, a rather painful contradiction which ought to be resolved. The industry, ever eager to point out that each project is unique, still professes a desire to use "standard" models with which to describe these projects. Then, to increase the confusion, the models so devised are neither truly nomothetic nor truly idiographic. That there is such overlap of measurable work (and, hence, replication of measurement rules) is illustrated by Table 15, which shows the types of construction work common to three typical methods of measurement, all of which (at least in part) could be applied to Petrochemical Civil Engineering Work.

TABLE 15: COMMONALITY OF MEASUREMENT COVERAGE IN 3 SELECTED STANDARD METHODS OF MEASUREMENT

WORK SECTION	REGIONS IN WHICH THE MEASUREMENT RULES RESIDE
General Rules	SMM7∩CESMM∩SMMIEC
Preliminaries	SMM7∩CESMM∩SMMIEC
Demolitions	SMM7∩CESMM
Earthworks	SMM7∩CESMM
Piling	SMM7∩CESMM
Insitu Concrete	SMM7∩CESMM
Precast Concrete	SMM7∩CESMM
Masonry	SMM7∩CESMM
Structural Metalwork	SMM7∩CESMM
Steelwork	SMM7∩CESMM∩SMMIEC
Structural Timber	SMM7∩CESMM
Cladding / Roofing	SMM7
Waterproofing	SMM7∩CESMM
Linings + Partitions	SMM7
Windows, Doors, Stairs	SMM7
Finishings	SMM7
Furniture + Fittings	SMM7

TABLE 15: COMMONALITY OF MEASUREMENT COVERAGE IN 3 SELECTED STANDARD METHODS OF MEASUREMENT (CONTD.)

WORK SECTION	REGIONS IN WHICH THE MEASUREMENT RULES RESIDE
Joinery	SMM7
External Services	SMM7∩CESMM
Roads + Pavings	SMM7∩CESMM
Fencing + Gates	SMM7∩CESMM
Drainage	SMM7∩CESMM
Mechanical Services	SMM7∩SMMIEC
Electrical Installation	SMM7∩SMMIEC
Painting	SMM7∩CESMM∩SMMIEC
Ground Investigation	CESMM
Geotechnical Processes	CESMM
Pipework	SMM7∩CESMM∩SMMIEC
Rail Track	CESMM
Tunnels	CESMM
Sewer Renovation	CESMM
Scaffolding	SMMIEC
Plant	SMMIEC
Ductwork	SMM7∩SMMIEC
Instrumentation	SMMIEC
Insulation	SMM7∩SMMIEC

Chapter 8 will present Conclusions and Recommendations.

CHAPTER 8:
CONCLUSIONS AND RECOMMENDATIONS

8.1 REGARDING PROBLEM STATEMENT

Chapter 1 identified the problem of a collaborating Petrochemical Civil Engineering Organisation needing to identify an appropriate measurement and cost control model for use on capital construction contracts in the field of Petrochemical Civil Engineering. The Chapter concluded that the conventional model consisted basically of the general building model, adopted without material revision, and that there were assumptions regarding its applicability as opposed to empirical evidence to justify its applicability. This was partly attributed to the fact that criticisms of such models tend to centre around their internal consistency, as it were assuming their inherent validity, as opposed to the theoretical underpinning behind the formulation of their constituent parameters.

8.2 REGARDING THEORETICAL UNDERPINNING OF MODELS

Chapter 2 discussed aspects of theoretical underpinning of models and concluded that there is a lack of true theoretical development in building economics, characterised by the practice of group paradigms prior to theory formulation. The conventional Petrochemical Civil Engineering cost model is a manifestation of such practice. There is little rational evidence to justify the formulation or adoption of this model. The model (as well as the general Building model, of which it is an unabridged version) is too often merely presumed to possess intrinsic merit.

8.3 REGARDING THE OBJECTIVES OF A COST MODEL FOR PETROCHEMICAL CIVIL ENGINEERING WORK RELATED TO ORTHODOX CONVENTIONS

Chapter 3 discussed the requirements of cost models of the type under study and criticised the Conventional Petrochemical Civil Engineering Cost Model as an information communication medium. The Chapter then discussed the requirements of such a cost model and criticised the Conventional Petrochemical Civil Engineering Cost Model in terms of level of abstraction of detail. Chapter 2 then discussed the requirements of a cost model and criticised the Conventional Petrochemical Civil Engineering Cost Model in terms of its relevance to the design and costs of the building or structure which it purports to represent. The Chapter concluded that conventional measurement and cost planning models do not recognise the true determinants of building cost. This is not inconsistent with the intention that the models are for the use of the design team for the purpose of approximating the cost not of changes to the methods of production, but to changes in design. However, much of the content of this model carries little cost importance and in cases can bear little resemblance to the actual, or any intended, design.

This is a severe criticism given that it is supposed to be primarily a design-based model. A hypothetical model for Petrochemical Civil Engineering should be characterised by a reduction in the amount of redundant or entropic information contained in the conventional model. Chapter 3 criticised the basis of the conventional model's formulation and concluded that the conventional measurement and cost planning models are prescriptive of cost behaviour rather than representative of it. Their underlying measurement conventions are capable of producing "noise" for the sake of having it. Due to their manner of formulation their constituent parameters make no attempt to reflect the relative cost importance of cost centres. A model should be formulated on the basis of prior empirical observation of cost behaviour in the appropriate data. The model should be made to fit the "facts", such as they are. The "facts" should not be so formulated as to satisfy the prescriptive requirements of the model. This approach will not undermine the group paradigm, as it envisages the utilisation of a model of the same generic type as the paradigm model, but will contribute towards a rational, rather than sociological, step towards the development of measurement and cost planning theory.

Chapter 3 further concluded that the paradigm practice of abstracting an over-simplified cost planning model from an over-detailed measurement model is an unnecessary duplication of effort and produces two inappropriate models at inappropriate levels of abstraction. The identification should be attempted of consistent cost centres which exist at a suitable level of abstraction for use in both models, or in a single model which performs both functions simultaneously. The consistent cost centres so identified should be capable of being expressed in terms of design parameters, but the facility should be available to input costs of the factors of production if desired. These cost centres should therefore take the form of a "neutral" language capable of being commutative between these two domains.

8.4 REGARDING REVIEW OF RESEARCH METHODS

Chapter 4 briefly reviewed the overall state of research development in building economics, pointed out some of its weaknesses and reported some proposed agenda for cost modelling research. The Chapter set out a basic strategy for the research in this thesis and then reviewed and criticised the research methods (the data collection tools) used in the thesis. Chapter 4 concluded that in respect of models of the type discussed in this thesis little attempt has been made to verify conventional practice. Current understanding is limited to experience and intuition and future investigations should attempt to build on a factual basis, not on the possibility of false assumptions. There is a need for empirical work on the naive cost planning methods currently in use, and for research into the "human expertise" which forms a rather vague or subjective reasoning behind the conventional models. There is a need to focus on the inherent or implicit assumptions conventionally built into cost models and also to focus on the inherent assumptions made about their validity.

Chapter 4 identified a commencing inductive strategy for the work; the main objective being to use observations of behaviour of cost data in the conventional Petrochemical Civil Engineering cost model to formulate a hypothetical model. This is considered to be a step towards a more rational formulation for the sociological paradigm, which is empirically weak, and will bring it closer to true "theoretical" status.. The paradigm is not being tested as such, but a rational basis for its formulation is argued for. Owing to a lack of theoretical development in the field of Petrochemical Civil Engineering cost modelling and the general Building cost modelling field from which it is drawn, Chapter 4 rejected a strategy of middle range theory. An emphasis on a grounded theory approach was recommended which would encourage model formulation without preconceived theoretical "truths".

Chapter 4 recommended statistical analysis of the conventional Petrochemical Civil Engineering measurement and cost control data in order to obtain empirical observations of its cost behaviour patterns. The Chapter then proposed a survey among all likely end-users, inviting their judgement on the hypothetical measurement model so formulated. Such interviews should seek to ascertain whether the end-users consider that the hypothetical model would achieve its stated objectives. Such a survey would also enable the respondents to comment on whether they agree with its stated objectives, given that its hypothetical statements have been formulated following empirical observation. The Chapter then proposed an experimental measurement exercise whereby a known historical project would be re measured using the hypothetical model and priced as a *bona fide* tender. This would constitute the beginning of a hypothetico-deductive phase; that is of model-testing.

Chapter 4 questioned whether there need be an *overt* intention (as pure and social scientists often presume) to generalise to the whole population (in this case the whole industry). It was suggested that an empirical model which follows an individual situation, or a limited number of situations of similar character, be sought. Thus the Chapter recommended some further discussion and study of the principles of idiographic models.

8.5 Regarding the Formulation of Cost Models in Related Fields

Chapter 5 commenced by giving some brief overall treatment of the epistemology of model-building and pointed out the epistemological requirement for a theoretical basis upon which to found the actual building of the model. Without some theoretical basis, the model is vacuous. In the general context there is a need for a more substantial body of theory upon which to base model-building.

Chapter 5 argued that "ease of use" and "practicality" do not, alone, constitute "validity". The perceived "strength" of the conventional building model, that it parallels the design process and is therefore relatively easy to use, can in fact be a weakness: by the same token it is relatively easy to abuse. Lack of empirical formulation renders the conventional model (or its user) incapable of preventing the incorporation of information which bears no relationship to the design and, therefore, to any current or eventual facts. The intrinsic merit of a model, measured against the degree of its internal consistency alone, is insufficient to guarantee that what it models is necessarily what ought to be modelled. Without rational consideration of what the "facts" to be modelled ought to be the exercise is no more than one of data collection. This is especially likely if the conventional rules of measurement have been formulated more by a process of negotiation between interested parties than by any prior substantial data analysis.

Chapter 5 then argued that the idea of standard Elements, and of standardisation of Elemental cost behaviour for cost analysis and planning purposes, is a weak idea as long as conventional definitions of Elements are retained. Conventional Elemental cost classifications display high cost variability. Standardisation can therefore only remain justifiable to a certain degree, owing to the inherently uniqe nature of the entities which are being observed and modelled. Conventional models which seek to universally standardise what the construction industry freely admits to be variable in character are much like the *Procrastian Bed* of Greek Mythology. The data could be made to obey the parameters of an ideological model instead of the data dictating the parameters which a logical model ought to possess. Chapter 5 proceeded to review the idiographic approach to the modelling of construction projects and argued for serious consideration of such approaches.

Chapter 5 then briefly reviewed the formulation of, and discussed some methodological issues concerning, the formulation of models in related fields bearing similar characteristics to the hypothetical model formulated in this work. The models so reviewed were: the Civil Engineering Cost Model, the Building Cost Model, the Shorter Bills of Quantities Model, the Iterative Civil Engineering Model, the Builder's Quantities Model, the International Engineering Construction Model, a Rational Bill of Quantities Model for Civil Engineering Work and Elemental Models.

Chapter 5 concluded that the formulation of a hypothetical Petrochemical Civil Engineering Cost model should involve the requirement for some theoretical basis upon which to decide which are the important facts to collect. This is in order to have the model better represent what it is supposed to represent. Also, the hypothetical model should not attempt overtly to become a "general, universal standard". Standard models are ideological; they cannot fit any individual observable situation. In obeying a standard model we must distort the observations so as to fit the model. Chapter 5 further suggested that individual models based on prior empirical observation, though they have limitations, are more logical than those which do not. They do not place their own limitations outside the boundaries of the population segments to which they have been formulated to apply. Over-stretching has caused theories and paradigms to fail. The Chapter suggested that a feature of conventional models is that they are neither truly nomothetic nor truly idiographic; there is unnecessary overlap. The Chapter also suggested that the hypothetical Petrochemical Civil Engineering model should obey empirical observation of the cost behaviour of the data. It should not be an ideological model.

Chapter 5 proposed that rank order distributions of cost of the type characterised by the Method-Related Civil Engineering model, and by the Iterative Civil Engineering Model, should be identified in the Petrochemical Civil Engineering data. The significant cost centres so identified should be used to define the guiding parameters of a hypothetical model for Petrochemical Civil Engineering. A move towards greater simplification of detail should be sought than was achieved by the Building Cost Model (SMM7), which has been criticised as having fallen short of the objective of simplification.

Chapter 5 proposed that the behaviour of costs of Elements should be observed in the Petrochemical Civil Engineering data with a view to redefining, or finding alternatives to, conventional Element classifications. Cost planning and measurement data could eventually be subsumed in a single model, at an appropriate level of abstraction between that of the over-complicated conventional Bill of Quantities and the over-simplified conventional Elemental Cost Analysis. That we structure our conventions such that the models start as "general" models and develop into "unique" models (singularities) is a reversal of the normal direction of scientific development.

Chapter 5 finally concluded that the conventional measurement model contains so much detail *in toto* that much of it constitutes mere noise, liable to distort the intended message. Further, its detailed legalistic rules demand facts to fit the model, as opposed to a model to fit the facts.

8.6 Regarding the Formulation of a Hypothetical Petrochemical Civil Engineering Measurement and Cost Control Model

Chapter 6 described the statistical analyses used to formulate (by empirical observation) the hypothetical Petrochemical Civil Engineering model. The "Preliminary Analysis at Bill of Quantities Item Level of Abstraction" section described the analysis of historical cost data in numerous Bills of Quantities by rank order distribution of cost (apportioned by builders). It was shown that invariably a large proportion of items have little significance to builders in pure cost items and that such items aggregate to a very small proportion of the total cost of any given construction project. Distinction was drawn between items which are measurable by virtue of being observable physical entities and items which, although not directly visible as a function of building design, can nevertheless be priced separately from the measurement provided.

The section "Comprehensive Analysis at Bill of Quantities Item Level of Abstraction" described analysis of data following "normalisation". Item values in Bills of Quantities were standardised by dividing each item value by the mean item value. For each Bill of Quantities tabulations were produced of mean item value, standard deviation and skewness. It was shown that in all Bills of Quantities item cost distributions were highly skewed, that is, not normally distributed. Invariably a few very high value items contribute the bulk of the total cost. Removal of unmeasured items in SMM5 Bills reduced the mean item value, suggesting a preponderance of high value items which are not measured (quantified). Removal of unmeasured items in SMM6 Bills sometimes increased the mean item value, suggesting that in some cases the highest value items were subject to measurement (quantification).

The sections "Analysis at Trade and Trade Subsection Level of Abstraction" illustrated that the "abnormal" cost distributions replicate at these higher levels of abstraction (*i.e.* at lower levels of detail). Those Trades and Trade Subsections in which cost-insignificant Bill items proliferate were identified. A cost-insignificant item was defined for the purpose of the study as being one of the lowest value Bill Items which collectively aggregate to the last 5% of the Bill Total (when placed in descending rank order of value). Practitioners frequently expect to achieve such levels of estimating accuracy, thiugh this claim is largely untested. It was shown that in all Bills certain Trades consistently generated a *marginally* higher proportion of the total of cost-insignificant items. It was recommended that elimination of cost-insignificant items from the measurement system should commence with those Trades. Preliminary conclusions were offered regarding the scope for not measuring (or changing the approach to the measurement of) cost-insignificant items.

The section "Recommendations Regarding Cost-insignificant Parameters and Generic Families of Parameters" identified those items which permanently resided in the cost-insignificant category previously described. Their omission from the measurement system was suggested. Those generic families of items which are similar in nature but conventionally classified in separate measurement rules, and identically or similarly priced, were identified. The simplification of their measurement was suggested, by virtue of reducing the number of measurement categories for such items or by amalgamating such items into composite items. At this stage further conclusions were offered concerning the results and the validity of the original hypothesis. Proposals for an experimental method of measurement were set out.

In the section "Analysis at Elemental Level of Abstraction" the data were grouped by building Element. Elemental cost distributions by project and incidence of Elements across all projects were computed. It was argued that the data were insufficient to yield conclusive Elemental breakdowns and incidence. It was concluded that this type of analysis requires a greater number of construction projects than were available. It was shown, however, that for certain types of building certain Elements will have sufficiently negligible cost input to warrant detailed measurement attention. Discussion was offered as to whether data classification using conventional Elements is capable of leading to standardisation of costs, in terms of being consistent.

Study of idiographic, as opposed to nomothetic, models for cost analysis and planning was recommended. The heterogeneous nature of the Elemental Cost data must be stressed. Future work in this area should be executed with this in mind, as the data have the capacity to contradict the underlying assumption behind Elemental cost analysis and planning that buildings be selected which are characterised by similarity.

Chapter 6 classied Elements by the rate at which they generate costs (attract prices from Tenderers). It was shown that classification can be attempted on the basis of an Element being a Major Cost Generator or a Minor Cost Generator. Minor Cost Generators will display the property of generating costs more slowly per item than do items across the whole project. It was suggested that Minor Cost Generator Elements may have scope for being subject to simplified measurement conventions; alternatively there may be scope for removing them entirely from the measurement system.

8.7 Regarding the Validation of a Hypothetical Petrochemical Civil Engineering Measurement and Cost Control Model

Chapter 7 described the validation of the hypothetical model which was formulated on the basis of the empirical observations in Chapter 6. A survey of all potential model users was executed in order to solicit the judgement of these experts as to whether the proposed method of measurement would achieve its stated objectives. The respondents concluded that the hypothetical model would produce fewer items to measure, reduced measurement time overall, reduced measurement time on "small" items, reduced working-up time overall, reduced working-up time on "small" items, adequate units of measurement, reduced time in preparing Tenders, a more acceptable level of detail, and no foreseeable problems in pricing Bills of Quantities.

The respondents concluded that the hypothetical model would be a simpler and clearer document, would make clearer provision for specifications, would provide adequate information for tendering purposes, would achieve reduced time valuing post contract variations and preparing interim valuations. The respondents were seen to have mixed feelings as to whether the hypothetical model would be a more readable document (though this appears to contrast with earlier responses)or would be adequate for the purpose of assigning prices to Bills of Quantities (which also appears to contradict earlier responses). The respondents were seen to harbour doubts as to whether the hypothetical model adequately defines where the costs of small items no longer measured were included, and foresaw problems with Bill of Quantities preparation (though some earlier responses suggested otherwise).

In Chapter 7 the first test of the hypothetical model was carried out by re-measuring an existing historical project using the hypothetical model as the method of measurement and having one of an approved panel of contractors price the project again as a *bona fide* Tender. Comment by the Tenderer and the expert user who "re measured" the project on the use of the document for Tendering purposes was incorporated. The feedback from measurer and tenderer was largely of a technical nature, illustrating the conventional tendency to appraise models on the basis of their internal consistency rather than on the epistemological factors surrounding their formulation. It was seen that the *bona fide* Tender so produced came in exceptionally close to the original and that the Tendering process was not significantly affected by the use of a simplified model for measurement. It was argued that the Experimental system of measurement, lacking the detail of conventional systems, did not materially obstruct the Tendering process.

Chapter 7 described two brief tests to compare SMM7, The Hypothetical Model and "Shorter Bills of Quantities" in terms of their relative simplification of detail. On the basis of the two tests described "Shorter Bills of Quantities" was seen to have simplified the measurement conventions to a greater extent than the hypothetical model. Overall, the hypothetical model had fewer items due to massive savings in a small number of Trades. It was suggested that the hypothetical model would operate satisfactorily in practice on the basis that "Shorter Bills of Quantities" can be utilised for the same purposes without causing discernible problems in the processes of estimating, tendering, valuing variations and final accounts.

It should be stressed that the testing of the model was limited and constrained somewhat by an inability to obtain or sustain prolonged direct contact with tenderers. Future work in the area should concentrate on the perceptions of tenderers regarding such models.

8.8 RECOMMENDATIONS

The formulation of a hypothetical measurement and cost control model for Petrochemical Civil Engineering work has contributed to the proliferation of such models on a rational, as opposed to sociological basis. Insufficient recognition of the sociological factors surrounding model formulation and practice exists in the industry. In the process, though an idiographic approach to modelling has been argued to be worth studying, an overlap of idiographic and nomothetic characteristics has been identified in some conventional models. Thus they are not truly "standard", and reliance on "standard" models may be inappropriate to the "unique" situations likely to be encountered. Therefore a range of relatively unique models is argued for. However, the statistical methods employed in this thesis are capable of replication should generalisation be considered desirable.

The Element costs studied have violated every principle of cost consistency suggested by Morrison and Stevens (1983). The coefficients of variation of the conventional Element classifications were so great as to require (following Morrison and Stevens' account) their breakdown into sub-elements or constituent components of greater predictability. Elements as currently defined are inconsistent in their cost behaviour; we have defined them as design parameters rather than on true cost determinants; it may be that immutable components of Elements could be identified which give greater consistency of cost behaviour. An alternative set of cost centres should be identified and applied which can be recognised and predicted as being significant or insignificant in cost terms.

Given the nature of the construction work under study, the cost model used should be capable of facilitating inputs of the costs of the factors of production into the design-based cost centres. This could interface between the design and production team during design and should suit some of the requirements of this type of construction work (and probably others). To this end, equivalents to the Lead Positions of the Diederichs-Hepermann model (1985) should be investigated and applied.

It is argued that if the Petrochemical cost model is produced in the format of a somewhat more detailed Elemental Cost Analysis than those currently employed (*i.e.* a less-detailed Bill of Quantities than is conventionally employed) then sufficient detail will be provided to enable the processes of tendering and valuation of post contract variations to occur without undue hindrance. Simultaneously, a better level of detail will be provided for the purpose of more objectively carrying out Elemental Cost Planning. Also, as the two documents would thus become a single document, the effort of producing a Bill of Quantities and then using it to produce an Elemental Cost Analysis is dispensed with. It is argued that these separate efforts are undesirable because neither Bill of Quantities nor Elemental Cost Analysis have an adequate enough format for the uses to which they are put.

It is argued that the most suitable model to test in the given context would be the *Diederichs-Hepermann* model. Its attempt to link designer and producer at an early stage is perceived to be of potential benefit. Indeed, it may well have usefulness in other domains, if it be accepted that involving the builder in the early stages of the process has intrinsic value, which it presumably does. Also, the model can be made to fit an existing set of design-based Elements with which design teams ought to be familiar, though its recognisable cost centres are not Elementally based. The set of "significant cost centres" upon which it is based is, itself, perceived to be an improvement on its United Kingdom counterpart. There are United Kingdom equivalents to these cost centres which could be used and adapted for this purpose, though they are not currently employed in that way.

References

Ashworth, A. (1994). "Cost Studies of Buildings", 2nd Edition. Longman Scientific and Technical. 313-328.

Ashworth, A. and Skitmore, R. M. (1983). "Accuracy in Estimating". Chartered Institute of Building. Occasional Paper Nr 27.

Azzarro, D., Hubbard, J. and Robertson, D. (1987). "Contractors' Estimating Procedures: AnOverview".

Baccarini, D. J. (1984a) "Brickwork - Fairface and Facework". Chartered Quantity Surveyor. April. 352.

Baccarini, D. J. (1984b). "Formwork". Chartered Quantity Surveyor. June. 417.

Barnes, N. M. L. (1971). "The Design and Use of Experimental Bills of Quantities for Civil Engineering Works". PhD Thesis. University of Manchester Institute of Science and Technology.

Barnes, N. M. L. (1977). "Measurement in Contract Control". Institution of Civil Engineers. 2.

Benham, N. and Capon, K. (1983). "SMM7". In Chartered Quantity Surveyor. 324.

Bennett, J. (1986). "QS as Don". In Chartered Quantity Surveyor. 30-31.

Bennett, J. (1983). "SMM7". In Chartered Quantity Surveyor. 363.

Bowen, P. A. and Edwards, P. J. (1985). Cost Modelling and Price Forecasting: Practice and Theory in Perspective. In Construction Management and Economics. E. & F. N. Spon. 3|199-215.

Brandon, P. S. (1982). "Building Cost Research: Need for a Paradigm Shift?". Transactions. Building Cost Techniques: New Directions. Portsmouth Polytechnic. 8.

Brown, H. W. (1984). "Cost Prediction of Building Services, A Holistic Appraisal in the Context of Design Management". MSc Thesis. Heriot-Watt University.

Building Cost Information Service (1969). "Standard Form of Cost Analysis". Royal Institution of Chartered Surveyors.

Building Cost Information Service (1980). "Study of Preliminary Percentages". Royal Institution of Chartered Surveyors. Study Nr 17A.

Civil Engineering Standard Method of Measurement (1976). Institution of Civil Engineers. Thomas Telford.

Cirillo, R. (1979). The Economics of Vilfredo Pareto. Frank Cass. 61-87.

Civil Engineering Standard Method of Measurement, 2nd Edition (1985). Institution of Civil Engineers. Thomas Telford.

Civil Engineering Standard Method of Measurement, 3rd Edition (1991). Institution of Civil Engineers. Thomas Telford.

Daly, I. M. (1981). "What's the Use of the Bill of Quantities?". In Building Economist.

Davies, A. J. and Greenwood, D. J. (1994). "A Proposed New Approach to Elemental Cost Planning for Designers and Builders". Transactions. Association of Researchers in Construction Management. Skitmore, R. M. and Betts, M., Eds.. Loughborough University of Technology. 402-409.

De Troyer, F. (1990). "Cost Breakdown in Functional Macro-elements and Sub-Elements - A Design Tool". Transactions. Counseil International du Batiment pour la Recherche, L'Etude et la Documentation. University of Technology, Sydney. 100-111.

Deutsches Institut für Normung (1984). DIN 276 - Kostengliederung für Hochbauten.

Diederichs, C.J. and Hepermann, H. (1985) "Kosteneinflußfaktoren bei den Leitpositionen von Standardleistungsbeschreibungen für die Kostengruppe 3.1 nach DIN 276". Bergische Universität Wuppertal.

Dirksen, H-G. (1982). "A German Contractor Thinks Aloud". Chartered Quantity Surveyor. 312.

Dobson, C. B., Hardy, M. R., Heyes, S. W., Humphreys, A. and Humphreys, P. W. (1980). "Understanding Psychology".

Dominowski, R. L. (1980). "Research Methods". Prentice-Hall, Inc.. 178.

Drucker, P. F. (1978). "People and Performance". Heinemann. 104-105.

Emmett, J. J. (1990). "Shorter Bills of Quantities for Simplicity and Efficiency". Building. August. 24.

Ferry, D. J. and Brandon, P. S (1984). "Cost Planning of Buildings", 5th Edition. Collins. 101-188.

Feyerabend, P. K. (1970). "Consolations for the Specialist". In Criticism and the Growth of Knowledge. Cambridge University Press. 197-230.

Feyerabend, P. K (1975). "Against Method". New Left Books. 45, 47.

Feyerabend, P. K (1978). "In Defence of Aristotle". In Progress and Rationality in Science. Radnitzky, G. R. and Andersson, G., Eds.. vLVII. Reidel. 143-180.

Fine, B. (1982). "The Use of Simulation as a Research Tool". Transactions. "Building Cost Techniques: New Directions". Portsmouth Polytechnic. E & F N Spon. Brandon, P. S., Ed.. 68.

Fine, B. and Hackemar, G. (1970). "Estimating and Bidding Strategy". Building Technology and Management. 8-9.

Flanagan, R. (1980). "Tender Price and Time Prediction for Construction Work". PhD Thesis. University of Aston.

Fletcher-Moore, Monk-Dunstone (1986). "Shorter Bills of Quantities: The Concise Standard Phraseology and Library of Descriptions". The Builder Group.

Gates, M. (1967). "Bidding Strategies and Probabilities". ASCE Journal of the Construction Division. 75-107.

Goldratt, E. M. (1990). The Haystack Syndrome: Sifting Information Out of the Data Ocean. North River Press.

Grünbaum, A. (1978). "Popper vs Inductivism". In Progress and Rationality in Science. Radnitzky, G. and Andersson, G. (Eds.). Reidel. 117-142.

Hardcastle, C. (1992) "An Information Model Of The Construction Cost Estimating Process". PhD Thesis. Heriot-Watt University.

Hardcastle, C., Brown, H. W. and Davies, A. J. (1987a). "Statistical Modelling of Civil Engineering Costs in the Petrochemical Industry". Transactions. Building Cost Modelling and Computers. University of Salford.

Hardcastle, C., Brown, H. W. and Davies, A. J. (1987b). "Statistical Modelling of Civil Engineering Costs in the Petrochemical Industry". Transactions. CIB Fourth International Symposium on Building Economics, Copenhagen.

Hardcastle, C., Brown, H. W. and Davies, A. J. (1988). "Control of Petrochemical Civil Engineering Costs". Transactions. American Association of Cost Engineers, Tenth International Cost Engineering Congress, New York, NY.

Harsanyi, J. (1955). "Cardinal Welfare, Individual Ethics and Inter-personal Comparisons of Utility". In J. political Econ. 63.

Heath, R. L. and Bryant, J. (1992). Human Communication Theory and Research. Lawrence Erlbaum Associates.

Heather, N. (1976). "Radical Perspectives in Psychology". Methuen.

Hindness, B. (1977). Philosophy and Methodology in the Social Sciences. John Spiers. 142-163.

HoAI (1984). "Verordnungen über die Honoräre und Leistungen der Architekten und Ingenieure". Bundesministerium für Raumordnung, Bauwesen und Städtebau.

Holt, G. D., Olomolaiye, P. O. and Harris, F. C. (1994). "Evaluating Performance Potential in the Selection of Construction Contractors". In Engineering, Construction and Architectural Management. Blackwell Science. 1|1, 29-50.

Hooker, R. J. (1985). "Standard Method of Measurement 7th Edition". In The Quantity Surveyor. 166-170.

Hooker, R.J. "Towards the Twenty First Century - Measurement Conventions for the Future". In the Quantity Surveyor. v35|2. 264-269.

Horner, R. M. W. and Saket, M. M. (1984). "Cost Significance and Iterative Estimating". University of Dundee.

Horner, R. M. W., McKay, K. J. and Saket, M. M. (1986). "Simple Computer Models of the Construction Process". Transactions. International Association for Bridge and Structural Engineering, Zurich.

Horner, R. M. W. and Saket, M. M. (1984). "Cost Significance and Iterative Estimating". University of Dundee.

Hughes, G A. (1983) "SMM7". In Chartered Quantity Surveyor. May. 324-325.

Katona, G. (1963). Psychological Analysis of Economic Behaviour. McGraw-Hill. 67-73.

Keating, C. J. (1977). "Looking Back at Cost Estimating and Control". Transactions. American Association of Cost Engineers. 12-20.

Kenley, R. and Wilson, O. D. (1986). "A Construction Project Cash Flow Model - an Idiographic Approach". In Construction Management and Economics. 4|213-232.

Kenny, D. A. (1979). Correlation and Causality. John Wiley and Sons, Inc. 1-12.

Koertge, N. (1978). "Towards a New Theory of Scientific Enquiry". In Progress and Rationality in Science. Radnitzky, G. and Andersson, G. (Eds.).. Reidel. 253-278.

Kuhn, T. S. (1962). The Stucture of Scientific Revolutions. Chicago University Press.

Kuhn, T. S. (1972). The Essential Tension. Chicago University Press.

Layder, D. (1993). New Strategies in Social Research. Polity Press. 19-70.

Lukacs, G. (1971). History and Class Consciousness. Merlin Press.

Marks, P I, Jaggar, D M, Al-Shawi, M. and Bird, D (1990). "Design Cost Control in Civil Engineering Projects - the Development of a Viable System". Transactions. Counseil International du Batiment pour la Recherche, L'Etude et la Documentation. University of Technology, Sydney. 164-171.

Masterman, M. (1970). "The Nature of a Paradigm". In Criticism and the Growth of Knowledge. Cambridge University Press. 59-89.

McDonough, R. (1978). "Ideology as False Consciousness". In On Ideology. Schwarz, W., Ed.. Hutchinson. 3-44.

Medawar, P. (1982). "Pluto's Republic". Oxford University Press. 86.

Moore, T. and Ashworth, G. (1986). "Publication Produces Shorter Bills". Chartered Quantity Surveyor. 5.

Morrison, N. and Stevens, S. (1981). "Cost Planning and Computers". University of Reading and the Property Services Agency. 29.

Mower, K. (1982). "SMM7". Chartered Quantity Surveyor. 165.

Musgrave, A. (1978). "Evidential Support, Falsification, Heuristics, and Anarchism". In Progress and Rationality in Science. Radnitzky, G. R. and Andersson, G., Eds. vLVII. Reidel. 181-201.

Nachmias, D. and Nachmias, C. (1976). Research Methods in the Social Sciences. Edward Arnold. 52-53.

National Consultative Council Working Group on Indices for Building Contracts (1979). "Price Adjustment Formulae for Building Contracts (Series 2 Revised): Description of the Indices". Property Services Agency.

Neale, J. M. and Liebert, R. M. (1980). Science and Behaviour: An Introduction to Methods of Research. Prentice-Hall.

Newton, S. (1991). "An Agenda for Cost Modelling Research". In Construction Management and Economics. E. & F. N. Spon. 9|97-112.

Ng, S. T. and Skitmore, R. M. (1994). "Decision Support System for Construction Prequalification". Transactions. Association of Researchers in Construction Management. Skitmore, R. M. and Betts, M., Eds.. Loughborough University of Technology.

Pasquire, C. (1993). Builders' Quantities for Contractors' Management. Chartered Institute of Builders. Occasional Paper Nr 55. iii-1.

Popper, K. R. (1959). "The Logic of Scientific Discovery". Hutchinson.

Post, H. (1978). "Objectivism vs. Sociologism". In Progress and Rationality in Science. Radnitzky, G. R. and Andersson, G., Eds.. vLVII. Reidel. 311-318.

Principles of Measurement (International) For Works of Construction (Undated). Royal Institution of Chartered Surveyors.

Property Services Agency (1983). "Estimating Information - Significant Items and Average Measured Rates".

Putnam, H. (1991). "The 'Corroboration' of Theories". In The Philosophy of Science. Boyd, R., Gasper, P. and Trout, J. D.. Eds.. Massachussetts Institute of Technology Press. 121-137.

Quier, J. A. (1992). Author; "Shorter Bills of Quantities: The Concise Standard Phraseology and Library of Descriptions". Interview. August.

Raftery, J. (1991). "Models for Construction Cost and Forecasting". Transactions. First National RICS Research Conference. E. & F. N. Spon. Chapman and Hall.

Royal Institution of British Architects (1973). Handbook of Architectural Practice and Management: Plan of Work". v2|s3.220.

Saket, M. M. (1986). "Cost Significance Applied to Estimating and Control of Construction Costs". PhD Thesis. University of Dundee.

Saket, M. M. (Undated). "Results of Testing Iterative Estimating". University of Dundee. Report Nr 84|12.

Seeley, I. H. (1988). "Building Quantities Explained", 4th Edition. Macmillan Education.3.

Sen, A. (1970). "Rational Fools: A Critique of the Behavioural Foundations of Economic Theory". In Criticism and the Growth of Knowledge. Cambridge University Press. 1-25.

Silverton, G. R. (1983). "SMM7". In Chartered Quantity Surveyor. 325.

Singh, G. and Banjoko, O. O. (1990). "The Development of a Rational Bill of Quantities". In Construction Management and Economics. 8|31-47.

Skinner, D W H. (1979). "An Analysis of the Utility of Bills of Quantities in the Process of Building Contracting". PhD Thesis. University of Aston.

Skinner, D. W. H. and Jepson, W. (1980). "The Contractor's Use of Bills". In Chartered Quantity Surveyor. September.

Skoyles, E. R. and Fletcher, L. (1964). "Introduction to Operational Bills". Building Research Station. Paper CP DS 32.

Skoyles, E. R. and Fletcher, L. (1970) "Bill of Quantities or the Operational Bill". Architect's Journal.

Skoyles, E. R. (1986). "Research and the QS". In Chartered Quantity Surveyor. 34.

Smith, G. M. (1979). "Can the Quality of Data Be Improved in BOQs". Building Trades Journal. 16.

Snell, R. G. (1973). "The Bill - Its Use and Abuse". Chartered Quantity Surveyor. 13-14.

Southgate, A. (1988a). "A New Approach [Part 1]". In Chartered Quantity Surveyor. November. 35-36.

Southgate, A. (1988b). "A New Approach [Part 2]". In Chartered Quantity Surveyor. December. 25.

Stamper, R. (1973). "Information in Business and Administrative Systems". B. T. Batsford. 24-27, 48-50, 76-79.

Standard Method of Measurement of Building Works, 5th Edition (Metric) (1968). Royal Institution of Chartered Surveyors.

Standard Method of Measurement of Building Works, 6th Edition (1981). Royal Institution of Chartered Surveyors.

Standard Method of Measurement of Building Works, 7th Edition (1988). Royal Institution of Chartered Surveyors and Building Employers' Confederation.

Standard Method of Measurement for International Engineering Construction (1984). The Association of Cost Engineers and the Royal Institution of Chartered Surveyors. 9.

Strotton, C. (1988). "SMM7 Review". In Chartered Quantity Surveyor. April. 27.

Tong, Y. and Lu, Y. (1992). "Unbalanced Bidding on Contracts with Variation Trends in Client-Provided Quantities". In Construction Management and Economics. E. & F. N. Spon. 10|69-80.

Toulmin, S. (1970). "Does the Distinction Between Normal and Revolutionary Science Hold Water?". In Criticism and the Growth of Knowledge. Cambridge University Press. 39-48.

Townsend, A. (1990). "Computerising Costs". In New Civil Engineer. December. 36.

Willis, C. J. and Newman, D. (1988). "Elements of Quantity Surveying", 8th Edition. BSP Professional Books.1-2.

Worthington, S. (1985). "Construction Design: the Design Process and the Rôle of the Site Survey within this Process". Dissertation. University of Northumbria.

BIBLIOGRAPHY

Ashworth, A. (1994). "Cost Studies of Buildings", 2nd Edition. Longman Scientific and Technical. 313-328.

Ashworth, A. and Skitmore, R. M. (1983). "Accuracy in Estimating". Chartered Institute of Building. Occasional Paper Nr 27. 10.

Azzarro, D., Hubbard, J. and Robertson, D. (1987). "Contractors' Estimating Procedures: An Overview".

Ashworth, A. and Barnes, N. M. L. (1981). "A Method to Reckon With". CIRIA. Report Nr 34.

Baccarini, D. J. (1984a) "Brickwork - Fairface and Facework". Chartered Quantity Surveyor. April. 352.

Baccarini, D. J. (1984b). "Formwork". Chartered Quantity Surveyor. June. 417.

Barnes, N. M. L. (1971). "The Design and Use of Experimental Bills of Quantities for Civil Engineering Works". PhD Thesis. University of Manchester Institute of Science and Technology.

Barnes, N. M. L. (1975). "The Standard Method of Measurement - Seventh Edition". In the Quantity Surveyor. March.

Barnes, N. M. L. (1977). "Measurement in Contract Control". Institution of Civil Engineers. 2.

Barnes, N. M. L. (1979). "Measurement Theory". In Chartered Quantity Surveyor.

Barry, P. (1985). "Getting Involved". In Chartered Quantity Surveyor. July. 482-483.

Beeston, D. (1980). "Measurement Theory Statistics Understated". In Chartered Quantity Surveyor. v2|8. 209.

Benedict, J. (1972). "The Unpriceable Items in Bills of Quantities". In Building Trades Journal. February.

Benham, N. and Capon, K. (1983). "SMM7". In Chartered Quantity Surveyor. April. 324.

Bennett, J. (1983). "SMM7". In Chartered Quantity Surveyor. 363.

Bennett, J. (1986). "QS as Don". In Chartered Quantity Surveyor. 30-31.

Bennett, J. and Barnes, N. M. L. (1979). "Outline of a Theory of Measurement". In Chartered Quantity Surveyor. October. 53-56.

Bishop, D. (1966). "Operational Bills and Cost Communications". Building Research Station. Paper CP DS 55.

Bowen, P. A. and Edwards, P. J. (1985). "Cost Modelling and Price Forecasting: Practice and Theory in Perspective". In Construction Management and Economics. E. & F. N. Spon. 3|199-215.

Brandon, P. S. (1982). "Building Cost Research: Need for a Paradigm Shift?". Transactions. Building Cost Techniques: New Directions. Portsmouth Polytechnic. 8.

Brown, H. W. (1984). "Cost Prediction of Building Services, A Holistic Appraisal in the Context of Design Management". MSc Thesis. Heriot-Watt University.

Braint, A K. (1985). "Estimating and Cost Control". Computer Technology in Construction. Telford. 29-35.

Building Cost Information Service (1969). "Standard Form of Cost Analysis". Royal Institution of Chartered Surveyors.

Building Cost Information Service (1980). "Study of Preliminary Percentages". Royal Institution of Chartered Surveyors. Nr 17A.

Burge, T. (1991). "Individualism and Psychology". In the Philosophy of Science. Boyd, R., Gasper, P. and Trout, J. D., Eds.. Massachussetts Institute of Technology Press. 687-712.

Burrows, M. (1983). "Problems in Measurement and Construction". In Building Trades Journal. v185, Nr 5510. 20.

Carnap, R. (1991). "Logical Foundations of the Unity of Science" In the Philosophy of Science. Boyd, R., Gasper, P. and Trout, J. D., Eds.. Massachussetts Institute of Technology Press. 121-137.

Cirillo, R. (1979). "The Economics of Vilfredo Pareto". Frank Cass. 61-87.

Civil Engineering Standard Method of Measurement (1976). Institution of Civil Engineers. Thomas Telford.

Civil Engineering Standard Method of Measurement, 2nd Edition (1985). Institution of Civil Engineers. Thomas Telford.

Civil Engineering Standard Method of Measurement, 3rd Edition (1991). Institution of Civil Engineers. Thomas Telford.

Coles, D C H. (1973). "A Re-Think On Operational Bills". In the Quantity Surveyor. July and August.

Copping, P. J. (1990). "The Pragmatic Method of Measurement". In the Building Economist. March. 5.

Daly, I. M. (1981). "What's the Use of the Bill of Quantities?". In Building Economist. September.

Davies, A. J. and Greenwood, D. J. (1994). "A Proposed New Approach to Elemental Cost Planning for Designers and Builders". Transactions. Association of Researchers in Construction Management. Skitmore, R. M. and Betts, M., Eds.. Loughborough University of Technology. 402-409.

Department of the Environment (1972). "A Report on the Arrangement of Information for Building Projects". HMSO.

De Troyer, F. (1990). "Cost Breakdown in Functional Macro-elements and Sub-Elements - A Design Tool". Transactions. Counseil International du Batiment pour la Recherche, L'Etude et la Documentation. University of Technology, Sydney. 100-111.

Deutsches Institut für Normung (1984). DIN 276 - Kostengliederung für Hochbauten.

Diederichs, C-J. and Hepermann, H. (1985) "Kosteneinflußfaktoren bei den Leitpositionen von Standardleistungsbeschreibungen für die Kostengruppe 3.1 nach DIN 276". Bergische Universität Wuppertal.

Dirksen, H-G. (1982). "A German Contractor Thinks Aloud". In Chartered Quantity Surveyor. May. 312.

Dobson, C. B., Hardy, M. R., Heyes, S. W., Humphreys, A. and Humphreys, P. W. (1980). "Understanding Psychology".

Dominowski, R. L. (1980). "Research Methods". Prentice-Hall, Inc.. 178.

Drucker, P. F. (1978). "People and Performance". Heinemann. 104-105.

Duhem, P. (1954). "The Aim and Structure of Physical Theory" [Trans. Wiener, P. P.]. Princeton University Press.

Emmett, J. J. (1990). "Shorter Bills of Quantities for Simplicity and Efficiency". In Building. August. 24.

Ferry, D. J. and Brandon, P. S. (1984). "Cost Planning of Buildings", 5th Edition. Collins. 101-188.

Feyerabend, P. K. (1970). "Consolations for the Specialist". In Criticism and the Growth of Knowledge. Cambridge University Press. 197-230.

Feyerabend, P. K. (1975). "Against Method". New Left Books. 45, 47.

Feyerabend, P. K. (1978). "In Defence of Aristotle". In Progress and Rationality in Science. Radnitzky, G. R. and Andersson, G., Eds. vLVII. Reidel. 143-180.

Fine, B. (1982). "The Use of Simulation as a Research Tool". Transactions. "Building Cost Techniques: New Directions". Portsmouth Polytechnic. E. & F. N. Spon. Brandon, P. S., Ed.. 68.

Fine, B. (1986). "Kitchen Sink Economics and the Construction Industry". Transactions. "Building Cost Modelling and Computers". Brandon, P. S., Ed.. University of Salford. E. & F. N. Spon.

Fine, B. and Hackemar, G. (1970). "Estimating and Bidding Strategy". Building Technology and Management. 8-9.

Flanagan, R. (1980). "Tender Price and Time Prediction for Construction Work". PhD Thesis. University of Aston.

Fletcher, L., Browne, G. R., Crisp, P., Deacon, J. E. A., Harrison, R. C., Hooker, R. J., Morris, H., Morris, P., Tompkins, W., White, P. and Ferry, D. J. (1972). "Report of the Joint Working Party on Measurement Conventions". Royal Institution of Chartered Surveyors and National Federation of Building Trades Employers. App. C| A8-A17.

Fletcher-Moore, Monk-Dunstone (1986). "Shorter Bills of Quantities: The Concise Standard Phraseology and Library of Descriptions". The Builder Group.

Francis, D. H. (1975). "Method -Related Charges and the Quantity Surveyor in Civil Engineering". In the Quantity Surveyor. March.

Freeman, G. (1987). "Quantity Surveying in Australia Today". In the Building Economist. December. 3-4.

Gates, M. (1967). "Bidding Strategies and Probabilities". ASCE Journal of the Construction Division. 75-107.

Goldratt, E. M. (1990). "The Haystack Syndrome: Sifting Information Out of the Data Ocean". North River Press.

Graves, R. (1959). "The Greek Myths". Penguin Books.

Gray, C. (1983). "Estimating Preliminaries". In Building Technology and Management.

Greig, M. D. (1981). "Construction Cost Advice, Is the Customer Satisfied?. A Study of Construction Cost Forecasting and Levels of Client Satisfaction". MSc Thesis. Heriot-Watt University.

Grünbaum, A. (1978). "Popper vs Inductivism". In Progress and Rationality in Science. Radnitzky, G. and Andersson, G. (Eds.).. Reidel. 117-142.

Hardcastle, C. (1978). "An Investigation of Current Methods of Presenting Prices for Construction Work". MSc Thesis. University of Strathyclyde.

Hardcastle, C. (1992) An Information Model Of The Construction Cost Estimating Process. PhD Thesis. Heriot-Watt University.

Hardcastle, C., Brown, H. W. and Davies, A. J. (1987a). "Statistical Modelling of Civil Engineering Costs in the Petrochemical Industry". Transactions. Building Cost Modelling and Computers. P. S. Brandon, Ed.. University of Salford.

Hardcastle, C., Brown, H. W. and Davies, A. J. (1987b). "Statistical Modelling of Civil Engineering Costs in the Petrochemical Industry". Transactions. CIB Fourth International Symposium on Building Economics, Copenhagen.

Hardcastle, C., Brown, H. W. and Davies, A. J. (1988). "Control of Petrochemical Civil Engineering Costs". Transactions. American Association of Cost Engineers, Tenth International Cost Engineering Congress, New York, NY.

Harsanyi, J. (1955). "Cardinal Welfare, Individual Ethics and Inter-personal Comparisons of Utility". In J. political Econ. 63.

Heath, R. L. and Bryant, J. (1992). "Human Communication Theory and Research". Lawrence Erlbaum Associates.

Heather, N. (1976). "Radical Perspectives in Psychology". Methuen.

Hindness, B. (1977). "Philosophy and Methodology in the Social Sciences". John Spiers. 142-163.

HoAI (1984). "Verordnungen über die Honoräre und Leistungen der Architekten und Ingenieure". Bundesministerium für Raumordnung, Bauwesen und Städtebau.

Hodgetts, M. F. (1987). "Risk Management and Cost Control". In the Building Economist. December. 17-20.

Holt, G. D., Olomolaiye, P. O. and Harris, F. C. (1994). "Evaluating Performance Potential in the Selection of Construction Contractors". In Engineering, Construction and Architectural Management. Blackwell Science. 1|1, 29-50.

Hooker, R. J. (1985). "Standard Method of Measurement 7th Edition". In the Quantity Surveyor. 166-170.

Hooker, R J. "Towards the Twenty First Century - Measurement Conventions for the Future". In the Quantity Surveyor. v35|2. 264-269.

Horner, R. M. W. and Saket, M. M. (1984). "Cost Significance and Iterative Estimating". University of Dundee.

Horner, R. M. W., McKay, K. J. and Saket, M. M. (1986). "Simple Computer Models of the Construction Process". Transactions. International Association for Bridge and Structural Engineering, Zurich.

Horner, R. M. W. and Saket, M. M. (1984). "Cost Significance and Iterative Estimating". University of Dundee.

Hughes, G A. (1983) "SMM7". In Chartered Quantity Surveyor. May. 324-325.

Hibbert, P. (1982). "The Case for Analytical Bills". In Chartered Quantity Surveyor. October. 96-97.

Hill, G C. (1969). "The Practical Operation of an Operational Bill by a London Borough". In the Quantity Surveyor. May.

Holes, L. G. (1990). "Finding an Alternative". In Chartered Quantity Surveyor. May. 10-11.

Holes, L. G. and Thomas, R. (1973). "Integrated Measurement". In Building. February.

Hooker, R. J. (1975). "Standard Method of Measurement 7th Edition". In the Quantity Surveyor. February. 166-170.

Hooker, R J. "Towards the Twenty First Century - Measurement Conventions for the Future". The Quantity Surveyor. v35, Nr 2. 264-269.

Horne, A. (1983). "CESSM & SMM6: The Differences". In Chartered Quantity Surveyor. November. 130-131.

Horner, R. M. W., McKay, K. J. and Saket, M. M. (1986). "Simple Computer Models of the Construction Process". Transactions. Workshop, International Association for Bridge and Structural Engineering, Zurich.

Horner, R. M. W. and Saket, M. M. (1984). "Cost Significance and Iterative Estimating". University of Dundee. November.

Hucker, M. (1993). "Measurement Legacies in Developing Commonwealth Countries". In the Building Economist. March. 14-15.

Hughes, G. A. (1983). "CESMM". In Chartered Quantity Surveyor. October. 78.

Hughes, G. A. "SMM7". In Chartered Quantity Surveyor. May 1983. 324-325.

Hughes, G. A. (1970). "The Civil Engineering Standard Method of Measurement". In the Quantity Surveyor. July.

Hunt, G. J. (1970). "Changing the Bill of Quantities". In the Quantity Surveyor. July.

January, M. (1990). "A Proposed New Method of Measurement". In the Building Economist. March. 4-5.

Jordan, P. (1982). "SMM7: Simplifying the Bills". In Building. 18 June. 25.

Katona, G. (1963). "Psychological Analysis of Economic Behaviour". McGraw-Hill. 67-73.

Keating, C. J. (1977). "Looking Back at Cost Estimating and Control". Transactions. American Association of Cost Engineers. 12-20.

Kenley, R. and Wilson, O. D. (1986). "A Construction Project Cash Flow Model - an Idiographic Approach". In Construction Management and Economics. 4|213-232.

Kenny, D. A. (1979). Correlation and Causality. John Wiley and Sons, Inc. 1-12.

Koertge, N. (1978). "Towards a New Theory of Scientific Enquiry". In Progress and Rationality in Science. Radnitzky, G. and Andersson, G., Eds.. Reidel. 253-278

Kuhn, T. S. (1962). "The Stucture of Scientific Revolutions". Chicago University Press.

Kuhn, T. S. (1972). "The Essential Tension". Chicago University Press.

Layder, D. (1993). "New Strategies in Social Research". Polity Press. 19-70.

Leon, G. (1971). "The Implications of a Simplified Method of Measurement for Site Management". Institute of Building Information Service. Nr 37. March.

Lees, M. A. (1986). "Abuse of Erroneous Rates Advantage". In Chartered Quantity Surveyor. March. 4.

Liddle, C. (1979). "Process Engineering - the QS Role". In Chartered Quantity Surveyor. October. 58-60.

Lukacs, G. (1971). "History and Class Consciousness". Merlin Press.

Marks, P I, Jaggar, D M, Al-Shawi, M. and Bird, D. (1990). "Design Cost Control in Civil Engineering Projects - the Development of a Viable System". Transactions. Counseil International du Batiment pour la Recherche, L'Etude et la Documentation. University of Technology, Sydney. 164-171.

Masterman, M. (1970). "The Nature of a Paradigm". In Criticism and the Growth of Knowledge. Cambridge University Press. 59-89.

McDonough, R. (1978). "Ideology as False Consciousness". In On Ideology. Schwarz, W., Ed.. Hutchinson. 3-44.

Method of Measurement for Road and Bridge Works (1987). Department of Transport. July.

Medawar, P. (1982). "Pluto's Republic". Oxford University Press. 86.

Miles, K. A. (1988). "Raising the Standard". In Chartered Quantity Surveyor. May.

Moore, T. and Ashworth, G. (1986). "Publication Produces Shorter Bills". In Chartered Quantity Surveyor. March. 5.

Morrison, N. and Stevens, S. (1981). "Cost Planning and Computers". University of Reading and the Property Services Agency. 29.

Mower, K. (1982). "SMM7". Chartered Quantity Surveyor. December. 165.

Musgrave, A. (1978). "Evidential Support, Falsification, Heuristics, and Anarchism". In Progress and Rationality in Science. Radnitzky, G. R. and Andersson, G., Eds.. vLVII. Reidel. 181-201.

Nachmias, D. and Nachmias, C. (1976). "Research Methods in the Social Sciences". Edward Arnold. 52-53.

National Consultative Council Working Group on Indices for Building Contracts (1979). "Price Adjustment Formulae for Building Contracts (Series 2 Revised): Description of the Indices". Property Services Agency.

Neale, J. M. and Liebert, R. M. (1980). Science and Behaviour: An Introduction to Methods of Research. Prentice-Hall.

Newton, S. (1991). "An Agenda for Cost Modelling Research". In Construction Management and Economics. E. & F. N. Spon. 9|97-112.

Ng, S. T. and Skitmore, R. M. (1994). "Decision Support System for Construction Prequalification". Transactions. Association of Researchers in Construction Management. Skitmore, R. M. and Betts, M., Eds.. Loughborough University of Technology.

Ogunlana, S. O. (1989) Accuracy In Design Cost Estimating. PhD Thesis. Loughborough University Of Technology.

Oppenheim, P. and Putnam, H. (1991). "Unity of Science as a Working Hypothesis". In the Philosophy of Science. Boyd, R., Gasper, P. and Trout, J. D., Eds.. Massachussetts Institute of Technology Press. 405-427.

Pasquire, C. (1993). Builders' Quantities for Contractors' Management. Chartered Institute of Builders. Occasional Paper Nr 55. iii-1.

Plowden, A. (1977). "CESMM: Brevity at All Costs". In Building. 15 April.

Popper, K. R. (1959). "The Logic of Scientific Discovery". Hutchinson.

Post, H. (1978). "Objectivism vs. Sociologism". In Progress and Rationality in Science. Radnitzky, G. R. and Andersson, G., Eds.. vLVII. Reidel. 311-318.

Principles of Measurement (International) For Works of Construction (Undated). Royal Institution of Chartered Surveyors.

Property Services Agency (1983). "Estimating Information - Significant Items and Average Measured Rates".

Putnam, H. (1991). "The 'Corroboration' of Theories". In the Philosophy of Science. Boyd, R., Gasper, P. and Trout, J. D., Eds.. Massachussetts Institute of Technology Press. 121-137.

Quier, J. A. (1992). Author, "Shorter Bills of Quantities: the Concise Standard Phraseology and Library of Descriptions". Interview. August.

Raftery, J. (1991). "Models for Construction Cost and Forecasting". Transactions. First National RICS Research Conference. E. & F. N. Spon. Chapman and Hall.

Redding, J. (1987). "Building services and the Challenge of Bills of Quantities". In the Building Economist. March. 9-10.

Rimmer, G. (1982). "SMM7 Progress Report". In Building. 2 April.

Roberts, C. F. (1987). "The Australian Standard Method of Measurement: Further Problems". In Building Economist. v25, Nr 4. 10-12.

Royal Institution of British Architects (1973). "Handbook of Architectural Practice and Management: Plan of Work". v2|s3:220.

Saket, M. M. (1986). "Cost Significance Applied to Estimating and Control of Construction Costs". PhD Thesis. University of Dundee.

Saket, M. M. (Undated). "Results of Testing Iterative Estimating". University of Dundee. Report Nr 84|12.

Schlick, M. (1991). "Positivism and Realism". In the Philosophy of Science. Boyd, R., Gasper, P. and Trout, J. D., Eds.. Massachussetts Institute of Technology Press. 37-55.

Scotford, A. (1990). "New Standard Method of Measurement". In the Building Economist. 11.

Seeley, I. H. (1988). "Building Quantities Explained", 4th Edition. Macmillan Education. 3.

Sen, A. (1970). "Rational Fools: A Critique of the Behavioural Foundations of Economic Theory". In Criticism and the Growth of Knowledge. Cambridge University Press. 1-25.

Sidwell, A. C. (1978). "The Measurement of Mechanical and Engineering Services in Buildings". In the Quantity Surveyor. v35, Nr 4. 316-317, 319-321.

Silverton, G. R. (1983). "SMM7". In Chartered Quantity Surveyor. May. 325.

Sims, J. (1978). "Drawing on Discipline". In Building. 3 November. 71.

Singh, G. and Banjoko, O. O. (1990). "The Development of a Rational Bill of Quantities". In Construction Management and Economics. 8|31-47.

Skinner, D. W. H. (1979). "An Analysis of the Utility of Bills of Quantities in the Process of Building Contracting". PhD Thesis. University of Aston.

Skinner, D. W. H. and Jepson, W. (1980). "The Contractor's Use of Bills". In Chartered Quantity Surveyor. September.

Skoyles, E. R. and Fletcher, L. (1964). "Introduction to Operational Bills". Building Research Station. Paper CP DS 32.

Skoyles, E. R. and Fletcher, L. (1970) "Bill of Quantities or the Operational Bill". Architect's Journal. 28 January.

Skoyles, E. R. (1986). "Research and the QS". In Chartered Quantity Surveyor. January. 34.

Smith, G. M. (1979). "Can the Quality of Data Be Improved in BOQs". In Building Trades Journal. 16.

Smith, J. and Wong, K. H. (1985). "Bills of Quantities in Singapore - A Survey of their Use and Application". In the Building Economist. September. 18-22.

Smith, R. (1987a). "Development Economics: Offices / Industrial Buildings". In Architect's Journal. 3 June. 57.

Smith, R. (1987b). "Development Economics: Factories / Warehouses, Initial Cost Estimating". In Architect's Journal. 21 October. 65.

Snell, R. G. (1973). "The Bill - Its Use and Abuse". In Chartered Quantity Surveyor. 13-14.

Southgate, A. (1988a). "A New Approach [Part 1]". In Chartered Quantity Surveyor. November. 35-36.

Southgate, A. (1988b). "A New Approach [Part 2]". In Chartered Quantity Surveyor. December. 25.

Stamper, R. (1973). "Information in Business and Administrative Systems". B. T. Batsford. 24-27, 48-50, 76-79.

Standard Code of Procedure for Measurement of Building Works (1988). Royal Institution of Chartered Surveyors and Building Employers Confederation.

Standard Method of Measurement for Mechanical Construction Works (1970). Standard Methods Publications Ltd.

Standard Method of Measurement for Onshore Pipeline Works (1982). Pipeline Industries Guild.

Standard Method of Measurement of Building Works, 5th Edition (Metric) (1968). Royal Institution of Chartered Surveyors.

Standard Method of Measurement of Building Works, 6th Edition (1981). Royal Institution of Chartered Surveyors.

Standard Method of Measurement of Building Works, 7th Edition (1988). Royal Institution of Chartered Surveyors and Building Employers' Confederation.

Standard Method of Measurement for International Engineering Construction (1984). The Association of Cost Engineers and the Royal Institution of Chartered Surveyors. 9.

Strotton, C. (1988). "SMM7 Review". In Chartered Quantity Surveyor. April. 27.

Summers, D. R. (1990). "Quantity Surveyor's Approach to Cost Control". In the Building Economist. June. 4-7.

Swanston, R. "Standard Method of Measurement of Building Works". In Chartered Surveyors Weekly. v111, Nr 5. 16-18.

Tong, Y. and Lu, Y. (1992). "Unbalanced Bidding on Contracts with Variation Trends in Client-Provided Quantities". In Construction Management and Economics. E. & F. N. Spon. 10|69-80.

Toulmin, S. (1970). "Does the Distinction Between Normal and Revolutionary Science Hold Water?". In Criticism and the Growth of Knowledge. Cambridge University Press. 39-48.

Townsend, A. (1990). "Computerising Costs". In New Civil Engineer. December. 36.

Turner, W. (1982). "Dispense With BQs - At Your Peril". In Chartered Quantity Surveyor. June. 345-346.

Unattributed (1970). "Operational Bills - Users' Comments". Architect's Journal. 11 March.

Unattributed (1978). "The New Standard Method of Measurement of Building Works (SMM) - Z: Pitfalls for Electrical Contractors Exist in Revised Guide". Electrical Contractor. v76, Nr 10. 25,28.

Watkins, J. (1991). "Methodological Individualism and Social Tendencies". In the Philosophy of Science. Boyd, R., Gasper, P. and Trout, J. D., Eds.. Massachussetts Institute of Technology Press. 121-137.

Watson, B. (1980). "Counting the Cost". In Building Services. v2, Nr 2. 42-43.

Willis, C. (1978). "Sixth Sense". In Building. 21 April.

Willis, C. (1982). "SMM7 Progress Report". In Building. 30 April. 28.

Willis, C. J. and Newman, D. (1988). "Elements of Quantity Surveying", 8th Edition. BSP Professional Books. 1-2.

Wood, R. D. (1973). "Is There a Need for a New Standard Method?". In Building Trades Journal. 4 May.

Worthington, S. (1985). "Construction Design: the Design Process and the Rôle of the Site Survey within this Process". Dissertation. University of Northumbria.

TOWARDS A METHOD OF MEASUREMENT AND COST CONTROL FOR CIVIL ENGINEERING WORK IN THE PETROCHEMICAL INDUSTRY

by

Alan James Davies

in collaboration with

Imperial Chemical Industries

A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of Doctor of Philosophy

University of Northumbria at Newcastle

August 1995

Volume 2 of 2

APPENDIX 1:
FORMULATION OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL (CH. 5.1-5.5)

A1.1 LEVEL OF ABSTRACTION: INDIVIDUAL BILL OF QUANTITIES ITEMS: RESULTS OF PRELIMINARY ANALYSIS (CH. 5.1 & 5.2)

TABLE 2 "LEAST VALUE" ITEMS IN 3 PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES

Contract Nr	% Of Measured Items to give 20% value of Contract Sum	% Of All Items to give 20% value of Contract Sum
2977 [01]	77%	80%
80142/80309 [02]	72%	85%
72757 [13]	87%	88%

TABLE 3: SMALL VALUE ITEMS IN 3 PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES

CONTRACT NR	% OF CONTRACT SUM CONTAINED IN "SMALL VALUE" MEASURED ITEMS [SMALLEST 40%]	% OF CONTRACT SUM CONTAINED IN "SMALL VALUE" ITEMS [ALL ITEMS] [SMALLEST 40%]
Foundations, Drainage, Roads + Superstructure [01]	2.65	2.18
Demolition + Superstructure [02]	4.93	2.65
Steelwork [Ancillary] [13]	-	-

It should be noted that contract 13 was a separate contract for steelwork only and was not included in this section of the analysis.

A1.2 Level of Abstraction: Individual Bill of Quantities Items: Results of Comprehensive Analysis (Ch. 5.3 & 5.4)

Data from 15 contract Bills of Quantities for Petrochemical Civil Engineering, representing thousands of items (measured and unmeasured) were collected and statistically analysed. Eight of the Bills were measured using SMM5 and seven were measured using SMM6. The following comments are offered regarding the quantity, adequacy and suitability of the data and the constraints surrounding such data:

1) The 15 contracts available were regarded as being as comprehensive a sample as was possible to obtain; they represented an almost complete current or recent workload at the organisation in question.

2) The decision to exclude CESMM Bills from the analysis was based on the fact that there was only one such contract available. Results from one such contract could not be construed as being reliable, although there is persuasive evidence (see above) that Bills prepared using CESMM behave much like Bills prepared from SMM5 or SMM6.

3) No data on SMM7 (1988), which was at the time undergoing development elsewhere, were available. No data using other measurement systems were available.

4) Any experimentation or recommendations for a new approach to measurement, therefore, were considered best if they were based on the analysis of the bulk of the data which were available, ie from SMM5 and SMM6.

5) The total number of Bill Items (statistical cases) analysed was some 10 900, of which some 7 100 were in SMM5 Bills and some 3 800 from SMM6 Bills. Inferences from this would be ill-advised. Whilst it is true that SMM6 was intended to produce fewer items of detail this could not have been said with certainty prior to the analysis. Some buildings are large and some

small. Sometimes one building is "Billed", sometimes more than one, in the same document. The contracts analysed were as in Table 4.

TABLE 4: PROJECTS ANALYSED (SMM5 AND SMM6)

SMM5 Bills		SMM6 Bills	
Bill 2	Melinar Plant (1965=£110 100)	Bill 11	Methanol Offloading (1984=£83 700)
Bill 3	Ethoxylates Plant (1980=£381 800)	Bill 12	Effluent Pipeline (1984=£95 200)
Bill 4	Ammonium Nitrate Plant (1980=£211 700)	Bill 13	Caustic Plant Structural Steelwork (1984=£463 800)
Bill 5	Contol Room Building + Alterations (1977=£190 900)	Bill 14	HCl Reaction + Compressor Sections (1985=£77 600)
Bill 6	Protein Plant Site Development Wks (1977=£301 100)	Bill 15	Bagged Salt Warehouse Extension (1984=£239 600)
Bill 7	Control Room Building (1974=£253 500)	Bill 16	Anhydrous Caustic Plant (1984=£687 100)
Bill 8	Substations (1980=£379 400)	Bill 17	Cool Firing Cement Plant (1984=£410 800)
Bill 9	Laboratory Extension & Refurb (1982=£149 300)		

A1.3 Level of Abstraction: Individual Bill of Quantities Items: Results of Comprehensive Analysis (Ch. 5.3 & 5.4)

For each of the 15 Bills of Quantities the items in the Bill were ranked in order of value (highest first) and cumulative totals computed for each item as follows:

1) Percentage of items generated as each item was added and

2) Percentage of total value generated as each item was added.

The data at 5% intervals from (1) and (2) were then used to produce plots showing the rate of cost generation in each Bill (see Diagram 1). A technique was then applied which investigated whether the removal of small value items (which form the majority of items in any Bill) would produce only a marginal reduction of the total cost. Taking the figure of +5% accuracy in construction price forecasting to which practitioners aspire, but which certain commentators, including Ashworth and Skitmore (1983), consider to be over optimistic the smallest value items which together amounted only to some 5% of the total contract cost were isolated. The following calculations were made for each Bill:

1) The number of items so removed and

2) The percentage of the total of all Bill items so removed.

The results were tabulated (see Table 5).

TABLE 5: EFFECT OF REMOVING FROM PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES THE "SMALLEST VALUE" ITEMS WHICH COLLECTIVELY COMPRISED ONLY 5% OF THE BILL TOTAL (ALL ITEMS)

BILL NR	NR OF ITEMS REMOVED	% OF ITEMS REMOVED	SMM
2	194	52.86	5
3	542	64.18	5
4	786	66.61	5
5	862	76.69	5
6	636	70.59	5
7	877	84.25	5
8	827	77.07	5
9	438	73.37	5
11	206	57.70	6
12	82	78.85	6
13	207	73.67	6
14	283	57.99	6
15	87	61.27	6
16	1154	68.41	6
17	513	69.70	6

A1.4 "NORMALISING" THE DATA (CH. 5.5)

Data for all 15 Petrochemical Civil Engineering Bills of Quantities, representing thousands of items (measured and unmeasured), were analysed in order to produce the following statistics representative of the nature of their cost distribution within their respective Bills of Quantities:

a) Frequencies,

b) Mean values (normalised for ease of reference),

c) Standard Deviations,

d) Skewness of Distribution and

e) Maximum values.

These statistics were then reproduced following the removal of unmeasured items from the data sample, in order to gain indications of the effect upon the results of so doing. The results were tabulated (see Tables 6 and 7).

TABLE 6: DESCRIPTIVE STATISTICS INDICATING COST DISTRIBUTION IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES (SMM5)

Bill Nr	2	3	4	5	6	7	8	9
SMM5 [All Items] [1]								
Mean	01.00	01.00	01.00	01.00	01.00	01.00	01.00	01.00
Standard Deviation	05.16	04.96	03.92	07.53	04.77	08.60	05.45	10.18
Skewness	14.21	13.27	09.52	17.68	11.22	18.90	11.47	21.96
Maximum Value	86.67	100.06	58.08	186.46	74.82	217.68	99.01	239.95
SMM5 [Measured Items] [2]								
Mean	00.54	00.65	00.89	00.37	00.38	00.37	00.51	00.31
Standard Deviation	01.28	02.16	02.68	01.02	03.01	01.40	01.31	00.83
Skewness	07.76	08.80	06.90	07.17	09.61	07.84	06.00	09.94
Maximum Value	15.45	31.21	30.01	14.91	43.92	18.03	17.27	14.31
Sign of Difference [1-2]								
Mean	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Skewness	-	-	-	-	-	-	-	-
Maximum Value	-	-	-	-	-	-	-	-

TABLE 7: DESCRIPTIVE STATISTICS INDICATING COST DISTRIBUTION IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES (SMM6)

Bill Nr	11	12	13	14	15	16	17
SMM6 [All Items] [1]							
Mean	01.00	01.00	01.00	01.00	01.00	01.00	01.00
Standard Deviation	02.95	03.02	02.99	03.06	02.96	04.12	04.10
Skewness	06.35	04.47	06.17	07.35	06.98	11.00	08.54
Maximum Value	27.65	21.31	32.14	31.45	28.99	73.66	55.19
SMM6 [Measured Items] [2]							
Mean	00.85	01.38	01.03	00.78	01.22	00.81	00.86
Standard Deviation	02.22	03.56	03.09	02.14	03.33	02.84	03.56
Skewness	05.92	03.71	06.28	08.52	06.38	09.89	08.60
Maximum Value	20.77	21.31	32.14	31.13	28.99	54.31	45.96
Sign of Difference [1 - 2]							
Mean	-	+	+	-	+	-	-
Standard Deviation	-	+	+	-	+	-	-
Skewness	-	+	+	+	+	-	+
Maximum Value	-	=	=	-	=	-	-

The following comments are offered in respect of the data and their validity:

1) The entire population of cases were used (*vide supra*)

2) For ease of reference the data were first standardised by dividing the value of each case by its own Bill mean value. This removed the effect of "absolute" values as absolute values were not of prime importance for the purpose of this exercise. Also this provided a common basis for comparison and removed the effect of time.

3) It is worth noting that although all the data in the sample used had positive values (in cost terms) per case, it is possible for an item to have a negative value. This occurs, for example,

in demolition work, where a Tenderer may offer the owner a credit in respect of some saleable valuable material recovered during the demolition work. This phenomenon would not alter the validity of such data or results.

4) Aggregate functions were computed by Bill Number. That is, the data were first split by Bill Number and statistics produced by Bill, rather than by entire population, for comparison purposes.

TABLE 8: SKEWNESS OF DISTRIBUTION OF COST DATA IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES (ALL ITEMS IN BQ)

STATISTIC	SMM5 BILLS OF QUANTITIES:	SMM6 BILLS OF QUANTITIES:
Skewness	009.52 - 021.96	004.47 - 011.00
Maximum Value	058.08 - 239.95	021.31 - 003.66
Mean Value	001.00	001.00
Standard Deviation	003.92 - 010.18	002.95 - 004.12

TABLE 9: SKEWNESS OF DISTRIBUTION OF COST DATA IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES (MEASURED ITEMS ONLY)

STATISTIC	SMM5 BILLS OF QUANTITIES	SMM6 BILLS OF QUANTITIES
Skewness	06.00 - 09.94 [average 08.00]	03.71 - 09.89 [average 07.04]
Maximum Value	14.31 - 43.92 [average 23.14]	20.77 - 54.31 [average 33.52]
Mean Value	00.31 - 00.89 [average 00.56]	00.78 - 01.38 [average 00.99]
Standard Deviation	00.83 - 03.01 [average 01.71]	02.22 - 03.56 [average 02.96]

APPENDIX 2:

FORMULATION OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL (CH. 5.7-5.8)

LEVEL OF ABSTRACTION: TRADE: RESULTS OF ANALYSIS OF COST-INSIGNIFICANT PARAMETERS

The data were split by Trade and tabulations produced showing:

a) what percentage of all items belonged to each Trade,

b) what percentage of items in the lowest 20% value band resided in each Trade,

c) what percentage of items in the lowest 15% value band resided in each Trade,

d) what percentage of items in the lowest 10% value band resided in each Trade and

e) what percentage of items in the lowest 5% value band resided in each Trade.

Thus, for example, if an item resided in, say, the lowest 15% value band that item was one of those items which collectively amounted to only 15% of their respective Bill Total, based on the technique of "ranked order" distribution, lowest first. The following comments are offered regarding the data and their validity:

(1) The entire data population was analysed (see *Chapter 3.2*).

(2) Those items which collectively comprised only 5% of their respective Bill Totals (see earlier) were taken to be cost-insignificant items.

TABLE 9.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE (SMM5)

SMM5 BILLS	% OF	ITEMS	IN		
TRADE	TRADE TOTAL	LOWEST 20% BAND	LOWEST 15% BAND	LOWEST 10% BAND	LOWEST 5% BAND
Demolitions	3.9	3.6	3.3	3.1	2.2
Excavation + Earthwork	9.6	8.4	8.2	8.1	8.2
Piling	0.1	0.1	0.1	0.1	0.1
Concrete Work	21.3	19.7	19.3	18.5	17.3
Brickwork +Blockwork	6.9	6.7	6.7	6.9	7.2
Roofing	0.6	0.6	0.6	0.5	0.4
Carpentry	0.7	0.8	0.7	0.8	0.9
Joinery	8.4	9.0	9.2	9.1	9.6
Structural Steelwork	1.5	1.4	1.4	1.5	1.6
Metalwork	4.1	4.0	4.0	3.9	4.0
Plumbing	10.8	12.3	12.7	13.1	14.0
Electrical Installation	4.7	4.9	5.0	5.0	5.0
Finishings	6.1	5.8	5.9	5.9	6.0
Glazing	0.7	0.8	0.9	0.8	0.9
Painting + Decorating	4.6	4.9	5.0	5.1	5.1
Drainage	15.7	16.8	17.0	17.4	17.6
Fencing + Gates	0.1	0.1	0.1	0.1	0.1
	100.0	100.0	100.0	100.0	100.0

Diagram 1.1: SMM5 BQ: Trade Items As % Of "Lowest Cost" Bands

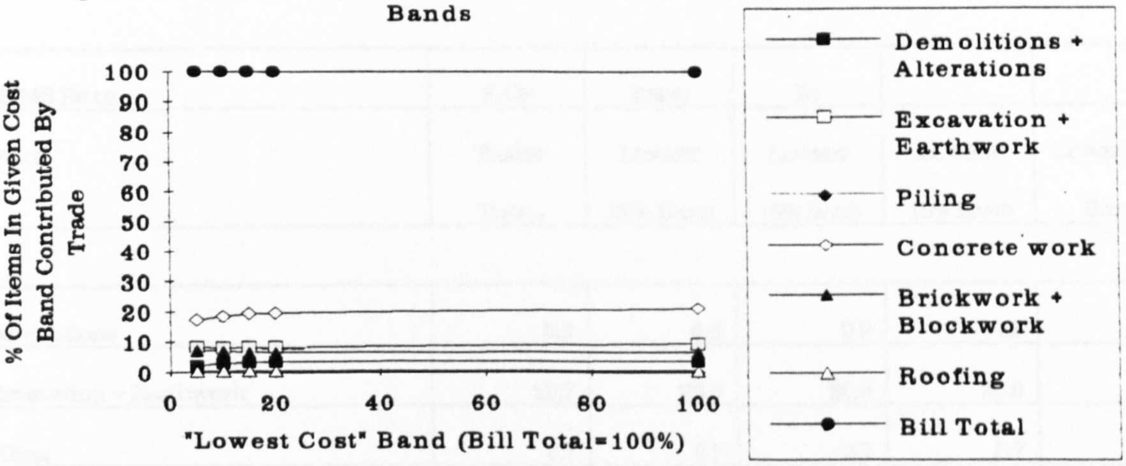


Diagram 1.2: SMM5 BQ: Trade Items As % Of "Lowest Cost" Bands

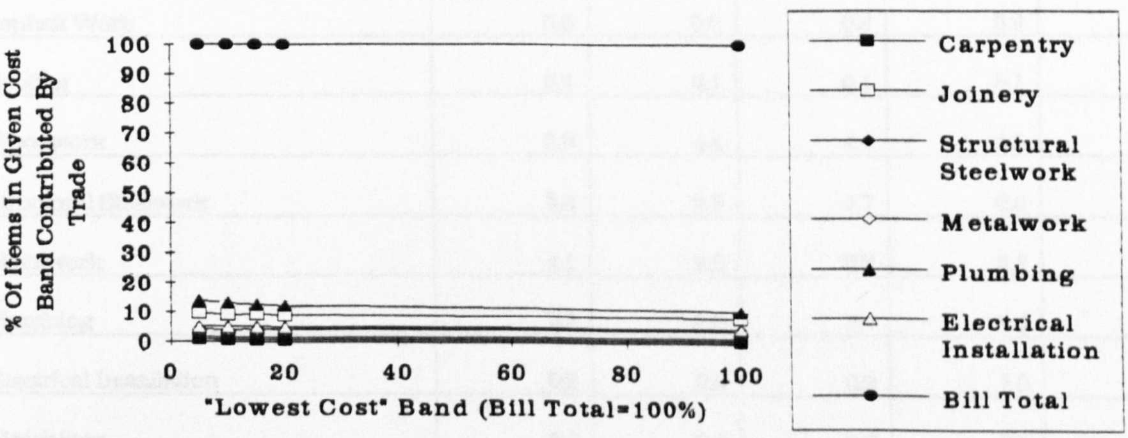


Diagram 1.3: SMM5 BQ: Trade Items As % Of "Lowest Cost" Bands

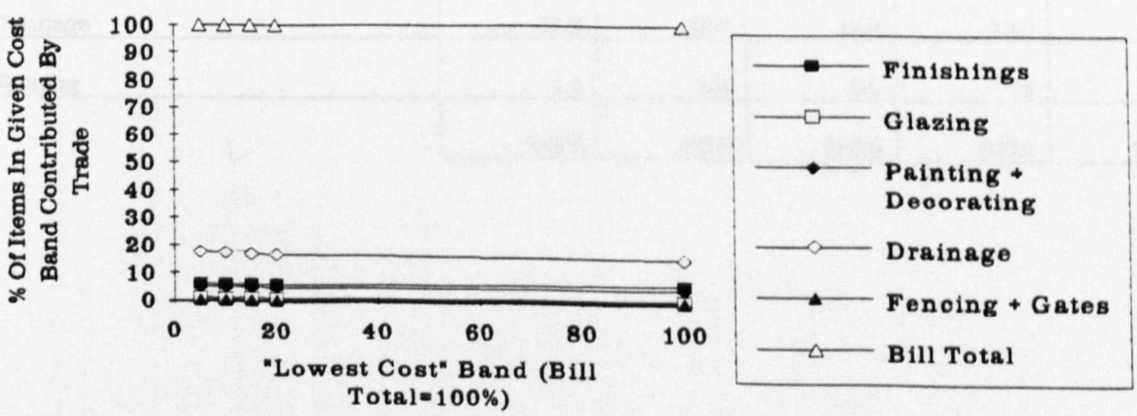


TABLE 9.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE (SMM6)

SMM6 BILLS	% OF	ITEMS	IN		
TRADE	TRADE TOTAL	LOWEST 20% BAND	LOWEST 15% BAND	LOWEST 10% BAND	LOWEST 5% BAND
Demolitions	0.9	0.6	0.9	0.8	0.7
Excavation + Earthwork	19.7	20.4	20.9	20.9	20.6
Piling	0.7	0.7	0.7	0.7	0.8
Concrete Work	39.8	36.9	35.9	34.6	32.5
Brickwork + Blockwork	2.4	2.5	2.6	2.6	2.8
Asphalt Work	0.8	0.8	0.8	0.8	0.8
Roofing	0.1	0.1	0.1	0.1	0.1
Woodwork	3.8	4.4	4.4	4.5	4.7
Structural Steelwork	5.4	5.5	5.7	6.0	6.5
Metalwork	4.1	3.8	3.7	3.8	4.0
Plumbing	2.9	3.2	3.4	3.6	4.1
Electrical Installation	0.8	0.9	0.9	1.0	1.1
Finishings	3.6	3.6	3.6	3.8	4.2
Glazing	0.3	0.4	0.4	0.4	0.5
Painting + Decorating	2.0	2.3	2.4	2.6	2.9
Drainage	11.6	12.7	12.9	13.0	13.2
Fencing	1.1	0.9	0.9	0.8	0.7
	100.0	100.0	100.0	100.0	100.0

Diagram 2.1: SMM6 BQ: Trade Items As % Of "Lowest Cost" Bands

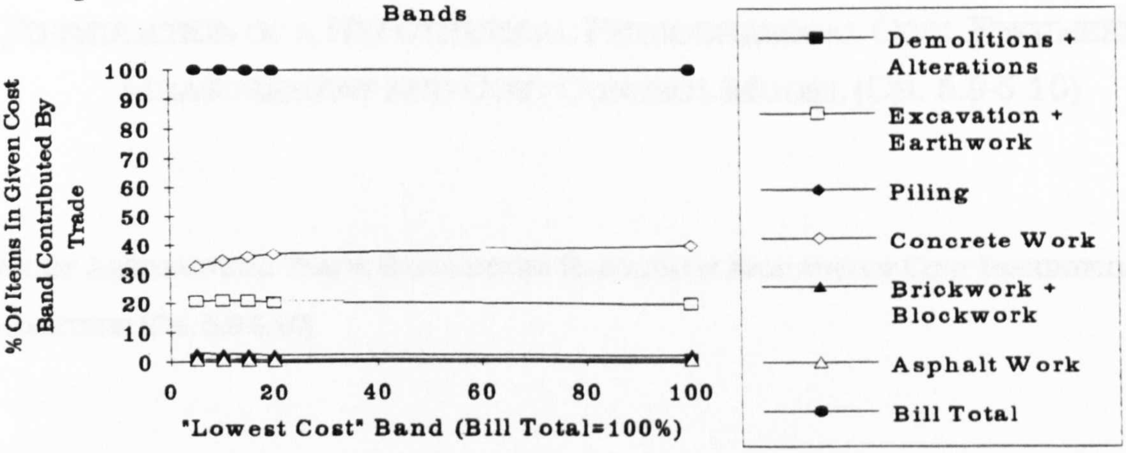


Diagram 2.2: SMM6 BQ: Trade Items As % Of "Lowest Cost" Bands

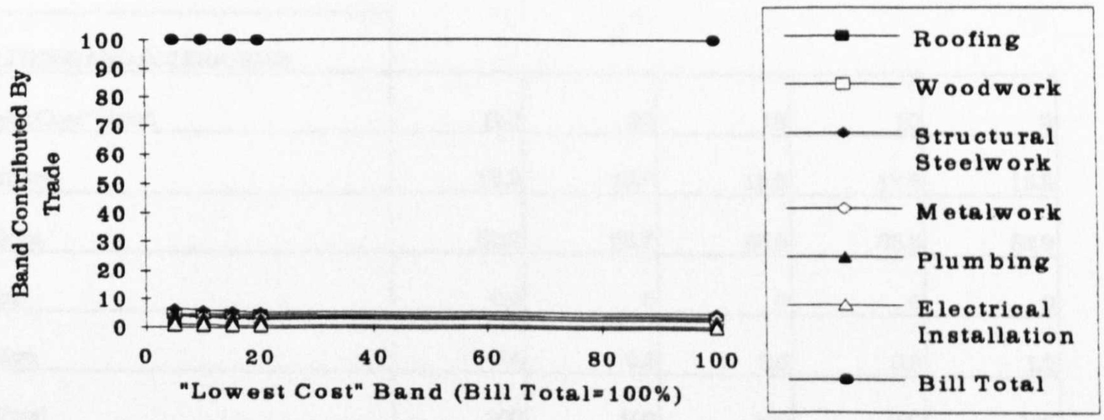
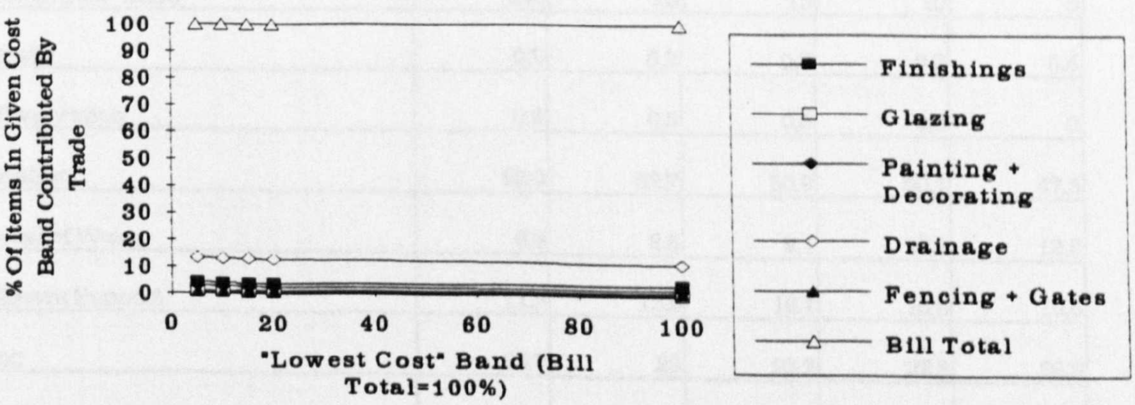


Diagram 2.3: SMM6 BQ: Trade Items As % Of "Lowest Cost" Bands



APPENDIX 3:
FORMULATION OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL (CH. 5.9-5.10)

LEVEL OF ABSTRACTION: TRADE SUBSECTION: RESULTS OF ANALYSIS OF COST-INSIGNIFICANT PARAMETERS (CH. 5.9-5.10)

TABLE 10.1: COST DISTRIBUTIONS IN "LOWEST COST" BANDS BY TRADE SUBSECTION (SMM5 BQ)

DEMOLITIONS AND ALTERATIONS					
% "Lowest Cost" Band	100	20	15	10	5
Demolitions	15.3	13.7	15.5	13.6	15.8
Alterations	83.8	85.7	83.9	85.6	82.9
Sundries	0.4	0	0	0	0
Protection	0.4	0.5	0.6	0.8	1.3
Trade Total	100	100	100	100	100

EXCAVATION + EARTHWORK					
% "Lowest Cost" Band	100	20	15	10	5
Generally	0.2	0.2	0.3	0.3	0.4
Site Preparation	0.5	0.5	0.5	0.3	0
Excavation	52.9	52.7	50.9	50.1	47.5
Disposal of Water	6.5	8.3	9.1	10.1	12.3
Earthwork Support	11.2	15.2	16.1	16.8	16.5
Filling	28.7	23	23.2	22.3	23.3
Trade Total	100	100	100	100	100

PILING					
% "Lowest Cost" Band	100	20	15	10	5
Generally	25	33.3	33.3	40	50
Wood or Concrete Piles	37.5	33.3	33.3	20	0
Sheet Steel Piling	37.5	33.3	33.3	40	50
Trade Total	100	100	100	100	100

CONCRETE WORK					
% "Lowest Cost" Band	100	20	15	10	5
Generally	0.3	0.3	0.2	0.1	0.2
Plain + Reinforced Concrete	32.7	31.1	30.3	29.1	29
Reinforcement	15.2	14.4	14.4	14	13.3
Formwork	27.5	27.4	28.2	29.5	29.5
Precast Concrete Units	0.2	0.1	0	0	0
Contractor-designed construction	0.1	0	0	0	0
Sundries	14.7	16.1	16.1	16.5	15.8
Protection	2.2	2.8	3.1	3.6	4.7
Trade Total	100	100	100	100	100

BRICKWORK + BLOCKWORK					
% "Lowest Cost" Band	100	20	15	10	5
Brickwork	20.8	17.7	17.4	17.7	16.1
Brick Facework	5.3	5.4	4.7	5.1	5.2
Facing Brickwork	20.3	18	17	16.3	15.7
Blockwork	20.1	18.3	18.9	19.4	19.7
Damp-proof Courses	9.6	12	12	12.2	13.7
Sundries	21.5	25.7	26.8	25.9	25.7
Protection	2.4	3	3.2	3.4	4
Trade Total	100	100	100	100	100

ROOFING					
% "Lowest Cost" Band	100	20	15	10	5
Profiled Sheet Roofing	23.7	20.7	23.1	21.7	13.3
Bitumen-felt Roofing	47.4	44.8	46.2	43.5	40
Flashings + Gutters	21.1	24.1	19.2	21.7	26.7
Protection	7.9	10.3	11.5	13	20
Trade Total	100	100	100	100	100

CARPENTRY					
% "Lowest Cost" Band	100	20	15	10	5
Structural Timbers	40.5	44.7	45.7	45.7	41.9
Boarding	4.8	2.6	2.9	2.9	3.2
Fillets, Grounds, Battens + Brackets	31	31.6	28.6	28.6	32.3
Sundries	11.9	10.5	11.4	11.4	9.7
Carpenter's Metalwork	11.9	10.5	11.4	11.4	12.9
Trade Total	100	100	100	100	100

JOINERY					
% "Lowest Cost" Band	100	20	15	10	5
Eaves + Verge Boarding	2.6	2.7	2.6	2.1	2.1
Linings, Casings + Partitions	1.4	1.1	1.2	1.3	1.5
Doors, Windows, Skylights	6.3	6.4	6.5	6.7	5.7
Frames, Sills, Kerbs	14.9	15.7	15.6	15.5	14.3
Fillets, Glazing-beads + Grounds	11.7	12.4	13	12.7	13.7
Skirtings, Architraves etc	4.4	4	3.5	3.6	3.3
Shelves, Table-tops + Seats	3	2.2	2.3	2.6	3
Sinks, Draining-boards + Backboards	0.4	0.4	0.5	0.5	0.6
Fittings + Fixtures	2.2	2.2	2.3	2.3	2.4
Staircases	1	1.1	1.2	1.3	1.5

Standard Units	14.3	10.8	9.3	6.7	5.1
Sundries	2.6	2.7	2.8	2.8	2.7
Ironmongery	34.1	36.7	37.7	39.9	42.4
Protection	1.4	1.5	1.6	1.8	1.8
Trade Total	100	100	100	100	100

STRUCTURAL STEELWORK					
% "Lowest Cost" Band	100	20	15	10	5
Generally	7.5	8.3	8.8	9.7	11.1
Grillages + Girders	6.5	2.8	2.9	3.2	0
Stanchions, Columns, Portal Frames	16.1	6.9	2.9	1.6	0
Roof Members, Braces, Struts + Rails	67.7	79.2	82.4	82.2	85.2
Sundries	2.2	2.8	3	3.3	3.7
Trade Total	100	100	100	100	100

METALWORK					
% "Lowest Cost" Band	100	20	15	10	5
Plates, Bars, Sections + Tubes	40.4	42	42.8	39.8	41.3
Wire Mesh, Expanded Metal	2.4	2.5	2.7	3	2.2
Composite Units	4.9	5.5	4.3	4.8	5.1
Standard Units	36.7	31	30.5	30.1	26.8
Sundries	10.6	13	13.4	15.1	15.9
Protection	4.9	6	6.4	7.2	8.7
Trade Total	100	100	100	100	100

PLUMBING ETC					
% "Lowest Cost" Band	100	20	15	10	5
Gutterwork	2.3	2.1	2.2	2.1	2.5
Rainwater Installation	5.8	5.5	5.2	5.2	5.1

Overflow Installation	2.6	2.8	2.9	3	3.5
Waste installation	11.6	11.4	11.8	12.3	13.6
Soil + Vent Installation	7.8	8.3	8.2	8.1	7.4
Cold Water Service	1.4	1.5	1.5	1.6	1.9
Trade Total	100	100	100	100	100
Water Mains	6	5.8	5.9	5.4	4.7
Equipment	0.2	0.2	0.2	0.2	0.2
Appliances	4.4	4.2	3.5	2.9	1.4
Sundries	2.9	3.1	3.2	3.2	3.7
Builder's Work	53.1	53.1	53.3	53.7	53.9
Protection	2.1	2.1	2.2	2.3	2.1
Trade Total	100	100	100	100	100

ELECTRICAL INSTALLATION					
% "Lowest Cost" Band	100	20	15	10	5
Equipment + Control Gear	0.7	0.4	0.4	0.5	0.6
Sundries	12.2	14.3	14.5	14.7	15.5
Builder's Work	84.6	82.4	82.1	81.5	79.9
Protection	2.4	2.9	3	3.3	4
Trade Total	100	100	100	100	100

FLOOR, WALL + CEILING FINISHES					
% "Lowest Cost" Band	100	20	15	10	5
Insitu Finishes	32.7	31.8	31.2	31.7	31.9
Tile, Slab + Block Finishes	32.2	34.3	35.5	35.3	35.7
Plain Sheet Finishes	14.3	12.5	12.3	11.6	11.4
Beds + Backings	9.7	8.7	8.8	7.6	5.7
Lathing + Baseboarding	1.1	1.4	1.4	1.2	1.4
Suspended Plain Sheet Linings	3.5	3.1	2.9	3.2	2.9

Protection	6.2	6.2	8.3	9.2	11
Fitted Carpeting	0.3	0.3	0	0	0
Trade Total	100	100	100	100	100

GLAZING					
% "Lowest Cost" Band	100	20	15	10	5
Glass In Openings	88.4	88.4	87.5	88.6	87.1
Mirrors	4.7	4.7	5	5.7	6.5
Protection	7	7	7.5	5.7	6.5
Trade Total	100	100	100	100	100

PAINTING + DECORATING					
% "Lowest Cost" Band	100	20	15	10	5
Painting etc	96.8	96.3	96.2	95.9	94.9
Polishing	0.7	0.8	0.8	0.9	1.1
Protection	2.5	2.8	3	3.2	4
Trade Total	100	100	100	100	100

DRAINAGE					
% "Lowest Cost" Band	100	20	15	10	5
Work In All Trades	96.4	96.1	95.9	95.8	95.9
Protection	2.5	2.8	3	3.2	4
Trade Total	100	100	100	100	100

FENCING + GATES					
% "Lowest Cost" Band	100	20	15	10	5
Open-type Fencing	83.3	80	100	100	100
Sundries	16.7	20	0	0	0
Trade Total	100	100	100	100	100

TABLE 10.2: COST DISTRIBUTIONS IN "LOWEST COST" BANDS BY TRADE SUBSECTION (SMM6 BQ)

DEMOLITIONS + ALTERATIONS					
% "Lowest Cost" Band	100	20	15	10	5
Generally	96.7	96.4	96	95.5	93.3
Protection	3.3	3.6	4	4.5	6.7
Trade Total	100	100	100	100	100

EXCAVATION + EARTHWORK					
% "Lowest Cost" Band	100	20	15	10	5
Generally	0.6	0.7	0.7	0.7	0.9
Site Preparation	1.9	2.1	2	2.2	2
Excavation	42.9	43.2	42.7	41	37.1
Earthwork Support	15.9	18	18.5	19.8	23
Disposal of Water	5.8	6.4	6.6	7.1	8.3
Disposal of Excavated Material	7.2	5.6	5.4	5.3	4.6
Filling	13	10.3	10.1	10.1	9.2
Surface Treatments	12.4	13.4	13.7	13.4	14.5
Protection	0.3	0.3	0.3	0.4	0.4
Trade Total	100	100	100	100	100

PILING					
% "Lowest Cost" Band	100	20	15	10	5
Piling	88.5	86.4	90	88.9	88.2
Diaphragm Walling	3.8	4.5	0	0	0
Protection	3.8	4.5	5	5.6	5.9
Unmeasured work	3.8	4.5	5	5.6	5.9
Trade Total	100	100	100	100	100

CONCRETE WORK					
% "Lowest Cost" Band	100	20	15	10	5
Generally	5	6.3	6.9	7.8	9.7
Insitu Concrete	44.3	44.6	44.3	43.8	42.9
Reinforcement	19.8	16.9	15.8	14.4	11.8
Formwork	25.2	25.7	26	26.1	26.2
Precast Concrete	3.3	3.4	3.7	4.2	4.7
Hollow Block Construction	0.1	0.1	0.1	0.1	0.1
Protection	2.4	3	3.2	3.7	4.6
Trade Total	100	100	100	100	100

BRICKWORK + BLOCKWORK					
% "Lowest Cost" Band	100	20	15	10	5
Generally	9.3	10.7	11	11.6	12.7
Brickwork	29.1	29.3	30.1	29	27
Facing Brickwork	20.9	17.3	16.4	17.4	17.5
Blockwork	8.1	6.7	5.5	5.8	4.8
Damp-proof Courses	7	8	8.2	8.7	9.5
Sundries	22.1	24	24.7	23.2	23.8
Protection	3.5	4	4.1	4.3	4.8
Trade Total	100	100	100	100	100

ASPHALT WORK					
% "Lowest Cost" Band	100	20	15	10	5
Mastic Asphalt	100	100	100	100	100
Trade Total	100	100	100	100	100

ROOFING					
% "Lowest Cost" Band	100	20	15	10	5
Bitumen-felt Roofing	100	100	100	100	100
Trade Total	100	100	100	100	100

WOODWORK					
% "Lowest Cost" Band	100	20	15	10	5
Carcassing	3	3.1	3.2	2.5	2.9
First Fixings	8.2	8.4	8.1	8.5	8.6
Second Fixings / Composite Items	45.5	44.3	42.7	42.4	40
Sundries	4.5	4.6	4.8	4.2	3.8
Ironmongery	38.1	38.9	40.3	41.5	43.8
Protection	0.7	0.8	0.8	0.8	1
Trade Total	100	100	100	100	100

STRUCTURAL STEELWORK					
% "Lowest Cost" Band	100	20	15	10	5
Generally	11.7	13.3	13.7	14.1	15.3
Steelwork	83	81.3	80.7	80.8	79.2
Protection	3.2	3.6	3.7	3.8	4.2
Unmeasured Work	2.1	1.8	1.9	1.3	1.4
Trade Total	100	100	100	100	100

METALWORK					
% "Lowest Cost" Band	100	20	15	10	5
Composite Items	52.4	50	50	51	53.4
Plates, Bars etc	35.2	37.7	38.7	38	37.5
Sheet Metal, Mesh etc	5.5	6.1	5.7	5	4.5
Holes, Bolts etc	5.5	4.4	3.8	4	2.8

Protection	1.4	1.8	1.9	2	2.3
Trade Total	100	100	100	100	100

PLUMBING ETC					
% "Lowest Cost" Band	100	20	15	10	5
Generally	11.7	13.3	13.7	14.1	15.3
Gutterwork	4	4.1	4.2	3.2	3.3
Rainwater Installation	8.9	9.3	9.4	9.6	10
Sanitary Installation	28.7	28.9	28.1	28.7	30
Hot + Cold Water Installation	5	5.2	5.2	5.3	5.6
Firefighting Installation	2	1	1	1.1	0
Chemical Installation	2	1	1	1.1	1.1
Other Equipment Installation	3	3.1	3.1	3.2	3.3
Equipment + Ancillaries	15.8	16.5	16.7	17	15.6
Sundries	7.9	8.2	8.3	8.5	8.8
Builder's Work	5	5.2	5.2	4.3	3.3
Protection	13.9	13.4	13.5	13.8	14.4
Trade Total	100	100	100	100	100

ELECTRICAL INSTALLATION					
% "Lowest Cost" Band	100	20	15	10	5
Generally	7.4	7.7	8	8	8.3
Conduit, Trunking etc	7.4	7.7	8	8	8.3
Cables	11.1	7.7	8	8	8.3
Builder's Work	70.4	73.1	72	72	70.8
Protection	3.7	3.8	4	4	4.2
Trade Total	100	100	100	100	100

FINISHES					
% "Lowest Cost" Band	100	20	15	10	5
Generally	3.2	3.7	3.9	4.1	4.3
Insitu Finishes	23.8	22.4	21.6	21.4	21.7
Beds + Backings	4.8	3.7	3.9	4.1	4.3
Tile, Slab + Block Finishes	27	27.1	26.5	25.5	23.9
Flexible Sheet Finishes	20.6	19.6	20.6	20.4	20.7
Dry Linings + Partitions	1.6	1.9	2	2	1.1
Suspended Ceilings	10.3	11.2	10.8	11.2	12
Protection	8.7	10.3	10.8	11.2	12
Trade Total	100	100	100	100	100

GLAZING					
% "Lowest Cost" Band	100	20	15	10	5
Glass in Openings	81.8	81.8	81.8	81.8	90
Mirrors	9.1	9.1	9.1	9.1	0
Protection	9.1	9.1	9.1	9.1	10
Trade Total	100	100	100	100	100

PAINTING + DECORATING					
% "Lowest Cost" Band	100	20	15	10	5
Painting + Polishing	98.6	98.6	98.5	98.5	98.5
Protection	1.4	1.4	1.5	1.5	1.5
Trade Total	100	100	100	100	100

DRAINAGE					
% "Lowest Cost" Band	100	20	15	10	5
Generally	2	2.1	2.2	2.4	2.7
Pipe Trenches	50	47.6	47	47.1	43.8

Manholes etc	40.9	42.6	42.9	42.4	44.5
Connections to Sewers etc	1.2	1.3	1.4	1.2	1
Testing	4.2	4.5	4.6	5	5.5
Protection	1.7	1.8	1.9	2.1	2.4
Trade Total	100	100	100	100	100

FENCING + GATES					
% "Lowest Cost" Band	100	20	15	10	5
Open-type Fencing	57.5	48.1	52	57.1	60
Gates	7.5	11.1	8	4.8	6.7
Sundries	32.5	37	36	33.3	26.7
Protection	2.5	3.8	4	4.8	6.6
Trade Total	100	100	100	100	100

TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION (SMM5 BQ)

SMM5 Trade	SMM5 Subsection	Tendency Towards Cost -Insignificant Items
3 Demolitions + Alterations	1 Generally	no data
	2 Demolitions	no real tendency
	3 Alterations	no real tendency
	4 Sundries	generally larger items [discernible]
	5 Protection	no real tendency

Diagram 4.1

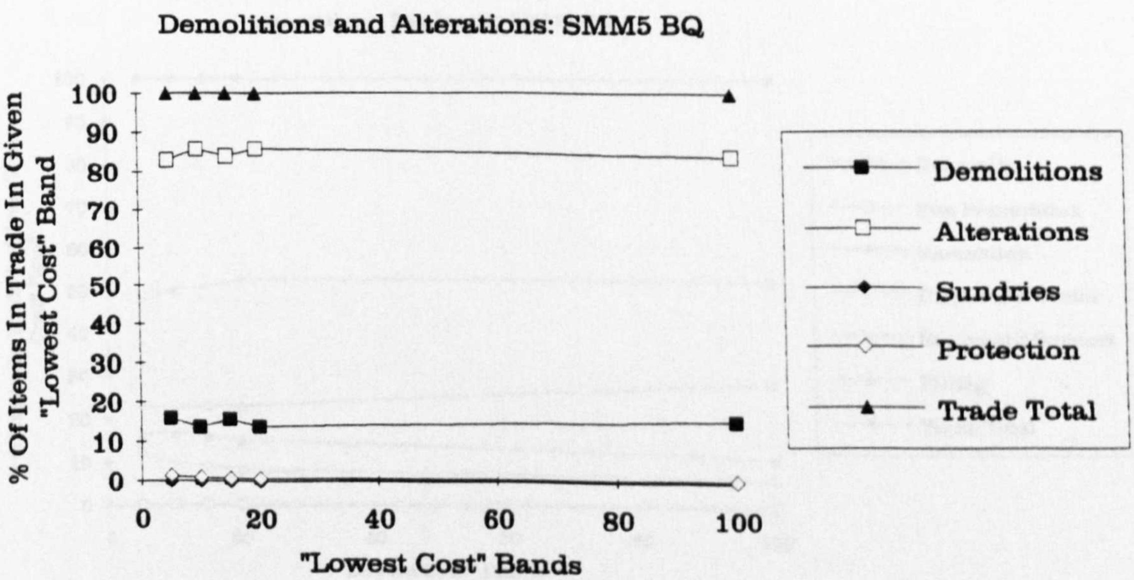


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM5 Subsection	Tendency Towards Cost -Insignificant Items
4 Excavation + Earthwork	1 Generally	no real tendency
	2 Site Preparation	generally larger items [marginal]
	3 Excavation	generally larger items [marginal]
	4 Disposal of Water	no real tendency
	Planking + Strutting	generally smaller items [discernible]
	6 Hardcore Filling	no real tendency

Diagram 4.2

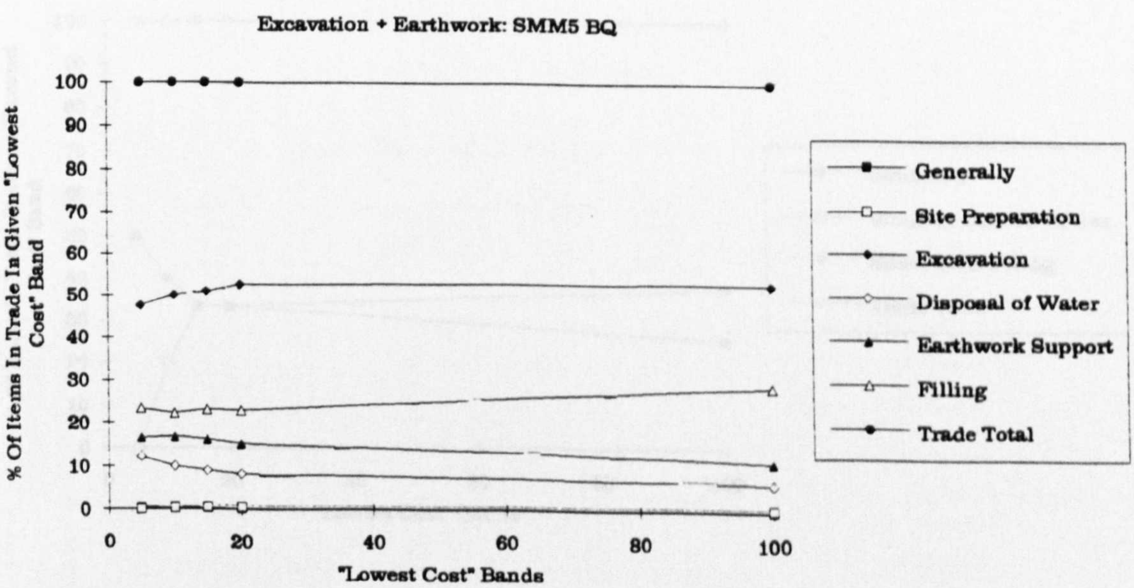


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM5 Subsection	Tendency Towards Cost-Insignificant Items
5 Piling	1 Generally	no real tendency
	2 Site Preparation	generally larger items [marginal]
	3 Contractor - Designed Concrete Piles	no data
	4 Sheet Steel Piling	no real tendency

Diagram 4.3

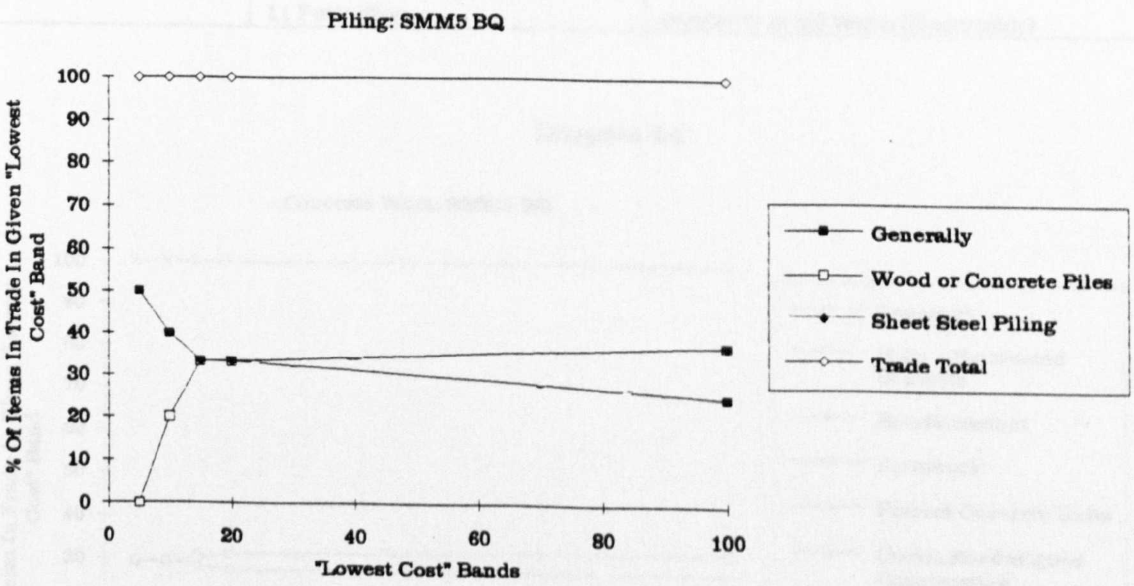


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM5 Subsection	Tendency Towards Cost-Insignificant Items
6 Concrete Work	1 Generally	no real tendency
	2 Plain + Reinforced Concrete	generally larger items [marginal]
	3 Reinforcement	generally larger items [marginal]
	4 Formwork	no real tendency
	5 Precast Concrete Units	no real tendency
	6 Hollow-block Suspended Construction	no data
	7 Prestressed Concrete	no data
	8 Precast Prestressed Units	insufficient data
	9 Contractor-designed Construction	no real tendency
	10 Sundries	no real tendency
	11 Protection	generally small items (discernible)

Diagram 4.4

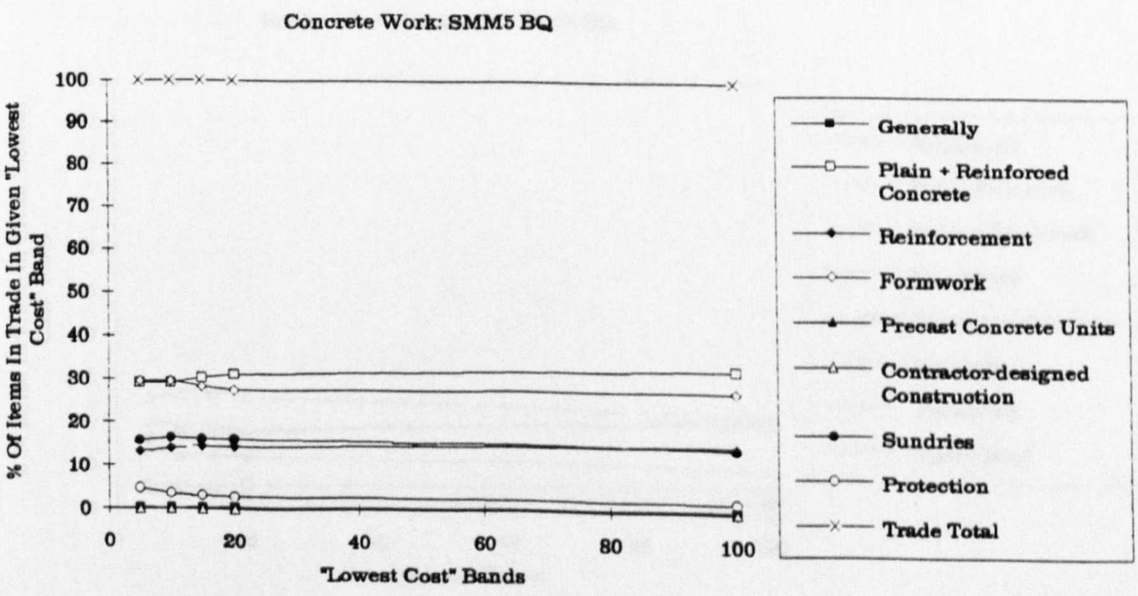


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5 Trade	SMM 5 Subsection	Tendency Towards Cost Insignificant Items
Brickwork + Blockwork	1 Generally	no data
	2 Brickwork	generally larger items (discernible)
	3 Brick Facework	no real tendency
	4 Facing Brickwork	generally larger items (discernible)
	5 Brickwork in connection with Boilers	no data
	6 Blockwork	no real tendency
	7 Damp-proof Courses	generally small items (discernible)
	8 Sundries	generally small items (discernible)
	9 Centering	no data
	10 Protection	generally small items

Diagram 4.5

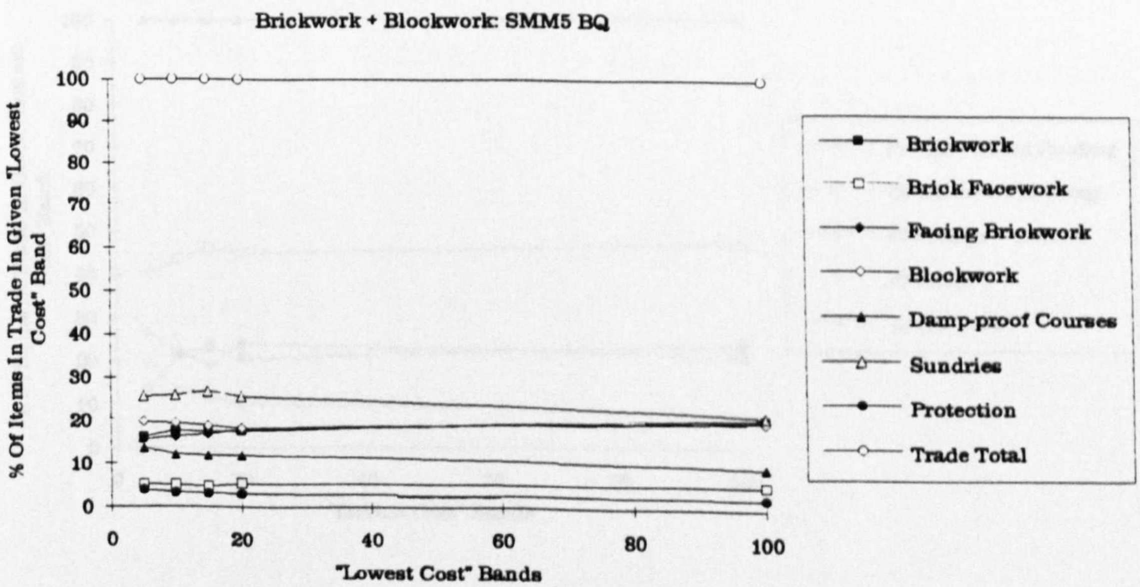


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM 5 Subsection	Tendency Towards Cost Insignificant Items
12 Roofing	1 Generally	no data
	2 Slate or Tile Roofing	no data
	3 Corrugated or Troughed Sheet Roofing	no real tendency
	4 Thatch Roofing	no data
	5 Roof Decking	no data
	6 Bitumen - Felt Roofing	generally larger items (marginal)
	7 Sheet Metal Roofing	no data
	8 Sheet Metal Flashings + Gutters	generally small items (discernible)
	9 Protection	generally small items (discernible)

Diagram 4.6

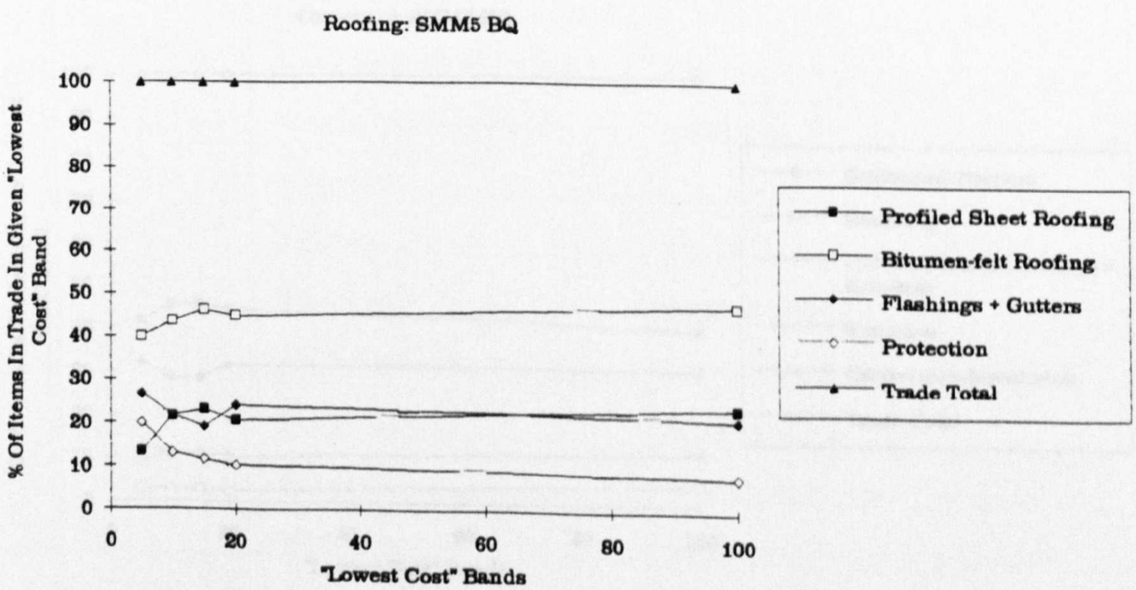


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM5 Subsection	Tendency Towards Cost -Insignificant Items
13 Carpentry	1 Generally	no data
	3 Structural	generally small items (discernible)
	4 Boarding	insufficient data
	5 Fillets Grounds Battens + Bracketing	generally small items(marginal)
	6 Sundries	no real tendency
	7 Metalwork	generally small items (marginal)

Diagram 4.7

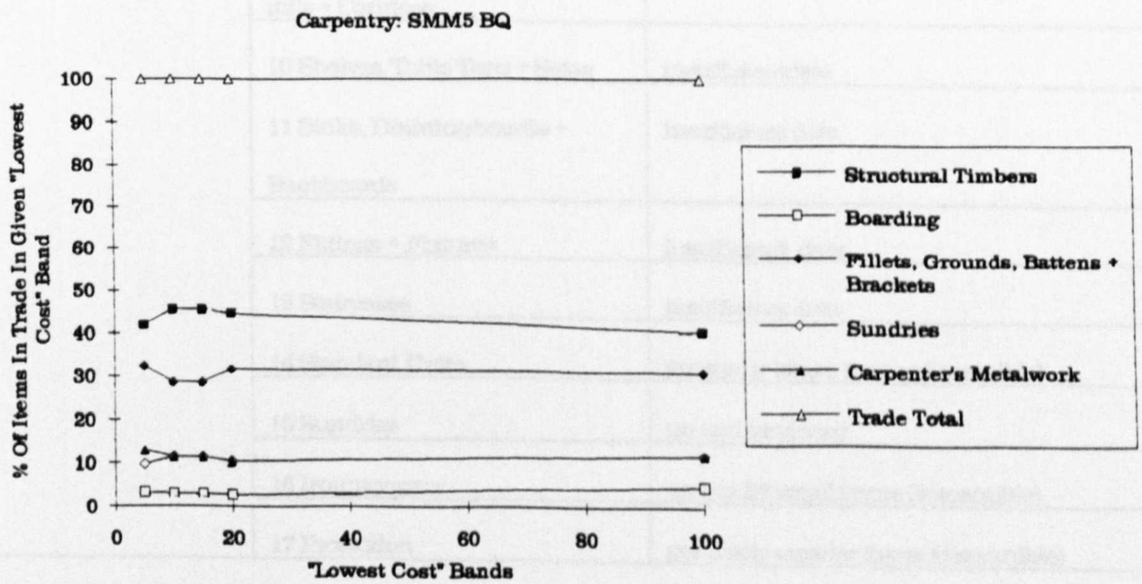


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM5 Subsection	Tendency Towards Cost - Insignificant Items
14 Joinery	1 Generally	no data
	2 Flooring	no data
	3 Eaves + Verge oarding	generally larger items (marginal)
	5 Plain or Panelled Linings, Casings + Partitions	insufficient data
	6 Doors, Windows, Skylights + Lanterns	no real tendency
	7 Frames, Sills + Kerbs	no real trend
	8 Fillets Glazing Beads + Grounds	generally small items(marginal)
	9 Skirtings, Architraves, Picture-rails + Cornices	generally larger items (marginal)
	10 Shelves, Table Tops + Seats	insufficientdata
	11 Sinks, Draining-boards + Backboards	insufficient data
	12 Fittings + Fixtures	insufficient data
	13 Staircases	insufficient data
	14 Standard Units	generally larger items (discernible)
	15 Sundries	no real tendency
	16 Ironmongery	generally small items (discernible)
	17 Protection	generally smaller items (discernible)

Diagram 4.8

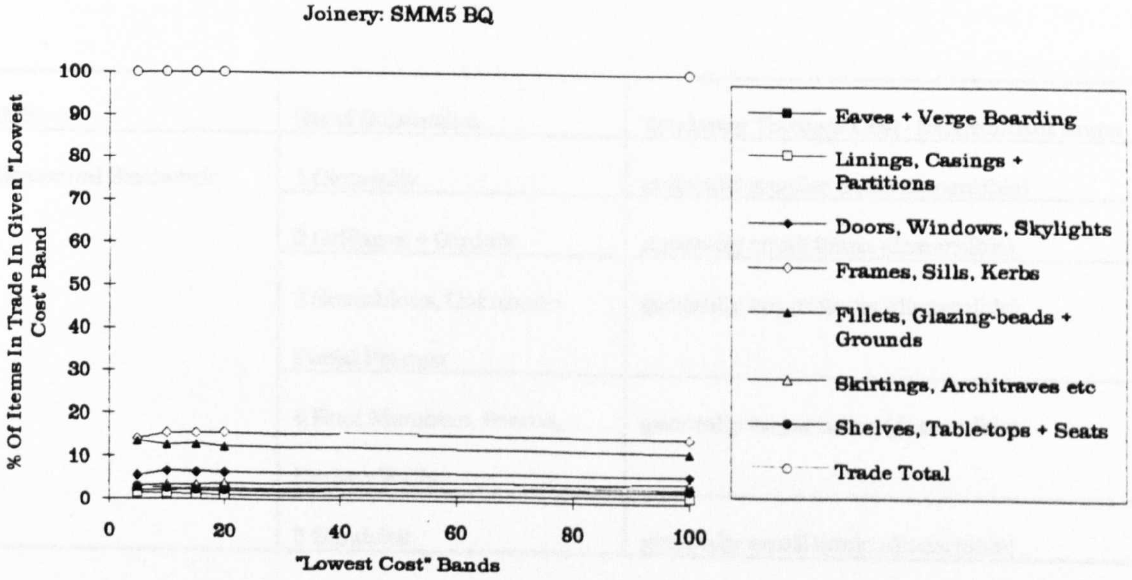


Diagram 4.8

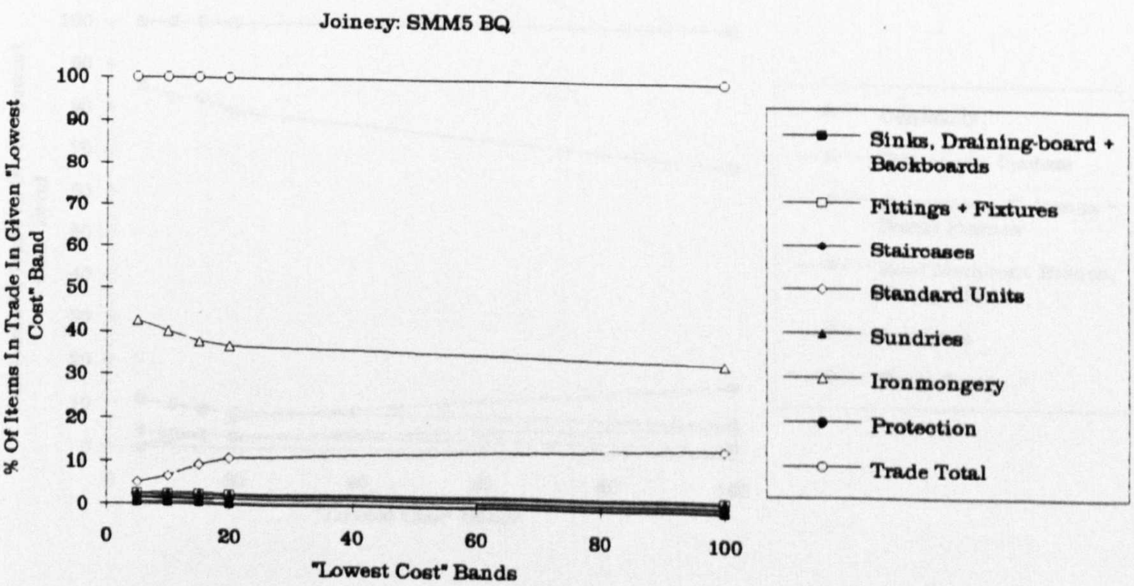


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost - Insignificant Items
15 Structural Steelwork	1 Generally	generally smaller items discernible)
	2 Grillages + Girders	generally small items (discernible)
	3 Stanchions, Columns + Portal Frames	generally larger items (discernible)
	4 Roof Members, Braces, Struts + Rails	generally larger items (discernible)
	5 Sundries	generally small items (discernible)

Diagram 4.9

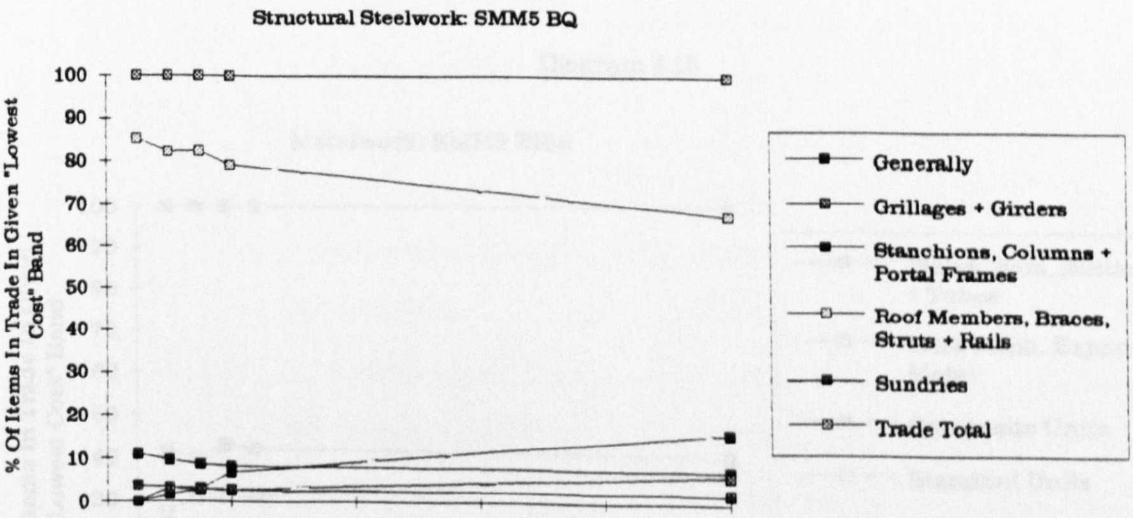


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost - Insignificant Items
16 Metalwork	1 Generally	no data
	2 Plates, Bars, Sections + Tubes	no real tendency
	3 Sheet Metal	no data
	4 Wire Mesh or Expanded Metal	no real tendency
	5 Composite Units	generally small items (marginal)
	6 Standard Units	generally larger items (discernible)
	7 Sundries	generally small items (discernible)
	8 Carpenter's Metalwork	no data
	9 Protection	generally small items (discernible)

Diagram 4.10

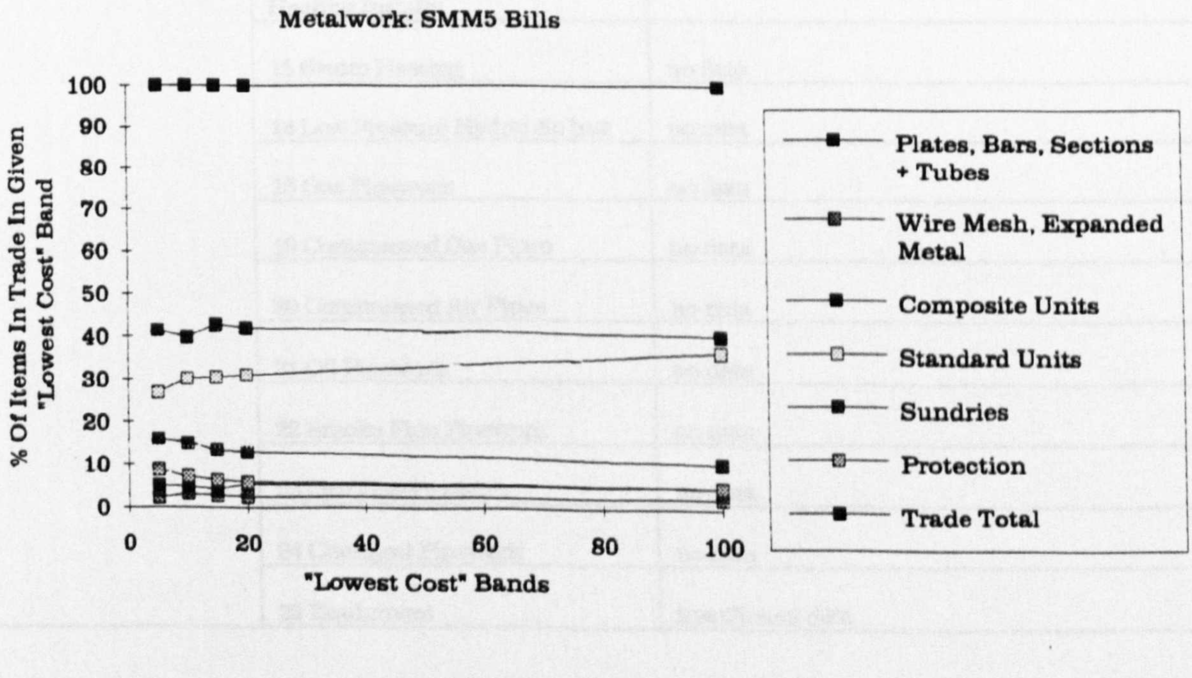


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost - Insignificant Items
17 Plumbing	1 Generally	no data
	2 Gutterwork	no real tendency
	3 Rainwater Installation	generally larger items (marginal)
	4 Overflow Installation	generally small items (discernible)
	5 Waste Installation	generally small items (marginal)
	6 Soil + Vent Installation	no real tendency
	7 Cold Water Service	generally small items (discernible)
	8 High Pressure Cold Water	no data
	9 Water Mains	generally larger items (discernible)
	10 Cooling-Water Installn	no data
	11 Condense Water Instn	no data
	12 Hot Water Service	no data
	13 Low Pressure Hot Water Heating Installn	no data
	14 High Pressure Hot Water Heating Installn	no data
	15 Steam Heating	no data
	16 Low Pressure Hydraulic Inst	no data
	18 Gas Pipework	no data
	19 Compressed Gas Pipes	no data
	20 Compressed Air Pipes	no data
	21 Oil Pipework	no data
	22 Smoke Flue Pipework	no data
	23 Gas Flue Pipework	no data
	24 Chemical Pipework	no data
	25 Equipment	insufficient data

TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost - Insignificant Items
Plumbing (Contd)	26 Appliances	generally larger items (discernible)
	29 Sundries	generally small items (discernible)
	31 Builder's Work	no real tendency
	32 Protection	generally small items (discernible)

Diagram 4.11

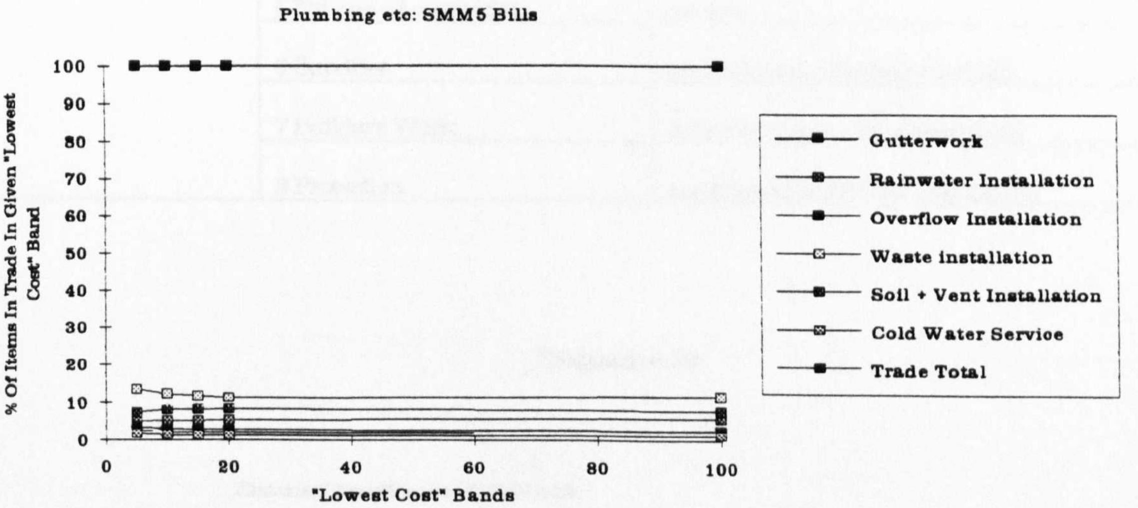


Diagram 4.12

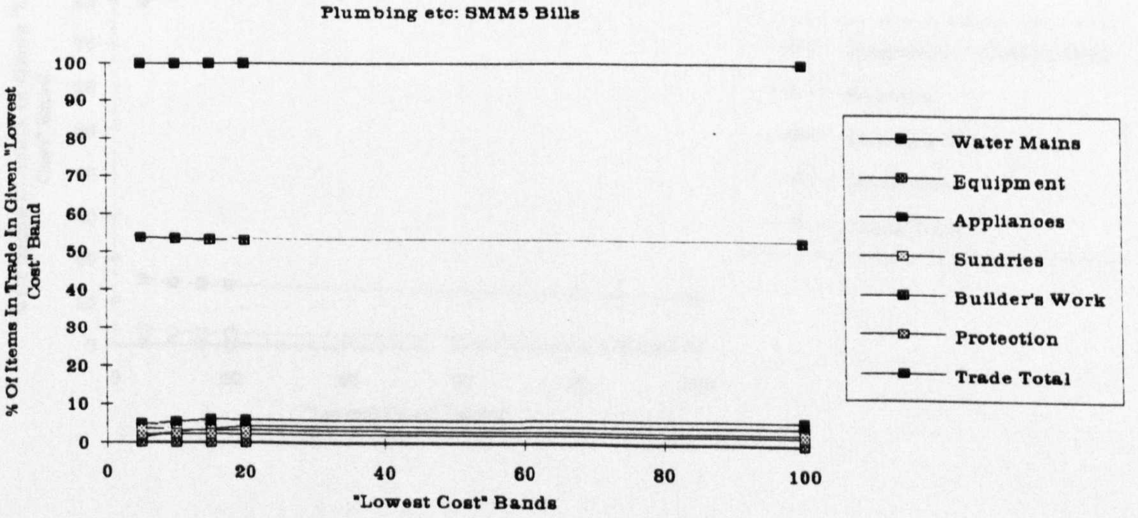


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost -Insignificant Items
18 Electrical Installation	1 Generally	no data
	2 Equipment + Control Gear	insufficient data
	3 Conduits, Trunking + Tray	no data
	4 Cables +Conductors	no data
	5 Fittings +Accessories	no data
	6 Sundries	generally small items (marginal)
	7 Builder's Work	generally larger items (marginal)
	8 Protection	generally small items (discernible)

Diagram 4.13

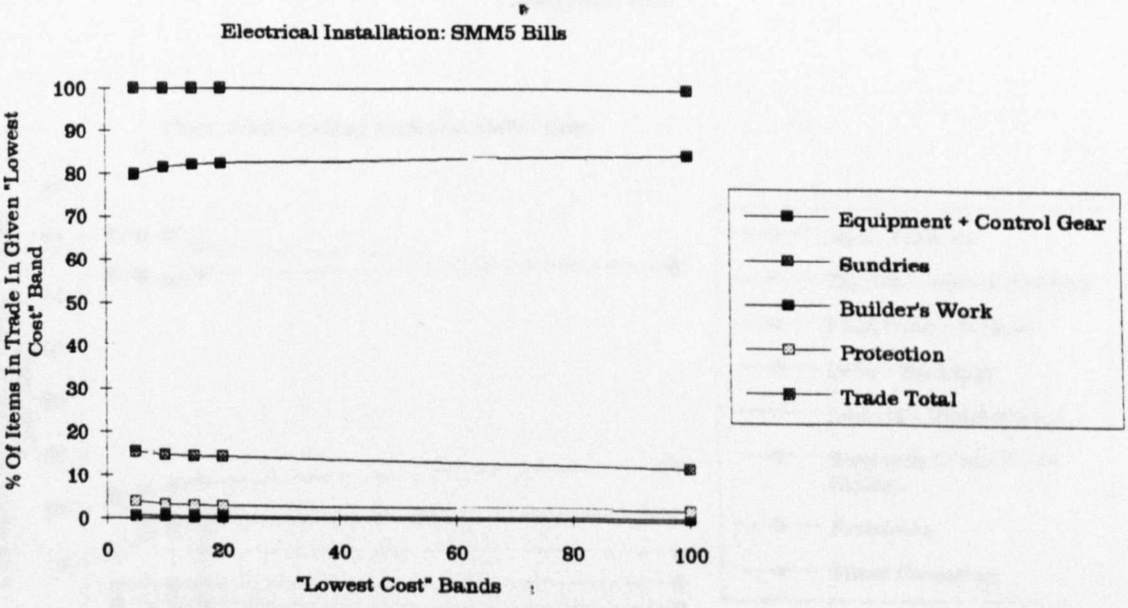


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost -Insignificant Items
19 Floor, Wall+ Ceiling Finishings	1 Generally	no data
	2 Insitu Finishings	no real tendency
	3 Tile, Slab or Block Finishings	generally small items (marginal)
	4 Plain Sheet Finishings	generally larger items (marginal)
	5 Beds + Backings	generally larger items (discernible)
	6 Lathing + Baseboarding	insufficient data
	7 Suspended Plain Sheet Linings	generally larger items (marginal)
	8 Fibrous Plaster	no data
	9 Self-Finished Partitions	no data
	10 Protection	generally small items (discernible)
	11 Fitted Carpeting	insufficient data

Diagram 4.14

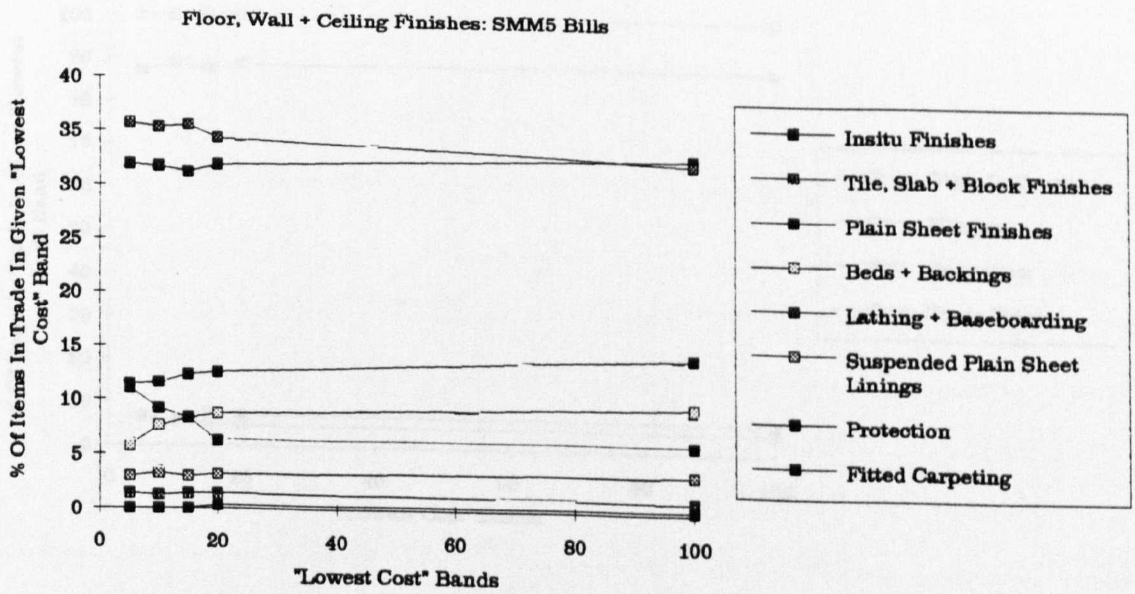


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost -Insignificant Items
20 Glazing	1 Generally	no data
	2 Glass in Openings	no real tendency
	3 Leaded Lights + Copper Lights in Openings	no data
	4 Mirrors	insufficient data
	5 Patent Glazing	no data
	6 Dome-Lights	no data
	9 Protection	insufficient data

Diagram 4.15

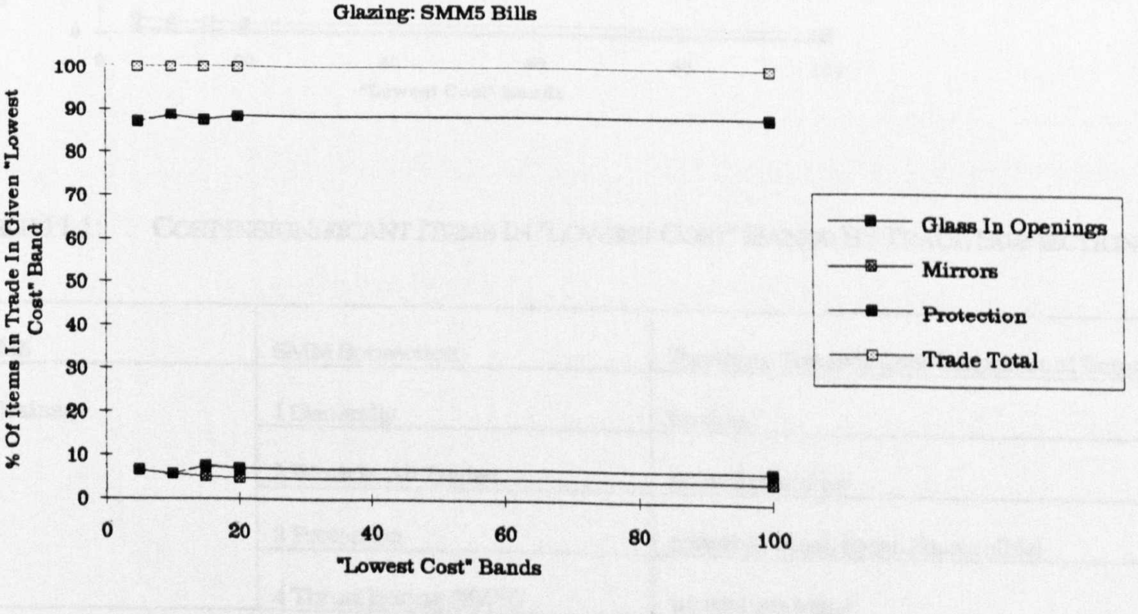


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost-Insignificant Items
21 Painting + Decorating	1 Generally	no data
	2 Painting etc	no real tendency
	3 Polishing	insufficient data
	4 Signwriting	no data
	5 Paperhanging	no data
	6 Protection	generally small items (discernible)

Diagram 4.16

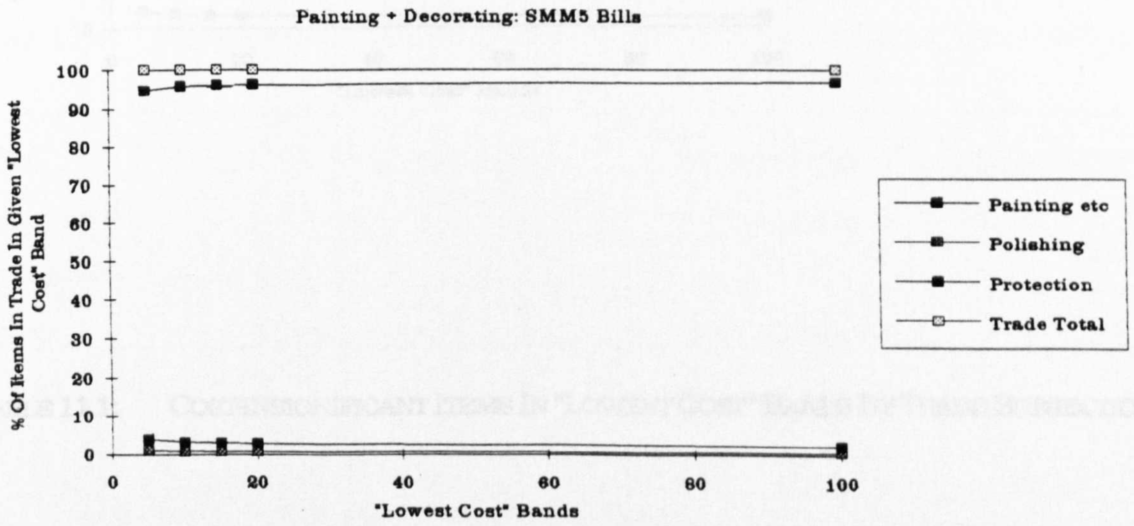


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost-Insignificant Items
22 Drainage	1 Generally	no data
	2 Work in All Trades	no real tendency
	3 Protection	generally small items (discernible)
	4 Thrust Boring (BWIC	no real tendency

Diagram 4.17

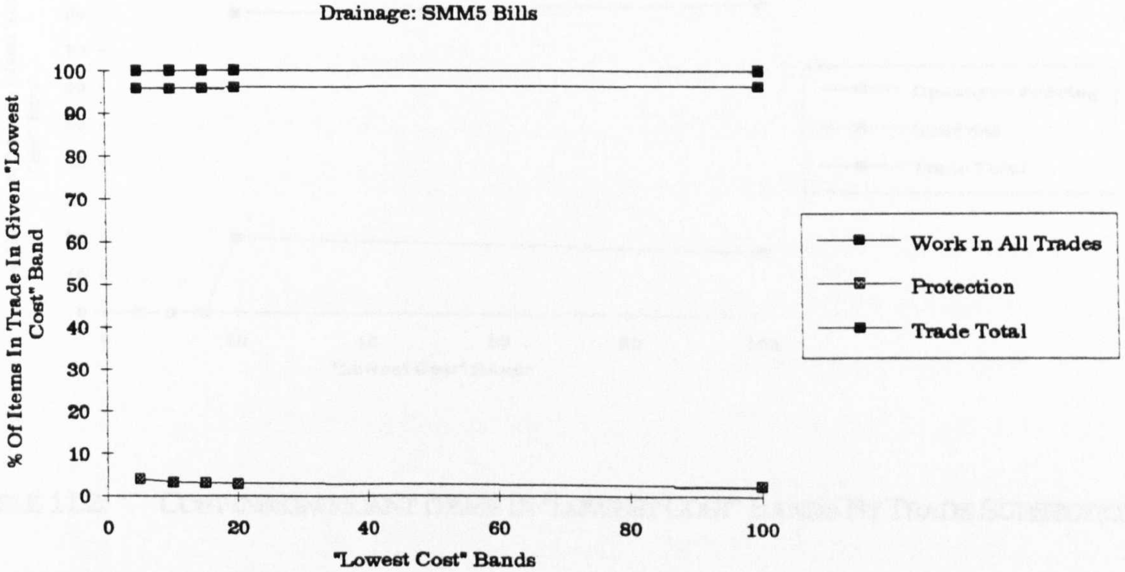


TABLE 11.1: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM5	SMM Subsection	Tendency Towards Cost-Insignificant Items
23 Fencing + Gates	1 Generally	no data
	2 Open-Type Fencing	insufficient data
	3 Close-Type Fencing	no data
	4 Gates	no data
	5 Sundries	insufficient data

Diagram 4.18

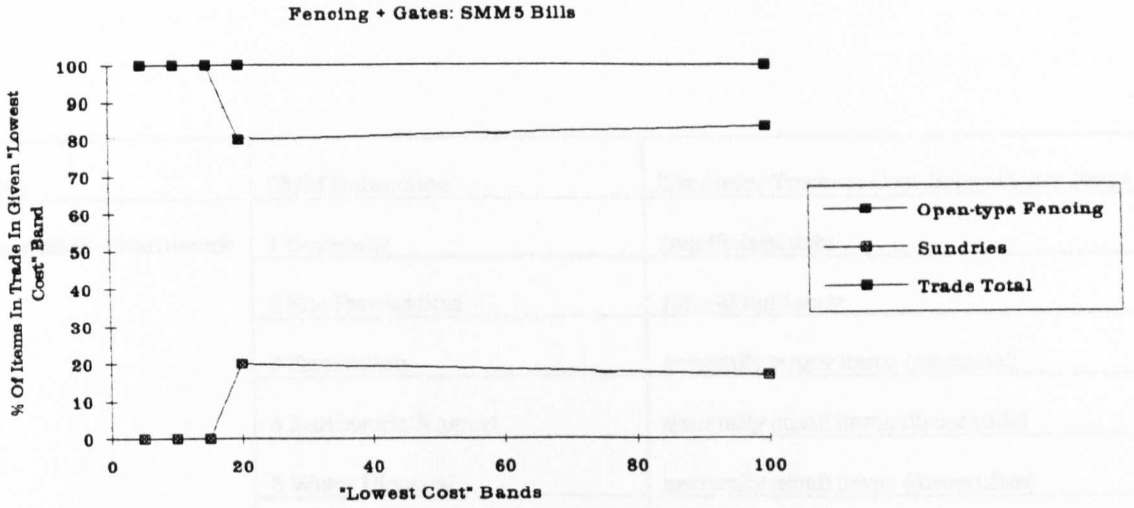


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost-Insignificant Items
3 Demolitions + Alterations	1 Generally	generally larger items (marginal)
	2 Protection	insufficient data

Diagram 5.1

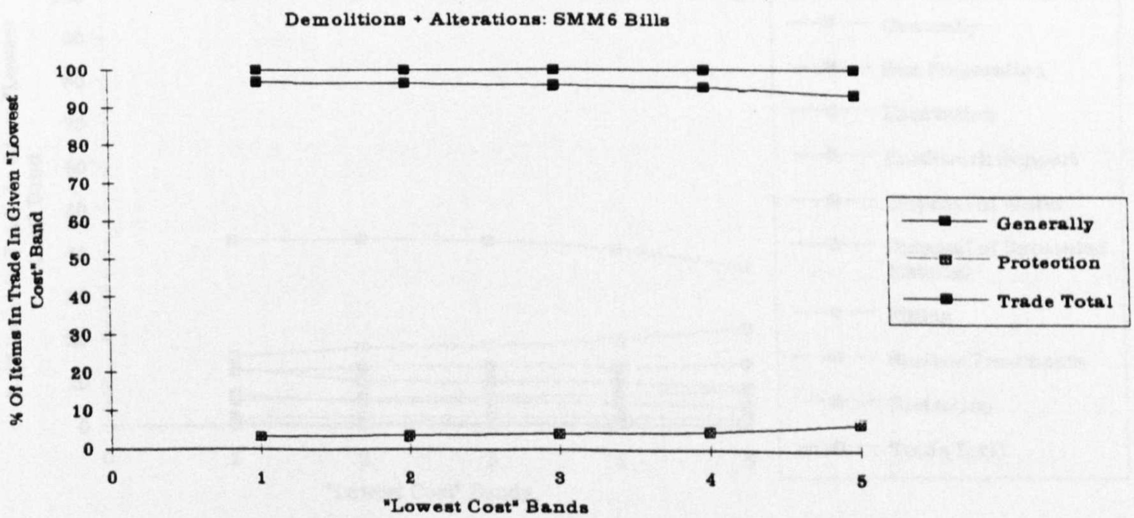


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
4 Excavation + Earthwork	1 Generally	insufficient data
	2 Site Preparation	no real tendency
	3 Excavation	generally larger items (marginal)
	4 Earthwork Support	generally small items discernible)
	5 Water Disposal	generally small items (discernible)
	6 Excavated Material Disposal	generally larger items (discernible)
	7 Filling	generally larger items (discernible)
	8 Surface Treatments	generally small items (marginal)
	9 Protection	insufficient data

Diagram 5.2

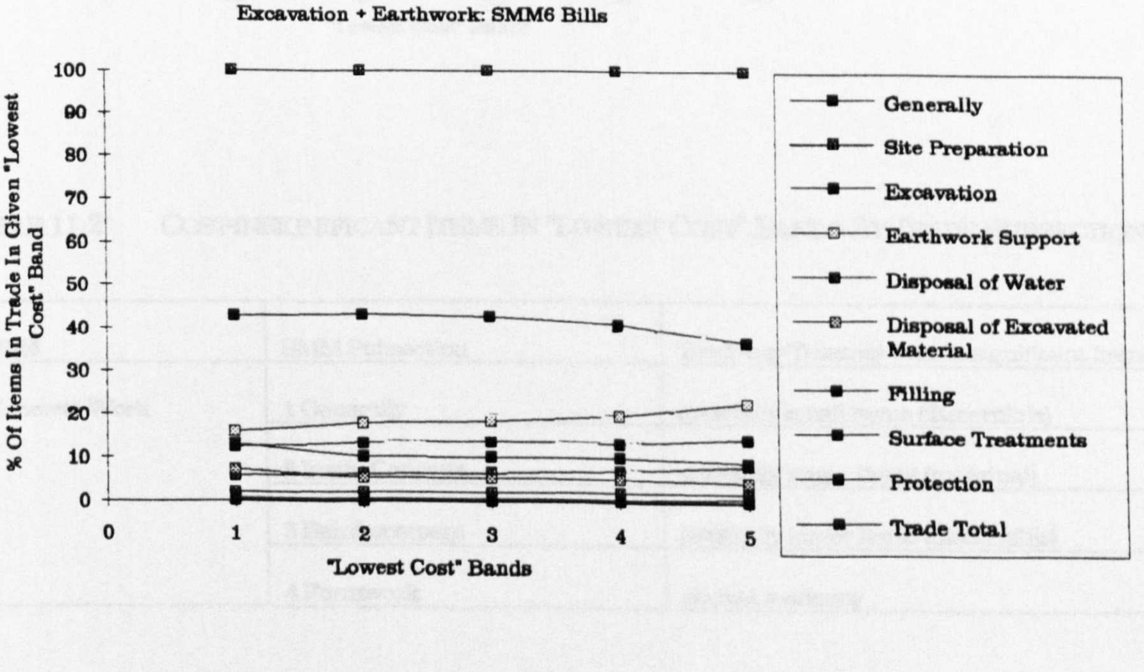


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost-Insignificant Items
5 Piling etc	1 Piling	no real tendency
	2 Diaphragm Walling	insufficient data
	3 Protection	insufficient data
	4 Unmeasured Work	insufficient data

Diagram 5.3

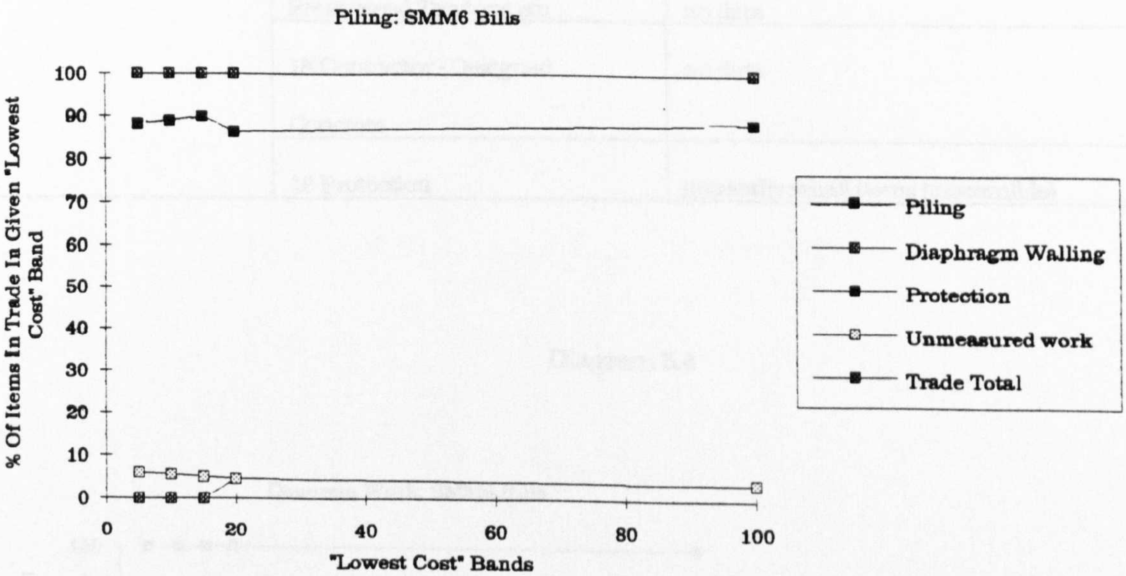


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost-Insignificant Items
6 Concrete Work	1 Generally	generally small items (discernible)
	2 Insitu Concrete	generally larger items (marginal)
	3 Reinforcement	generally larger items (discernible)
	4 Formwork	no real tendency

6 Concrete Work (Contd)	5 Precast Concrete	generally small items (marginal)
	7 Composite Insitu Concrete	no data
	8 Composite Reinforcement	no data
	9 Composite Formwork	no data
	11 Hollow Block Construction	insufficient data
	12 Prestressed Insitu Concrete	no data
	13 Prestressed Reinforcement	no data
	14 Prestressed Formwork	no data
	16 Prestressed Precast Concrete	no data
	Prestressed Tendons etc	no data
	18 Contractor - Designed Concrete	no data
	19 Protection	generally small items (discernible)

Diagram 5.4

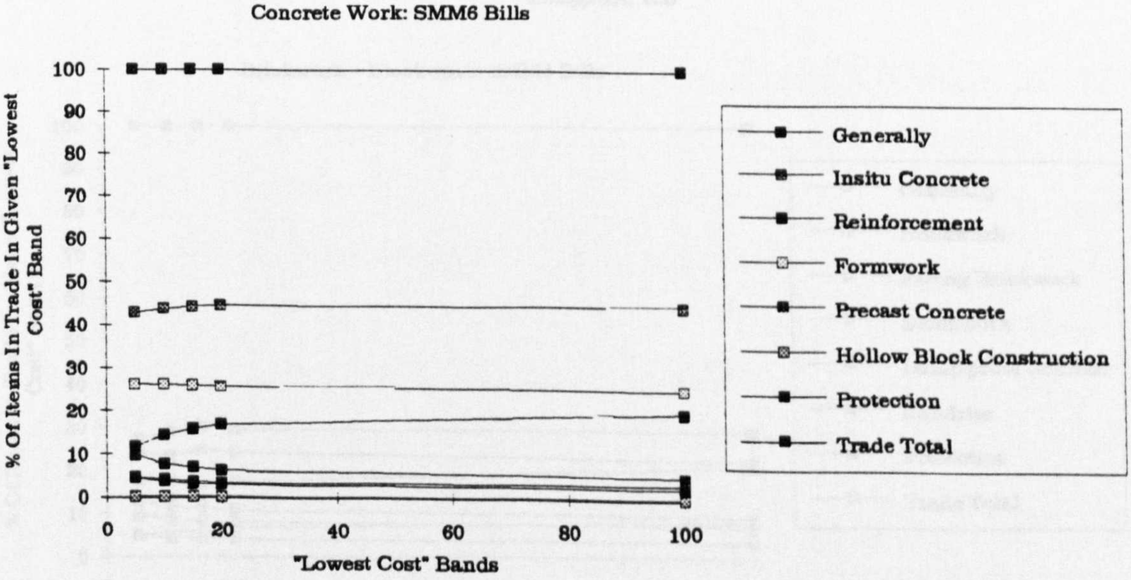


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
7 Brickwork + Blockwork	1 Generally	generally small items (discernible)
	2 Brickwork	generally larger items (marginal)
	3 Brick Facework	no data
	4 Facing Brickwork	generally larger items (marginal)
	5 Brickwork in Connection with Boilers	no data
	6 Blockwork	insufficient data
	7 Damp-proof Courses	insufficient data
	8 Sundries	generally small items (marginal)
	9 Protection	insufficient data

Diagram 5.5

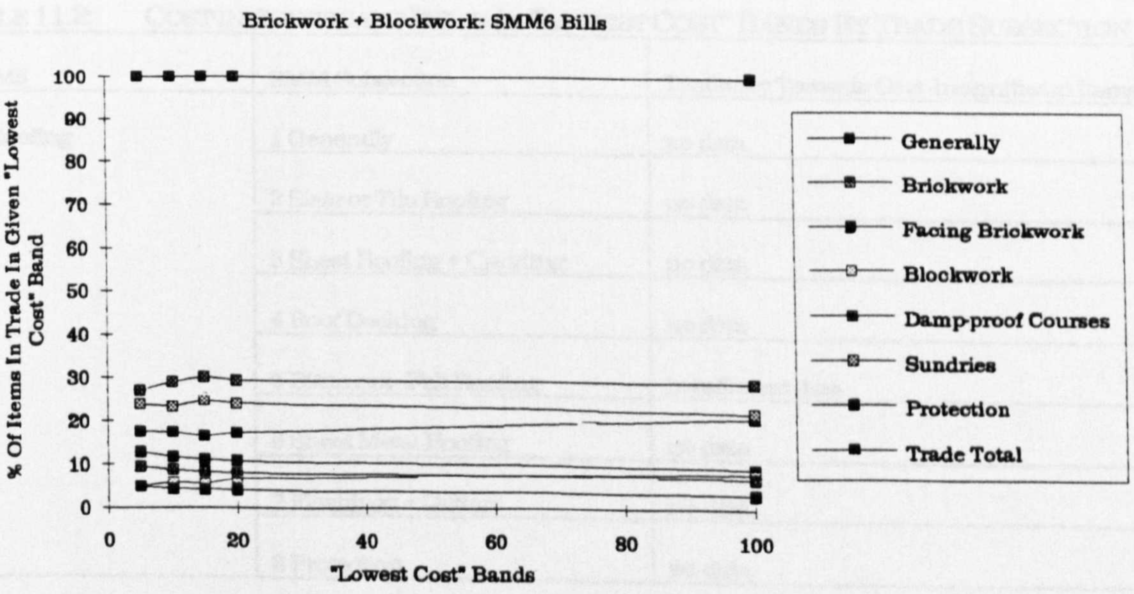


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost-Insignificant Items
11 Asphalt Work	1 Generally	no data
	2 Mastic Asphalt	no real tendency
	3 Protection	no data

Diagram 5.6

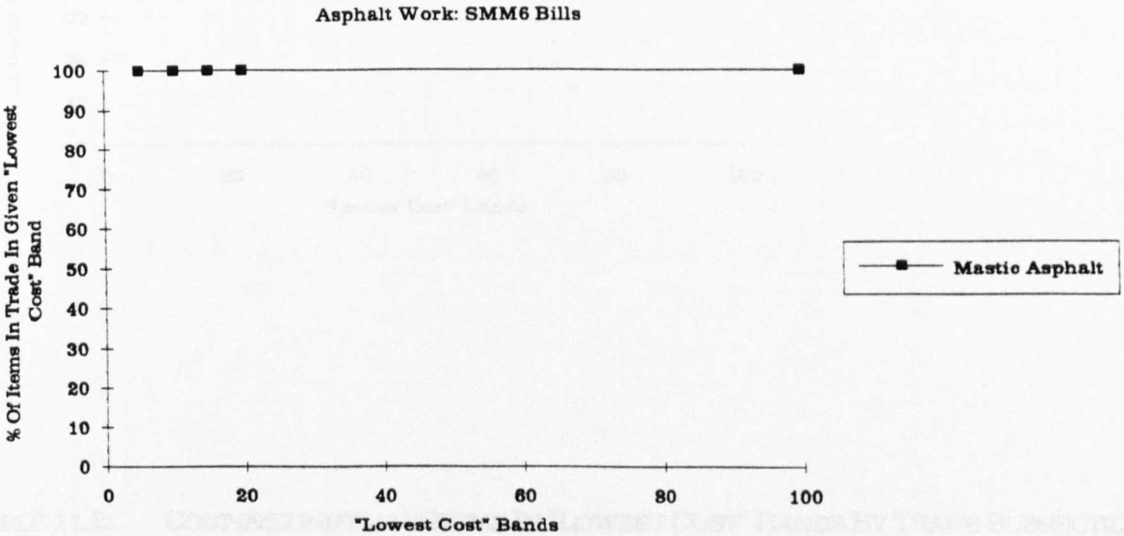


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost-Insignificant Items
12 Roofing	1 Generally	no data
	2 Slate or Tile Roofing	no data
	3 Sheet Roofing + Cladding	no data
	4 Roof Decking	no data
	5 Bitument - Felt Roofing	insufficient data
	6 Sheet Metal Roofing	no data
	7 Flashings + Gutters	no data
	8 Protection	no data

Diagram 5.7

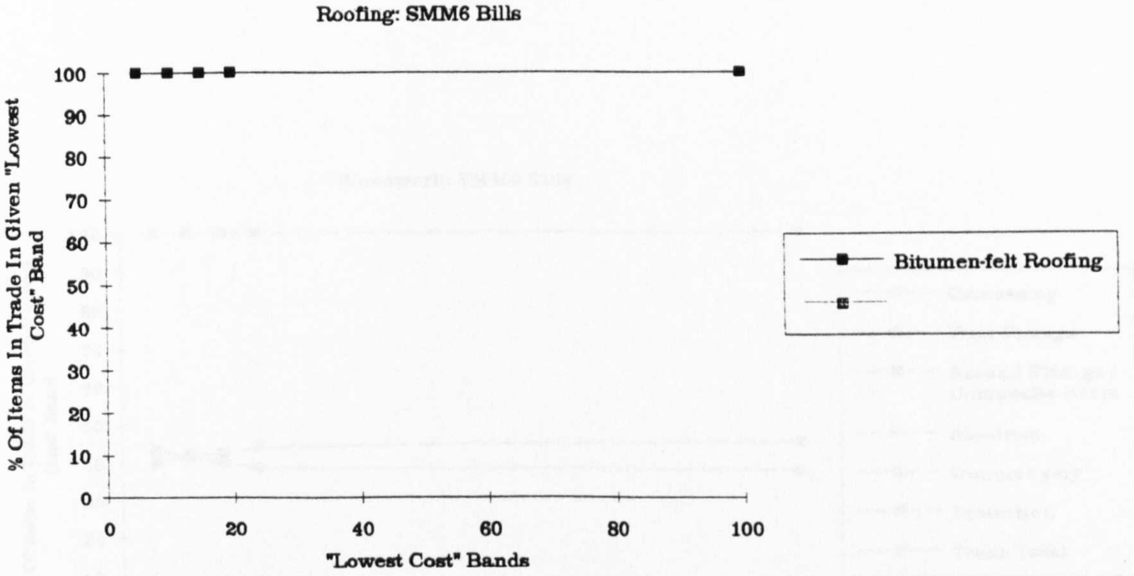


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
13 Woodwork	1 Carcassing	insufficient data
	2 First Fixings	generally small items (marginal)
	3 Second Fixings + Composite Items	generally larger items (marginal)
	4 Sundries	insufficient data
	5 Ironmongery	generally small items (discernible)
	6 Protection	insufficient data

Diagram 5.8

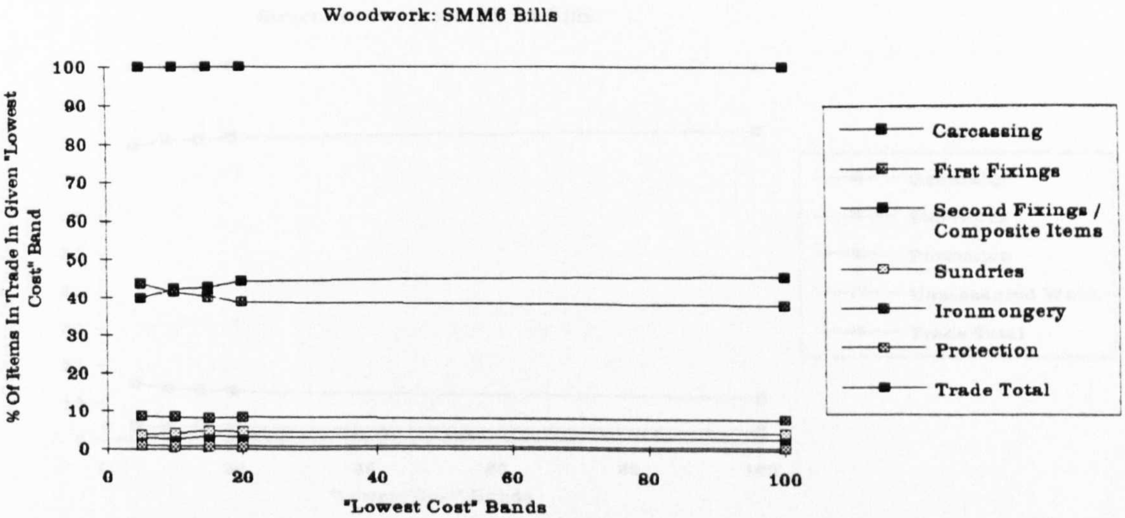


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost-Insignificant Items
14 Structural Steelwork	1 Generally	generally small items (discernible)
	2 Steelwork	generally larger items (marginal)
	3 Protection	insufficient data
	4 Unmeasured Work	insufficient data

Diagram 5.9

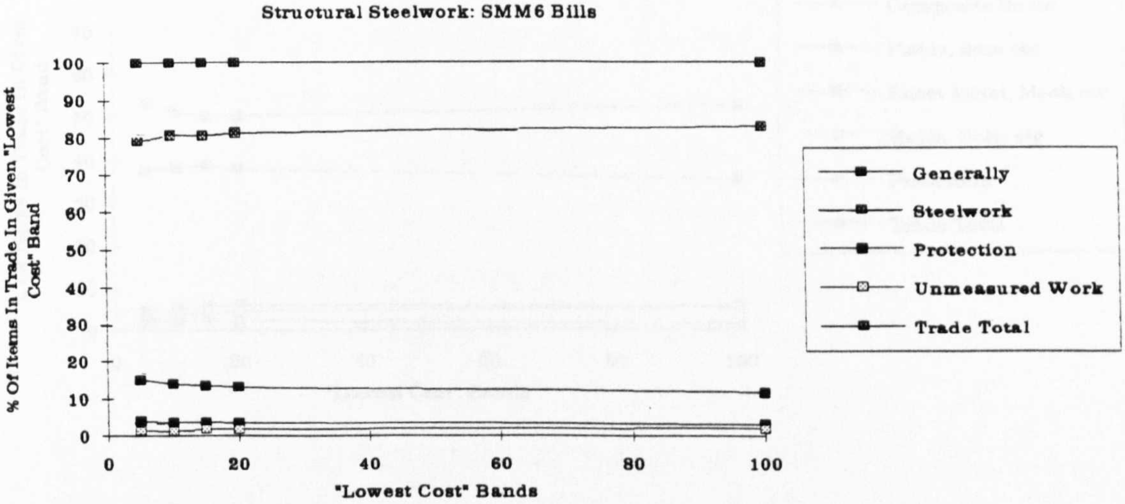


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost-Insignificant Items
15 Metalwork	1 Composite Items	no real tendency
	2 Plates Bars etc	generally small items (marginal)
	3 Sheet Metal + Mesh etc	insufficient data
	4 Holes Bolts etc	insufficient data
	5 Protection	insufficient data

Diagram 5.10

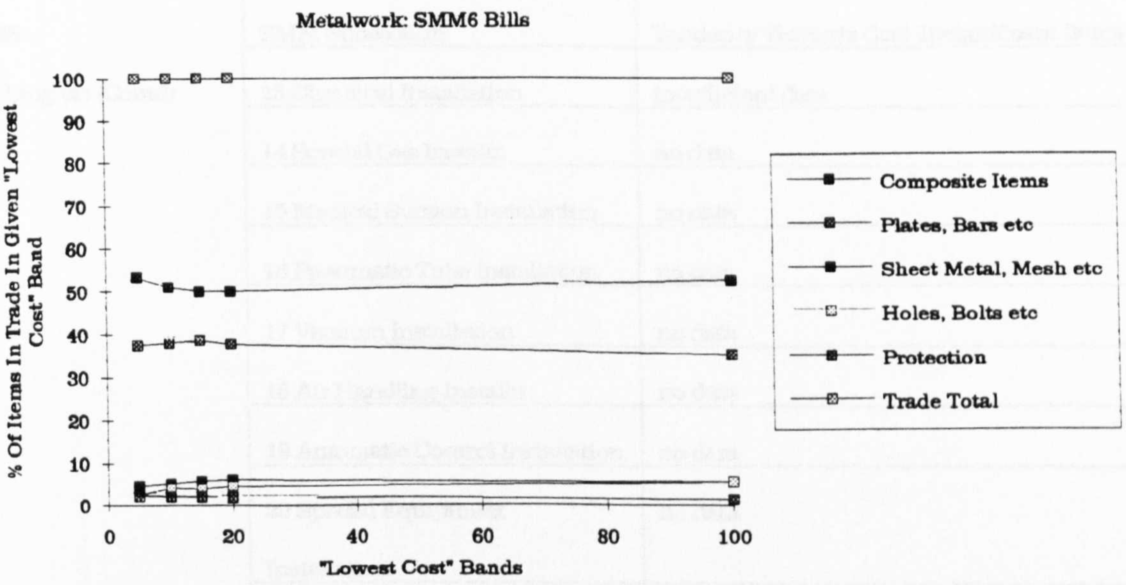


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost-Insignificant Items
16 Plumbing etc	1 Generally	insufficient data
	2 Gutterwork	insufficient data
	3 Rainwater Installation	generally small items (discernible)
	4 Sanitary Installation	no real tendency
	5 Hot + Cold Water Installation	insufficient data
	6 Fire-Fighting Installn	no data
	7 Heated Water Installn	no data
	8 Fuel Oil Installation	no data
	9 Fuel Gas Installation	no data
	10 Refrigeration Installn	no data
	11 Compressed Air Instn	no data
	12 Hydraulic Installation	no data

TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
Plumbing etc (Contd)	13 Chemical Installation	insufficient data
	14 Special Gas Installn	no data
	15 Medical Suction Installation	no data
	16 Pneumatic Tube Installation	no data
	17 Vacuum Installation	no data
	18 Air Handling Installn	no data
	19 Automatic Control Installation	no data
	20 Special Equipment Installation	no data
	21 Other Equipment Installation	insufficient data
	22 Supports for more than one Installation	no data
	23 Equipment, Ancillaries	no real tendency
	24 Sundries	generally small items (marginal)
	25 Builder's Work	insufficient data
	26 Protection	generally small items (marginal)

Diagram 5.11

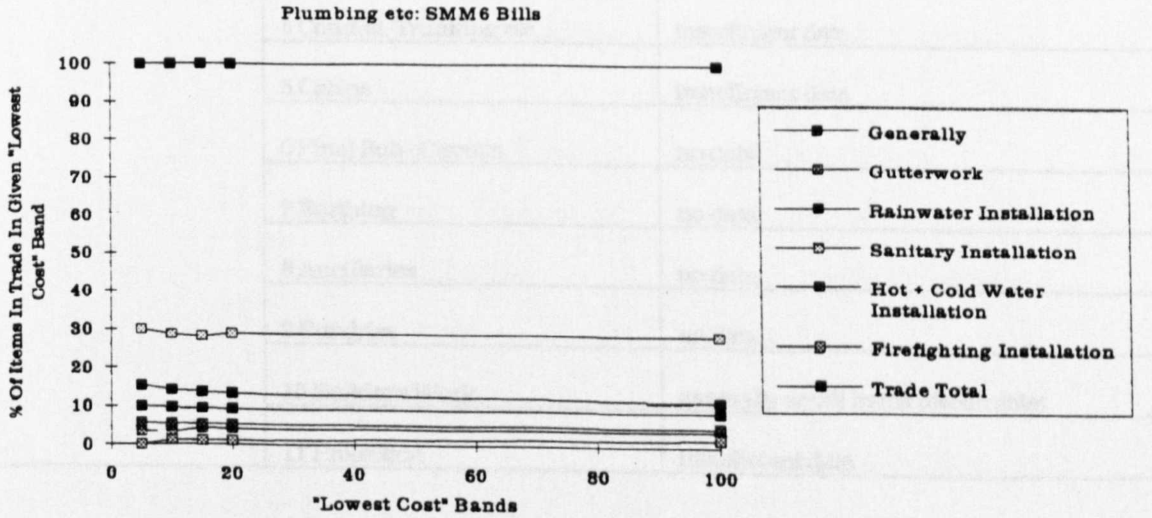


Diagram 5.12

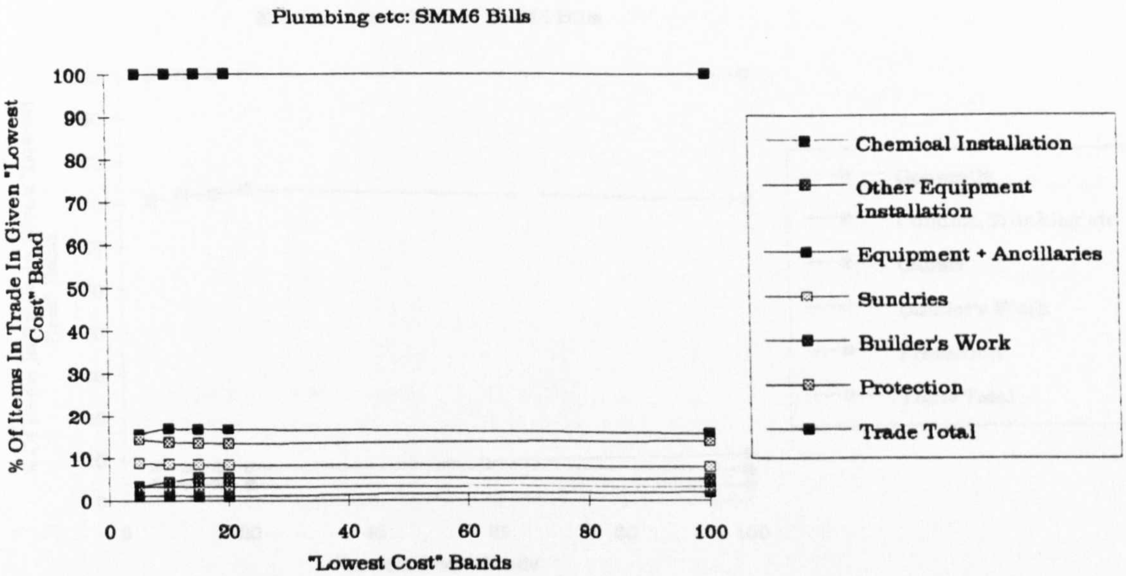


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
17 Electrical Installation	1 Generally	insufficient data
	2 Equipment + Control-Gear	no data
	3 Fittings + Accessories	no data
	4 Conduit, Trunking etc	insufficient data
	5 Cables	insufficient data
	6 Final Sub - Circuits	no data
	7 Earthing	no data
	8 Ancillaries	no data
	9 Sundries	no data
	10 Builder's Work	generally small items discernible)
	11 Protection	insufficient data

Diagram 5.13

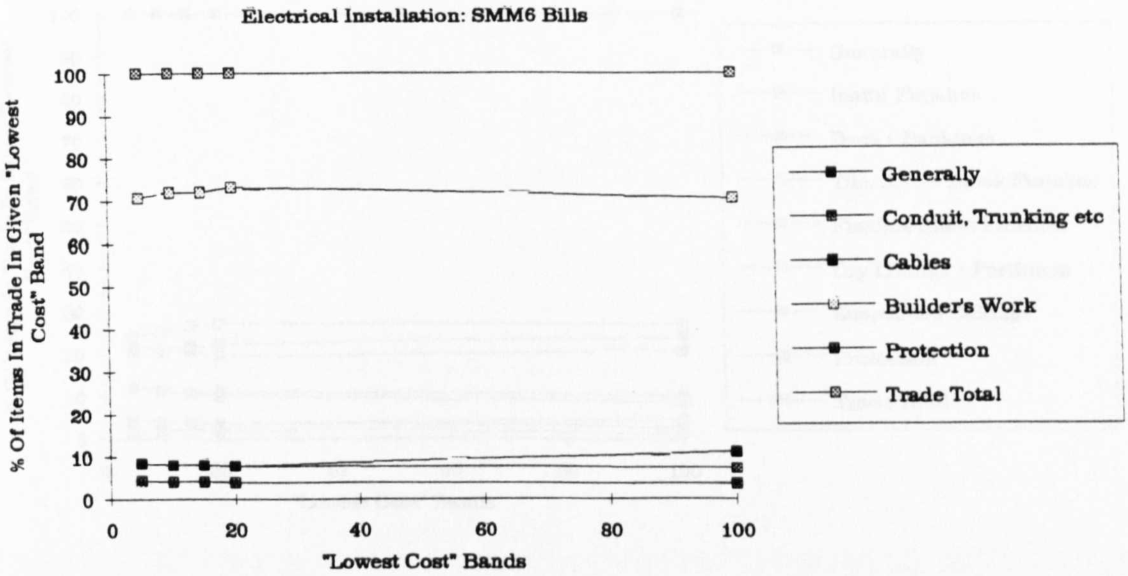


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
18 Finishings	1 Generally	insufficient data
	2 Insitu Finishings	generally larger items (marginal)
	3 Beds + Backings	insufficient data
	4 Tile Slab + Block Finishings	generally larger items (marginal)
	5 Mosaic Work	no data
	6 Flexible Sheet Finishings	no real tendency
	7 Dry Linings+ Partitions	insufficient data
	8 Suspended Ceilings	generally small items (marginal)
	9 Fibrous Plaster	no data
	10 Fitted Carpeting	no data
	11 Protection	generally small items (discernible)

Diagram 5.14

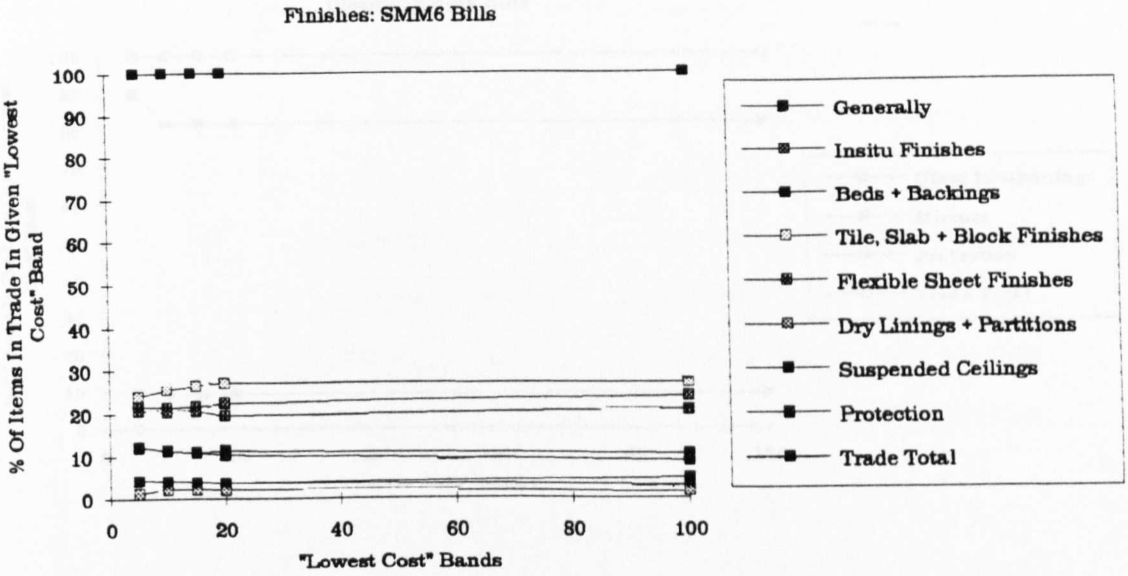


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
19 Glazing	1 Glass in Openings	generally small items (discernible)
	2 Leaded + Copper Lights	no data
	3 Mirrors	insufficient data
	4 Patent Glazing	no data
	5 Domelights	no data
	6 Protection	insufficient data

Diagram 5.15

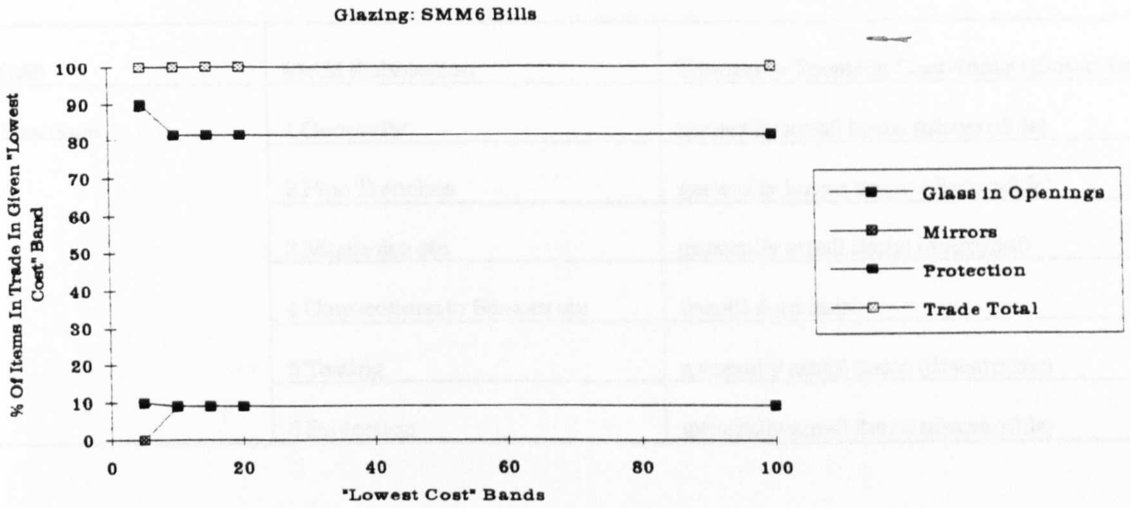


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
20 Painting + Decorating	1 Painting + Polishing	generally small items (marginal)
	2 Signwriting	no data
	3 Paperhanging etc	no data
	4 Protection	insufficient data

Diagram 5.16

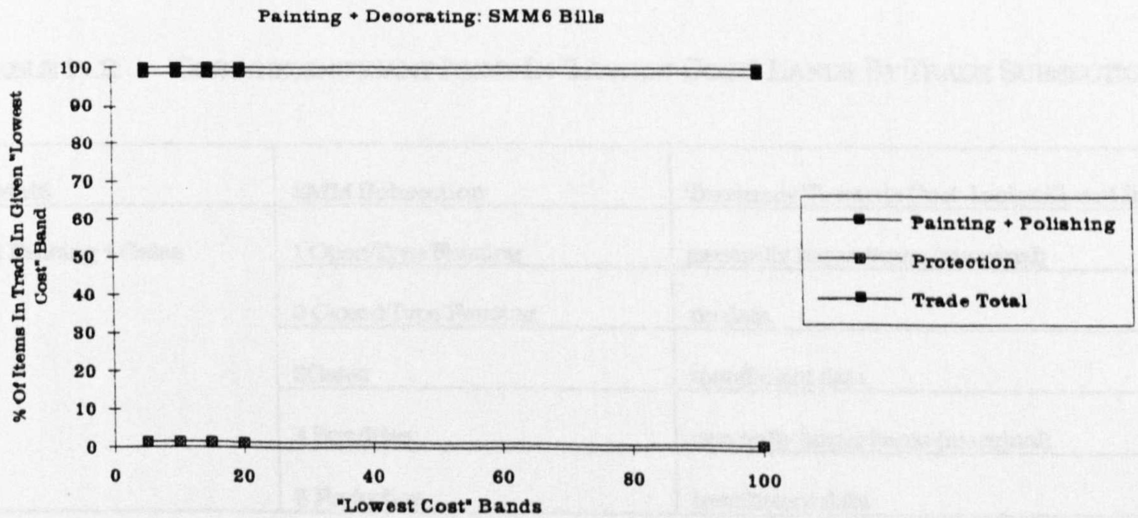


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
21 Drainage	1 Generally	generally small items (discernible)
	2 Pipe Trenches	generally larger items (discernible)
	3 Manholes etc	generally small items (marginal)
	4 Connections to Sewers etc	insufficient data
	5 Testing	generally small items (discernible)
	6 Protection	generally small items (discernible)

Diagram 5.17

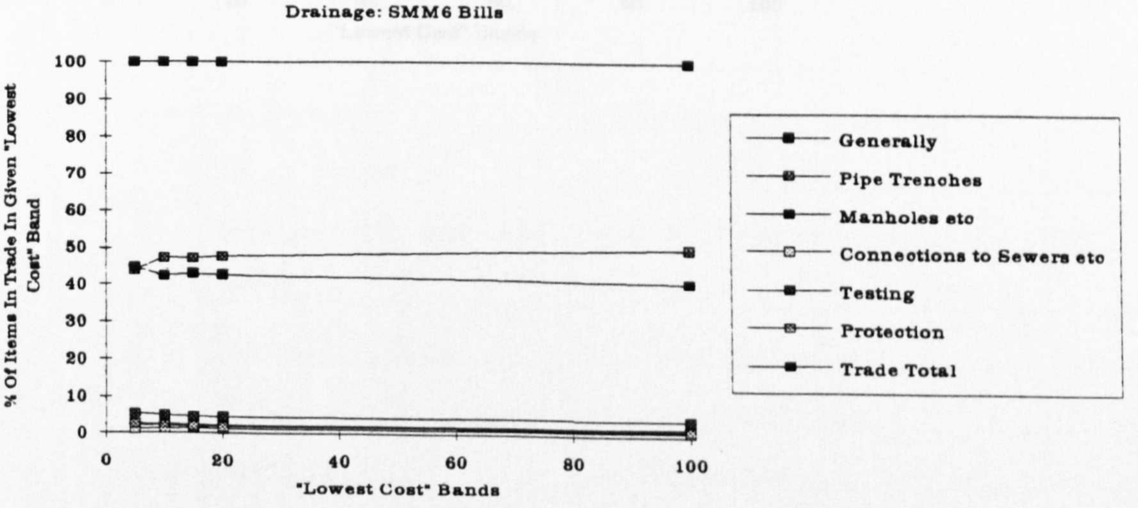
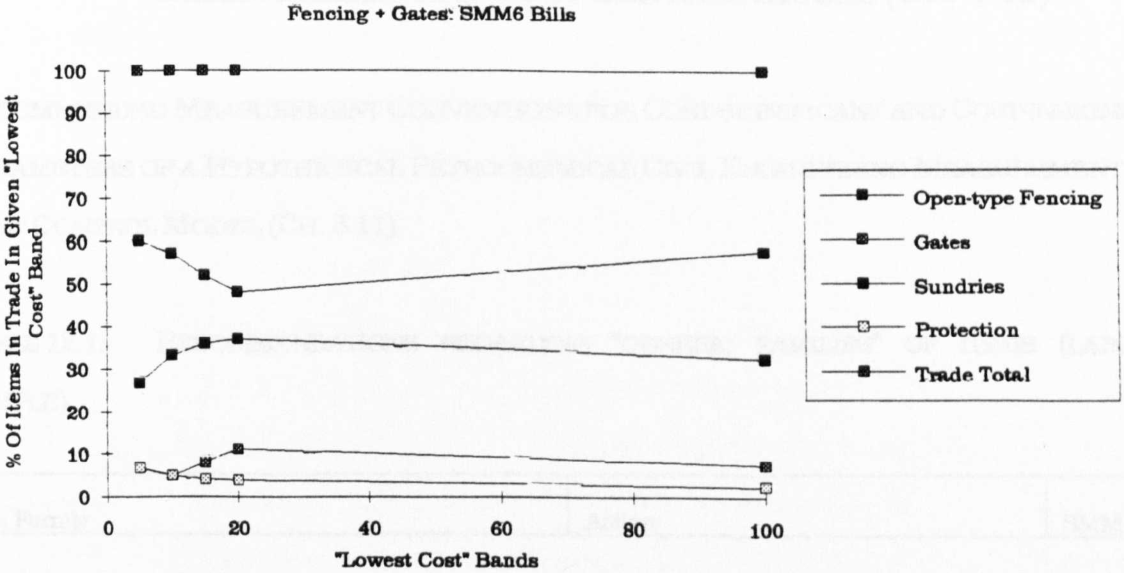


TABLE 11.2: COST-INSIGNIFICANT ITEMS IN "LOWEST COST" BANDS BY TRADE SUBSECTION

SMM6	SMM Subsection	Tendency Towards Cost -Insignificant Items
22 Fencing + Gates	1 Open-Type Fencing	generally larger items (marginal)
	2 Closed-Type Fencing	no data
	3Gates	insufficient data
	4 Sundries	generally larger items (marginal)
	5 Protection	insufficient data

Diagram 5.18


Fencing + Gates: SMM6 Bills
100
90
80
70
60
50
40
30
20
10
0
% Of Items In Trade In Given "Lowest Cost" Band
0
20
40
60
80
100
"Lowest Cost" Bands
Open-type Fencing
Gates
Sundries
Protection
Trade Total

APPENDIX 4:
FORMULATION OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL (CH. 5.11)

RECOMMENDED MEASUREMENT CONVENTIONS FOR COST-SIGNIFICANT AND COST-INSIGNIFICANT PARAMETERS OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL (CH. 5.11)

TABLE 12.1: RECOMMENDATIONS REGARDING "GENERIC FAMILIES" OF ITEMS (LARGER DATA SAMPLE)

Item Family		Action	SMM
Excavation	Pits for bases	Single item; no thickness ategories	5
	Foundation trenches	Fewer depth stages	5,6
	Break out reinforced concrete	Single item regardless of type of dig	5,6
	Earth filling	Inconclusive	5
	Treat surfaces of filling	Single item, disregard slopes etc	5
	Working space; pits / trenches	Single standard allowance	6
	Pipe trenches	See BWIC services	6
	Break out rock/ brickwork/ tarmac/ concrete/	Single item regardless of type of excavation	6
	Working space; ground beams	Single standard allowance	6
	Reduced level	No depth stages	6
	Soft spots etc	Single item regardless of type of dig	6
	Working space; reduced level excavation	Single standard allowance	6
	Fibre matting	Single item, m^2	6

Item Family		Action	SMM
Disposal of Water	Spring water	Deemed included with rates	5
Earthwork Support	Trenches / reduced level excavation/ generally/ next roadways/ next existing buildings	Deemed included in excavation rates Give extra over items for excavating next roadways, existing buildings etc	5/ 5/ 6/ 6/ 6
Hardcore Filling	To make up levels/ filling around foundations	Inconclusive	5/ 5
	Sand blinding etc	Give with associated fill item	5
	Handpacking	Single m^2 item regardless of slopes etc	5
Insitu Concrete	Foundations in trenches/ kerb foundations/ Small machine or pipe bases/ blinding -beds/ stanchion casings/ beams	Single item, no thickness or size categories State number of bases, beams, casings etc.	5,6/ 5/ 5,6/ 5/ 5,6/ 5
	Treating unset surfaces	Single item regardless of slopes etc.	5,6
	Large machine or pipe bases/columns etc/beds/ foundation bases/ ground beams	Single item, no thickness or size categories State number of bases, beams, columns etc	5,6/ 5/ 6/ 6/ 6/
	Kerb haunchings	Give with kerb. Or deem included	6
	Grouting in pockets etc	Give with associated component	6
	Designed joints	Inconclusive	6
	Resin grounting etc	Give with associated component	6
	Walls/ roads and pavings	Single item, no thickness or size categories	6/ 6

Item Family		Action	SMM
Formwork	Kerbs and upstands	Fewer width categories	5
	Walls and balustrades	Single item	5
	Columns, piers and stanchion-casings	Single m^2 item, state number	5,6
	Risers/foundations, ground beams, etc/ edges of suspended floors and roofs	Fewer width categories	5/ 5/ 5
	Ends of kerbs, steps etc.	Add to kerb or step quantity	5
	Grooves	Give with associated component	6
	Holes in machine bases	Smaller number of size categories	6
Precast Concrete	Kerbs	Inconclusive	5
Concrete Work Sundries	Mortices/cutting grooves	Give with associated component	5/ 5
	Bonding agents/ hacking face as key for finishings	Give with finishings specification	5/5
	Damp-proof membranes	Single m^2 item	5
Brickwork	Closing cavities	Group jambs, sills etc into single item	5,6
Facing Brickwork	Walls	Inconclusive	6
Blockwork	Fair returns/ rough cutting chamfered angles/ fair cutting/ bond to existing block walls/ bond to brick walls	Deemed included with rates	5/ 5/ 5/ 5/ 5/
Damp-proof Courses	Generally	Inconclusive	
	Mortices/ holes for pipes etc.	Smaller number of size categories	5/ 6
Brickwork + Blockwork Sundries	Brick reinforcement	Inconclusive	5
	Bed frames and sills	Deemed included in rates	5,6

Item Family		Action	SMM
Brickwork + Blockwork Sundries(Contd)	Expansion joints etc.	Inconclusive	5
	Bed wall ends into steel columns	Deemed included in rates	5
Asphalt Work	Insufficient data		
Profiled sheet roofing	Flashings	Inconclusive	5
Bitumen-felt roofing	Skirtings	Single Item, m2	5
Woodwork	Grounds and battens	Group together	5
	Door frames/ transomes/ frames	Group together	5/ 5/ 5
	Glazing beads etc/ bearers etc.	Group together	5,6/ 5,6
	Architraves/ skirtings/ cover-fillets/ cappings	Group together	5/ 5/ 5/ 5
	Handrails etc.	Inconclusive	
	Glazed screens etc.	Inconclusive	5
	Column casings/ beam casings	Single m^2 item, state number	5/ 5
	Bolts	Inconclusive	5
Structural Steelwork	Compound tank supports/ plain girders/ plain purlins and rails/ roof joists etc/ wall cappings etc/ fabricated steelwork	Single all-in item in tonnes by location in building/ function of member	5/ 5/ 5/ 5/ 5/ 6
	Repositioning members	Inconclusive	6
	Fittings	Deemed included with "parent" items	6
	Holes.	Deemed included in rates	6

Item Family		Action	SMM
Structural Steelwork (Contd)	Site bolts	Single item by weight	6
	Shop painting	Single m^2 item	6
	Galvanising	Give in specification	6
Metalwork	Handrail brackets/ mat frames/ toe-boards etc/ floor-plates/handrails/ balusters etc.	Inconclusive	5/ 5/ 6/ 6/ 5/ 5
	Holes	Deemed included in rates	5
Plumbing Installation	Gutterwork outlets	Inconclusive	5
BWIC Plumbing Installation	Concrete pipe beds and surrounds/ earthwork support to pits/ bar reinforcement to bases and blocks/ fabric; bases and blocks/ holes for ducts etc/ chamber pits/ anchor bases, blocks etc.	Composite items for pipe trenches and chambers Standard specifications and details recommended	5/ 5/ 5/ 5/ 5/ 5/ 5
BWIC Electrical Installation	Granular beds in cable trenches/ holes for ducts etc/ earthwork support to cable trenches/ concrete cable duct surrounds/ foundations in trenches/ formwork to foundations, bases etc/cable ducts	Composite items for pipe trenches	5/ 5/ 5/ 5/ 5/ 5/ 5

Item Family		Action	SMM
Insitu Finishings	Floors and pavements/ ceilings	Single item, no small areas	5/ 5
	Fair joints to existing finishings/ make good around pipes etc	Deemed included in rates	5/ 5
	Skirtings etc	Single item, m^2	5
Tile, Slab and Block Finishings	Floors and pavements/ pavings to drain outfalls etc	Single item, no small areas	5/ 5
	Rounded edges/ plain borders	Inconclusive	5
	Skirtings etc/ walls	Single item, m^2	5
Beds + Backings	Screeded floors/ trowelled floors	Single item, no small areas	5/ 5
Plain Sheet Finishings	Floors	Single item, no small areas	5
	Coved angles/ edge trim	Inconclusive	5/ 5
	Cut and fit around pipes, bars etc.	Deemed included in rates	5
Suspended Linings	Ceilings	Single item, no small areas	5
	Edge trim	Inconclusive	5
Lathing and Baseboarding	Cut and fit around pipes etc	Deemed included in rates	5
Glazing	Insufficient data		
Painting etc	Walls/ windows and doors/ ceilings/ radiators/ valley and parapet gutters	Single m^2 item	5/ 5/ 5/ 5/ 5

Item Family		Action	SMM
Drainage	BWIC Thrust boring	Inconclusive	5
	Formwork to chamber bases/ fabric to chamber bases/ concrete chamber bases/ excavating pits/ branch bends/fabric to chamber cover slabs	Composite items for chambers Standard specifications and details recommended	5/ 5/ 5,6/ 5/ 5/ 5
	Brickwork chamber walls/ blinding beds/ benchings/ modify manholes etc/ concrete chamber surrounds/ formwork to pipe holes	Composite items for chambers Standard specifications and details recommended	5/ 5/ 5/ 6/ 6/ 6
	Pipes/pipe fittings/ granular pipe beds/ grub up drains, fill in	Composite items for pipe trenches Standard specifications and details recommended	5/ 5/ 5/ 5
	Pipes/pipe fittings/ granular pipe beds/ grub up drains, fill in	Composite items for pipe trenches Standard specifications and details recommended	5/ 5/ 5/ 5
Fencing and gates	Re-erect existing signs etc/ Armco	Inconclusive	5/ 6
	Excavate and fill in baluster holes	Inconclusive	6

TABLE 12.2: RECOMMENDATIONS REGARDING COST-INSIGNIFICANT ITEMS (LARGER DATA SAMPLE)

Items		Action	SMM
Excavation + Earthwork Generally	Particulars of water table	Drawing or preamble	5
Excavation	Excavating in ground water	Do not measure. Deem included in rates	5
Earthwork Support	Generally	Deemed included in excavation rates	6
	Cuttings/ next roadways/ next existing buildings	Measure extra over for excavating next roadways and existing buildings	5,6/ 6/ 6
Disposal	Surface water	Deemed included with excavation rates	6
Surface Treatments	Embankments/ soiling/ sloping excavations	Single item; disregard slopes	6/ 6/ 6
Piling		Inconclusive	
Insitu Concrete	Kickers	Contractor's discretion	5
	Joint angles	Deem included with joints	6
	Cut rebates	Give with associated component	6
	Tanking fillets	Inconclusive	6
Reinforcement	Raking/ curved cutting/ bending fabric	Deem included with rates for fabric	5,6/ 6/ 6
Formwork	Upper surfaces	Only measure if > 15° from horizontal	5/
	Throats/ grooves/ chases/ joggles/ sinkings	Smaller number of size categories	5/ 5,6/ 5/ 5/ 5
	Wall mortices	Give with associated components	6
	Ends of walls/ wall soffits	Include with wall formwork	6/ 6
	Slab holes/ chamfers/ machine base holes/ rebates	Smaller number of size categories	6/ 6/ 6/ 6
	Slab holes/ chamfers/ machine base holes/ rebates	Smaller number of size categories	6/ 6/ 6/ 6

Item Family		Action	SMM
Precast Concrete	Holes for pipes etc.	Smaller number of size categories	6
Hollow-block Construction	Cut holes	Smaller number of size categories	6
Concrete Sundries	Hacking surfaces as key for finishings	Give with finishings spec	5
	Holes for ducting, trunking etc	Smaller number of size categories	5
	Work around pipesetc	Deemed included with rates	5
	Holes for bolts etc	Give with associated components	5
	Dishing into gullies etc	Deemed included with rates	5
Brickwork	Bond new walls to old	Deemed included with rates	5,6
Brick facework	Fair cutting	Deemed included with rates	5
Facing brickwork	Fair returns	Deemed included with rates	6
	Closing cavities	Group jambs, sills etc as single item	5
Blockwork	Rough cutting/ rough chamfered angles/ bond walls to brickwork	Deemed included with rates	5/ 5/ 5
	Closing cavities	Group jambs, sills etc as single item	5
Brickwork + Blockwork Sundries	Bed frames, plates, sills etc	Deemed included with rates	5,6
	Rake out joints for flashings/ skirtings	Give with associated components	6
	Build in windows	Deemed included with window	5
	Holes for pipes etc/ holes for ducting, trunking etc/ chases	Smaller number of size categories	6/ 5,6
	Pockets/ holes for bolts	Give with associated component	5/ 5
	Cut and fit around existing pipes etc/ weepholes	Deemed included with rates	6/ 5

Items		Action	SMM
Asphalt Work	Turning nibs into grooves	Give with associated skirtings	5
	Working into outlets	Deemed included with rates	6
	Angles on skirtings	Deemed included with skirtings	6
Sheet Roofing	Raking cutting/ forming small openings	Deemed included in rates	5/ 6
Bitumen-felt Roofing	Turn-down at verges/ turn-down at aprons/ turn-down at eaves	Amalgamate	5,6/ 5/ 6
Woodwork Carcassing etc	Notched ends	Deemed included in rates	6
	Trimming around openings	Add to timber quantity	6
First Fix	Scribing	Deemed included with rates	6
Second Fix	Mitred angles/ notches	Deemed included with rates	6/ 6
	Lippings	Give with associated items	5
Woodwork Composite Units	Fitting and hanging casements	Deemed included with casement	5
	Labours on doors and windows/ rebated stiles	Give with door or window	5/ 5
Woodwork Sundries	Holes for pipes etc	Smaller number of size categories	5,6
	Packers	Contractor's discretion	5

Items		Action	SMM
Ironmongery	Kicking plates/ knobsets/ bolts/ sash fasteners/ padlocks/ dowels/ escutcheons/ mortice deadlocks/ panic latches/ detector mechanisms/ plates/ cleats/ door grilles/ door seals and smoke-stops/ toilet roll holders/ indicator-bolts/ coat-hooks/ name-plates/ door-stops/ cupboard Door catches/ door-lippings/ barrel-bolts/ casement-stays/ door-stays/ ash trays/ doormats/ spring-hinges/ sex symbols/ shower curtains/ panic locks/ soap trays/ towel-rails/ water-bars/bolt-sockets/ push plates/ door channels etc/ bathroom locks/ rebate sets/ lever latch handles/ signs	Enumerate as packs from door/ window schedule	5/ 5,6/ 5/ 5/ 5/ 5/ 5/ 5,6/ 5,6/ 5,6/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5,6/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 6/ 6/ 6/ 6/ 6/ 6/ 6/ 6
Structural Steelwork Generally	General description of work	Preamble or Drawing	6
Steelwork	Welds on unframed steelwork	Deemed included with rates	5
Steelwork Sundries	Stanchion packers etc	Contractor's discretion	6
	Holes	Deemed included in rates	6
	Site welds	Inconclusive	6
	Galvanising	Give in specification	6

Items		Action	SMM
Metalwork Plates, Bars, Sections + Tubes	Raking cutting	Deemed included in rates	5
Metalwork Sundries	Slots/ holes	Small number of size categories or deem included	5/ 6
Rainwater Installation	Connections to fittings/ connections to drains/ connections to other materials	Deemed included with rates for fittings etc	6/ 6/ 6
	Pipe-clips/ pipe-brackets	Give in pipe specification	5/ 5
	Connections to gullies	Deem included with gullies	5
Overflow Installation	Splay cut pipe ends	Deemed included with rates	5
Waste Installation	Connections to different materials/ connections to appliances/ connections to drains	Deemed included with fittings etc	5/ 5/ 5
	Splay cut pipe ends	Deemed included in rates	5
Soil and Vent Installation	Connections to different materials	Deemed included with fittings etc	5
	Pipe-brackets/ pipe-hangers	Give with pipe specification	5/ 5
	Connections to drains/ connections to appliances/ pipe connectors	Deemed included with appliances, fittings etc	5/ 5/ 5
Sanitary Installation	Connections to appliances	Deemed included with appliances	6
	Splay out pipe ends	Deemed included in rates	6
Hot/ Cold Water Installation	Connections to different materials	Deemed included with fittings etc	5
	Holderbats/ pipe-hangers	Give in pipe specification	5
	Joints to taps	Included with taps	5

Items		Action	SMM
Hot/ Cold Water Installation (Contd0	Tank connectors/ connections to appliances	Deemed included with appliances	5
	Splay cut pipe ends	Deemed included in rates	6
Water Main Installation	Prepare pipe ends to receive fittings	Deemed included with fittings	5
Plumbing Sundries	Mark positions of holes, mortices etc.	Deemed included in rates	5,6
Testing	Testing plumbing	Deemed included in rates	6

Items		Action	SMM
BWIC Plumbing	Keep excavations free from water/ treat surfaces of excavation/ steel plates etc in chambers/ fill around chambers/ blinding-beds/ cover slabs/ formwork to slab soffits/ formwork to chamber slab edges/ flush pointing chamber walls/ building in pipe ends/ chamber oversailing courses/ cut formwork around pipes etc/ concrete kerbs/ sinkings in concrete/ hardcore beds/ kerb formwork/ disposal of spoil/ concrete chamber walls/ formwork to chamber walls/ expansion joints/ treat unset concrete/ fabric to cover slabs/ formwork to chamber bases/ rebates in slabs/ earthwork support to trenches etc/ chamber pits etc/ treat surfaces of filling/ working space fabric to chamber bases etc/ sand beds to pipes etc/ earthwork support to pits	Composite items for service trenches and chambers Standard specifications and details recommended	5,6/ 5,6/ 5/ 5,6/ 5/ 5/ 5/ 5/ 5/ 5 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5,6 5/ 5,6/ 5/ 5/ 6/ 6/ 6/ 6/ 6

Items		Action	SMM
Electrical Installation Sundries	Cut away, make good for equipment points/ cut away, make good for fitting outlet points	Amalgamate	5/ 5
BWIC Electrical Installation	Fitting outlet points/ socket outlet points	Amalgamate	6/ 6
BWIC Electrical Installation (Contd)	Cable trench filling/ cable covers/ notch timber around cables etc/ treat surfaces of excavation/ keep excavation free from water/ earthwork support to cable trenches etc/ formwork to duct surrounds/ earthwork support to chamber pits etc/ filling around chambers etc/ concrete chamber covers/ formwork to cover soffits/ formwork to edges of covers/ brick chamber walls/ flush point chamber walls/ chamber covers and frames/ hardcore beds/ concrete kerbs/ fabric to chamber bases etc/ formwork to kerbs/ joint old ducts to new	Composite items for service trenches and chambers Standard specifications and details recommended	5/ 6/ 6/ 5/ 5 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5/ 5

Items		Action	SMM
Insitu Finishings	Fair edges/ make good around steel sections/ make good around pipes, bars etc/ make good around ducting, trunking etc/ work into pipes, outlets etc/ dish into gullies etc	Deemed included in rates	5,6/ 5/ 5,6/ 5,6/ 5,6/ 5
	Tack-coats for pavings	Give in pavings specification	5
	Rounded external angles/ external angles	Inconclusive	6
	Joints to existingfinishings	Deemed included with rates	6
	Prepare existing to receive new	Give in specification for new finishings	6
Tile, Slab and Block Finishings	Ends of steps	Add to steps quantity	5
	Fair cutting to other finishings/ fair cutting to surrounds of openings/ cut and fit around pipes, bars etc/ cut and fit around ducting, trunking etc/ raking cutting/ angle units/ cut and fit into recessed covers etc/ cut and fit around steel sections/ fair edges	Deemed included in rates	5,6/ 5/ 5,6/ 5/ 5/ 6/ 6/ 6/ 6

Items		Action	SMM
Plain Sheet Finishings	Walls and splashbacks < 1 m2/ ceilings < 4 m2	No separate items for small areas	5/ 5
	Fair joints to other finishings/ cutting around openings/ cut and fit into recessed covers etc/ cut and fit around steel sections/ cut and fit around pipes, bars etc/ cut and fit around ducting, trunking etc/ work into outlets	Deemed included in rates	5/ 5/ 5/ 5/ 5/ 5/ 6
Beds and backings	Fair edges to other finishings/ working around steel sections	Deemed included in rates	5/ 5
	surface sealants	Give in specification	5
Baseboarding	Cut and fit around pipes, bars etc	Deemed included in rates	5
Suspended ceilings	Fit around pipes etc/ fit around ducting, trunking etc	Deemed included in rates	5,6/ 5
Fitted carpet	Fit around ducting trunking etc/ fair edges to other finishings/ perimeter fixings	Deemed included in rates	5/ 5/ 5/
Glazing		Insufficient data; inconclusive	
Painting etc	Edges of casements	Deemed included with casements	5,6
	Staircase soffits	Give item for soffits generally	6
Paperhanging	Extra; corners on wallpaper	Deemed included in rates	6

Items		Action	SMM
Drainage Generally	Disposal of general water/ disposal of ground water/ disposal of surface water	Deemed included in drainage rates	5/ 5,6/ 6/
Drainage Trenches	Joints to existing pipes	Inconclusive	6
	Holes for pipes	Smaller number of size categories	6
Testing Drainage	Testing	Deemed included in rates	6
Manhole Chambers etc	Earth backfilling/ treat surfaces of filling/ treat surfaces of excavation/ hardcore to make up levels/ concrete chamber bases etc/ flush pointing chamber walls/ render chamber walls/ branch bends/ chamber channels/ blinding beds/ fabric in chamber bases/ concrete chamber walls/ reinforcement to chamber walls/ build in pipe ends/ disposal of spoil to employer's tip/ formwork to wall kickers/ formwork to pipe holes	Composite items for chambers Standard specifications and details recommended	5/ 5/ 5,6/ 5/ 5/ 5,6/ 5/ 5,5/ 5,6/ 5/ 5/ 6/ 6/ 6/ 6/ 6
Fencing and Gates	Bends on metal fences/ connect to existing fences	Inconclusive	5/ 5,6
General Items In All Trades	Protection items/ testing items/ provide + remove plant/ maintain plant	Deemed included in rates for respective trades	5,6/ 5,6/ 6/ 6

APPENDIX 5:
FORMULATION OF A HYPOTHETICAL PETROCHEMICAL CIVIL ENGINEERING MEASUREMENT AND COST CONTROL MODEL (CH. 5.12-5.20)

A5.1 LEVEL OF ABSTRACTION: ELEMENT: RESULTS OF COMPREHENSIVE ANALYSIS (CH. 5.12)

The data for all 15 Petrochemical Civil Engineering Bills of Quantities were analysed to detect the behaviour of Elements across all such construction projects:

(1) The entire population of cases were used.

(2) The Element classifications used were those devised control purposes by the Bill users. These would be more readily identifiable by the users. Comments about the suitability of the Element classifications themselves are added later, using the benefit of hindsight. It was suspected, however, that classifications such as those of the BCIS (1969) did not wholly reflect Petrochemical Civil Engineering work.

(3) Analysis by Trade or Work Section is undertaken elsewhere. Trades and Work Sections can form parts of Elements.

The data were split by Elements within each Bill and for each such Element the proportion of its value as a percentage of its own Bill total was computed Tabulations were then produced which showed the incidence of Elements across all Bills and which showed the distributions of cost in the Elements (see Tables 13.1-13.3).

TABLE 13.1: INCIDENCE OF ELEMENTS IN PETROCHEMICAL CIVIL ENGINEERING BILLS (ALL ITEMS IN BILLS)

Elements [All Items] Incidence	Bill Nr [SMM5]								Bill Nr [SMM6]						
	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17
Preliminaries		*	*	*	*	*	*	*	*	*	*	*		*	*
Fixed, Time Charges	*							*					*		
Site Preparation			*		*							*			
Demolitions	*	*		*				*	*			*		*	*
Excavations	*	*						*	*			*		*	*
Foundations	*	*	*				*	*	*			*		*	*
Marine, River Works					*										
Reservoirs, Tanks	*	*		*										*	
Roads, Pavings		*	*	*	*		*			*		*		*	*
External Services		*			*		*		*	*				*	*
Drainage	*	*	*	*	*	*	*	*	*			*	*	*	*
Pipe Suppts, Culverts		*								*					
Chimneys etc		*												*	*
Substructure			*	*		*	*						*	*	*
Frame				*		*	*	*			*				*
Floors	*		*	*		*	*	*	*		*		*		*
Roof			*	*			*	*			*	*		*	*
External Walls	*		*	*		*	*	*	*		*	*		*	*
Internal Walls	*			*		*	*	*						*	
Stairs				*		*	*	*	*		*	*		*	*
Windows, Doors	*		*	*		*	*	*				*		*	*
Stairs, Lifts			*	*	*										
Internal Finishes			*	*		*	*	*	*			*	*	*	*
Fittings			*	*		*		*	*			*		*	*
BWIC Mechanical		*	*	*		*		*			*			*	*
BWIC Electrical			*	*		*	*	*	*					*	*
BWIC Plumbing			*	*		*	*	*						*	*
External Works		*			*		*	*	*					*	
Bridges											*				
Offplot Frame											*				
Dayworks									*	*	*	*	*	*	*

TABLE 13.2: INCIDENCE OF ELEMENTS IN PETROCHEMICAL CIVIL ENGINEERING BILLS (MEASURED ITEMS ONLY)

Elements [Measured Items] Incidence	Bill Nr [SMM5]	Bill Nr [SMM6]

	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17
Preliminaries															
Fixed, Time Charges															
Site Preparation			*									*			
Demolitions	*	*		*				*	*			*		*	*
Excavations	*	*						*	*			*		*	*
Foundations	*	*	*				*	*	*			*		*	*
Marine + River Wks															
Reservoirs, Tanks	*	*		*										*	
Roads, Pavings		*	*	*	*		*			*		*		*	*
External Services		*			*		*		*	*				*	*
Drainage	*	*	*	*	*	*	*	*	*			*	*	*	*
Pipe Supports etc		*								*					
Chimneys etc														*	*
Substructure			*	*		*							*	*	*
Frame				*		*	*	*			*				*
Floors	*		*	*		*	*	*	*		*		*		*
Roof			*	*		*		*				*		*	*
External Walls	*		*	*		*	*	*	*			*		*	*
Internal Walls	*			*		*	*	*						*	
Stairs				*		*	*	*	*		*	*		*	*
Windows, Doors	*		*	*		*	*	*				*		*	*
Stairs, Lifts				*	*										
Internal Finishes			*	*		*		*	*			*	*	*	*
Fittings			*	*		*		*	*			*		*	*
BWIC Mechanical			*	*		*					*			*	*
BWIC Electrical			*	*		*		*	*					*	*
BWIC Plumbing			*	*		*	*	*						*	*
External Wks		*			*		*	*	*					*	
Bridges											*				
Offplot Frame											*				
Dayworks															

TABLE 13.3: CONSISTENCY OF ELEMENTS ACROSS PETROCHEMICAL CIVIL BQ

Element [Measured Items] Where Occurring [As % Of Total Cost]	SMM5 Min %	SMM5 Max %	SMM6 Min %	SMM6 Max %	All Min %	All Max %
Preliminaries						
Fixed, Time Charges						
Site Preparation	0.02	0.02	0.76	0.76	0.02	0.76
Demolitions	0.20	18.97	0.01	5.02	0.01	18.97
Excavations	4.68	10.54	4.98	17.00	4.68	17.00
Foundations	4.61	33.06	36.29	67.28	4.61	67.28
Marine + River Works	-	-	-	-	-	-
Reservoirs, Tanks	0.04	26.43	1.94	1.94	0.04	26.43
Roads, Pavings	1.72	58.88	0.53	13.83	0.53	58.88
Extl Services	5.97	12.55	0.12	2.86	0.12	12.55
Drainage	1.02	27.91	1.32	20.65	1.02	27.91
Pipe Supports, Culverts	5.01	5.01	89.92	89.92	5.01	89.92
Chimneys, Cooling Towers	-	-	0.68	0.97	0.68	0.97
Substructure	3.40	31.17	0.62	75.20	3.40	75.20
Frame	0.42	12.64	0.02	42.77	0.02	42.77
Floors	1.42	9.18	0.85	28.24	0.85	28.24
Roof	3.03	9.85	0.46	2.89	0.46	9.85
External Walls	8.70	22.38	1.04	4.02	1.04	22.38
Internal Walls	0.09	8.53	0.07	0.07	0.07	8.53
Stairs	0.07	2.03	0.01	2.29	0.01	2.29
Windows, Doors	0.01	11.23	0.58	1.05	0.01	11.23
Stairs, Lifts	0.31	2.36	-	-	0.31	2.36
Internal Finishings	3.77	16.81	0.06	19.35	0.06	19.35
Fittings	0.65	4.02	0.35	3.39	0.35	4.02
BWIC Mechanical	0.14	0.52	0.07	3.55	0.07	3.55
BWIC Electrical	0.08	0.64	0.01	0.11	0.01	0.64
BWIC Plumbing	0.15	5.38	0.06	0.10	0.06	5.38
External Works	0.08	14.67	1.10	2.23	0.08	14.67
Bridges	-	-	1.93	1.93	1.93	1.93
Offplot Frame	-	-	21.78	21.78	21.78	21.78
Dayworks	-	-	-	-	-	-

TABLE 15.1: COEFFICIENT OF VARIATION OF ELEMENTAL COST BEHAVIOUR ACROSS PETROCHEMICAL CIVIL ENGINEERING BQ (SMM5)

ELEMENTS [ALL ITEMS] AS % OF TOTAL COST	BQ2	BQ3	BQ4	BQ5	BQ6	BQ7	BQ8	BQ9	Coeff Varn (%)
Preliminaries		14.70	15.54	16.45	13.27	9.70	17.81	3.35	38.34
Fixed, Time Charges	41.84							18.42	54.96
Site Preparation			0.02		0.17				111.65
Demolitions	9.38	0.13		2.30				1.46	124.77
Excavations	5.21	4.35						1.36	55.52
Foundations	16.50	5.25	14.31				11.21	1.77	62.93
Marine + River Works					0.50				
Reservoirs, Tanks	0.06	16.50		0.01					172.11
Roads, Pavings		26.04	28.03	0.48	42.29		3.60		87.92
External Services		8.20			17.66		3.16		76.10
Drainage	2.82	6.82	9.61	0.29	25.64	1.81	3.39	1.18	129.57
Pipe Supports, Culverts		3.13							
Chimneys, Cooling Towers		11.87							
Substructure			2.56	4.90		4.94	13.07		72.32
Frame				17.56		14.15	16.57	3.28	50.93
Floors	3.91		1.07	4.66		6.59	3.55	0.72	64.99
Roof			3.17	0.85			6.99	2.87	73.86
External Walls	9.71		7.52	13.99		16.65	7.36	3.81	47.99
Internal Walls	0.04			2.66		2.18	3.02	1.02	69.09
Stairs				0.02		0.59	0.10	0.20	111.05
Windows, Doors	10.52		5.35	5.81		2.74	3.18	3.27	56.69
Stairs, Lifts			1.24	2.04	0.22				78.19
Internal Finishings			2.84	5.96		6.96	2.44	3.06	46.41
Fittings			0.30	11.50		0.71		0.46	169.86
BWIC Mechanical		0.26	5.26	2.66		26.72		40.83	117.59
BWIC Electrical			2.54	7.09		5.48	0.13	7.11	68.42
BWIC Plumbing			0.63	0.77		0.78	0.13	1.57	66.62
External Works		0.05			0.24		4.30	4.27	107.97
Bridges									
Offplot Frame									
Dayworks									

TABLE 15.2: COEFFICIENT OF VARIATION OF ELEMENTAL COST BEHAVIOUR ACROSS PETROCHEMICAL CIVIL ENGINEERING BQ (SMM6)

ELEMENTS [ALL ITEMS] AS % OF TOTAL COST	BQ11	BQ12	BQ13	BQ14	BQ15	BQ16	BQ17	Coeff Varn (%)
Preliminaries	19.03	4.20	4.31	13.09		6.23	13.32	63.84
Fixed, Time Charges					0.20			
Site Preparation				0.54				
Demolitions	0.25			0.18		0.01	0.04	95.97
Excavations	12.32			3.55		4.93	13.88	65.04
Foundations	51.26			42.96		28.45	54.93	31.04
Marine + River Works								
Reservoirs, Tanks						1.52		
Roads, Pavings		7.60		0.38		10.86	5.83	75.46
Extl Services	2.19	1.89				0.49	0.10	90.16
Drainage	2.85			0.94	18.79	5.43	1.84	118.69
Pipe Supports, Culverts		84.64						
Chimneys, Cooling Towers						0.53	0.80	37.66
Substructure					69.96	17.71	0.50	116.37
Frame			38.08					
Floors	1.17		25.14		2.11		0.69	145.28
Roof			2.32	2.07		1.24	0.63	55.12
External Walls	2.03		0.58	1.96		3.15	0.85	64.45
Internal Walls						0.06		
Stairs	1.31		1.53	1.63		0.76	0.01	68.10
Windows, Doors				0.46		1.01	0.48	55.16
Stairs, Lifts								
Internal Finishings	0.05			16.39	1.66	2.06	0.27	152.01
Fittings	2.38			2.42		0.53	0.89	68.47
BWIC Mechanical			3.16			3.01	0.25	81.33
BWIC Electrical	0.06					1.54	0.01	140.25
BWIC Plumbing						0.05	0.08	42.09
External Wks	2.07					0.87		67.19
Bridges			1.72					
Offplot Frame			19.39					
Dayworks	3.05	1.67	3.77	12.43	7.27	9.57	4.49	67.31

TABLE 15.3: COEFFICIENT OF VARIATION OF ELEMENTAL COST BEHAVIOUR ACROSS PETROCHEMICAL CIVIL ENGINEERING BQ (SMM5)

ELEMENTS [MEASURED ITEMS ONLY] AS % OF TOTAL COST	BQ2	BQ3	BQ4	BQ5	BQ6	BQ7	BQ8	BQ9	Coeff Varn (%)
Preliminaries									
Fixed, Time Charges									
Site Preparation			0.02						
Demolitions	18.97	0.20		8.21				5.02	98.27
Excavations	10.54	6.97						4.68	39.93
Foundations	33.06	4.61	18.98				7.86	6.06	85.09
Marine + River Works									
Reservoirs, Tanks	0.13	26.43		0.04					171.55
Roads, Pavings		40.45	37.18	1.72	58.88		8.57		80.81
Extl Services		6.20			12.55		5.97		45.32
Drainage	5.71	10.05	12.59	1.02	27.91	5.67	8.08	4.04	88.38
Pipe Supports, Culverts		5.01							
Chimneys, Cooling Towers									
Substructure			3.40	17.50		16.91	31.17		65.76
Frame				0.42		12.64	0.13	11.27	110.67
Floors	7.91		1.42	9.18		7.49	6.43	2.48	53.99
Roof			4.20	3.03				9.85	64.06
External Walls	19.65		9.89	16.41		22.38	17.56	8.70	34.38
Internal Walls	0.09			8.53		7.47	7.20	3.49	65.45
Stairs				0.07		2.03	0.23	0.68	118.27
Windows, Doors	3.93		7.10	8.18		6.97	0.01	11.23	61.72
Stairs, Lifts				2.36	0.31				108.58
Internal Finishings			3.77	16.81		15.46	5.82	10.51	54.76
Fittings			0.39	4.02		0.65		1.56	99.97
BWIC Mechanical			0.14	0.32		0.52			58.19
BWIC Electrical			0.08	0.31		0.64		0.38	65.41
BWIC Plumbing			0.84	1.87		1.36	0.15	5.38	106.06
External Wks		0.08			0.34		0.82	14.67	179.38
Bridges									
Offplot Frame									
Dayworks									

TABLE 15.4: COEFFICIENT OF VARIATION OF ELEMENTAL COST BEHAVIOUR ACROSS PETROCHEMICAL CIVIL ENGINEERING BQ (SMM6)

Elements [Measured Items Only] As % Of Total Cost	BQ11	BQ12	BQ13	BQ14	BQ15	BQ16	BQ17	Coeff Varn (%)
Preliminaries								
Fixed, Time Charges								
Site Preparation				0.76				
Demolitions	0.32			1.66		0.01	0.18	139.30
Excavations	16.13			4.98		6.29	17.00	57.14
Foundations	67.13			59.45		36.29	67.28	25.43
Marine + River Works								
Reservoirs, Tanks						1.94		
Roads, Pavings		8.07		0.53		13.83	7.14	73.70
Extl Services	2.86	2.01				0.63	0.12	89.42
Drainage	3.73			1.32	20.65	6.83	2.19	114.40
Pipe Supports, Culverts		89.92						
Chimneys, Cooling Towers						0.68	0.97	24.86
Substructure					75.20	22.59	0.62	116.83
Frame			42.77				0.02	141.29
Floors	1.53		28.24		2.32		0.85	162.12
Roof				2.89		0.46	0.77	96.30
External Walls	2.66			2.75		4.02	1.04	46.66
Internal Walls						0.07		
Stairs	0.14		1.72	2.29		0.97	0.01	96.24
Windows, Doors				0.65		1.05	0.58	33.37
Stairs, Lifts								
Internal Finishings	0.06			19.35	1.88	2.63	0.32	169.11
Fittings	3.12			3.39		0.35	0.48	89.60
BWIC Mechanical			3.55			0.07	0.30	148.94
BWIC Electrical	0.08					0.11	0.01	76.97
BWIC Plumbing						0.06	0.10	35.36
Extl Works	2.23					1.10		47.99
Bridges			1.93					
Offplot Frame			21.78					
Dayworks								

A5.2 Results of analysis of Cost-Generation by Element in Petrochemical Civil Engineering Bills of Quantities (Ch. 5.18)

The data were split by contract Bill and aggregate functions were computed for mean Bill item values. Each item was divided by the mean item value for that Bill as absolute values were not required; the purpose being to study behaviour relative to some "bench-mark". The data were then split further by Element within each Bill and a mean item value was computed for each such Element.

The mean Element item value was taken to represent the mean rate at which that Element generated costs. The mean item value for the entire Bill was taken to represent the mean rate at which the Bill as a whole generated costs. Any Element which generated mean costs more rapidly than did the Bill as a whole was termed, for the purpose of the exercise, a "Major Cost Generator". Any Element which generated mean costs more slowly than did the Bill as a whole was termed, for the purpose of the exercise, a "Minor Cost Generator". These relative values were tabulated and compared (Tables 16.1-16.4 refer). The following comments are offered regarding the data and the analysis:

1) As in previous analyses, the whole data population was used.

2) For consistency, the original Element classifications were retained.

3) Analysis by Trade of Work Section was deferred for reasons discussed earlier.

4) Although it was suspected following the previous analysis (*vide supra*) that the data were possibly insufficient in quantity it was nevertheless considered that further knowledge might be gained by further exploration of the existing data.

TABLE 16.1: MAJOR AND MINOR COST GENERATING ELEMENTS IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES

ELEMENTS [ALL ITEMS]: MEAN RATE OF COST GENERATION [SMM5]	BILL 2	BILL 3	BILL 4	BILL 5	BILL 6	BILL 7	BILL 8	BILL 9
Preliminaries		7.33	1.16	1.06	1.14	0.62	1.27	20.00
Fixed, Time Charges	8.51							
Site Preparation			0.20		1.50			
Demolitions	0.39	1.08		0.23				0.26
Excavations	0.54	1.26						0.53
Foundations	0.90	0.61	0.82				3.16	0.53
Marine + River Works					2.24			
Reservoirs, Tanks	0.23	0.61		0.12				
Roads + Pavings		1.34	1.65	0.45	2.80		0.76	
External Services		0.62			0.67		0.33	
Drainage	0.26	0.46	0.44	0.20	0.63	0.13	0.29	0.13
Pipe Supports, Culverts		0.32						
Chimneys, Cooling Towers		100.28						
Substructure			1.08	1.19		0.47	0.77	
Frame				11.61		3.51	9.88	0.47
Floors	0.57		1.81	1.38		2.29	0.45	1.06
Roof			3.39	0.32			9.37	1.14
External Walls	0.66		1.85	1.92		2.89	0.70	0.27
Internal Walls	0.54			1.03		0.78	0.61	0.61
Stairs				0.12		0.19	0.09	0.24
Windows + Doors	1.07		0.83	0.30		0.20	2.85	0.24
Stairs + Lifts			3.66	0.51	0.06			
Internal Finishings			0.41	0.43		0.56	0.34	0.20
Fittings			0.10	4.31		0.26		0.25
BWIC Mechanical		2.22	3.44	1.36		18.54		60.94
BWIC Electrical			1.50	3.07		1.78	0.71	3.03
BWIC Plumbing			0.29	0.12		0.09	0.41	0.18
External Works		0.13			0.11		4.19	0.85
Bridges								
Offplot Frame								
Dayworks								
Bill Mean	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 16.2: MAJOR AND MINOR COST GENERATING ELEMENTS IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES

ELEMENT [ALL ITEMS]: MEAN RATE OF COST GENERATION [SMM6]	BILL 11	BILL 12	BILL 13	BILL 14	BILL 15	BILL 16	BILL 17
Preliminaries	4.85	4.37	6.06	4.56		7.51	7.00
Fixed, Time Charges					0.02		
Site Preparation				2.63			
Demolitions	0.29			0.41		0.12	0.21
Excavations	0.65			0.35		0.46	1.76
Foundations	1.05			0.76		1.04	1.57
Marine + River Works							
Reservoirs + Tanks						0.38	
Roads + Pavings		2.63		1.84		1.61	0.52
External Services	1.12	0.33				0.20	0.18
Drainage	0.42			0.24	0.56	0.54	0.18
Pipe Supports + Culverts		1.14					
Chimneys + Cooling Towers						0.60	0.31
Substructure					1.74	1.50	0.25
Frame			0.81				0.11
Floors	0.59		1.41		3.00		0.18
Roof			2.17	0.48		0.99	0.22
External Walls	0.66		0.54	1.20		0.63	0.30
Internal Walls						0.11	
Stairs	1.56		2.15	1.59		0.31	0.51
Windows + Doors				0.38		0.47	0.11
Stairs + Lifts							
Internal Finishings	0.06			2.50	2.36	0.29	0.27
Fittings	0.77			0.69		0.29	0.27
BWIC Mechanical			0.40			7.25	0.61
BWIC Electrical	0.11					1.37	0.03
BWIC Plumbing						0.05	0.03
External Works	0.74					0.86	
Bridges			0.37				
Offplot Frame			2.48				
Dayworks	0.57	0.09	0.56	2.43	0.47	7.02	1.58
Bill Mean	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 16.3: MAJOR AND MINOR COST GENERATING ELEMENTS IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES

ELEMENTS [MEASURED ITEMS]: MEAN RATE OF COST GENERATION [SMM5]	BILL 2	BILL 3	BILL 4	BILL 5	BILL 6	BILL 7	BILL 8	BILL 9
Preliminaries								
Fixed, Time Charges								
Site Preparation			0.20					
Demolitions	0.39	1.06		0.23				0.26
Excavations	0.54	1.26						0.37
Foundations	0.92	0.34	0.81				0.98	0.53
Marine + River Works								
Reservoirs, Tanks	0.23	0.61		0.12				
Roads + Pavings		1.31	1.65	0.45	2.80		0.76	
External Services		0.31			0.35		0.27	
Drainage	0.26	0.42	0.44	0.20	0.51	0.12	0.29	0.13
Pipe Supports, Culverts		0.32						
Chimneys, Cooling Towers								
Substructure			1.08	1.19		0.47	0.77	
Frame				0.10		1.01	0.11	0.47
Floors	0.57		1.81	1.31		0.95	0.36	1.06
Roof			3.39	0.32				1.14
External Walls	0.66		1.91	0.68		1.21	0.70	0.18
Internal Walls	0.05			1.06		0.78	0.61	0.61
Stairs				0.12		0.19	0.09	0.24
Windows + Doors	0.25		0.83	0.13		0.16	0.01	0.24
Stairs + Lifts				0.16	0.06			
Internal Finishings			0.41	0.37		0.42	0.34	0.20
Fittings			0.10	1.27		0.08		0.25
BWIC Mechanical			0.10	0.06		0.20		
BWIC Electrical			0.07	0.05		0.08		0.07
BWIC Plumbing			0.29	0.06		0.05	0.21	0.18
External Works		0.13			0.11		0.46	0.85
Bridges								
Offplot Frame								
Dayworks								
Bill Mean	0.54	0.65	0.89	0.37	0.83	0.37	0.51	0.31

TABLE 16.4: MAJOR AND MINOR COST GENERATING ELEMENTS IN PETROCHEMICAL CIVIL ENGINEERING BILLS OF QUANTITIES

ELEMENTS [MEASURED ITEMS]: MEAN RATE OF COST GENERATION [SMM6]	BILL 11	BILL 12	BILL 13	BILL 14	BILL 15	BILL 16	BILL 17
Preliminaries							
Fixed, Time Charges							
Site Preparation				2.63			
Demolitions	0.29			0.41		0.12	0.21
Excavations	0.65			0.35		0.46	1.76
Foundations	1.05			0.75		1.04	1.57
Marine + River Works							
Reservoirs, Tanks						0.38	
Roads + Pavings		2.63		1.84		1.62	0.52
External Services	1.12	0.33				0.20	0.18
Drainage	0.42			0.24	0.56	0.54	0.18
Pipe Supports, Culverts		1.42					
Chimneys, Cooling Towers						0.60	0.31
Substructure					1.74	1.50	0.25
Frame			0.81				0.11
Floors	0.60		1.41		3.00		0.18
Roof				0.48		0.34	0.22
External Walls	0.66			1.20		0.63	0.30
Internal Walls						0.11	
Stairs	0.19		2.15	1.59		0.31	0.06
Windows + Doors				0.38		0.41	0.11
Stairs + Lifts							
Internal Finishings	0.06			2.32	2.36	0.29	0.06
Fittings	0.77			0.69		0.18	0.14
BWIC Mechanical			0.40			0.30	0.61
BWIC Electrical	0.11					0.09	0.03
BWIC Plumbing						0.05	0.03
External Works	0.68					0.86	
Bridges			0.37				
Offplot Frame			2.48				
Dayworks							
Bill Mean	0.85	1.38	1.03	0.78	1.22	0.81	0.86

Appendix 6

Validation of the Hypothetical Model: Results of Structured Interview Survey of Model Users (Stage 1) (Ch. 6.1-6.5)

Results of Survey of User Attitudes to Hypothetical Model (Stage 1) (Ch. 6.3)

The original plan was to interview 7 users in the North-West of England and 6 in the North-East. Staff availability dictated that only the North-West users were available to comment on the Draft Measurement Rules at this stage, but see *Appendix 7*. The following comments are offered regarding the survey:

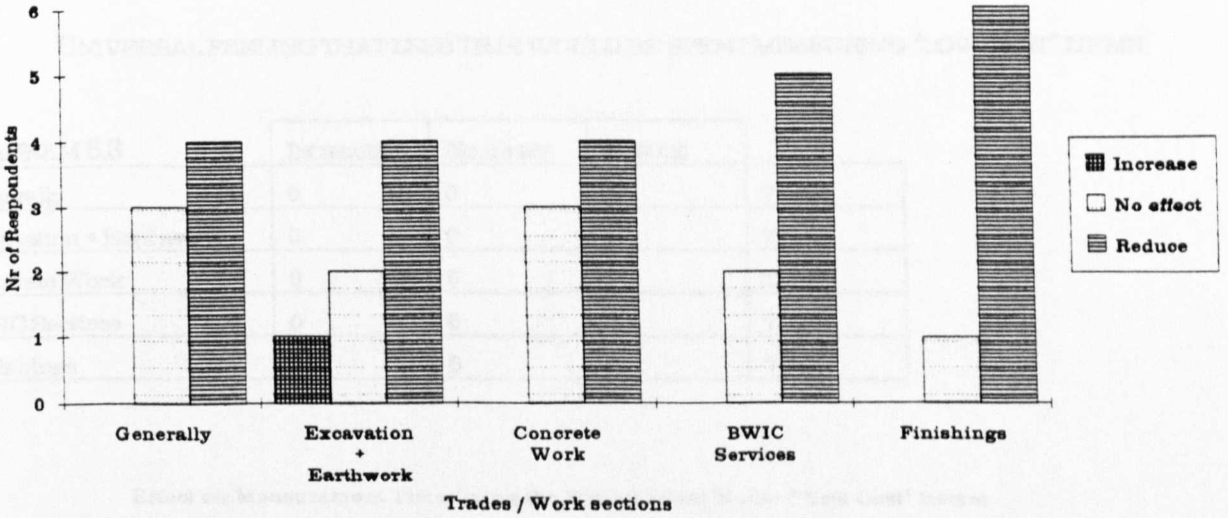
1) A possible total of 13 respondents appears small and, hence, limits the reliability of any results obtained. These 13 respondents, however, represented all of the personnel who were likely to become involved in preparation of Bills of Quantities. The sample size could not realistically have been increased.

2) The parties to the research project were satisfied therefore that consultation with all likely users of the hypothetical measurement model would yield sufficient information to enable reasoned comment to be drawn from the results.

1 VERY STRONG FEELING THAT THERE WOULD BE FEWER ITEMS TO MEASURE.

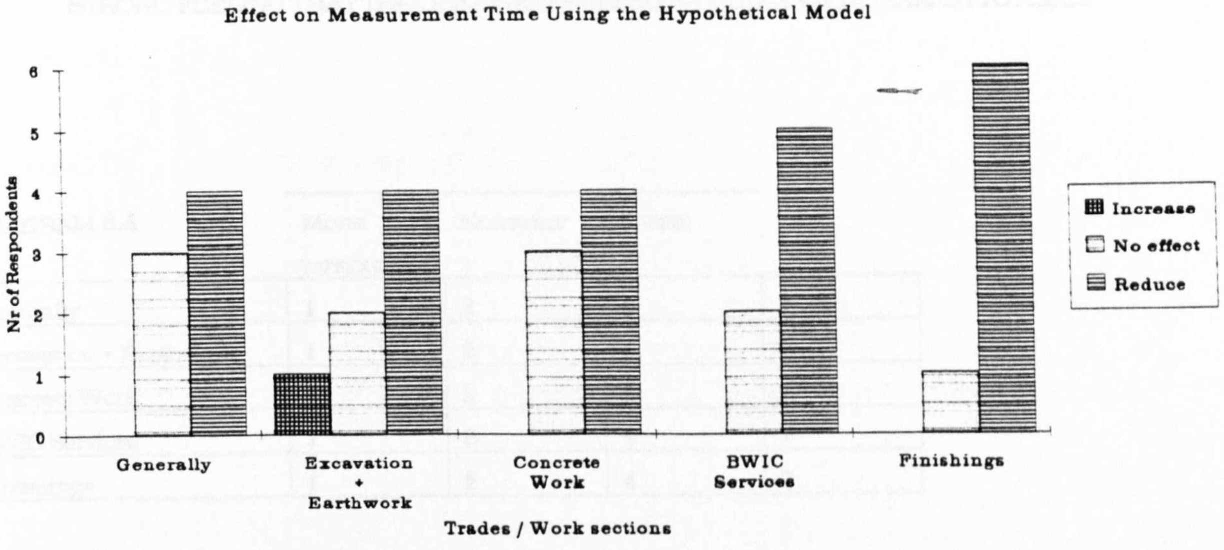
DIAGRAM 6.1	MORE	NO EFFECT	FEWER	
Generally	0	0	7	7
Excavation + Earthwork	0	0	7	7
Concrete Work	0	1	6	7
BWIC Services	0	1	6	7
Finishings	0	0	7	7

Items to Measure Using the Hypothetical Model



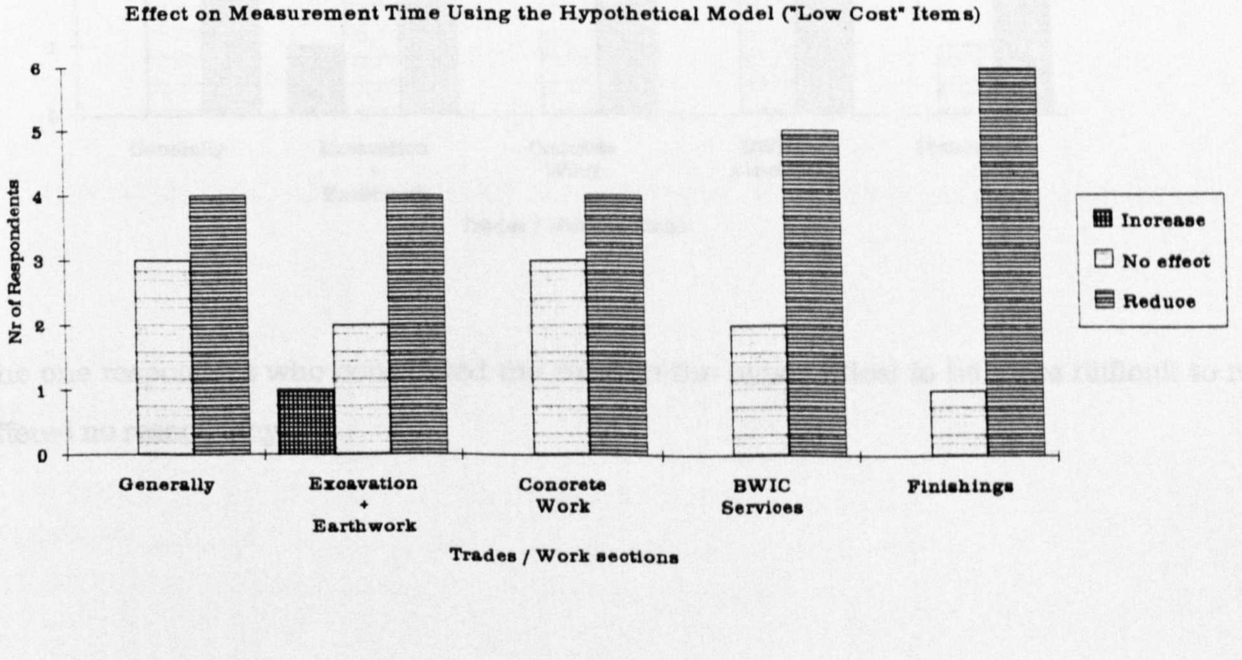
2 STRONG FEELING THAT MEASUREMENT TIME WOULD REDUCE.

DIAGRAM 6.2	INCREASE	NO EFFECT	REDUCE	
Generally	0	3	4	7
Excavation + Earthwork	0	2	5	7
Concrete Work	0	3	4	7
BWIC Services	0	2	5	7
Finishings	0	0	7	7



3 UNIVERSAL FEELING THAT LESS TIME WOULD BE SPENT MEASURING "LOW COST" ITEMS.

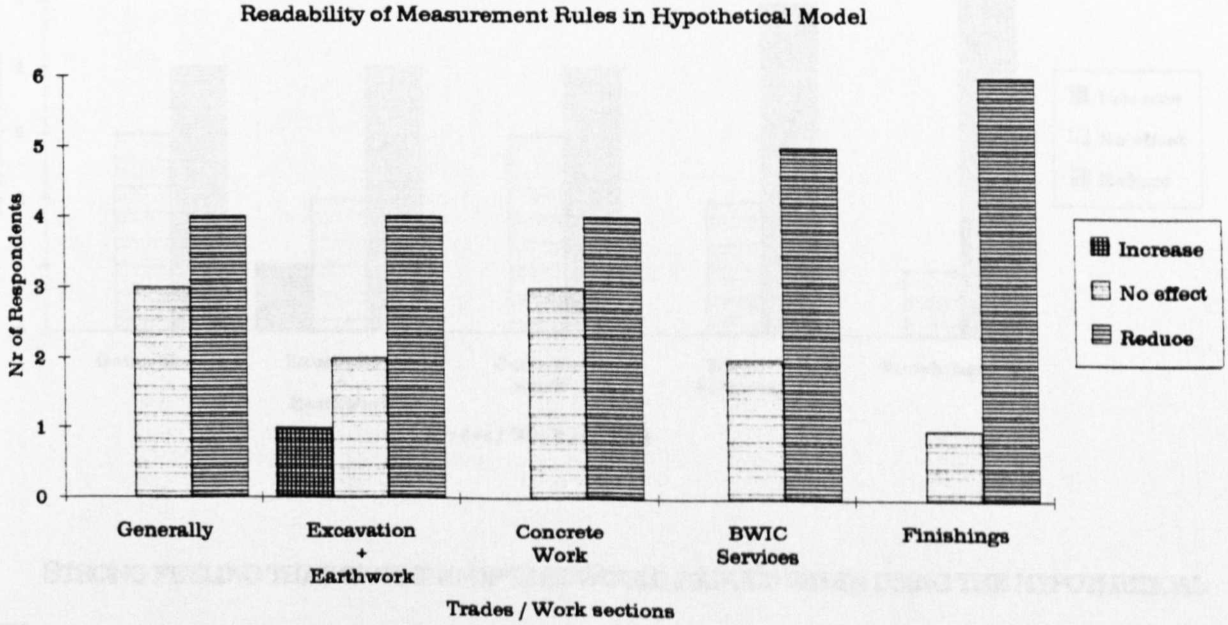
DIAGRAM 6.3	INCREASE	NO EFFECT	REDUCE	
Generally	0	0	7	7
Excavation + Earthwork	0	0	7	7
Concrete Work	0	0	7	7
BWIC Services	0	0	7	7
Finishings	0	0	7	7



4 STRONG FEELING THAT THE DRAFT MEASUREMENT RULES WERE EASIER TO READ.

DIAGRAM 6.4

	MORE DIFFICULT	NO EFFECT	EASIER	
Generally	1	2	4	7
Excavation + Earthwork	1	2	4	7
Concrete Work	1	2	4	7
BWIC Services	1	2	4	7
Finishings	1	2	4	7

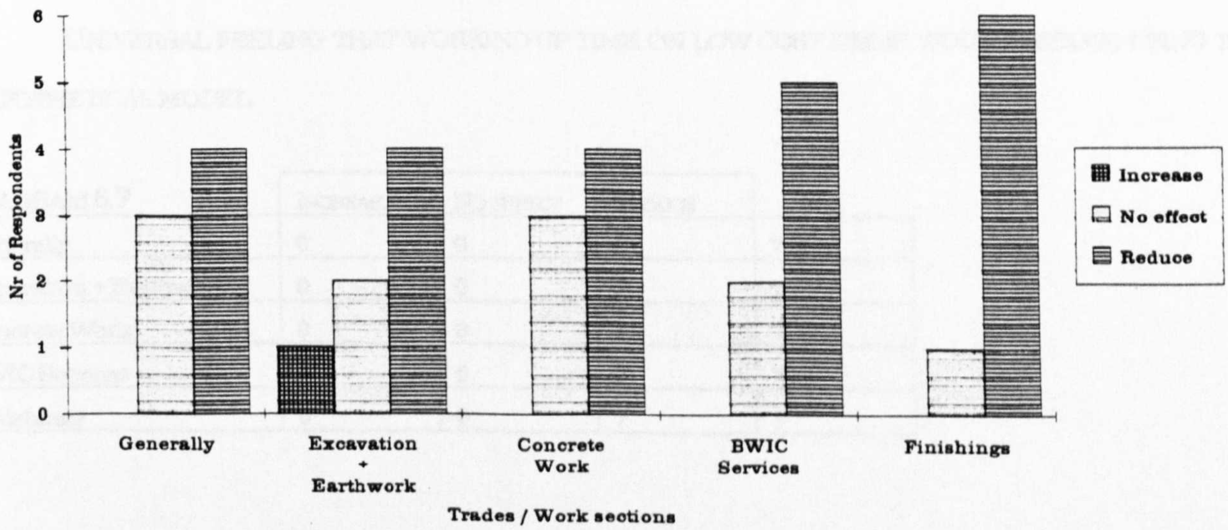


The one respondent who considered the rules in the hypothetical to be more difficult to read offered no reason why.

5 STRONG FEELING THAT THE MEASUREMENT RULES IN THE HYPOTHETICAL MODEL WERE SIMPLER AND CLEARER.

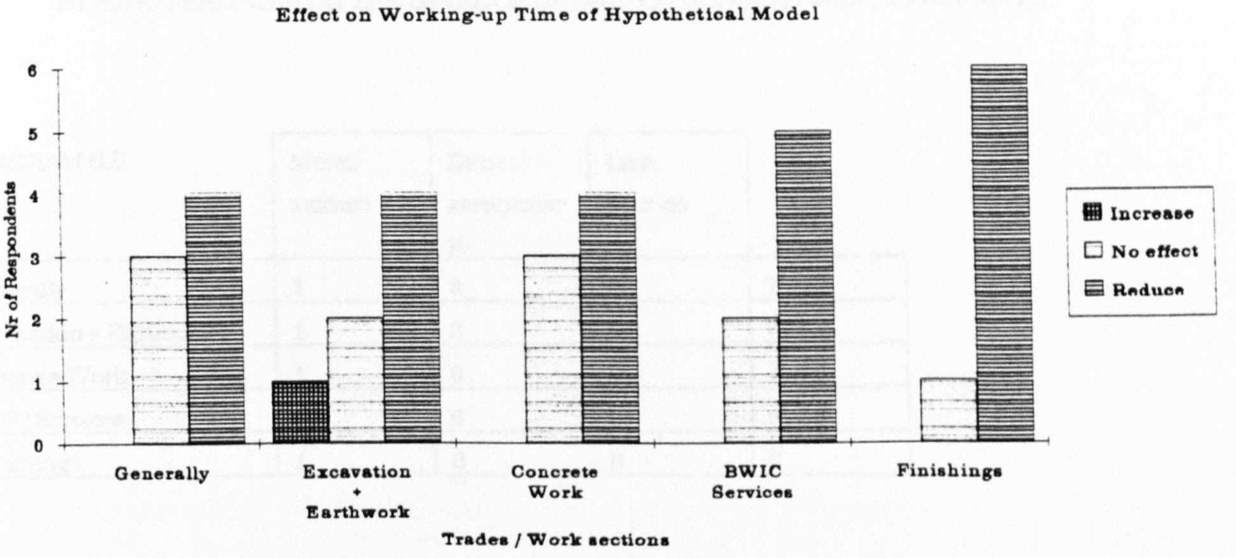
DIAGRAM 6.5	LESS SIMPLE AND CLEAR	NO EFFECT	MORE SIMPLE AND CLEAR	
Generally	1	2	4	7
Excavation + Earthwork	1	2	4	7
Concrete Work	1	2	4	7
BWIC Services	1	2	4	7
Finishings	1	2	4	7

Simplicity and Clarity of Measurement Rules in Hypothetical Model



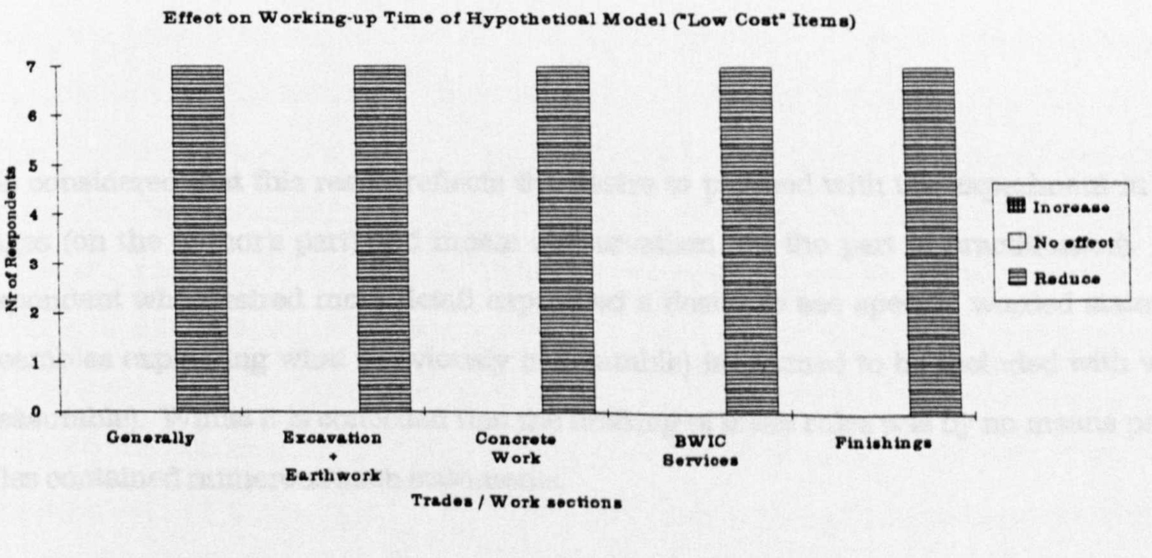
6 STRONG FEELING THAT WORKING-UP TIME WOULD REDUCE WHEN USING THE HYPOTHETICAL MODEL.

DIAGRAM 6.6	INCREASE	NO EFFECT	REDUCE	
Generally	0	3	4	7
Excavation + Earthwork	1	2	4	7
Concrete Work	0	3	4	7
BWIC Services	0	2	5	7
Finishings	0	1	6	7



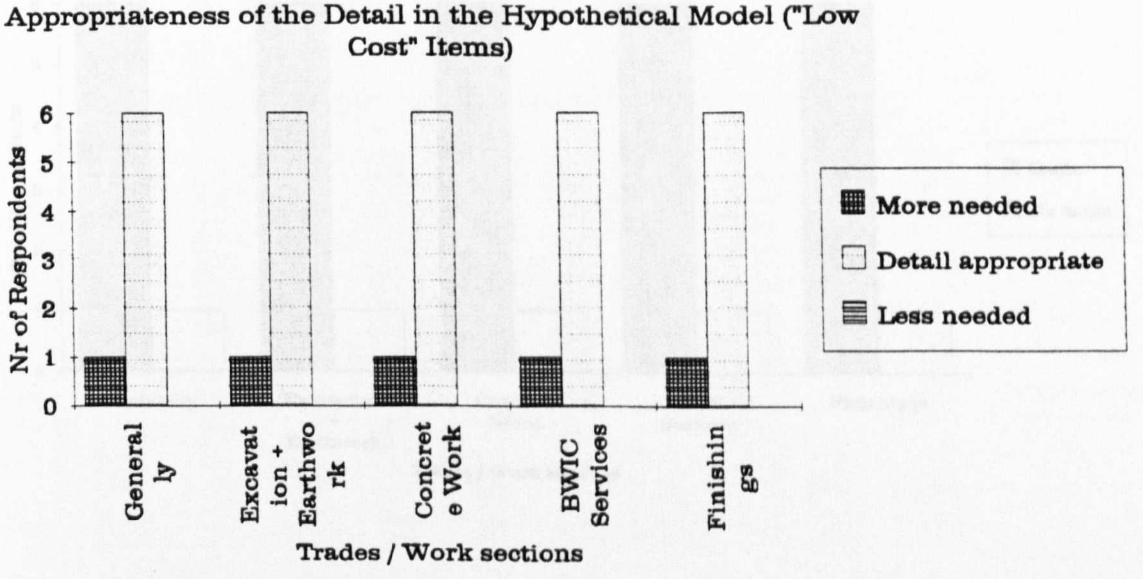
7 UNIVERSAL FEELING THAT WORKING-UP TIME ON LOW COST ITEMS WOULD REDUCE USING THE HYPOTHETICAL MODEL.

DIAGRAM 6.7	INCREASE	NO EFFECT	REDUCE	
Generally	0	0	7	7
Excavation + Earthwork	0	0	7	7
Concrete Work	0	0	7	7
BWIC Services	0	0	7	7
Finishings	0	0	7	7



8 STRONG FEELING THAT THE LEVEL OF DETAIL SO PRODUCED WAS APPROPRIATE.

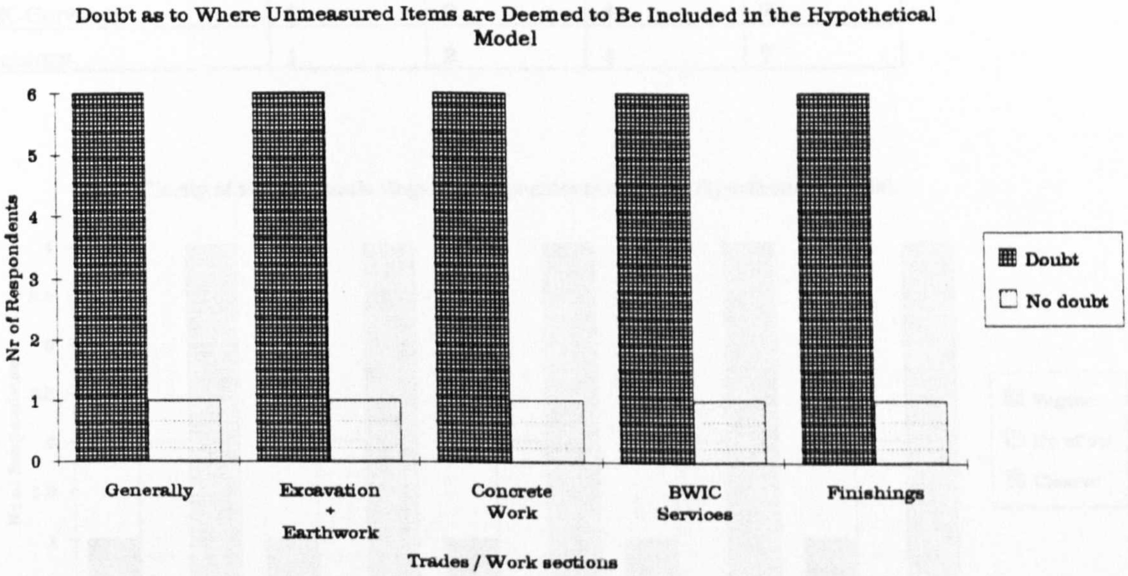
DIAGRAM 6.8	MORE NEEDED	DETAIL APPROPRIATE	LESS NEEDED	
Generally	1	6	0	7
Excavation + Earthwork	1	6	0	7
Concrete Work	1	6	0	7
BWIC Services	1	6	0	7
Finishings	1	6	0	7



It is considered that this result reflects the desire to proceed with the experiment in cautious stages (on the author's part) and innate conservatism (on the part of practitioners). The one respondent who desired more detail expressed a desire to see specific worded statements or preambles explaining what (previously measurable) is deemed to be included with what (still measurable). Whilst it is conceded that the drafting of these rules was by no means perfect, the rules contained numerous such statements.

10 A STRONG FEELING OF DOUBT AS TO WHERE THINGS ARE INCLUDED.

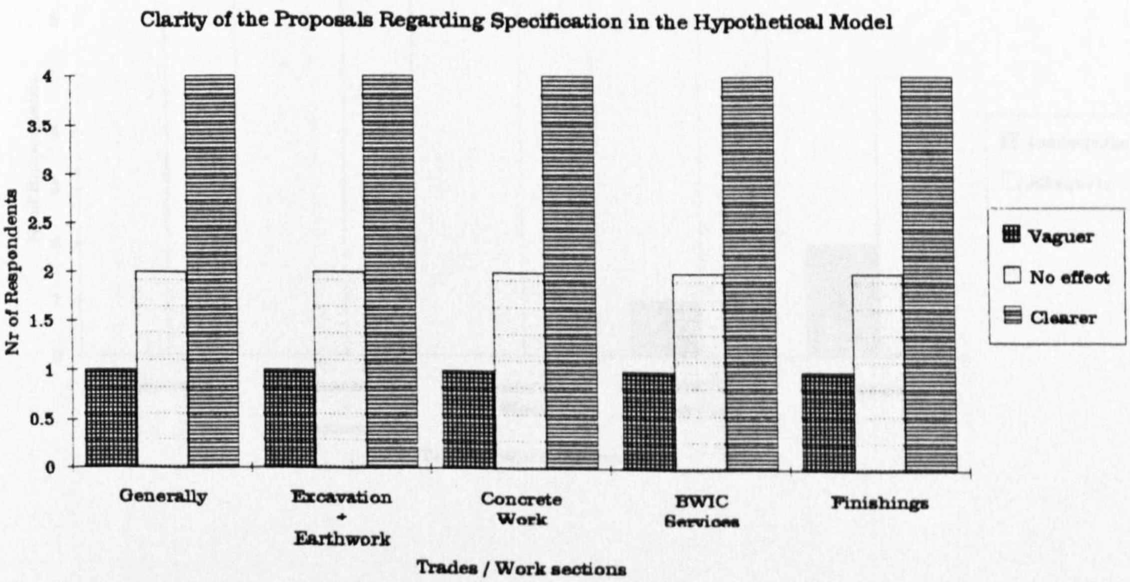
DIAGRAM 6.9	DOUBT	NO DOUBT	
Generally	6	1	7
Excavation + Earthwork	6	1	7
Concrete Work	6	1	7
BWIC Services	6	1	7
Finishings	6	1	7



Most respondents cited confusion as to whether information was in the specification, in a Preamble or with the measured item itself. This is a clear indication that the experimental model would have to be more meticulously drafted. One respondent mentioned the risk of claims if the work changed drastically. It is contended that there is precedent for declaring Bills of Quantities rates invalid if the work changes drastically; it would no longer be the work (and working conditions) originally tendered for. It would matter little which measurement model was involved; no Bill of Quantities could be adequate if the eventual work done did not remotely resemble that described by said Bill. It has already been mentioned that certain sections of the Petrochemical Civil Engineering Bills analysed appeared not to have been derived from the design, but merely inserted in order to cover the allowed budget. There would seem little point, therefore, in adding over-complexity to inherent inadequacy.

12 A STRONG FEELING THAT THE PROPOSALS FOR SPECIFICATION WERE CLEARER.

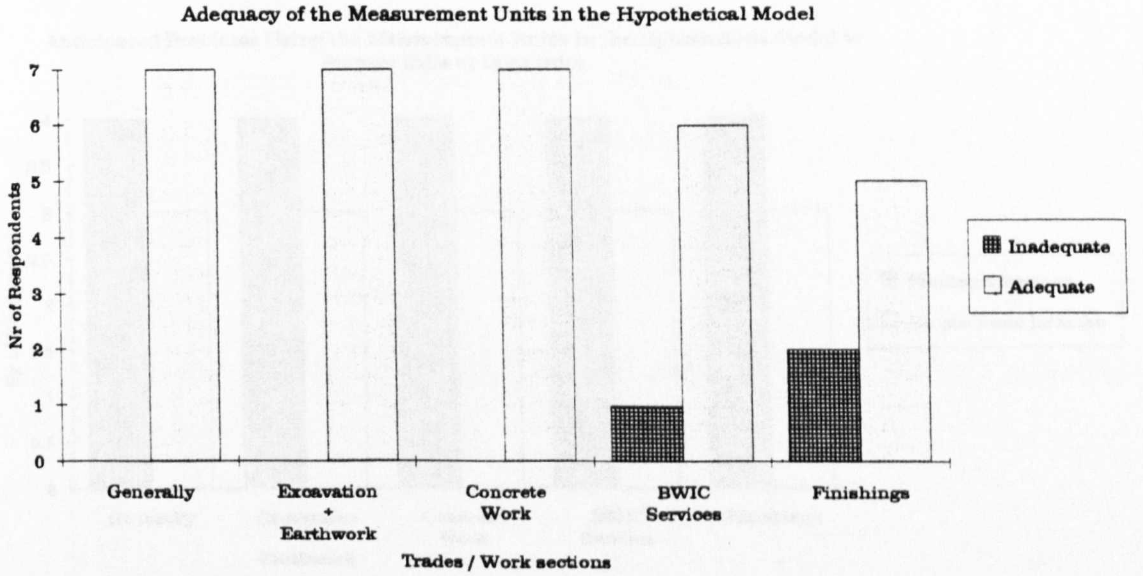
DIAGRAM 6.10	VAGUER	NO EFFECT	CLEARER	
Generally	1	2	4	7
Excavation + Earthwork	1	2	4	7
Concrete Work	1	2	4	7
BWIC Services	1	2	4	7
Finishings	1	2	4	7



This seems to contradict some of the responses to Question 10. Perhaps Question 10 could be taken to be a response to the proposed measurement document in general as opposed to Specifications in particular. It is nevertheless puzzling to witness the apparent confusion which arises when a statement is made that "what is measured must be specified". It would seem obvious. SMM7 (1988), which was still being developed at the time of this survey, eventually placed heavy reliance on reference to the specification as being the only information without which builders could not price construction work (*vide supra*).

13 A VERY STRONG FEELING THAT THE PROPOSED UNITS OF MEASUREMENT WERE ADEQUATE.

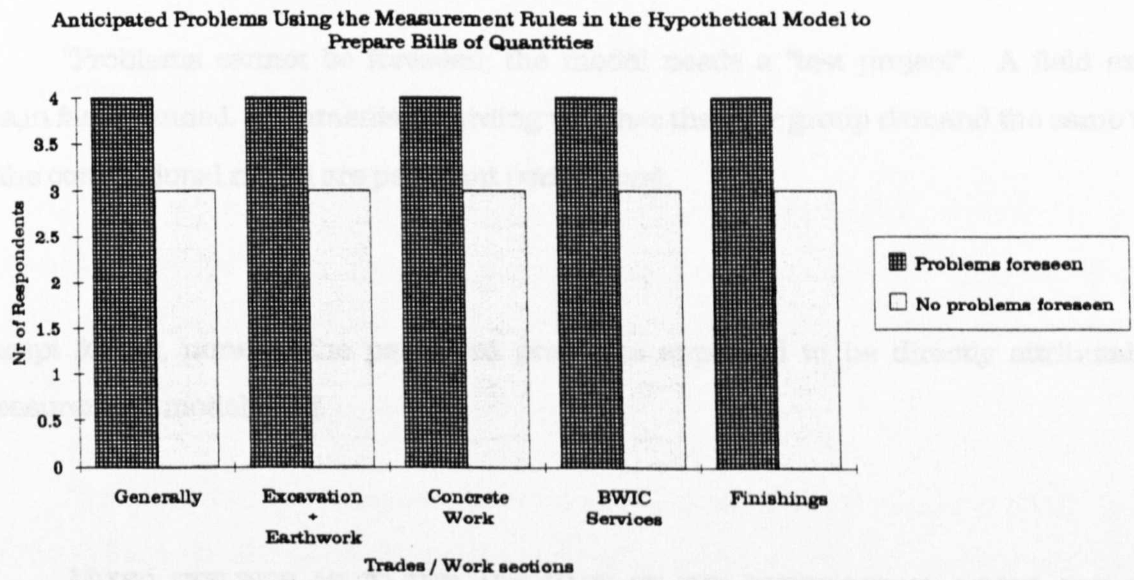
DIAGRAM 6.11	INADEQUATE	ADEQUATE	
Generally	0	7	7
Excavation + Earthwork	0	7	7
Concrete Work	0	7	7
BWIC Services	1	6	7
Finishings	2	5	7



One or two respondents harboured personal doubts as to whether Finishings ought to be simplified. The results of the data analyses used to test the conventional model, however, would suggest otherwise.

14 MIXED FEELINGS AS TO WHETHER THERE WOULD BE ANY PROBLEMS USING THE DRAFT MEASUREMENT RULES FOR PREPARING BILLS OF QUANTITIES.

DIAGRAM 6.12	PROBLEMS FORESEEN	NO PROBLEMS FORESEEN	
Generally	4	3	7
Excavation + Earthwork	4	3	7
Concrete Work	4	3	7
BWIC Services	4	3	7
Finishings	4	3	7



15 OF THE RESPONDENTS WHO FORESAW PROBLEMS, NUMEROUS STATEMENTS WERE OFFERED:

a) "The confusion in Question 10". This is not disputed.

b) "Simplification of Finishings". The simplification was based on the *observed* tendency for the only marginal effect of the inclusion of complexity.

c) "The Client dictates what Method of Measurement to use." It is contended here that the surveyor should so advise, as a relative expert in these matters.

d) "The difficulty of persuading an entire industry to adopt the model at present under experiment". Whilst this cannot be gainsaid, it does not necessarily constitute a defect. This is more evidence that the criteria underpinning model selection can be sociological, and can be applied without recourse to empirical evidence.

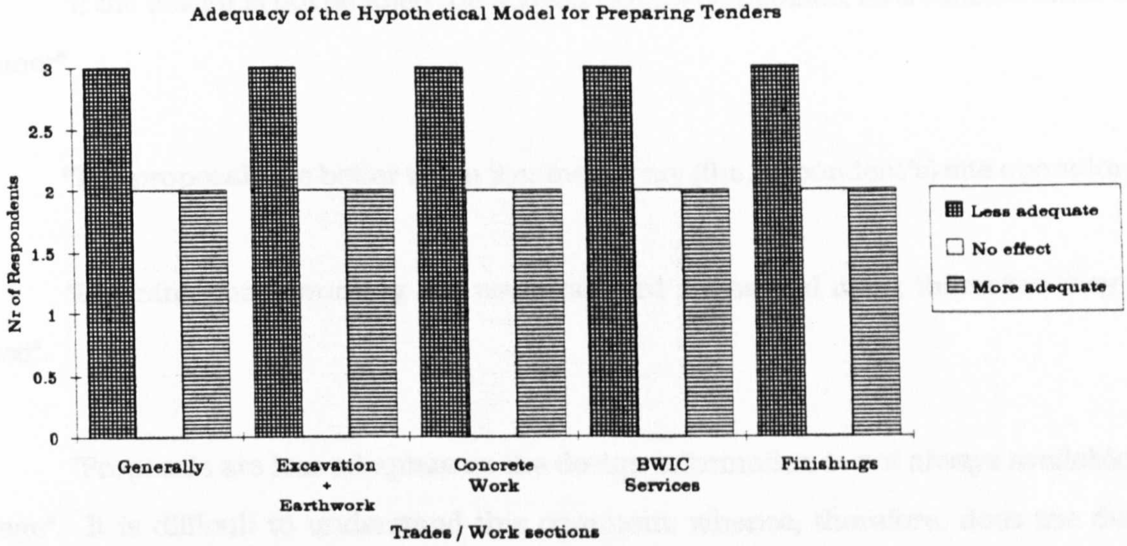
e) "Lack of familiarity and "the learning curve". Again, this is undeniable, but not necessarily a defect. Another sociological criterion.

f) "Problems cannot be foreseen; the model needs a "test project". A field experiment was,in fact, planned. Comments regarding whether the user group demand the same treatment of the conventional model are pertinent (*vide supra*).

Except for (a), none of the perceived problems appeared to be directly attributable to the measurement model itself.

16 MIXED FEELINGS AS TO THE ADEQUACY OF THE HYPOTHETICAL MODEL FOR PREPARING TENDERS.

DIAGRAM 6.13	LESS ADEQUATE	NO EFFECT	MORE ADEQUATE	
Generally	3	2	2	7
Excavation + Earthwork	3	2	2	7
Concrete Work	3	2	2	7
BWIC Services	3	2	2	7
Finishings	3	2	2	7



Comments offered included:

a) "The Tenderer would have to think about the scope of the work or be given some indicative drawings". The case has been already for referring to the drawings for whatever degree of detail exists. A Tender can be prepared without a Bill of Quantities regardless of its level of detail.

b) "By not giving the Tenderer much information more risk is apportioned to him/her". See remarks about drawings and about whether this information was "created out of nothing" by the method of measurement itself.

c) "Tenderers are not interested in Bills of Quantities with thousands of items". The results of the analyses of the conventional model strongly support this respondent's statement.

d) "Tenderers should be given detailed drawings". This can only occur if detailed drawings exist. If not, as is very often the case, detailed measurement would seem inappropriate. As this respondent appears to suggest, there would be no need for the measurements themselves to convey the detail to be communicated twice.

e) "If the design is not detailed the take-off cannot be detailed, so a concise SMM has to be a winner".

f) "The proposals are better when it comes to my (the respondent"s) site operations".

g) "Learning curve working out new Standard prices and rates; thereafter they can be re-used".

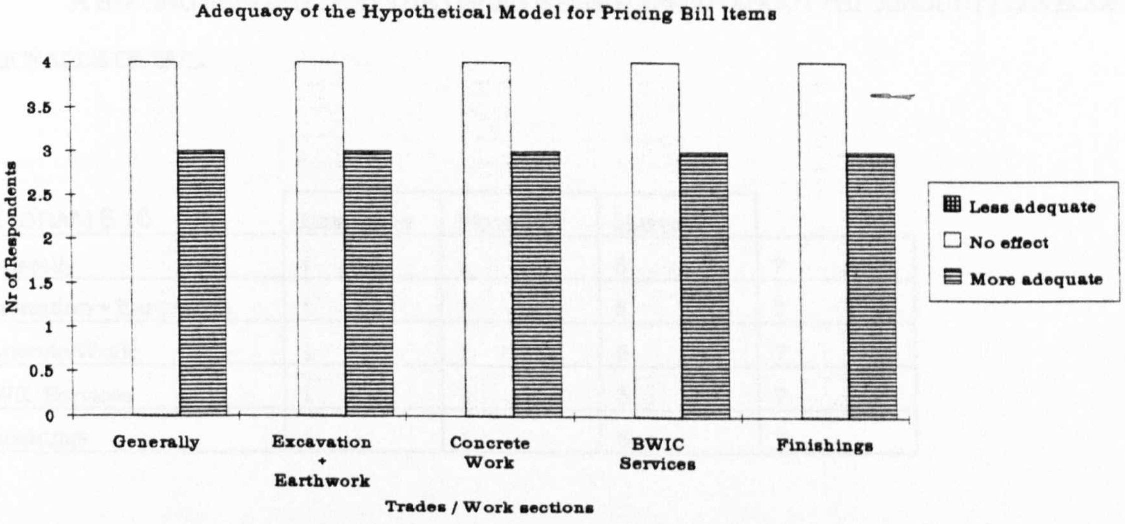
h) "Proposals are less adequate as the design information is not always available at Tender Stage". It is difficult to understand this comment: whence, therefore, does the detail come? What relevance do the measurements have? *Vide supra.*

i) "The reliance on specification gives ground for concern". Work cannot be priced without a specification. This response is extremely curious. It could not be the case that people did not specify things; therefore they should be relied upon.

Comments (c), (d) and (e) were most welcome. They echoed some of the "foundation"arguments behind the approach to the research (see *Chapter 2*).

19 NO DIFFICULTY FORESEEN IN PRICING ITEMS MEASURED BY THE DRAFT RULES.

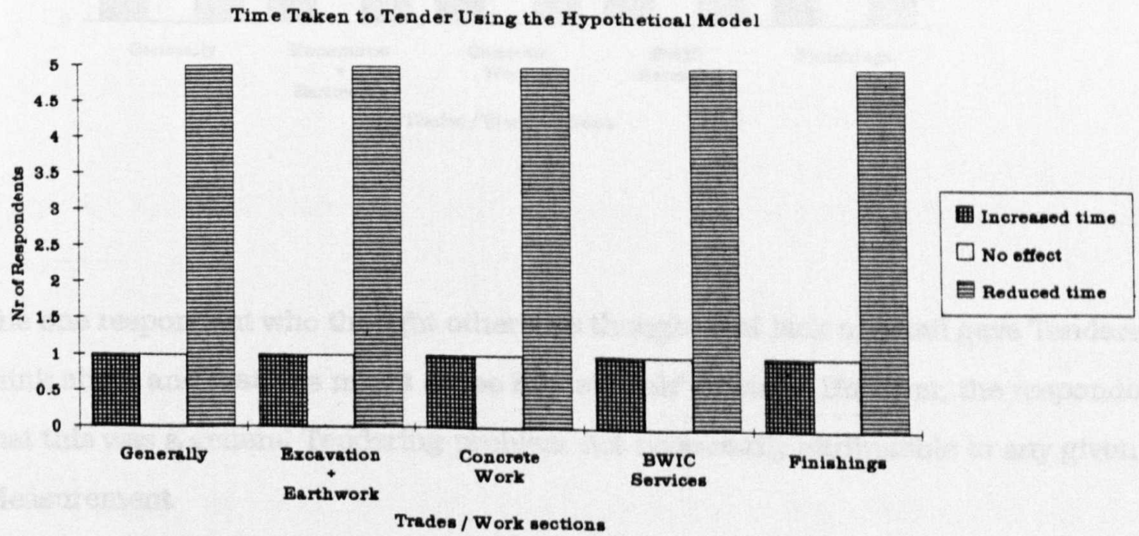
DIAGRAM 6.14	LESS ADEQUATE	NO EFFECT	MORE ADEQUATE	
Generally	0	4	3	7
Excavation + Earthwork	0	4	3	7
Concrete Work	0	4	3	7
BWIC Services	0	4	3	7
Finishings	0	4	3	7



20 A STRONG FEELING THAT THE TIME TAKEN TO TENDER WILL REDUCE.

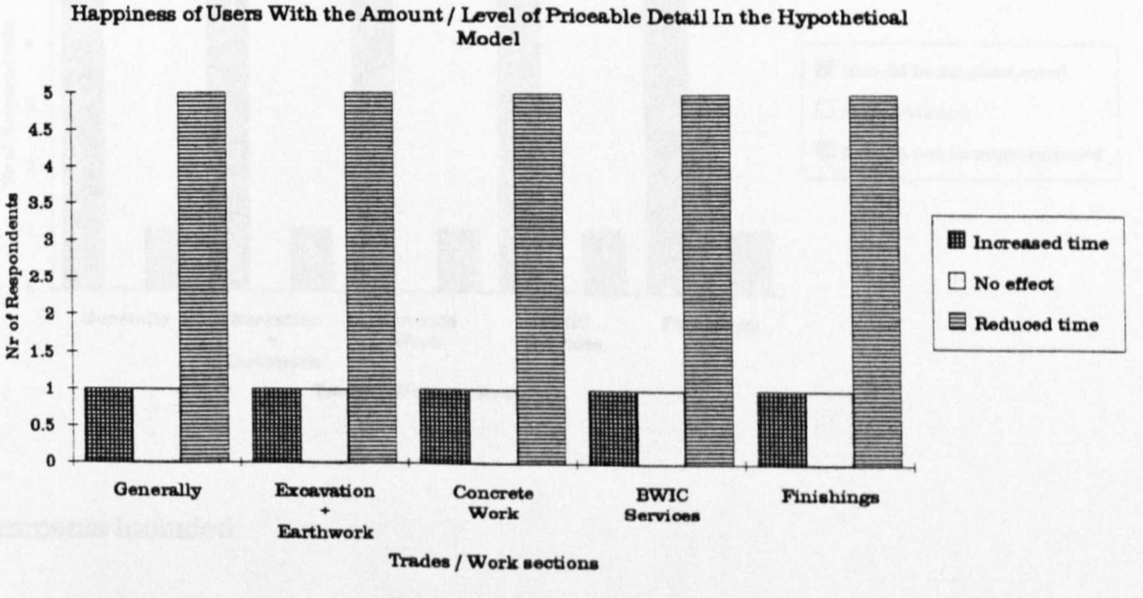
DIAGRAM 6.15

	INCREASED TIME	NO EFFECT	REDUCED TIME	
Generally	1	1	5	7
Excavation + Earthwork	1	1	5	7
Concrete Work	1	1	5	7
BWIC Services	1	1	5	7
Finishings	1	1	5	7



21 A STRONG FEELING THAT THE USERS WERE HAPPIER ABOUT THE AMOUNT / LEVEL OF PRICEABLE DETAIL.

DIAGRAM 6.16	LESS HAPPY	NO EFFECT	HAPPIER	
Generally	1	1	5	7
Excavation + Earthwork	1	1	5	7
Concrete Work	1	1	5	7
BWIC Services	1	1	5	7
Finishings	1	1	5	7

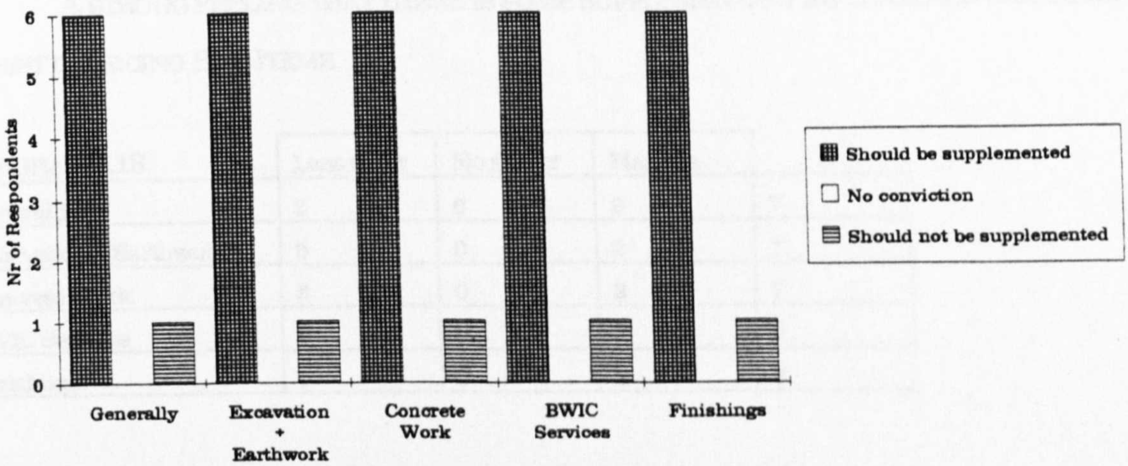


The one respondent who thought otherwise thought that lack of detail gave Tenderers more to think about and that this might cause higher "risk" pricing. However, the respondent thought that this was a general Tendering problem not necessarily attributable to any given Method of Measurement.

22 A STRONG FEELING THAT THE MEASUREMENT RULES SHOULD BE SUPPLEMENTED BY FURTHER INFORMATION TO ASSIST TENDERING.

DIAGRAM 6.17	LESS HAPPY	NO EFFECT	HAPPIER	
Generally	6	0	1	7
Excavation + Earthwork	6	0	1	7
Concrete Work	6	0	1	7
BWIC Services	6	0	1	7
Finishings	6	0	1	7

The Measurement Rules In theHypothetical Model Should Be Supplemented By Further Information to Assist Tendering



Comments included:

a) "Indicators of scope and detail". It is argued that this would be difficult in the case of incomplete design.

b) "Where to allow money for unmeasured items". See Question 8. Also, it has to be said that with any existing Method of Measurement, nobody but the Tenderer knows where the true costs of things have been included. The hypothetical model could not be any worse in this respect.

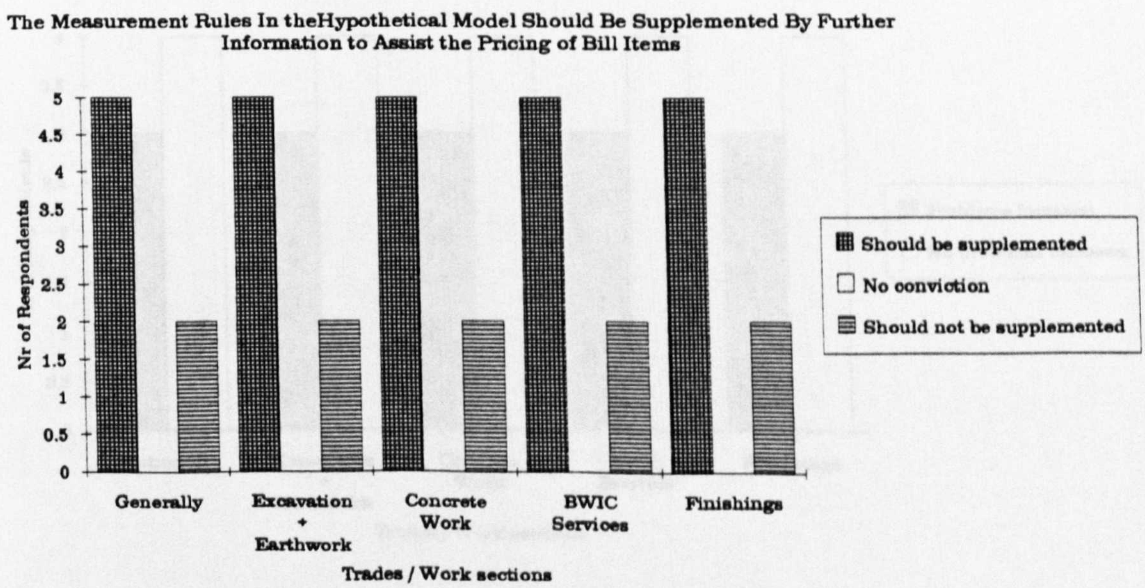
c) "Diagrams for unusual items". This is fair comment. It is accepted as good practice so to do. It is debatable, though, whether it would be wise to misdirect effort on the invention of measurement rules to cater for the measurement of what seldom occurs.

d) "Specifications". This is in contrast to Question 18 (i).

e) "Better explanation of item coverage, what is deemed to be included *etc.*". This is accepted as a shortcoming of drafting.

24 A STRONG FEELING THAT THERE IS SOME SUPPLEMENTARY INFORMATION NECESSARY TO ASSIST IN PRICING BILL ITEMS.

DIAGRAM 6.18	LESS HAPPY	NO EFFECT	HAPPIER	
Generally	5	0	2	7
Excavation + Earthwork	5	0	2	7
Concrete Work	5	0	2	7
BWIC Services	5	0	2	7
Finishings	5	0	2	7



Despite the apparent contrast to the response to Question 18, responses included:

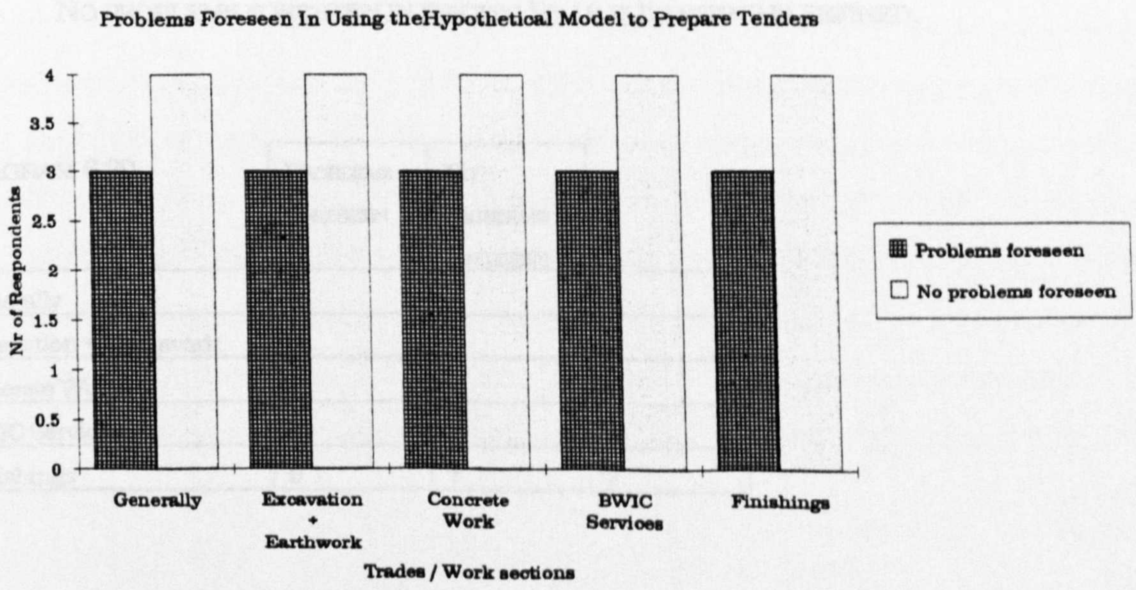
a) As Question 22.

b) "Phasing restrictions on proposed construction work".

25 MIXED FEELINGS AS TO PROBLEMS FORESEEN IN PREPARING TENDERS (DRAFTING PROBLEMS APART).

DIAGRAM 6.19

	PROBLEMS FORESEEN	NO PROBLEMS FORESEEN	
Generally	3	4	7
Excavation + Earthwork	3	4	7
Concrete Work	3	4	7
BWIC Services	3	4	7
Finishings	3	4	7



Problems foreseen included:

a) As question 22.

b) "Learning curve". See previous comments.

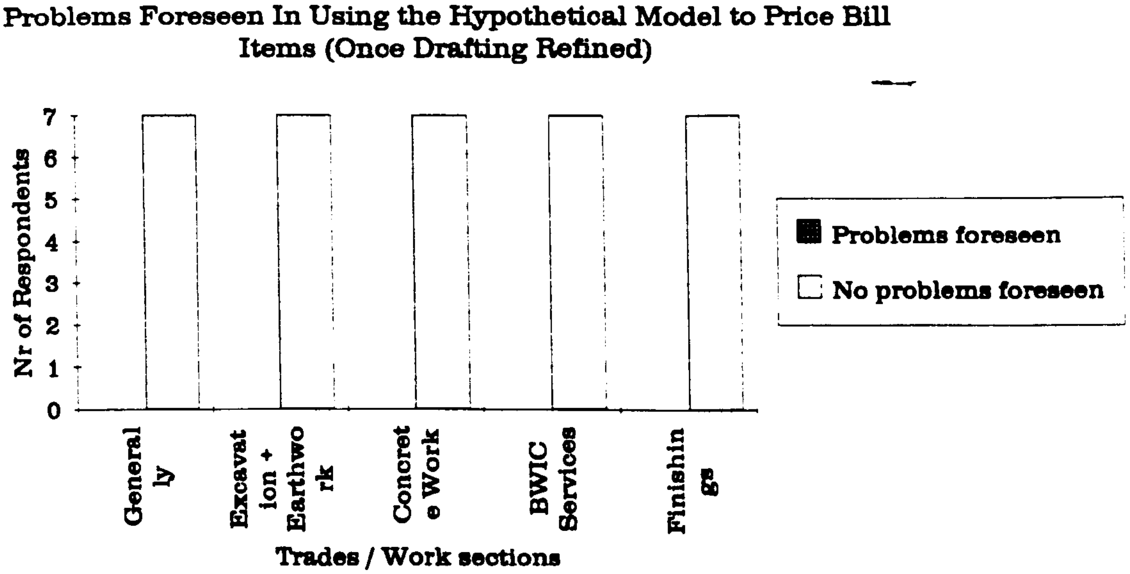
c) "Acceptance by industry". See previous comments.

d) "We need a "test" project". See previous comments.

e) "Less measurement detail needs more advanced design". Again, it may be a contradiction in terms to expect detailed measurement of a 'not-detailed' design. Agreed, in the case of advanced design, simple measurement is easy, but in the case of incomplete design it is difficult to envisage how complex measurements could have actually been obtained, save by creation for creation's sake.

26 NO PROBLEMS FORESEEN IN PRICING BILLS IF DRAFTING IS REFINED.

DIAGRAM 6.20	PROBLEMS FORESEEN	NO PROBLEMS FORESEEN	
Generally	0	7	7
Excavation + Earthwork	0	7	7
Concrete Work	0	7	7
BWIC Services	0	7	7
Finishings	0	7	7

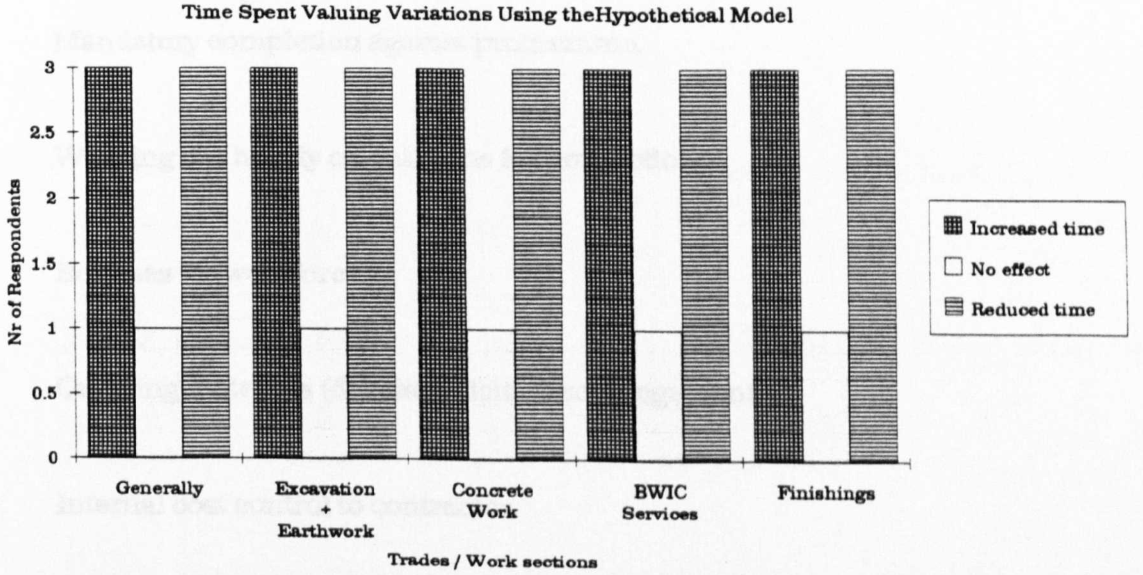


30 THE USES OF MEASURED BILL OF QUANTITIES SECTIONS IN THE PREPARATION OF TENDERS (AS EXPRESSED BY THE USER GROUP OF MEASURERS).

Responses were (with one or two exceptions of detail) comparatively vague, suggesting that the respondents were not too sure. This appeared to contradict any misgivings the respondents may have had about the suitability of the draft measurement rules in the Tendering Period (Questions 16-29). Having doubted the suitability of the document for tendering, the respondents seemed to have no clear view of how it was actually used used by tenderers. Curiously, the respondent who was most critical of the hypothetical model actually confessed to being "not really sure" how it was used. This invites the assertion that surveyors are in no position to make firm conclusions as to the suitability of tender documents if they do not know how builders use them.

31 POLARISATION OF OPINION ON WHETHER TIME SPENT VALUING VARIATIONS WOULD REDUCE USING THE HYPOTHETICAL MODEL.

DIAGRAM 6.21	INCREASED TIME	NO EFFECT	REDUCED TIME	
Generally	3	1	3	7
Excavation + Earthwork	3	1	3	7
Concrete Work	3	1	3	7
BWIC Services	3	1	3	7
Finishings	3	1	3	7



Comments included:

a) "Time problems in breaking down composite items".

b) "The time effect if "narrow widths" change dramatically". Again, it must be contested that if such things are unpriced, derisorily priced or priced the same as "wide areas" then "narrow width classifications" become a time-wasting irrelevance. It would matter little if their quantities varied in the extreme.

c) "Claims due to complexity changes". If the Tenderer attaches no importance to such items in the first place then such claims cannot involve much money.

d) "Learning curve and initially working out new standard prices". This was a common response.

32 SUGGESTIONS FROM THE USER GROUP OF MEASURERS AS TO HOW MEASURED ITEMS ARE USED IN POST CONTRACT PRODUCTION PLANNING INCLUDED:

a) Mandatory completion against programme.

b) Working out hourly calculations for production.

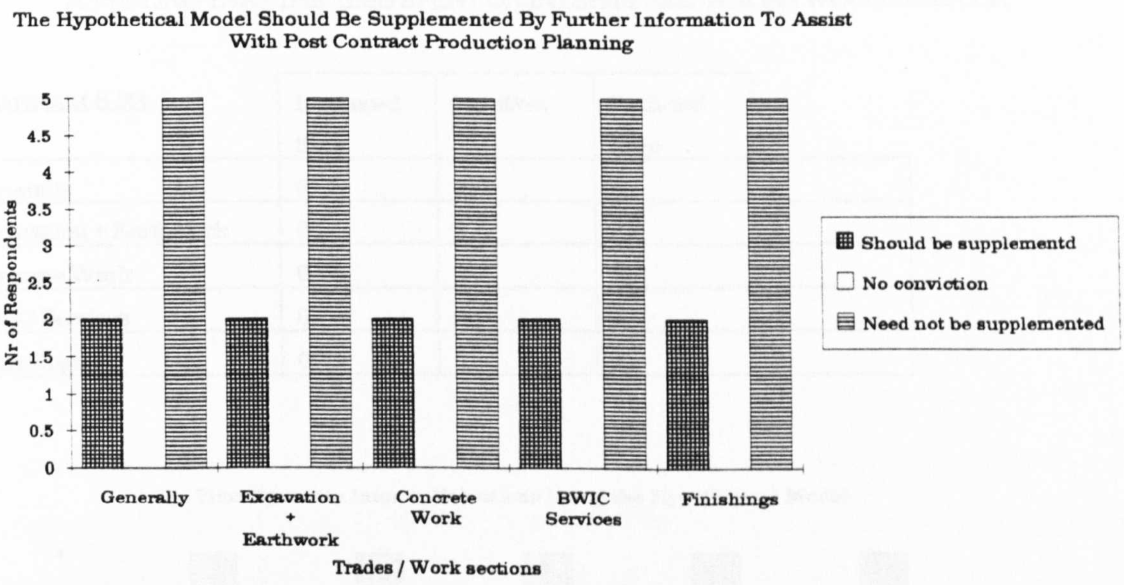
c) Bonuses for workforce.

d) Ordering materials (despite official discouragement)

e) Internal cost control to contractor.

33 A STRONG FEELING THAT NO ADDITIONAL INFORMATION NEED BE GIVEN TO ASSIST WITH POST CONTRACT PRODUCTION PLANNING.

DIAGRAM 6.22	INCREASED TIME	NO EFFECT	REDUCED TIME	
Generally	2	0	5	7
Excavation + Earthwork	2	0	5	7
Concrete Work	2	0	5	7
BWIC Services	2	0	5	7
Finishings	2	0	5	7



The respondents did not consider that measured sections were necessarily used for that purpose. Suggestions, though, included:

a) Ground conditions (which can vary); but this is not a method of measurement fault.

b) Constraints on phasing of work/Employer"s programme.

c) "Do not impart too much information; you might be held to it" This was a very interesting comment. Detailed measurements derived from design lacking in detail could be construed as being too much information about nothing of particular relevance.

d) "I can't think of anything to aid the contractor in actually building". The Bill of Quantities never purprted to represent the building process; therefore it could never define the true costs of building.

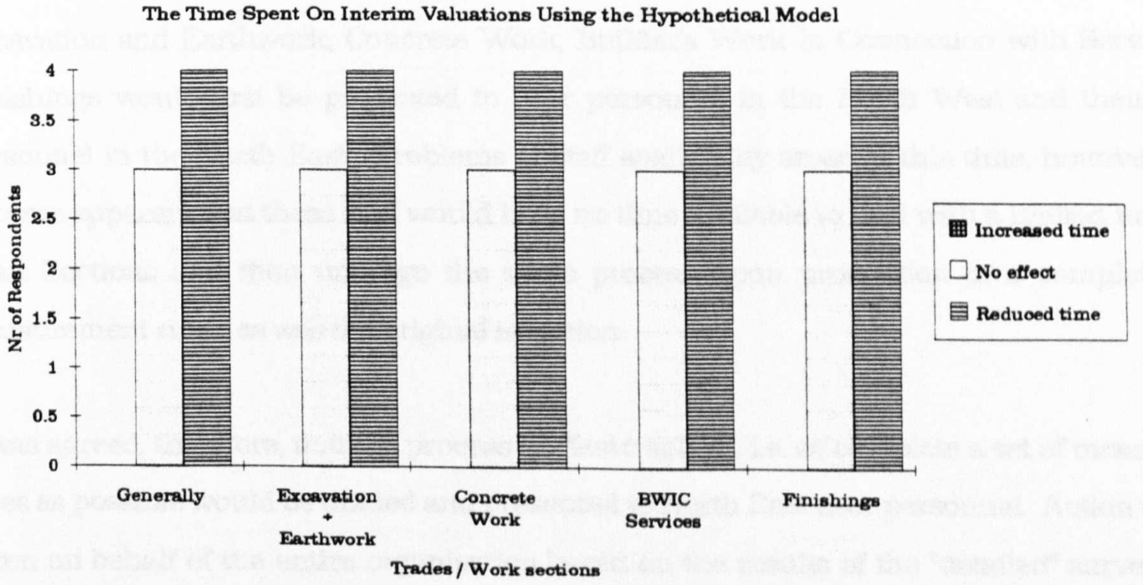
e) "Drawings are far more important".

f) "Do not dictate to the builder how to do the work; this is dangerous".

35 A FEELING THAT THE TIME SPENT ON INTERIM VALUATIONS WOULD REDUCE.

DIAGRAM 6.23

	Increased time	No effect	Reduced time	
Generally	0	3	4	7
Excavation + Earthwork	0	3	4	7
Concrete Work	0	3	4	7
BWIC Services	0	3	4	7
Finishings	0	3	4	7



Comments included:

a) "Most people do not use individual items for such a purpose".

b) "Could increase if complexity changes". See previous discussions.

c) "Valuations depend upon people's attitudes rather than any other factors".

d) "Much less. Much better".

APPENDIX 7:
VALIDATION OF THE HYPOTHETICAL MODEL: RESULTS OF STRUCTURED INTERVIEW SURVEY OF MODEL USERS (STAGE 2) (CH. 6.4-6.11)

FURTHER VALIDATION

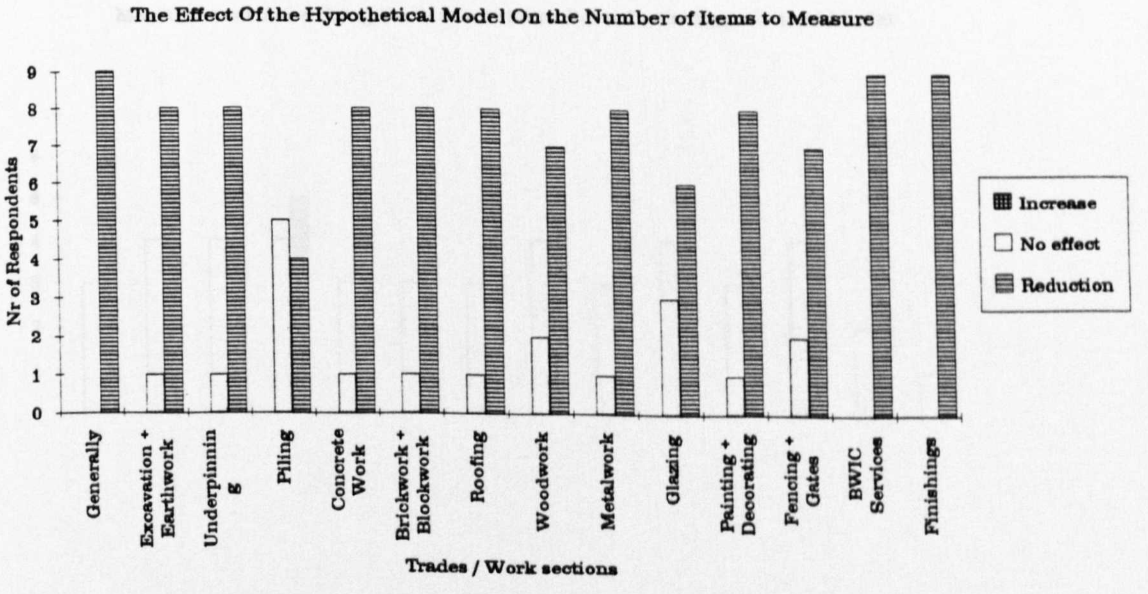
As stated in Appendix 6 it was originally planned that the Draft Measurement Proposals for Excavation and Earthwork, Concrete Work, Builder's Work in Connection with Services and Finishings would first be presented to user personnel in the North West and then to user personnel in the North East. Problems of staff availability arose at this time, however, and it became apparent that these staff would have no time available to deal with a limited number of Draft Sections and then undergo the same process upon production of a complete set of measurement rules, as was the original intention.

It was agreed, therefore, that the process be "fast-tracked", i.e. as complete a set of measurement rules as possible would be drafted and presented to North East user personnel. Action would be taken on behalf of the entire organisation based on the results of the "detailed" survey carried out in the North East. To lend weight to the results the "detailed" North East survey would be participated in by 3 staff members in the North West who were available. The number of respondents, therefore, would be 9. This still represented a large proportion of the key staff who would ever be likely to use such a measurement document. As complete a set of hypothetical measurement rules as possible was drawn up using the same principles as were used in Chapter 6.3 (Appendix 6).

RESULTS OF SURVEY OF USER ATTITUDES TO HYPOTHETICAL MODEL (STAGE 2) (CH. 6.5)

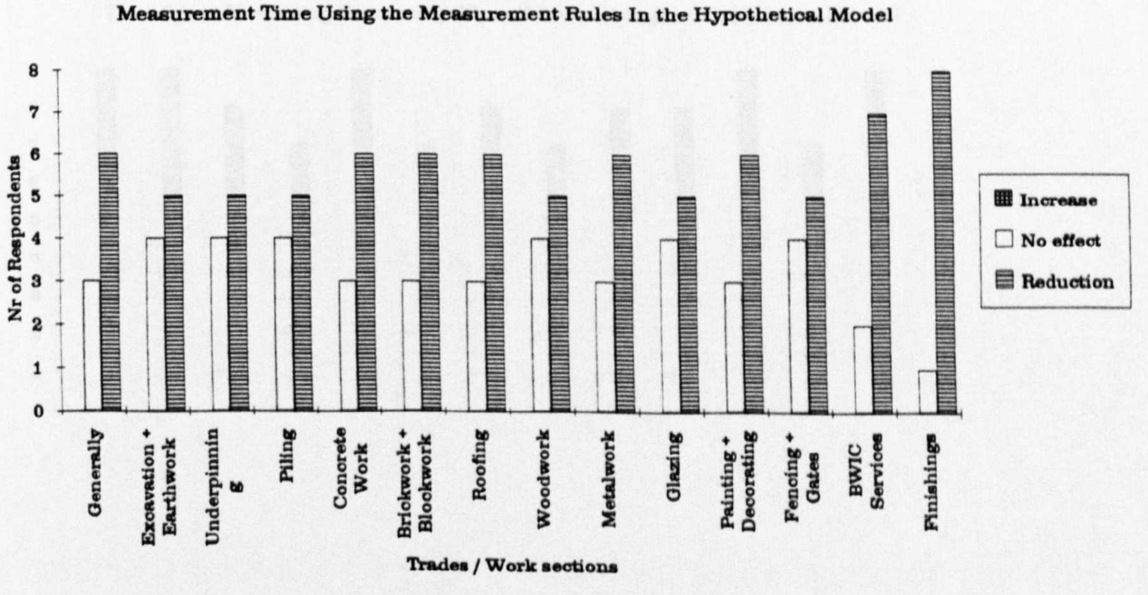
1 THERE WOULD BE A REDUCTION IN THE NUMBER OF ITEMS TO MEASURE USING THE HYPOTHETICAL MODEL.

DIAGRAM 7.1	Increase	No effect	Reduction	
Overall	0	0	9	9
Excavation + Earthwork	0	1	8	9
Underpinning	0	1	8	9
Piling	0	5	4	9
Concrete Work	0	1	8	9
Brickwork + Blockwork	0	1	8	9
Roofing	0	1	8	9
Woodwork	0	2	7	9
Metalwork	0	1	8	9
Glazing	0	3	6	9
Painting + Decorating	0	1	8	9
Fencing + Gates	0	2	7	9
BWIC Services	0	0	9	9
Finishings	0	0	9	9



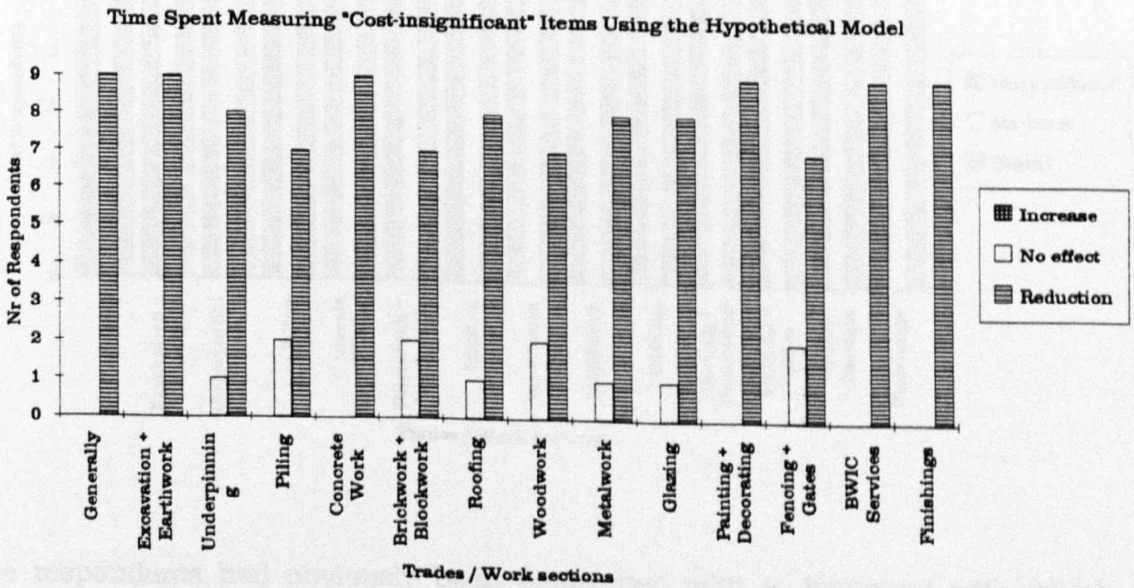
2 THERE WOULD BE REDUCED MEASUREMENT TIME USING THE MEASUREMENT RULES IN THE HYPOTHETICAL MODEL.

DIAGRAM 7.2	Increase	No effect	Reduction	
Overall	0	3	6	9
Excavation + Earthwork	0	4	5	9
Underpinning	0	4	5	9
Piling	0	4	5	9
Concrete Work	0	3	6	9
Brickwork + Blockwork	0	3	6	9
Roofing	0	3	6	9
Woodwork	0	4	5	9
Metalwork	0	3	6	9
Glazing	0	4	5	9
Painting + Decorating	0	3	6	9
Fencing + Gates	0	4	5	9
BWIC Services	0	2	7	9
Finishings	0	1	8	9



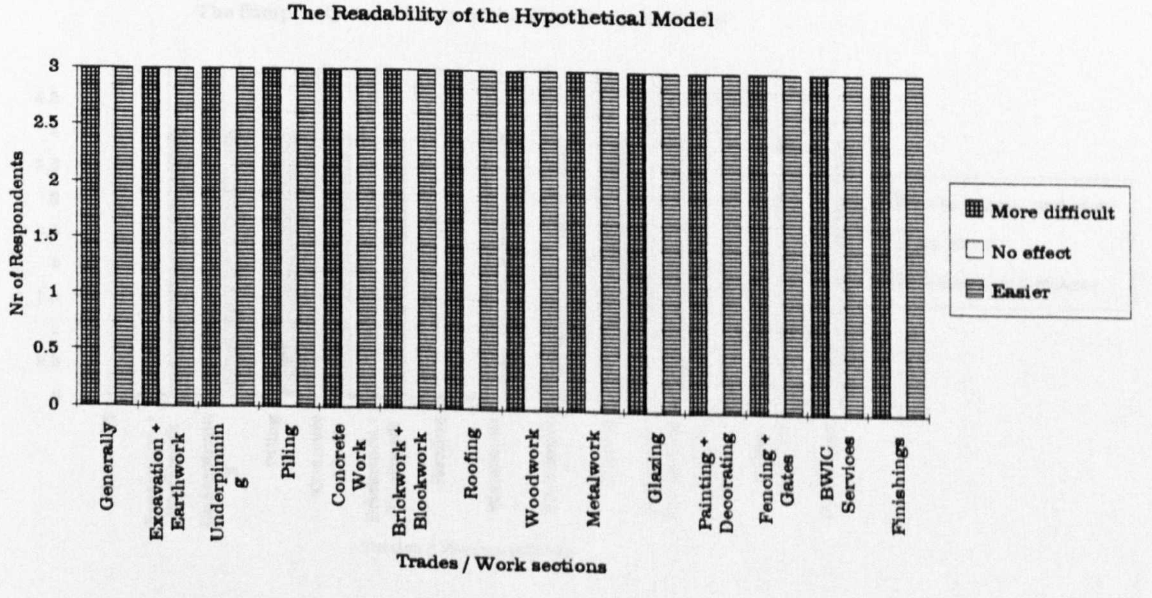
3 THE TIME SPENT MEASURING "COST-INSIGNIFICANT" ITEMS WILL REDUCE USING THE HYPOTHETICAL MODEL.

DIAGRAM 7.3	Increase	No effect	Reduce	
Overall	0	0	9	9
Excavation + Earthwork	0	0	9	9
Underpinning	0	1	8	9
Piling	0	2	7	9
Concrete Work	0	0	9	9
Brickwork + Blockwork	0	2	7	9
Roofing	0	1	8	9
Woodwork	0	2	7	9
Metalwork	0	1	8	9
Glazing	0	1	8	9
Painting + Decorating	0	0	9	9
Fencing + Gates	0	2	7	9
BWIC Services	0	0	9	9
Finishings	0	0	9	9



4 MIXED VIEWS REGARDING THE READABILITY OF THE HYPOTHETICAL MODEL.

DIAGRAM 7.4	More difficult	No effect	Easier	
Overall	3	3	3	9
Excavation + Earthwork	3	3	3	9
Underpinning	3	3	3	9
Piling	3	3	3	9
Concrete Work	3	3	3	9
Brickwork + Blockwork	3	3	3	9
Roofing	3	3	3	9
Woodwork	3	3	3	9
Metalwork	3	3	3	9
Glazing	3	3	3	9
Painting + Decorating	3	3	3	9
Fencing + Gates	3	3	3	9
BWIC Services	3	3	3	9
Finishings	3	3	3	9

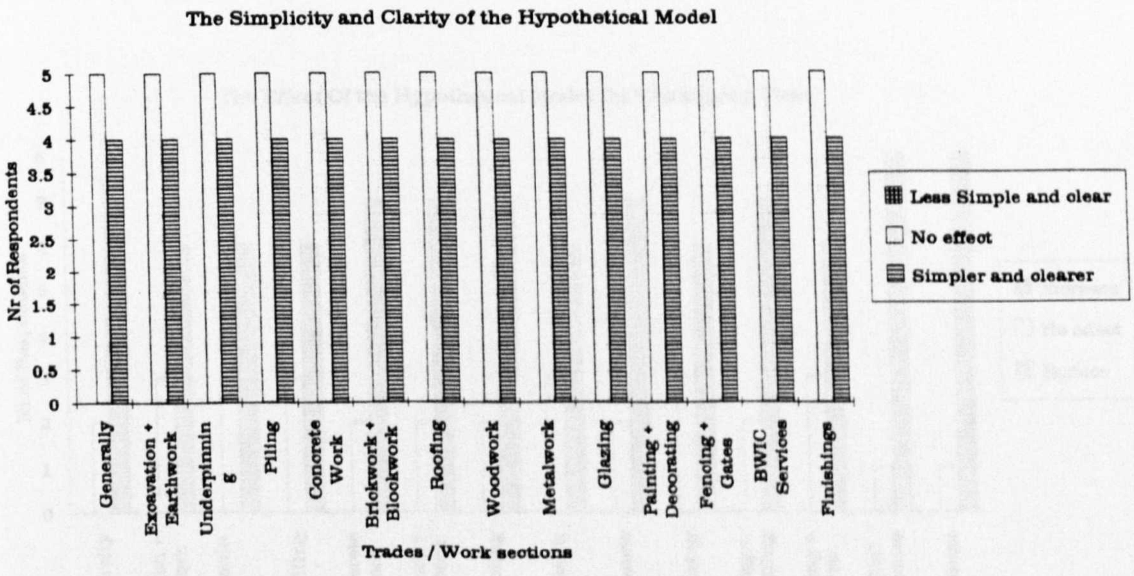


The respondents had obviously been confronted with a document with which they were completely unfamiliar; the results, therefore, are perhaps not surprising. It is again clear that the drafting of the document requires more attention.

5 THE HYPOTHETICAL MODEL IS SIMPLER AND CLEARER.

DIAGRAM 7.5

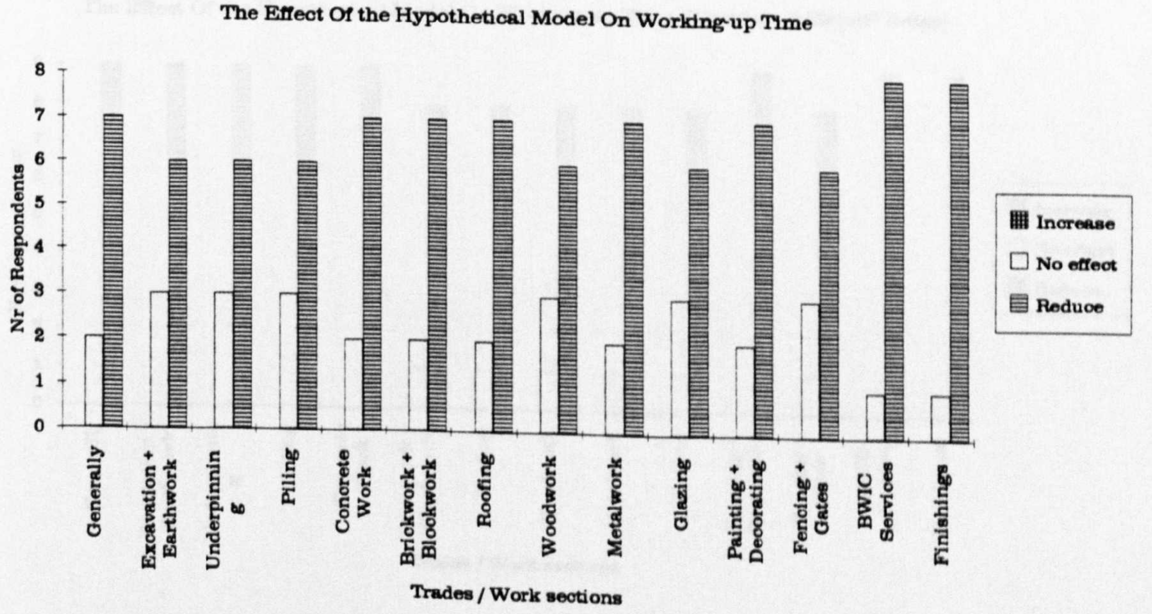
	Less simple and clear	No effect	Simpler and clearer	
Overall	0	5	4	
Excavation + Earthwork	0	5	4	
Underpinning	0	5	4	
Piling		5	4	
Concrete Work	0	5	4	
Brickwork + Blockwork	0	5	4	
Roofing	0	5	4	
Woodwork	0	5	4	
Metalwork	0	5	4	
Glazing	0	5	4	
Painting + Decorating	0	5	4	
Fencing + Gates	0	5	4	
BWIC Services	0	5	4	
Finishings	0	5	4	



There appeared to be a contradiction. The respondents simultaneusly considered the hypothetical model to be "more difficult to read" and "simpler and clearer". An interpretation could be that they consider the format to be better and the detailed wording to be wanting.

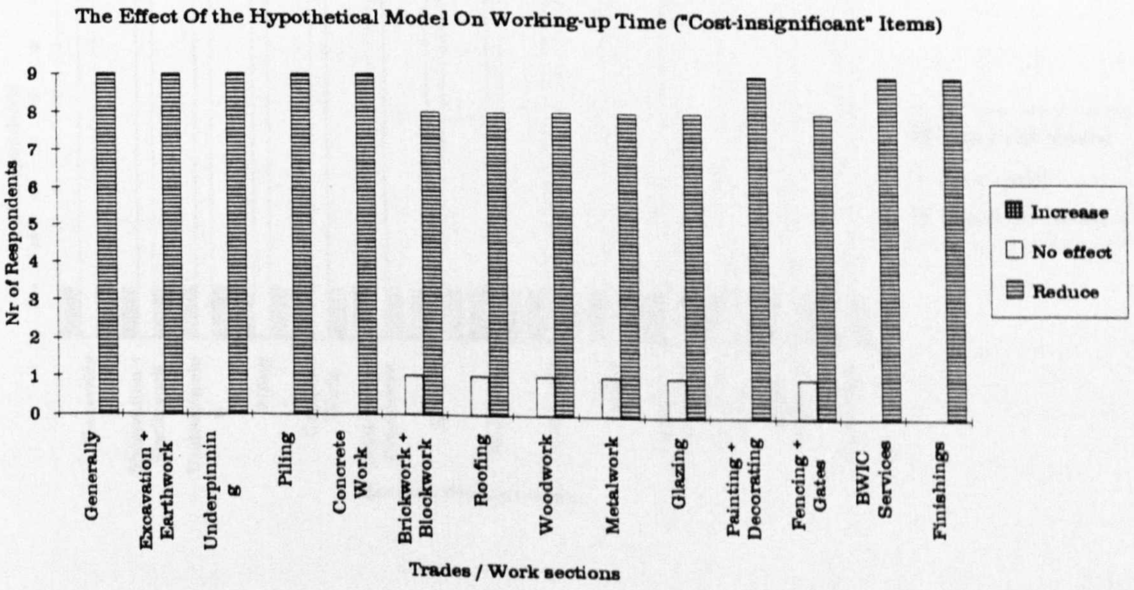
6 WORKING-UP TIME WILL REDUCE USING THE HYPOTHETICAL MODEL.

DIAGRAM 7.6	Increase	No effect	Reduce	
Overall	0	2	7	9
Excavation + Earthwork	0	3	6	9
Underpinning	0	3	6	9
Piling	0	3	6	9
Concrete Work	0	2	7	9
Brickwork + Blockwork	0	2	7	9
Roofing	0	2	7	9
Woodwork	0	3	6	9
Metalwork	0	2	7	9
Glazing	0	3	6	9
Painting + Decorating	0	2	7	9
Fencing + Gates	0	3	6	9
BWIC Services	0	1	8	9
Finishings	0	1	8	9



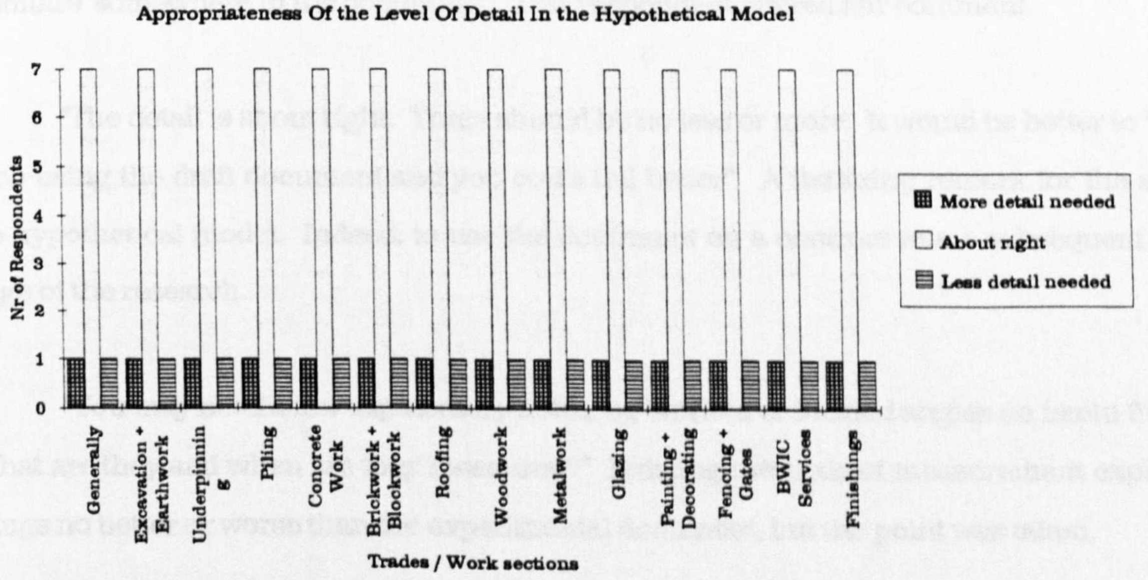
7 WORKING-UP TIME ON "COST-INSIGNIFICANT" ITEMS WILL REDUCE USING THE HYPOTHETICAL MODEL.

DIAGRAM 7.7	Increase	No effect	Reduce	
Overall	0	0	9	9
Excavation + Earthwork	0	0	9	9
Underpinning	0	0	9	9
Piling	0	0	9	9
Concrete Work	0	0	9	9
Brickwork + Blockwork	0	1	8	9
Roofing	0	1	8	9
Woodwork	0	1	8	9
Metalwork	0	1	8	9
Glazing	0	1	8	9
Painting + Decorating	0	0	9	9
Fencing + Gates	0	1	8	9
BWIC Services	0	0	9	9
Finishings	0	0	9	9



8 THE LEVEL OF DETAIL IN THE HYPOTHETICAL MODEL IS APPROPRIATE.

DIAGRAM 7.8	More detail needed	About right	Less detail needed	
Overall	1	7	1	9
Excavation + Earthwork	1	7	1	9
Underpinning	1	7	1	9
Piling	1	7		9
Concrete Work	1	7	1	9
Brickwork + Blockwork	1	7	1	9
Roofing	1	7	1	9
Woodwork	1	7	1	9
Metalwork	1	7	1	9
Glazing	1	7	1	9
Painting + Decorating	1	7	1	9
Fencing + Gates	1	7	1	9
BWIC Services	1	7	1	9
Finishings	1	7	1	9



It is interesting to note that one of the respondents was of a conservative bent and one of them was more radical in approach.

9 FURTHER COMMENTS FOLLOWING FROM QUESTION 8:

(a) "The amount of detail given in the measurement depends upon the type of contract. What type of contracts will the proposed SMM be used for?" It would, of course, be used for petrochemical civil engineering contracts. It is contended, moreover, that the efficacy of a measurement model is not necessarily affected by the type of contract used (*vide "Shorter Bills of Quantities, supra*).

(b) "Given advance design the Bills can refer to drawings / standard details and the need for long item descriptions will reduce". This is agreed. It is repeated that the measurer needs to use imagination to create detail which incomplete design does not contain.

(c) "We need specific provision for things such as work below water tables and work in toxic areas. Use either an elaborated description, a separate measured item or a general 'aide - memoire' somewhere in the document." This respondent offered fair comment.

(d) "The detail is about right. There should be no less or more. It would be better to "take off" a job using the draft document and you couls tell better". A flattering remark for the author of the hypothetical model. Indeed, to use the document on a contract was a subsequent planned stage of the research.

(e) "You may need a few explanatory notes, eg 'worked or formed angles on insitu finishings' - what are they and when are they measured?" Existing methods of measurement explain such things no better or worse than the experimental document, but the point was taken.

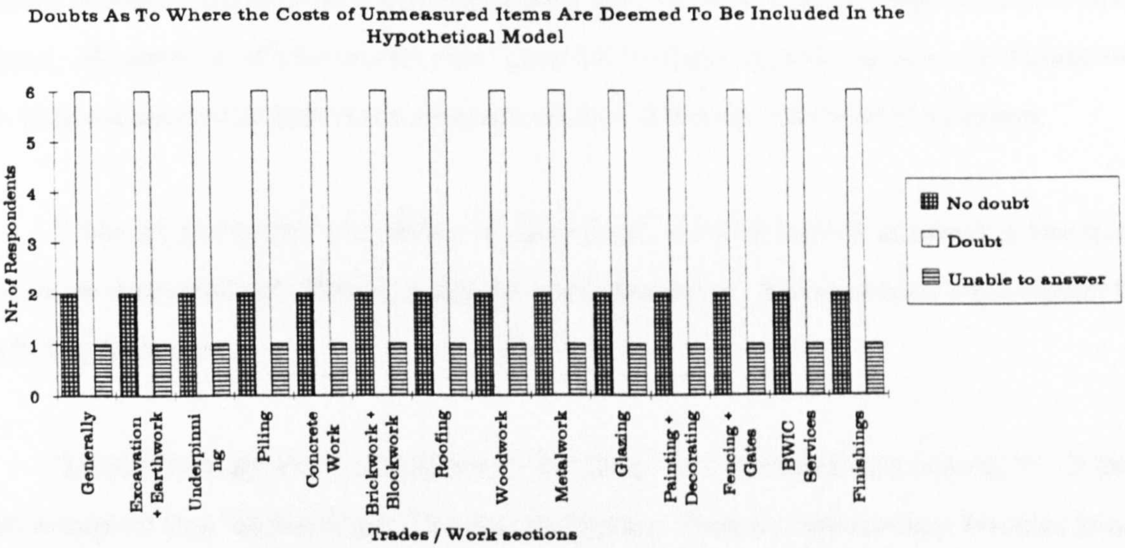
(f) "The danger of over - simplification is obvious. It should not have more detail". A key argument is that the "danger" so described may well be exaggerated.

(g) "There may be scope later for amplifying or simplifying certain sections to suit". This is indeed the case. Such is the virtue of cautious progress and refinement.

(h) "We have no united front regarding this project. We shall rationalise and agree our approach upon production of the final document. It will be a long time before we use a new SMM formally. Each QS is left to produce his own Bill of Quantities on whatever SMM (in his judgement) is most suitable. I may use your proposed SMM, but it would not be official policy if I did. We have many interested parties and they need to be educated". A well - put point, but with a hint of the over - cautious... ?

10 A MEASURE OF DOUBT AS TO WHERE THE COSTS OF UNMEASURED ITEMS ARE INCLUDED IN THE HYPOTHETICAL MODEL.

DIAGRAM 7.9	No doubt	Doubt	Unable to answer	
Overall	2	6	1	9
Excavation + Earthwork	2	6	1	9
Underpinning	2	6	1	9
Piling	2	6	1	9
Concrete Work	2	6	1	9
Brickwork + Blockwork	2	6	1	9
Roofing	2	6	1	9
Woodwork	2	6	1	9
Metalwork	2	6	1	9
Glazing	2	6	1	9
Painting + Decorating	2	6	1	9
Fencing + Gates	2	6	1	9
BWIC Services	2	6	1	9
Finishings	2	6	1	9



Drafting needed to be more meticulous. Unfamiliarity, though cmay be an influencing factor. In the first user survey there were several comments about "familiarity" and "learning curves.

11 FURTHER USER GROUP COMMENTS FOLLOWING QUESTION 10:

1] "There are some instances of items being deemed included, whilst there is a requirement to specify it. This should be more explicit: either deemed included or specified". It is suggested that whether something is measured or not , it should be specified if it is required to be provided. Otherwise the builder cannot allow for its costs. In contracts without Bills of Quantities, where nothing is measured, things must be specified. This must still hold in contracts like the Petrochemical Civil Engineering projects analysed, where some things are not measured but still have to be included in the Tender.

2] "Who decides what items are not measureable? I can foresee problems with contractors at postcontract stage, especially as the preamble clauses are brief". It is the Method of Measurement which dictates what to measure, at least in a conventional (ideological) model. In this case it is a hypothetical (logical) model, based on copious analysis of data. In the case of conventional (ideological) methods of measurement the drafting committees include the post contract "victims", the builders, but regrettably this could not be the case with the experimental method. However it will be shown (see *Chapter 5*) that a similar parallel development, drafted with little contractor involvement, appears not to exhibit the "problems" foreseen.

3] "I would like a trial run using the proposed method before answering the questions. I have some reservations". This is perhaps understandable. It has already been stated that a trial was being planned.

4] "Doubt through lack of familiarity (in part). An explanatory booklet...?". It has already been accepted that "unfamiliarity" is playing a part. That an explanatory booklet is considered necessary is not disastrous. It eventually happened with (eg) SMM7.

5] "Cannot already answer until tests show results. I am happy with the principles behind the document". This is fair comment.

6] "Okay overall, but watch out for the word 'specify', which could be misunderstood. Your idea on specification is okay, but too many people treat the SMM as a 'bible', not as a guide. You should obviously give more or less information as you think fit".

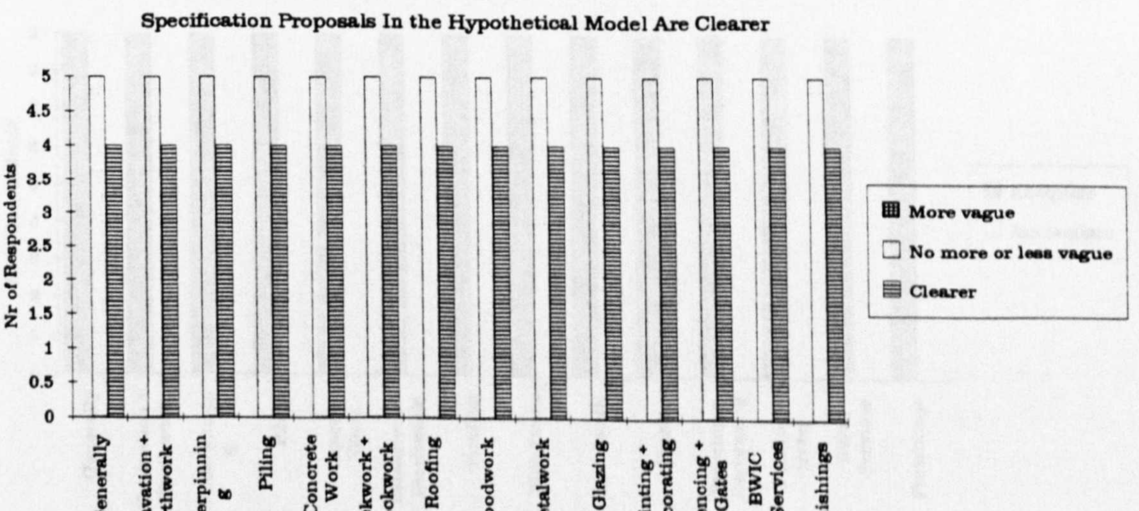
The requirement to specify is reemphasised. It is unavoidable. Certainly, though, it is regarded as good practice to provide information additional to that provided by the SMM if, inevitably, it fails to cope with the unusual or the unique. it is interesting that this respondent alludes to the existence of a sociological paradigm as an article of religious faith; *in deo fidemus.*

7] "I see a danger in the use of composite items, eg the problem of prices if, say, the specification of a pipe surround in a trench changed. If people took alittle more time to produce a decent specification it would be okay. My doubt may be due to unfamiliarity." This respondent appears to support the idea of the importance of the specification addressed in the guidance notes to the hypothetical model.

12 THE PROPOSALS REGARDING SPECIFICATION IN THE HYPOTHETICAL MODEL ARE CLEARER.

DIAGRAM 7.10

	Vaguer	No more or less vague	Clearer	
Overall	0	5	4	9
Excavation + Earthwork	0	5	4	9
Underpinning	0	5	4	9
Piling	0	5	4	9
Concrete Work	0	5	4	9
Brickwork + Blockwork	0	5	4	9
Roofing	0	5	4	9
Woodwork	0	5	4	9
Metalwork	0	5	4	9
Glazing	0	5	4	9
Painting + Decorating	0	5	4	9
Fencing + Gates	0	5	4	9
BWIC Services	0	5	4	9
Finishings	0	5	4	9

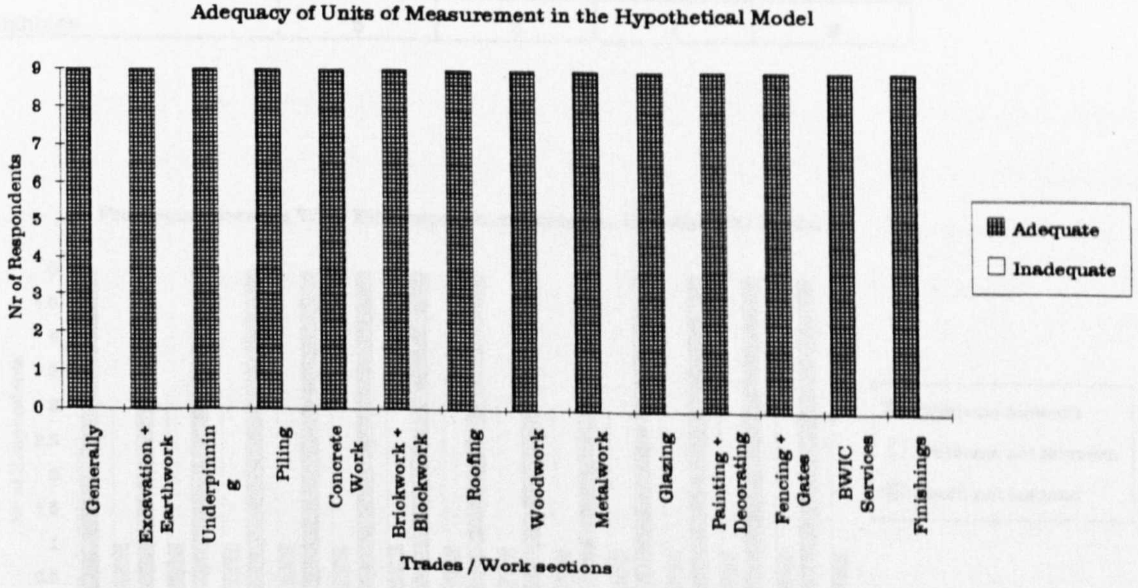


No respondent appeared to think that the proposed document was worse than existing ones, despite the individual criticisms voiced earlier.

13 PROPOSALS REGARDING UNITS OF MEASUREMENT IN THE HYPOTHETICAL MODEL ARE ADEQUATE.

DIAGRAM 7.11

	Adequate	Inadequate	
Overall	9	0	9
Excavation + Earthwork	9	0	9
Underpinning	9	0	9
Piling	9	0	9
Concrete Work	9	0	9
Brickwork + Blockwork	9	0	9
Roofing	9	0	9
Woodwork	9	0	9
Metalwork	9	0	9
Glazing	9	0	9
Painting + Decorating	9	0	9
Fencing + Gates	9	0	9
BWIC Services	9	0	9
Finishings	9	0	9

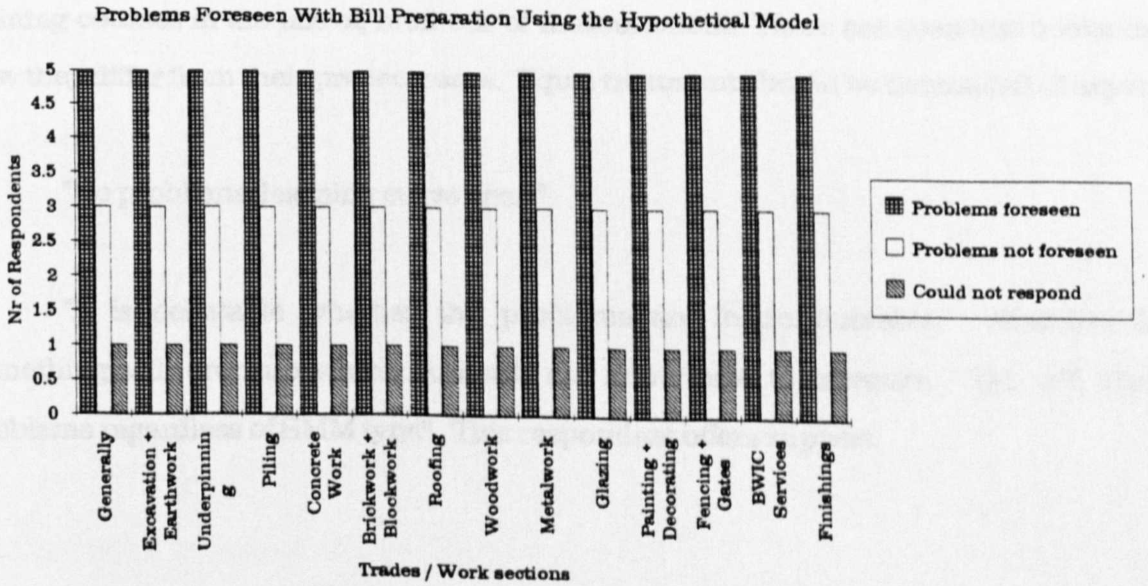


One of the respondents considered the approach to Finishings to be too simplistic. The proposals, however, were based on empirical analysis of data, which detected measurement complexity which had no substantial influence on pricing.

14 PROBLEMS FORESEEN WITH BILL OF QUANTITIES PREPARATION USING THE HYPOTHETICAL MODEL.

DIAGRAM 7.12

	Problems foreseen	Problems not foreseen	Could not respond	
Overall	5	3	1	9
Excavation + Earthwork	5	3	1	9
Underpinning	5	3	1	9
Piling	5	3	1	9
Concrete Work	5	3	1	9
Brickwork + Blockwork	5	3	1	9
Roofing	5	3	1	9
Woodwork	5	3	1	9
Metalwork	5	3	1	9
Glazing	5	3	1	9
Painting + Decorating	5	3	1	9
Fencing + Gates	5	3	1	9
BWIC Services	5	3	1	9
Finishings	5	3	1	9



15 COMMENTS FOLLOWING FROM QUESTION 14:

1] "Need for acclimatisation. Time saving will only be achieved long term by adopting the new model on all projects". This is not disputed.

2] "The danger of getting rid of narrow widths in Finishings, especially when using Bills of Approximate Quantities". Approximate Quantities Bills imply that there may be insufficient drawn detail for the measurer to ascertain the extent of such narrow widths, except by the the use of the imagination... ?

3] "Problems in introducing a new SMM to the industry, especially if contractors have had no input". This comment is valid, but *vide supra*.

4] "Throughput of Bills is not continuous. The learning curve may repeat itself for outside consultants". This would be true of any method of measurement were it not in continuous use.

5] "Initially, problems with people familiarising themselves with the document. But for how long, I do not know". This is applicable to any document. There are user guides for, and training courses in the use of, methods of measurement. There are even text books explaining how they differ from their predecessors. Equal treatment should be demanded of *any* model.

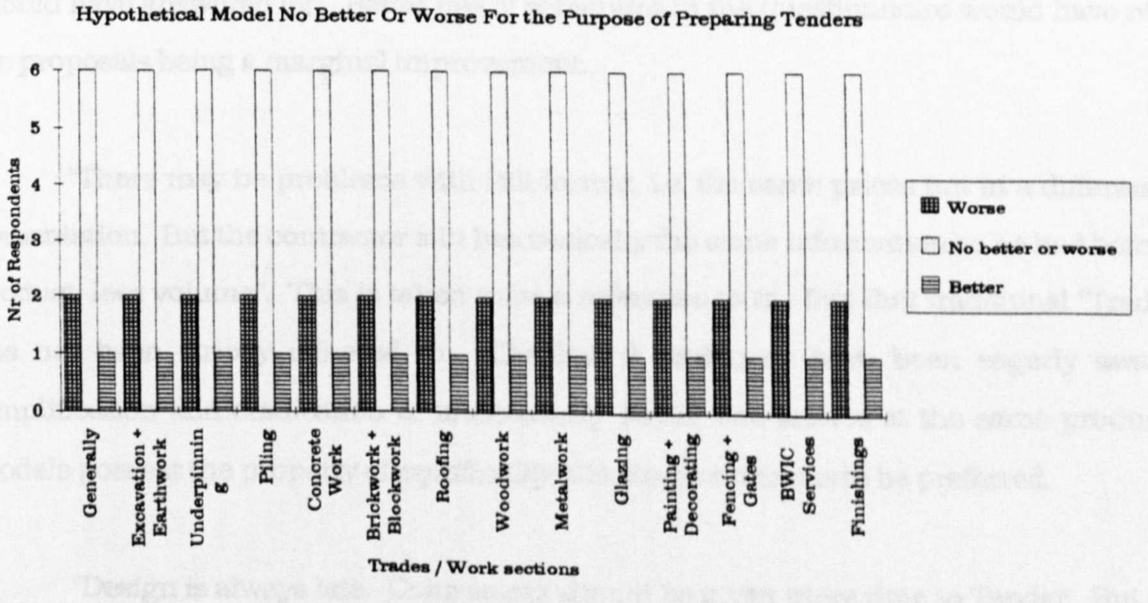
6] "No problems, learning curve apart".

7] "It is debatable whether the problems are insurmountable. Whatever the SMM something will crop up which you will not know how to measure. You will always have problems regardless of SMM type". This respondent offers support.

16 THE INFORMATION IN THE HYPOTHETICAL MODEL IS NO BETTER OR WORSE FOR THE PURPOSE OF PREPARING TENDERS.

DIAGRAM 7.13

	Worse	No better or worse	Better	
Overall	2	6	1	9
Excavation + Earthwork	2	6	1	9
Underpinning	2	6	1	9
Piling	2	6	1	9
Concrete Work	2	6	1	9
Brickwork + Blockwork	2	6	1	9
Roofing	2	6	1	9
Woodwork	2	6	1	9
Metalwork	2	6	1	9
Glazing	2	6	1	9
Painting + Decorating	2	6	1	9
Fencing + Gates	2	6	1	9
BWIC Services	2	6	1	9
Finishings	2	6	1	9



There remains a "balance of neutrality".

17 COMMENTS FOLLOWING FROM QUESTION 16:

1] "There appears to be a greater contractor's risk". The respondent did not identify the risk.

2] "The simplified approach will put greater onus on the contractor initially. This should, of course, reduce as he becomes more proficient in the use of the Method of Measurement. I think overall he will do more work".

3] "It is more adequate for estimators, who do not involve themselves with SMM intricacy. They do not like to read detailed SMMs. At least in the draft they can see "at a glance"; they do not have to look far to see where small items are included. However, how can they tell how intricate the work is? How can they gauge complexity?" Fulsome praise, tempered by a "sting in the tail". If the detail is representative of the design it exists on the drawings, for it was derived thence. If not, the detail is potentially misleading.

4] "The question should have read "suitable or better" instead of inadequate, in which case I should have answered [c]". Better use of semantics in the questionnaire would have resulted in the proposals being a marginal improvement...

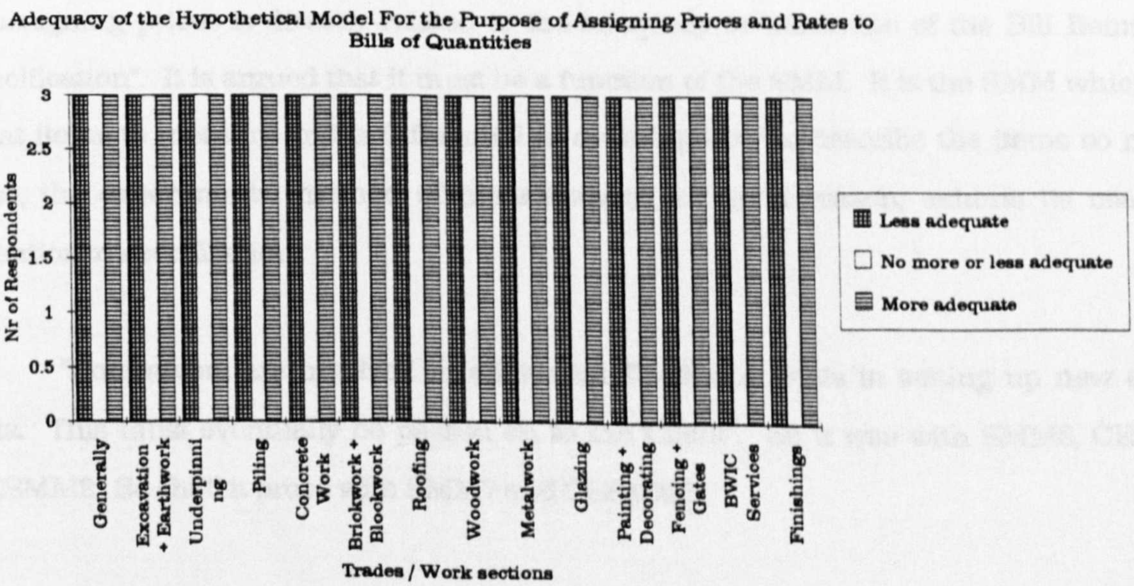
5] "There may be problems with Bill format, i.e. the same prices but in a different order of presentation. But the contractor still has basically the same information as he had before. Same product, less volume". This is taken to be a reference to the fact that traditional "Trade" format has not been strictly adhered to. The last 2 sentences have been eagerly awaited. By simplification and eradication of unnecessary detail, one arrives at the same product. If two models possess the property of *equifinality*, the simpler one has to be preferred.

6] "Design is always late. Contractors should be given more time to Tender. But this is not a function of SMM type. Even though BQ production time might reduce with your draft document, to use this as an excuse to reduce further an already "squeezed" programme would be unfair".

18 MIXED FEELINGS AS TO WHETHER THE INFORMATION IN THE HYPOTHETICAL MODEL WAS ADEQUATE FOR THE PURPOSE OF ASSIGNING PRICES AND RATES TO BILLS OF QUANTITIES.

DIAGRAM 7.14

	Less adequate	No more or less adequate	More adequate	
Overall	3	3	3	9
Excavation + Earthwork	3	3	3	9
Underpinning	3	3	3	9
Piling	3	3	3	9
Concrete Work	3	3	3	9
Brickwork + Blockwork	3	3	3	9
Roofing	3	3	3	9
Woodwork	3	3	3	9
Metalwork	3	3	3	9
Glazing	3	3	3	9
Painting + Decorating	3	3	3	9
Fencing + Gates	3	3	3	9
BWIC Services	3	3	3	9
Finishings	3	3	3	9



The respondents commented as follows:

1] "It contains the same information as before". This appears to support the argument that the simplified approach does not significantly affect the pricing of the work.

2] "It is more attuned to "Builder's Quantities and therefore more adequate.
Another respondent favoured a simpler approach. *Vide infra.*

3] "There may be mileage into breaking down the Bill rates into labour, materials and plant... this is critical on large projects as they can run out of control". Operational Bills never found much support in "traditional" construction. But see Diederichs and Hepermann (1985).

4] "This is difficult. I am not a contractor. The answer is between [b] and [c], really". Better use of semantics would have gained a more favourable result.

19 COMMENTS FOLLOWING FROM QUESTION 18:

1] "Surely this is not a function of any method of measurement. The difficulty or otherwise of assigning prices is directly related to the adequacy or otherwise of the Bill Items and the specification". It is argued that it must be a function of the SMM. It is the SMM which dictates what items to measure and is influential in dictating how to describe the items so measured. Also, the experimental method of measurement, for good reason, exhorts its users to pay attention to specification.

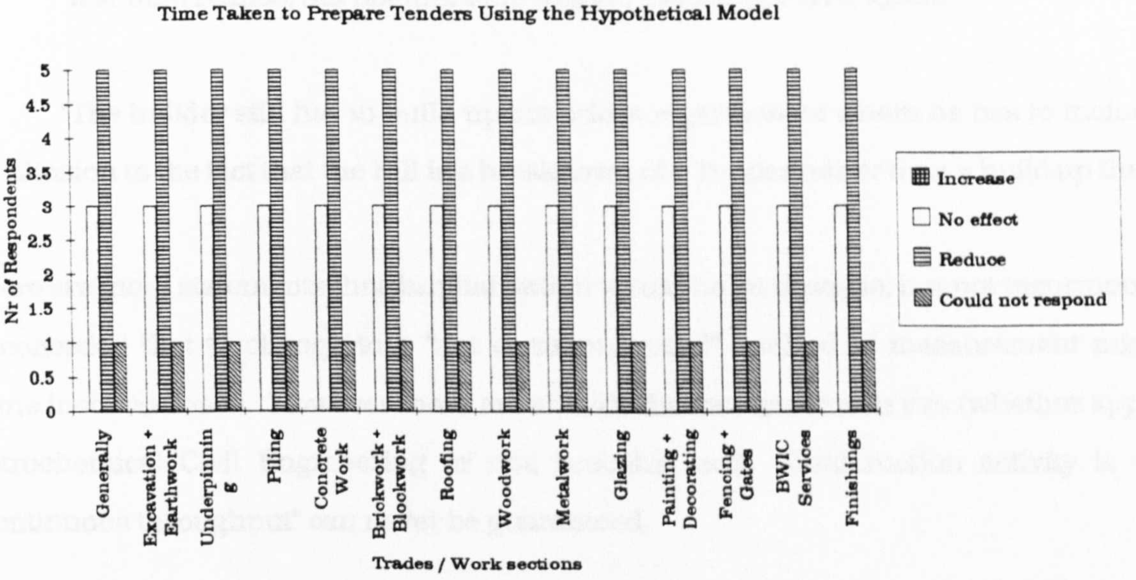
2] "Contractors are involved in additional Tendering costs in setting up new estimating data. This must eventually be passed on to the Client". So it was with SMM6, CESMM and CESMM2. So shall it prove with SMM7 and CESMM3.

3] "The contractor will still need to look at drawings to study complexity. This is okay given that design is fairly well established". This is fair comment. If design is distinctly undeveloped then no SMM could be totally adequate.

4] "It conflicts with existing databases which are geared up for other SMMs. There will not be a constant flow of data from [this organisation]. Separate databases would be needed for [our] jobs". This is fair comment as far as it applies to contractors, who deal with the idiosyncrasies of many clients and design teams. It is less easy to see it being a problem "in-house". In the end analysis, if contractors want the work they will have to deal with the data as structured and presented.

20 THE TIME TAKEN TO PREPARE TENDERS, USING THE HYPOTHETICAL MODEL, WILL REDUCE.

DIAGRAM 7.15	Increase	No effect	Reduces	Could not respond	
Overall	0	3	5	1	9
Excavation + Earthwork	0	3	5	1	9
Underpinning	0	3	5	1	9
Piling	0	3	5	1	9
Concrete Work	0	3	5	1	9
Brickwork + Blockwork	0	3	5	1	9
Roofing	0	3	5	1	9
Woodwork	0	3	5	1	9
Metalwork	0	3	5	1	9
Glazing	0	3	5	1	9
Painting + Decorating	0	3	5	1	9
Fencing + Gates	0	3	5	1	9
BWIC Services	0	3	5	1	9
Finishings	0	3	5	1	9



Respondents commented as follows:

1] "A marginal reduction owing to the numbers of items generally being reduced".

2] "It will reduce when the contractor becomes familiar with the method of measurement".

3] "I cannot answer. I cannot generalise. Could reduce where estimators work *ad hoc* instead of using standard systems". Here is an exposition of the fact that it is difficult to generalise from singularities, and that idiographic approaches may be more suitable than nomothetic ones.

4] "Subcontractors include the small items in with the large ones anyway". This could be interpreted as being supportive.

5] "Once our contractors are familiar with the document it should reduce. Give them a month in which to Tender... give them 2 weeks or 5 weeks... and they will do it in the last week of that period". Interesting it is to note that if all Tenders are produced at the "last moment" then perhaps a simplified document would be a help rather than a hindrance.

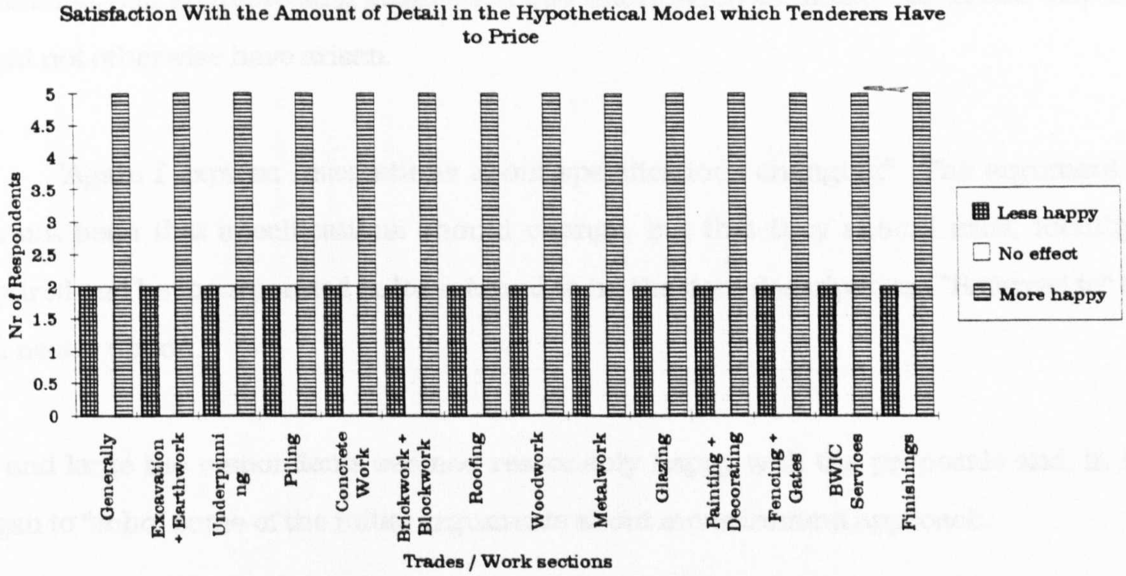
6] "It should reduce, but not first time round". Learning curve, again.

7] "The builder still has to build up his prices regardless of where he has to include them". An allusion to the fact that the Bill is a breakdown of a Tender rather than a build-up thereof...

There are more statements that familiarisation would be an obstacle, but not insurmountable. It is conceded that to change to a "not commonly-used" method of measurement might cause some inconvenience. However there are already diverse systems in use (whether applicable to Petrochemical Civil Engineering or not; probably not). Construction activity is such that "continuous throughput" can never be guaranteed.

21 RESPONDENTS ARE HAPPIER WITH THE AMOUNT OF DETAIL IN THE HYPOTHETICAL MODEL WHICH TENDERERS HAVE TO PRICE.

DIAGRAM 7.16	Less happy	No effect	More happy	
Overall	2	2	5	9
Excavation + Earthwork	2	2	5	9
Underpinning	2	2	5	9
Piling	2	2	5	9
Concrete Work	2	2	5	9
Brickwork + Blockwork	2	2	5	9
Roofing	2	2	5	9
Woodwork	2	2	5	9
Metalwork	2	2	5	9
Glazing	2	2	5	9
Painting + Decorating	2	2	5	9
Fencing + Gates	2	2	5	9
BWIC Services	2	2	5	9
Finishings	2	2	5	9



Respondents commented as follows:

1] "Items must be explicit in order that Tenderers know exactly what they are pricing". See *'Specification"*.

2] "There is more time spent arguing over small items than over large ones. I am happier. Contractors were happier with the old "Housing Small Code" which is similar in principle to your draft". Obsession with the trivial content of the ranked order distribution consumes time and money. The professional societies show that they are not averse to proliferation of codes of measurement for so-called "specialist" situations, if only on the grounds of vested interest rather than on "scientific fact".

3] "Ideas about complexity can be had from drawings. The answer rreally depends on having seen the proposed SMM used".

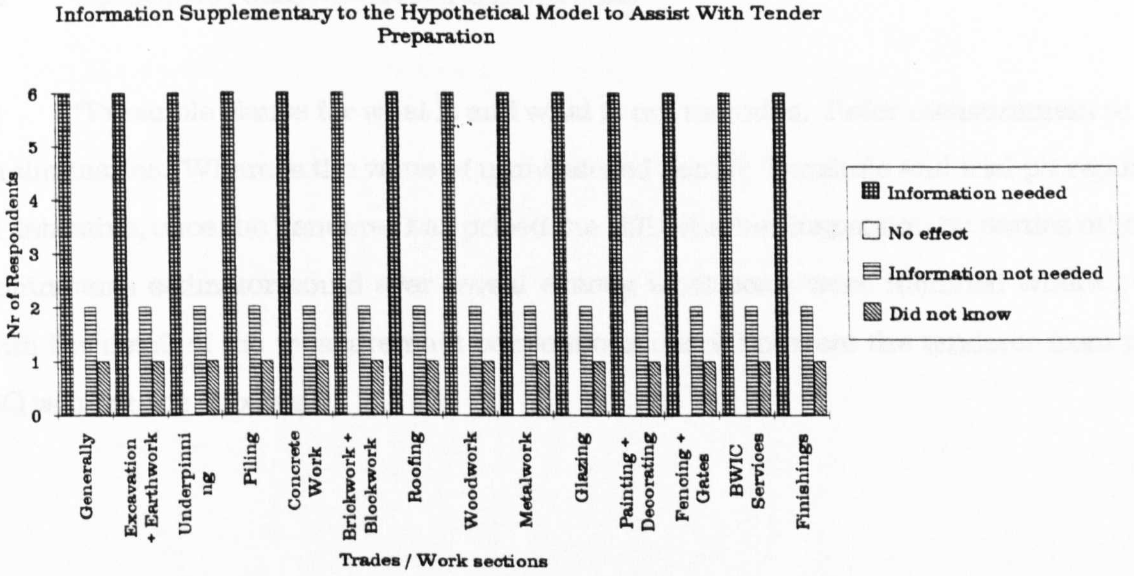
4] "The more detail is provided, the more diverse are the arguments which can arise. My answer is [c] provided your explanatory notes are clear and unambiguous". More drafting comments, and an interesting suggestion that information as "noise" can create disputes which might not otherwise have arisen.

5] "Again I express reservations about specifications changing". The argument all along has not been that specifications should change, but that they should exist, identify what is required and be incorporated in [or referred to in] the item descriptions. "Referred to" is a better and neater option.

By and large the respondents seemed reasonably happy with the proposals and, in instances, began to "echo" some of the initial arguments about measurement approach.

22 THERE IS SOME INFORMATION WHICH OUGHT TO BE GIVEN SUPPLEMENTAL TO THE DRAFT MEASURED ITEMS TO ASSIST WITH PREPARING TENDERS

DIAGRAM 7.17	Information needed	No effect	Information not needed	Did not know
Overall	6	0	2	1
Excavation + Earthwork	6	0	2	1
Underpinning	6	0	2	1
Piling	6	0	2	1
Concrete Work	6	0	2	1
Brickwork + Blockwork	6	0	2	1
Roofing	6	0	2	1
Woodwork	6	0	2	1
Metalwork	6	0	2	1
Glazing	6	0	2	1
Painting + Decorating	6	0	2	1
Fencing + Gates	6	0	2	1
BWIC Services	6	0	2	1
Finishings	6	0	2	1



Respondents commented as follows:

1] "There is no more or less information to give, except maybe on specialist or proprietary items, eg... give trade literature (which the client must have looked at and must possess anyway)". Measurement and specification can (and should) be separated.

2] "Once again, specification is important. It should be adequate. Much more specification should be given than is given in the draft document". The defence is offered that the draft document was a measurement document, not a specification document. It gave guidelines as to what the relationship should be between measurement and specification. It did not purport to be a specification document. No method of measurement should (or could) so purport.

Overall it was made clear that there is information other than that created by measurement conventions which influences the pricing decisions of Tenderers. The method of measurement, therefore, is not the single most important document in this respect. Perhaps this puts the necessity for detailed measurement into better perspective. Specification is indispensible to client and contractor. The latter cannot know it until the former knows it.

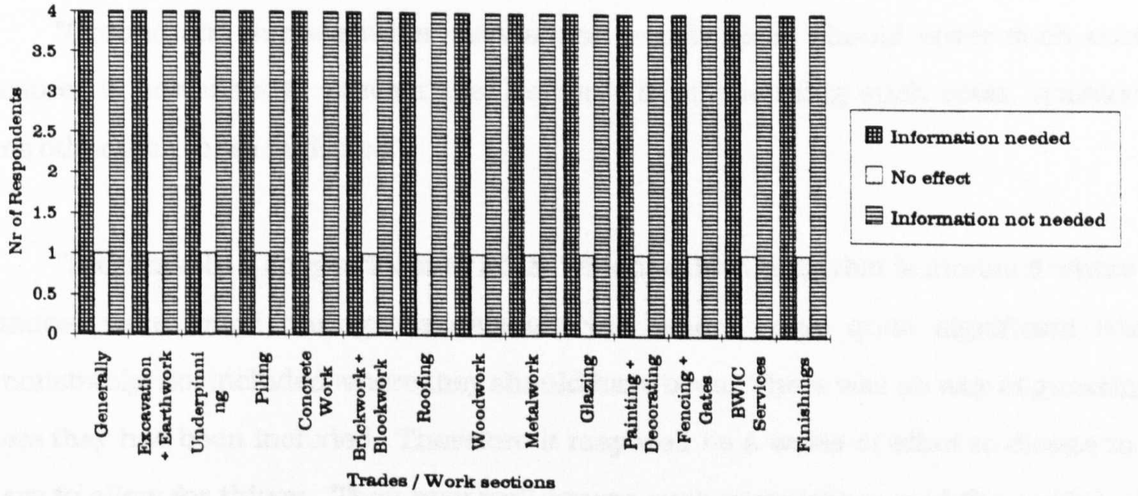
23 COMMENTS FOLLOWING FROM QUESTION 22:

1] "Preamble clause for what is and what is not included. Refer measurement to drawings. Preliminaries. Where is the value of unmeasured items? Borehole and trial pit reports etc.". It is debatable, once the Tenderer has priced the Bill, whether inspection by parties other than the contractor's estimator could ever reveal exactly what costs were included where. Obsession with the detail of the measurement conventions cannot prevent the tenderer from pricing the BQ as he or she chooses.

24 THERE IS SOME INFORMATION WHICH SHOULD BE GIVEN SUPPLEMENTARY TO THE DRAFT MEASURED ITEMS TO ASSIST IN ASSIGNING PRICES AND RATES TO BILLS OF QUANTITIES.

DIAGRAM 7.18	Information needed	No effect	Information not needed	
Overall	4	1	4	9
Excavation + Earthwork	4	1	4	9
Underpinning	4	1	4	9
Piling	4	1	4	9
Concrete Work	4	1	4	9
Brickwork + Blockwork	4	1	4	9
Roofing	4	1	4	9
Woodwork	4	1	4	9
Metalwork	4	1	4	9
Glazing	4	1	4	9
Painting + Decorating	4	1	4	9
Fencing + Gates	4	1	4	9
BWIC Services	4	1	4	9
Finishings	4	1	4	9

Information Supplementary to the Hypothetical Model to Assist With Assigning Prices and Rates to Bills of Quantities



The respondents commented as follows:

1] "There is nothing to be gained by it". This is highly debatable. Unfortunately the respondent gave no grounds for making the statement.

2] "Your draft will allow them to price a job. Unusual features should be highlighted." An encouraging comment.

3] "No, as long as descriptions are adequate. I assume we employ intelligent people who employ the correct techniques and give adequate information in descriptions. An SMM cannot cover everything. By all means amplify things if you judge it necessary". No criticism is inferred here. It would be interesting, nevertheless, to compare the possible criteria used to define a "correct" technique.

25 COMMENTS FOLLOWING FROM QUESTION 24:

1] "Ground and surface water details, and which items should cover such costs". The measurer is powerless to prevent the Tenderer from allocating such costs, undetectably, to items other than those indicated.

2] "Presumably, a copy of the new SMM which will tell him what is included where". Again, instances were found during the data analysis where some quite significant costs were, demonstrably, not included where they should have been. There was no way of guessing, either, where they had been included. Therefore it may well be a waste of effort to dictate to buliders where to allow for things. They may well ignore such instructions and the reader of the Bill cannot always tell if such instructions have been ignored.

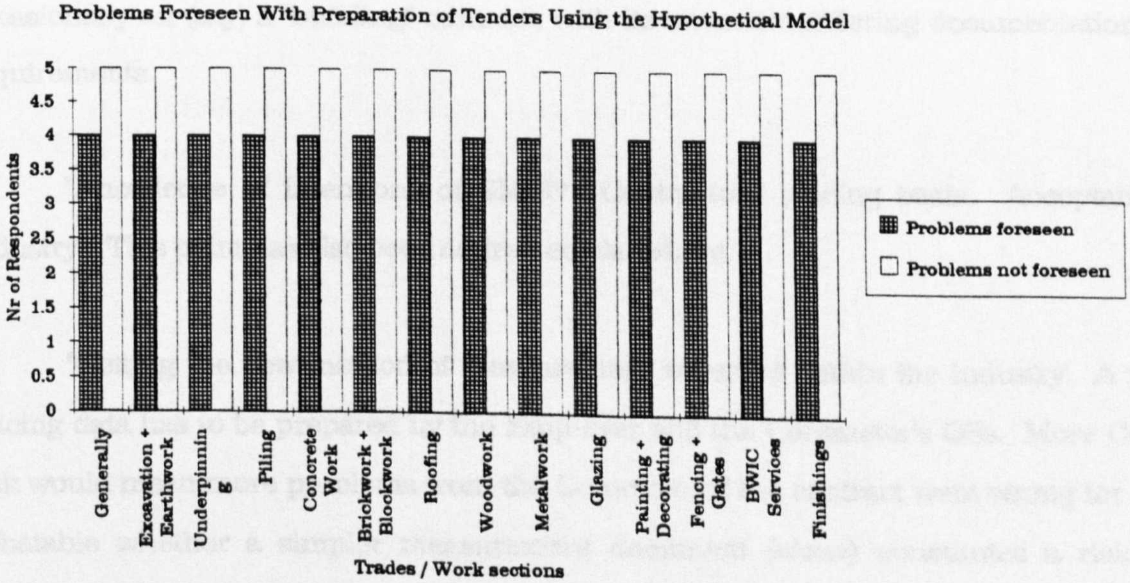
3] "Sketches, Bill Diagrams - as with the existing SMM". This would appear to be entirely reasonable in the case of unusual features.

Comments in this section appear to have been very constructive.

26 PROBLEMS FORESEEN WITH THE PREPARATION OF TENDERS USING THE HYPOTHETICAL MODEL.

DIAGRAM 7.19

	Problems foreseen	Problems not foreseen	
Overall	4	5	9
Excavation + Earthwork	4	5	9
Underpinning	4	5	9
Piling	4	5	9
Concrete Work	4	5	9
Brickwork + Blockwork	4	5	9
Roofing	4	5	9
Woodwork	4	5	9
Metalwork	4	5	9
Glazing	4	5	9
Painting + Decorating	4	5	9
Fencing + Gates	4	5	9
BWIC Services	4	5	9
Finishings	4	5	9



Specific comments were:

1] "I never see the problems. We can get round them anyway".

2] "I cannot foresee problems. They will manifest themselves when tests are done".

3] "Not once contractors get used to it".

4] "Again, I think there are doubts about specification". A respondent with conviction. See earlier comments.

27 COMMENTS FOLLOWING FROM QUESTION 26:

1] "Lack of familiarity. Low frequency of Tenders (*i.e.* iterative learning curve for our consultants)". This comment was made (and addressed) elsewhere. Regarding the relative infrequency of Tenders and the new databases involved, it may be that this fear is exaggerated. It is not unheard of for a company which specialises in (say) Civil Engineering contracts to work occasionally on (say) a "building" contract, with its attendant differing documentation and data requirements.

2] "Knowledge of intentions of SMM? Contractors' pricing basis. Acceptance within industry". This point has also been addressed elsewhere.

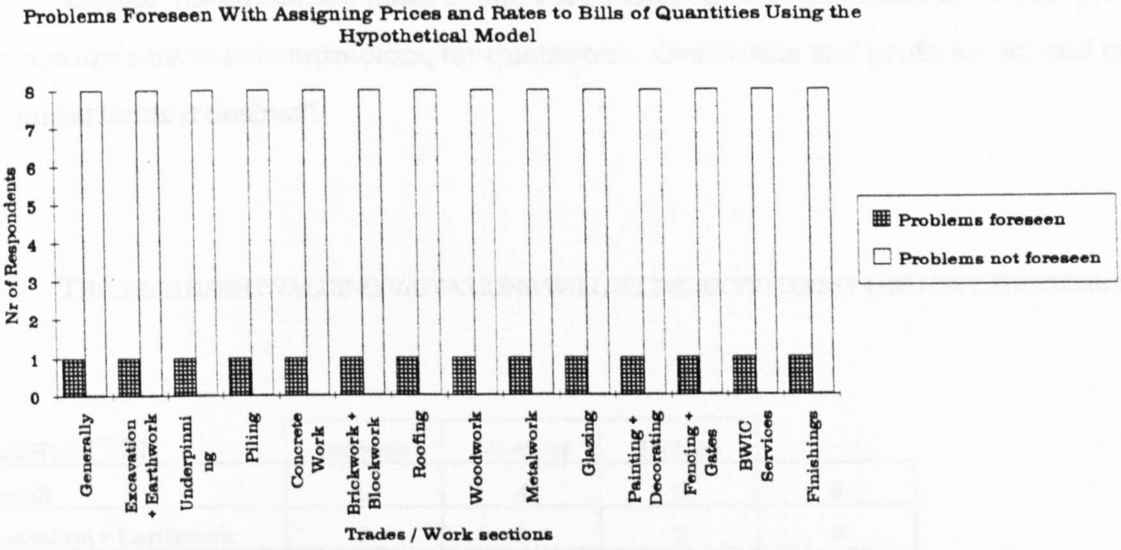
3] "Getting the new method of measurement accepted within the industry. A new set of pricing data has to be prepared by the Employer and the Contractor's QSs. More Contractor's risk would mean more problems from the Contractor if the contract went wrong for him". It is debatable whether a simpler measurement document (alone) constitutes a risk. Risk is inherent in construction projects as a fucnction of the uncertainties surrounding productivity of the factors of production. Methods of Measurement tend not deal with such factors and, if they did, could never predict the likely required amounts of such uncertain factors.

4] "The major problem will be one of familiarity. Tenderers must be allowed adequate time to tender. Initially, perhaps, an extended Tender period will be necessary. Once approved Tenderers have become familiar with the document and the types of Bills resulting from its use, I see no problem. Non-approved firms will find problems initially". Familiarity (again).

28 Problems foreseen with with assigning prices and rates to Bills of Quantities using the hypothetical model.

Diagram 7.20

	Problems foreseen	Problems not foreseen	
Overall	1	8	9
Excavation + Earthwork	1	8	9
Underpinning	1	8	9
Piling	1	8	9
Concrete Work	1	8	9
Brickwork + Blockwork	1	8	9
Roofing	1	8	9
Woodwork	1	8	9
Metalwork	1	8	9
Glazing	1	8	9
Painting + Decorating	1	8	9
Fencing + Gates	1	8	9
BWIC Services	1	8	9
Finishings	1	8	9



29 COMMENTS FOLLOWING FROM QUESTION 28:

1] "Lack of familiarity. Low frequency of [our] Tenders (iterated learning curve)".

30 RESPONDENTS' UNDERSTANDING OF HOW THE MEASURED BILL SECTIONS ARE USED BY CONTRACTORS WHEN PREPARING TENDERS:

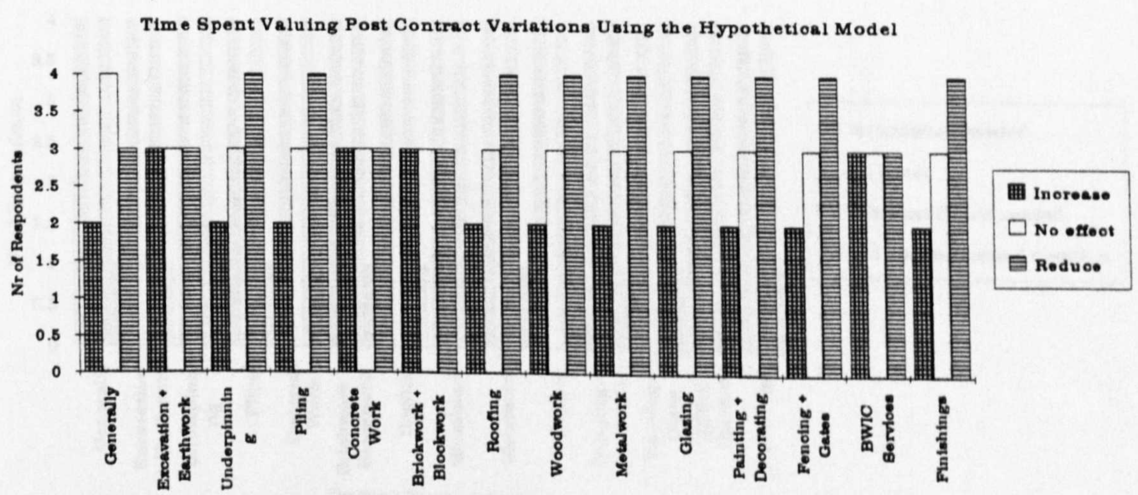
1] "Sections are sent out *en bloc* for specialist subcontract quotations. For concrete, brickwork, joinery, some external works and drainage the main items are priced by labour, materials and plant to produce a nett priced Bill. Subsequently preliminaries are added. Then at a Tender Meeting profit etc is decided upon for bidding purposes. As a form of front loading Trades 'in the ground' will have profit in the rates as these Trades are subject to most 'upward variation'. If he makes no money in the 'ground Trades' he will never make any later". Evidence to support earlier arguments. The Bill rates are a notional breakdown of a Tender. They do not purport to represent the cost of doing the work. They are prone to abuse.

2] "Subcontract quotations. They clearly get information from Bills. But there are cases where the Bills might not be used for the stated purpose. They are obviously useful". For what, the respondent did not say.

3] "Labour, materials and plant content are assigned to all Bill items for domestic work. Bill sections are sent to subcontractors, for quotations. Overheads and profit are spread around the measured items if desired".

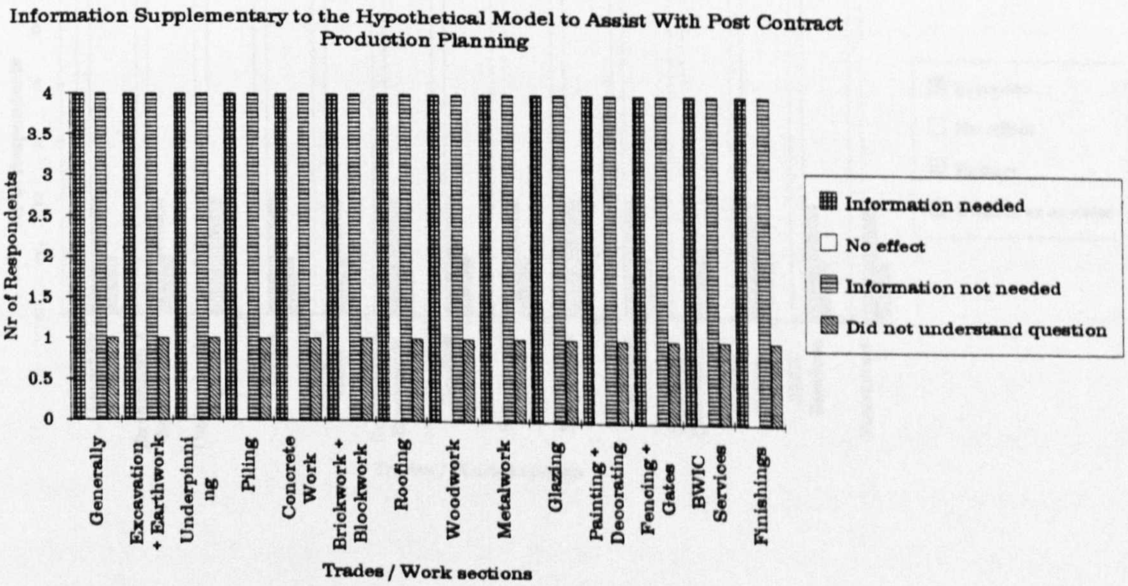
31 THE TIME SPENT VALUING VARIATIONS WILL BE REDUCED USING THE HYPOTHETICAL MODEL.

DIAGRAM 7.21	Increase	No effect	Reduce	
Overall	2	4	3	9
Excavation + Earthwork	3	3	3	9
Underpinning	2	3	4	9
Piling	2	3	4	9
Concrete Work	3	3	3	9
Brickwork + Blockwork	3	3	3	9
Roofing	2	3	4	9
Woodwork	2	3	4	9
Metalwork	2	3	4	9
Glazing	2	3	4	9
Painting + Decorating	2	3	4	9
Fencing + Gates	2	3	4	9
BWIC Services	3	3	3	9
Finishings	2	3	4	9



33 THERE IS INFORMATION WHICH OUGHT TO BE GIVEN SUPPLEMENTAL TO THE HYPOTHETICAL MODEL TO ASSIST IN POSTCONTRACT PRODUCTION PLANNING.

DIAGRAM 7.22	Information needed	No effect	Information not needed	Did not understand question	
Overall	4		4	1	9
Excavation + Earthwork	4		4	1	9
Underpinning	4		4	1	9
Piling	4		4	1	9
Concrete Work	4		4	1	9
Brickwork + Blockwork	4		4	1	9
Roofing	4		4	1	9
Woodwork	4		4	1	9
Metalwork	4		4	1	9
Glazing	4		4	1	9
Painting + Decorating	4		4	1	9
Fencing + Gates	4		4	1	9
BWIC Services	4		4	1	9
Finishings	4		4	1	9

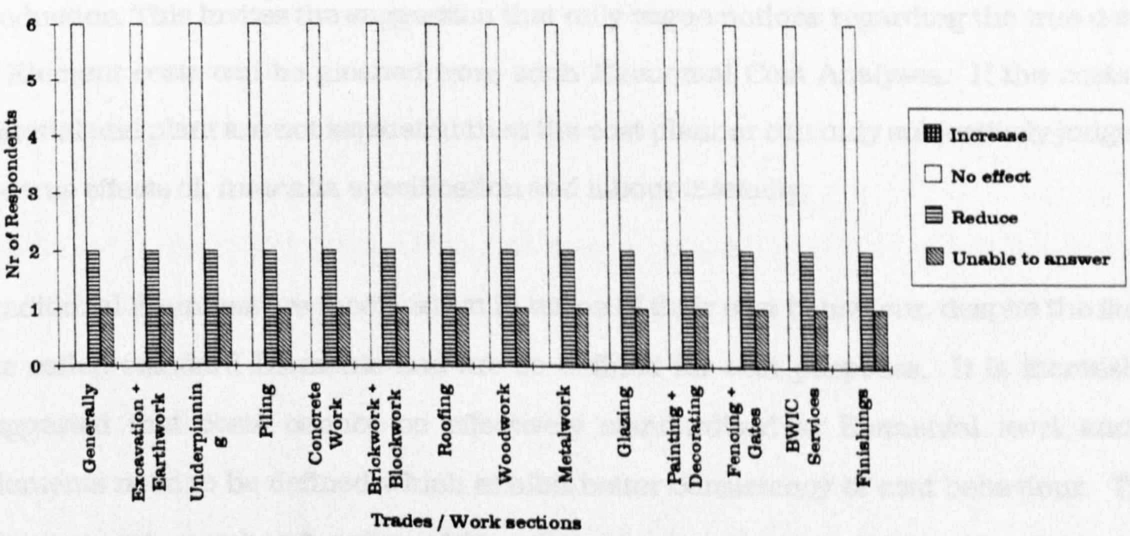


35 THE TIME SPENT ON INTERIM VALUATIONS WILL REDUCE USING THE HYPOTHETICAL MODEL.

DIAGRAM 7.23

	Increase	No effect	Reduce	Unable to respond	
Overall		6	2	1	9
Excavation + Earthwork		6	2	1	9
Underpinning		6	2	1	9
Piling		6	2	1	9
Concrete Work		6	2	1	9
Brickwork + Blockwork		6	2	1	9
Roofing		6	2	1	9
Woodwork		6	2	1	9
Metalwork		6	2	1	9
Glazing		6	2	1	9
Painting + Decorating		6	2	1	9
Fencing + Gates		6	2	1	9
BWIC Services		6	2	1	9
Finishings		6	2	1	9

Time Spent on Interim ValuationsUsing the Hypothetical Model



APPENDIX 8:
A SUGGESTED LEVEL OF ABSTRACTION FOR COST CENTRES FOR COST PLANNING AND CONTROL IN PETROCHEMICAL CIVIL ENGINEERING WORK

This Appendix is an expanded version of Davies and Greenwood (1994); being a further investigation carried out pursuant to the aims of this thesis.

THE CURRENT PROBLEM

The building Element classifications traditionally used in the United Kingdom for Cost Analysis and Cost Planning purposes do little, if anything, to prevent the separation of design and production. These Elements are defined on the basis of their physical function in their finished state, assuming that a building's function dictates its physical form and, hence, its cost.

Such Element classifications use not the costs of the factors of the production but some notional breakdown of a Tender, derived in many cases from priced Bills of Quantities. These contain measurements of design features and mask the relative contribution of the factors of production. This invites the suggestion that only vague notions regarding the true determinants of Element costs can be gleaned from such Elemental Cost Analyses. If the costs of labour, material and plant are not separated then the cost planner can only subjectively judge regarding the true effects of, *inter alia*, specification and labour intensity.

Traditional Elements are inconsistent in terms of their cost behaviour, despite the fact that they are called standard Elements and are so defined for cost purposes. It is increasingly being suggested that costs cannot be effectively standardised at Elemental level and that Sub-Elements need to be defined which exhibit better consistency of cost behaviour. The variable Element costs may be a function of the existence of one or more (relatively more cost-consistent) Sub-Elements. Design-based Element costs are merely visual manifestations, in the format which we choose, of the behaviour of the true determinants of cost and, in their traditional format, do not enable those determinants to be recognised. Assuming that builders attempt to compute costs using estimates of labour, material and plant costs, it is suggested that in the Design and Build domain it would be more desirable to the design and production processes by adopting an approach to Cost Analysis and Prediction which feeds the costs of the factors of production into the design-based Element framework.

It is argued that the factors of production themselves may provide more stable and definable cost inputs and may, in fact, act as more stable Subelements. This may facilitate improvements to Cost Analysis, Planning and Prediction and simultaneously improve communication between designer and builder by providing a logical link between the previously- separated design team and building team cost models. This is perceived to be of potential benefit in the Design and Build domain as, by logical inference, designer and builder are expected to cooperate more readily during the Design Stage.

Such an approach to Cost Analysis and Planning, however, might also have application in domains other than Design and Build because, *prima facie*, there can be no disadvantage in inviting input from builders at any stage of the process. Even if a Design Team did not wish to involve the builder in the Design Stage, it is argued that if the Cost Analyses available to the Design Team were structured according to the factors of production then this would be a better tool for aiding Cost Planning in any event. It could not be but advantageous to have such a cost model which could be structured for ready use either by designer or producer.

In order for published Elemental Cost Analyses to be so structured, however, it would, of course, be necessary to structure Bills of Quantities such that the successful tenderer had to apportion labour, material and plant costs to the items contained therein. In the current climate, and until the possible benefits of so doing are recognised, it is considered expedient to commence the investigation in the Design and Build domain, where such obstacles , presumably, do not exist. Perhaps as a result of such investigation the benefits will be perceived to have wider application.

A Suggested Element Classification

Diederichs and Hepermann (1985), in the domain of housing and administrative buildings, claim to have identified some 45 key cost parameters which exist for construction work practically independent of the type of structure. These parameters are allegedly subject only to marginal variation and are predictable to high degrees of accuracy. Significantly, these costs are expressly structured in terms of the factors of production (labour, materials and plant) but are assigned to an existing design-based set of building Elements (Deutsches Institut für Normung, 1983). Thus this model claims to bridge the "gap of definition" between the design team cost model and the building team cost model. Additionally, it permits meaningful input by the builder during design and planning. It has long been held that there is a separation between Design and Production in the Construction Industry, and the Diederichs-Hepermann Model, or one similar, appears to be a useful interface to help bring them together.

Design and production matters aside, there is a measure of opinion in the professions that existing Elemental Cost Models such as the BCIS Standard Form of Cost Analysis (1969) are inadequate in terms of the way in which they require the cost information to be formatted. The *BCIS* Form is defective in certain respects; *eg* in certain Elements [*eg* Roof] it is impossible to discern between Roof structure and Roof coverings, which invites subjectivity at best.

It is suggested that a suitable Form of Elemental Cost Analysis has already been devised which structures the information into a better logical format than the BCIS form. This Form is DIN 276 (Deutsches Institut für Normung, 1983), the Standard form of Cost Analysis used in the Federal Republic of Germany. It should be readily adaptable to use in the United Kingdom as it exists in a format recognisable to UK users, but with the recognition of structural and non-structural function suggested by Southgate (1988a, 1988b). It does this not by grouping Elements together, but by separating each individual Element into its structural, non-structural, cladding and interior or exterior components.

This, it is argued, is a more logical approach, enabling the user to deal with Element costs at any desired level of detail; from costs of discrete components of Elements to costs of whole Elements. This cannot be effectively done using the BCIS Form. A further advantage of DIN 276 is that it groups Elements with other Elements to which they are related. It separates, eg, Internal Finishings into those pertaining to Interior and Exterior Walls of buildings; this is not possible with the BCIS and Southgate Models and serves to illustrate the potential of DIN 276 to offer a subtler approach to Elemental Cost Planning.

Similarly, DIN 276 does not express the costs of the Structural Frame Element as a single "vague" cost, rendered devoid of any of the detail of, eg a Bill of Quantities; it identifies separately, and relates to other Elements which give rise to them, the constituent parts of the Structural Frame. For example, "Beams" belong in the Element "Upper Floors", thus more adequately recognising their specific function, and "Columns" are associated with the Wall Elements to which they are proximate. Such logic and sophistication of analysis cannot be obtained using the BCIS Form.

SHORTCOMINGS OF EXISTING COST ANALYSES AND BILLS OF QUANTITIES

Elemental Cost Analyses, for the most part, are derived by abstraction of detailed price data in Bills of Quantities, which are, arguably, the most prolific source of building cost data available. Most cost data, regardless of the form in which they are eventually published, first appeared in Bills of Quantities which were priced by builders. The prices of the many detailed items in the Bills are aggregated together in order to arrive at overall costs of defined building Elements.

Bills of Quantities, arguably, contain too much detail for the uses to which they are put. Successive Standard Methods of Measurement for Bills of Quantities have sought to reduce the amount of measurement detail commensurate with the types of construction work (or, more appropriately, design features) which they purport to represent. There exists some opinion in the industry that even the latest editions of such Standard Methods of Measurement still contain too much unnecessary detail. Moreover, even if the level of detail which they provide was appropriate, Elemental Cost Analyses misuse and, in fact, ignore it. Even were this an appropriate level of detail, conventional Elemental Cost Analyses are not structured to use it. Existing BCIS Cost Analyses are oversimplifications of, and use insufficient of the detail of, such Bills to be effective tools for meaningful cost analysis and prediction. The detail even of Detailed Cost Analyses is insufficient to enable Elemental Cost Planning to be carried out as effectively as it might be. A new approach to these cost models is suggested.

The Bill Of Quantities And The Elemental Cost Analysis Should Be The Same Document

Traditional Bills of Quantities contain more detail than do existing the Detailed Cost Analyses prepared therefrom. Much of the detail of traditional Bills of Quantities is, arguably, superfluous on the grounds that (a) tenderers attach little cost significance thereto and (b) such detail is often created to satisfy the rules of measurement rather than for any other reason. Existing Detailed Cost Analyses contain insufficient detail of the required type, which, in cases, reduces Elemental Cost Planning to a somewhat subjective exercise.

It is argued that if the Bill of Quantities is produced in the format of a somewhat more detailed Elemental Cost Analysis than those currently employed, then sufficient detail will be provided to enable the processes of tendering and valuation of postcontract variations to occur. Simultaneously, a better level of detail will be provided for the purpose of more objectively carrying out Elemental Cost Planning. Also, as the two documents will become a single document, the effort of producing a Bill of Quantities and then using it to produce an Elemental Cost Analysis is dispensed with. It is argued that these separate efforts are undesirable because neither Bill of Quantities nor Elemental Cost Analysis have an adequate enough format for the uses to which they are put.

There is no reason not to attempt to produce a document which simultaneously fulfils both of the above functions; the functions, in fact, are much the same as each other. The Bill of Quantities is the basis for costing variations to an existing representation of a design in the post contract (an accountancy exercise) and the Elemental Cost Analysis is the basis for costing variations to representations of design in the pre contract (a prediction exercise). Given that both mechanisms are the same (they just occur at different times) a single document with dual purpose would appear feasible.

A Proposed Investigation of a Cost Analysis and Planning Model Which Interfaces Design and Production

It is considered that the most suitable model to test in the Design and Build domain would be the Diederichs-Hepermann model. Its attempt to link designer and producer at an early stage is perceived to be of potential benefit. Indeed, it may well have usefulness in other domains, if it be accepted that involving the builder in the early stages of the process has intrinsic value, which it presumably does. Also, the model fits an existing set of design-based Elements with which design teams ought to be familiar. The set of design-based Elements upon which it is based is, itself, perceived to be an improvement on its United Kingdom counterpart.

It is proposed not to investigate pure Civil Engineering matters, as work done in this area by other researchers would, presumably, be more useful in that context. The Diederichs-Hepermann model, in any event, uses the relative effects of labour, plant and material inputs based on "traditional" building construction. The balance of these inputs, as discussed earlier, is expected to be somewhat different in pure Civil Engineering.

A SUGGESTED DESIGN-BASED SET OF ELEMENTS TO FACILITATE THE INPUT OF THE COSTS OF THE FACTORS OF PRODUCTION

The Diederichs-Hepermann model was derived, in the domain of housing and public buildings, on behalf of a German Ministry. It uses DIN 276. DIN 276 is the German equivalent of the BCIS Standard Form of Cost Analysis. It defines Elements as design features, as does the BCIS Cost Analysis, but is in many respects more logically set out and is considered to have certain advantages.

For example, DIN 276 recognises the distinction between structure and cladding/ finishings to external walls less clumsily than does the BCIS Form. DIN 276 separates internal and external wall finishings. The BCIS Form does not. DIN 276 identifies separately the structural and non-structural components of all Elements. BCIS does not. DIN 276 classifies separately openings in floors and ceilings, external walls, internal walls and roofs. BCIS only classifies "Internal Doors" and "External Doors and Windows". This is somewhat illogical and serves rather to mask the true contributions of individual components. The BCIS Form of Cost Analysis has not had any meaningful revision to its format for some three decades and it would be healthy to contemplate some improvement.

Tables 17 and 18 illustrate the Elemental Classifications of BCIS Cost Analysis and DIN 276 respectively. It should be noted that DIN 276 is not intended for use with Building Services; some other document should be consulted in that regard, or suitable Classifications added to DIN 276. BCIS has 15 classifications for Building Services, not all of which will exist on any given project and which are frequently covered by a single Prime Cost Sum in any case. Although the Building Services classifications in BCIS are more complex, their cost breakdowns are frequently vague.

The converse could be argued for the other Elements of the building. Excluding Building Services, Fittings and Furniture and the site-dependent Elements (Preliminaries, Substructure, Site Work, Drainage, External Services, Minor Building Works and the DIN 276 equivalents), BCIS possesses 11 classifications compared to 28 in DIN 276. The Elements in question in BCIS are 1 (Substructure) to 3C (Ceiling Finishes) (inclusive). The corresponding Elements in DIN 276 are AWF (Aussenwandfläche) (External Wall Surfaces) to DAF (Dachfläche) (Roof Surfaces) (inclusive).

It appears that the BCIS Cost Analysis is too crude and simplistic to enable any truly systematic Cost Analysis to be carried out. In contrast, DIN 276 appears to be sufficiently logically formatted and sophisticated to enable a better and more systematic such exercise to be undertaken. DIN 276 is structured in 3 hierarchical levels as opposed to BCIS's 2: it defines design Subelements better than does BCIS. BCIS Cost Analyses inadequately represent the costs of functional parts of buildings because its Element classifications are too crude even to identify them all. It would be better, for such purposes, to use a system such as DIN 276. *Tables 1 and 2* should reveal that it is a more logical and systematic classification of component parts of buildings.

THE BASIC PRINCIPLES OF THE DIEDERICHS-HEPERMANN MODEL

1 Consistent with counterpart thinking in the UK, it recognises that most cost in a construction project is generated by a relatively small number of cost determinants, and that the costs of these determinants should be addressed as early as possible during design, which does not really happen using customary practice.

2 It is structured to accord with HOAI [12], which is the equivalent of the RIBA Plan of Work [13] used in the UK. Both systems define appropriate design phases and time points for appropriate stages of cost forecasting, but HOAI goes further than the RIBA Plan of Work in that it defines the types of costs which should be concentrated upon at the key time points which are identified. The RIBA Plan of Work makes no such definitions as UK conventions leave such matters to a cost planner who is not, in fact, the designer. Thus, in customary practice, the UK cost planner will not necessarily isolate the most significant determinants of cost for special

attention. Diederichs and Hepermann recognise a similar shortcoming by alleging that relatively few practitioners actually use HOAI, preferring to rely on their own idiosyncratic practices.

3 The "significant determinants of cost" are called *Lead Positions*. They are 45 in number, exist in various combinations on all projects regardless of type of structure and invariably account for 80-90% of total cost. They are listed in *Table 19* and are structured according to a widely-recognised set of Work Category Classifications; therefore no user should fail to recognise them. *Lead Positions* represent relatively immutable constituents of Elements and illustrate the notion that Element costs are manifestations of the existence or otherwise of such constituent entities: a *Lead Position* can belong to more than one Element and a single Element can be made up of several different *Lead Positions*. Thus Element Classifications become somewhat arbitrary, because building costs do not depend upon such Classifications, but they have to exist in order that we might recognise what the building design looks like.

4 The *Lead Positions* were selected on an intuitive basis at first, but the list of *Lead Positions* was verified and refined following analysis of 10 projects (housing and administrative buildings). The *Lead Positions* are very similar to the *Work Categories* which are used in the UK for valuing fluctuations on building contracts; that is to say, they represent types of construction work which have their own inherent characteristics and whose costs are calculable using weighted inputs of labour, plant and materials. Thus it is argued that it may be possible to use, e.g., the widely-recognised NEDO or CPI Work Categories in an attempt to find *Lead Positions* or significant determinants of cost applicable to UK construction projects during design. Work Categories in the UK are customarily used in a single, very limited situation in the post contract. The attribution of allegedly unique models to allegedly unique situations belies the fact that changes to design and cost in the pre contract are essentially the same as changes to design and cost in the post contract. Culturally, we assume that models in the post contract must in some way to be fundamentally different to those in the pre contract, despite the fact that the determinants of cost remain fundamentally the same.

5 *Lead Positions*, whilst always being significant determinants of cost, can possess different "levels of influence" on cost. For example, some cost-determinants can have a range of possible design or construction options, some relatively few. the wider the range of design or construction options, the wider the expected ranges of possible cost and. hence, the greater the "level of influence". This is consistent with UK thinking on "cost-sensitivity" of Elements; the difference now being that attempts to measure cost-sensitivity can be made on cost-determinant *Work Categories* rather than on a rather arbitrary, vaguer set of Elements.

6 There exist *Remainder Positions*, as Diederichs and Hepermann term them, which comprise those work categories which contribute the minority of overall cost. These can be costed as an overall parcel of cost, rather than costed out individually. Examples are listed in *Table 4*. They never singly contribute more than, say, 1% of total cost.

7 The model can accommodate design changes in the pre contract or the post contract, by very virtue of the fact that it uses significant building *Work Categories*, calculated in terms of material, plant and labour costs: it does not use one technique for one phase of the project and another for another: cost is determined by the same things at all times: there is no need to cloud the issue by inventing techniques which are (often mistakenly) considered only to apply to a unique situation.

8 The model defines *Special Positions* which are cost -determining *Work Categories* which occur relatively uniquely, or only occasionally, to buildings which have particular requirements not common to buildings in general. They should be costed individually, on an *ad hoc* basis, as well as possible. They are likely to prove to be *Lead Positions* when they have occurred on sufficient occasions for cost records to become reliable enough. Because they are special or unique requirements, their costs on such a unique project are likely to be significant for that project. an example could be a *Work Category* called "Soil Improvement Techniques" which occur on a minority of construction projects but, if required, would almost certainly be cost-significant for that project. If it subsequently occurred on many projects it would be become defined as a *Lead Position*.

9 It should be expected that the *Lead Positions* exhibited for buildings in Germany should be exhibited for buildings in the UK as construction techniques and architecture do not vary a great deal between countries nowadays. Obviously there may be minor differences reflecting traditional building practice (e.g. timber ground floors would seldom be encountered in Germany and hard, cold floor finishings would be less common in the UK) but it is seen as a suitable starting point to select, say, the NEDO or CPI Work Categories which most closely reflect the *Lead Position* categories: therefore this has been done in *Table 19.*

COMPARABILITY OF *LEAD POSITIONS* AND *WORK CATEGORIES*

There are some differences attributable to design and construction tradition (styles of Finishings are somewhat different and concrete floor construction is almost universal in Germany). There is no complete overlap between the *Lead Positions* and the UK *Work Categories*. However, *Lead Positions* and UK *Work Categories* are sufficiently alike to enable testing, in the UK, of a model which substitutes *Work Categories* for *Lead Positions* at a level of detail between that of the over-detailed UK Bill of Quantities and the under-detailed UK Elemental Cost Analyses, and which could be used during the pre contract and the post contract. UK *Work Categories* are used in the post contract with the design-based Bill of Quantities as a basis for calculation. Therefore they should be adaptable, *mutatis mutandis*, for use in the precontract.

TABLE 17: DIN 276 ELEMENT CLASSIFICATION

GROBELEMENTE: BASISFLÄCHE	CRUDE ELEMENTS: BASE SURFACES
Gebäude-Elemente	**Building Elements**
3.1.1.1 Baugrube	Excavation + Earthwork
3.1.1.2 Fundamente und Unterboden	Foundations + Filling

GROBELEMENTE: AUßENWANDFLÄCHE	CRUDE ELEMENTS: EXTERNAL WALL PLANES
Gebäude-Elemente	**Building Elements**
3.1.2.1 Tragende Außenwände, Außenstützen	Loadbearing External Walls, External Columns
3.1.3.1 Nichttragende Außenwände und zugehörige Konstruktionen	Non-loadbearing External Walls and Associated Construction

GROBELEMENTE: INNENWANDFLÄCHE	CRUDE ELEMENT: INTERNAL WALL SURFACES
Gebäude-Elemente	**Building Element**
3.1.2.2 Tragende Innenwände, Innenstützen	Loadbearing Internal Walls, Internal Columns
3.1.3.2 Nichttragende Innenwände und zugehörige Konstruktionen	Non-loadbearing Internal Walls and Associated Construction

Gebäude-Unterelemente	Building Subelements
3.1.1.1 [1] Baugrube	Excavation + Earthwork
3.1.1.2 [1] Fundamente	Foundations
3.1.1.2 [2] Unterboden	Filling
3.1.1.2 [3] Bauwerksohlen	Ground Floor
3.1.1.3 [6] Bodenbelage auf Bauwerksohle	Finishings to Ground Floor

Gebäude-Unterelemente	Building Subelements
3.1.2.1 [1] Tragende Außenwände, Tragkonstruktionen	Loadbearing External Walls, Loadbearing Construction
3.1.2.1 [2] Außenstützen, Tragkonstruktionen	External Columns, Loadbearing Construction
3.1.3.1 [1] Nichttragende Aussenwände, Konstruktionen	Non-loadbearing External Walls, Construction
3.1.3.1 [2] Außentüren, Außenfenster	External Doors, External Windows
3.1.3.1 [3] Wandbekleidungen außen	External Wall Finishings Externally
3.1.3.1 [4] Wandbekleidungen innen Außenwand	External Wall Finishings Internally
3.1.3.1 [5] Fassadenelemente	Facade Elements
3.1.3.1 [6] Schutzelemente Außenwand	External Wall Protection Elements

Gebäude-Unterelemente	Building Subelements
3.1.2.2 [1] Tragende Innenwände, Tragkonstruktionen	Loadbearing Internal Walls, Loadbearing Construction
3.1.2.2 [2] Innenstützen, Tragkonstuktionen	Internal Columns, Loadbearing Construction
3.1.3.2 [1] Trennwände	Internal Partitions
3.1.3.2 [2] Innentüren, Innenfenster	Internal Doors, Internal Windows
3.1.3.2 [3] Innenwandbekleidungen	Internal Wall Finishings
3.1.3.2 [4] Wandelemente	Demountable Partitions
3.1.3.2 [5] Schutzelemente Innenwand	Internal Wall Protection Elements

CRUDE ELEMENT: HORIZONTALE TRENNFLÄCHE — CRUDE ELEMENT: HORIZONTAL DIVISION SURFACES

Gebäude-Elemente	Building Element
3.1.2.3 Tragende Decken, Treppen	Loadbearing Upper Floors, Stairs
3.1.3.3 Nichttragende Konstruktionen der Decken, Treppen und zugehörige Baukonstruktionen	Nonloadbearing Upper Floors, Stairs and Associated Construction

GROBELEMENTE: DACHFLÄCHE — CRUDE ELEMENT: ROOF PLANES

Gebäude-Elemente	Building Element
3.1.2.4 Tragende Dächer, Dachstuhle	Loadbearing Roofs
3.1.3.4 Nichttragende Konstruktionen der Dächer und zugehörige Baukonstruktion	Nonloadbearing Roof Construction and Associated Construction

GROBELEMENTE: SONSTIGE KONSTRUKTIONEN — CRUDE ELEMENT: OTHER CONSTRUCTION

Gebäude-Elemente	Building Element
3.1.9.1 Baustelleneinrichtung	Preliminaries
3.1.9.9 Sonstige Baukonstruktionen	Other Construction

Gebäude-Unterelemente	Building Subelements
3.1.2.3 [1] Deckenplatten, Balken, Tragkonstruktionen	Upper Floors, Beams, Loadbearing Construction
3.1.2.3 [2] Treppenlaufe, Zwischenpodeste, Tragkonstruktionen	Stair Flights, Landings, Loadbearing Construction
3.1.3.3 [1] Bodenbelage	Floor Finishings to Upper Floors
3.1.3.3 [2] Treppenbelage	Floor Finishings to Stairs, Landings
3.1.3.3 [3] Deckenbekleidungen	Ceiling Finishings
3.1.3.3 [4] Treppenbekleidungen	Ceiling Finishings to Stairs, Landings
3.1.3.3 [5] Schutzelemente Decken	Floor Protection Elements

Gebäude-Unterelemente	Building Subelements
3.1.2.4 [1] Tragende Dachkonstruktionen	Roof Structure
3.1.3.4 [1] Dachbelage	Roof Finishings
3.1.3.4 [2] Dachbekleidungen	Ceiling Finishings to Roofs
3.1.3.4 [3] Dachöffnungen	Roof Openings
3.1.3.4 [4] Schutzelemente Dächer	Roof Protection Elements
3.1.9.1 [1] Baustelleneinrichtung	Preliminaries
3.1.9.9 [1] Schachte, Kanäle	Drainage, Internal + External
3.1.9.9 [2] Räumliche Fertigbauteile	Prefabricated Building Compartments
3.1.9.9 [3] Abbruch von Baukonstruktionen	Demolitions

Table 18: BCIS Element Classification

Building Group Element	Building Element
1 Substructure	1 Substructure
2 Superstructure	2A Frame
	2B Upper Floors
	2C Roof
	2D Stairs
	2E External Walls
	2F Windows and External Doors
	2G Internal Walls and Partitions
	2H Internal Doors
3 Internal Finishes	3A Wall Finishes
	3B Floor Finishes
	3C Ceiling Finishes
4 Fittings and Furnishings	4 Fittings and Furnishings
5 Services	5A Sanitary Appliances
	5B Services Equipment
	5C Disposal Installations
	5D Water Installations
	5E Heat Source
	5F Space Heating and Air Treatment
	5G Ventilating System
	5H Electrical Installations
	5I Gas Installations
	5J Lift and Conveyor Installations
	5K Protective Installations
	5L Communication Installations
	5M Special Installations
	5N Builder's Work in Connection With Services
6 External Works	5O Builder's Profit and Attendance on Services
	6A Site Work
	6B Drainage
	6C External Services
	6D Minor Building Works
[Unnumbered] Preliminaries	[Unnumbered] Preliminaries

TABLE 19: LEAD POSITIONS AND THEIR UK EQUIVALENTS

"LEAD POSITIONS"	CORRESPONDING UK WORK CATEGORIES
002.01 Aushub Baugrube	Site + Reduced Level Excavation (01)
002.02 Aushub Fundamente und Rohrgräben	Excavation For Foundations and Pipe Trenches
012.01 Mauerwerk d <= 0.30m	Masonry (Walls + Partitions) (02)
012.02 Mauerwerk d = 0.24m	Masonry (Walls + Partitions)
012.03 Mauerwerk d <= 0.175m	Masonry (Walls + Partitions)
012.04 Mauerwerk d = 0.115m	Masonry (Walls + Partitions)
012.05 Mauerwerk d < 0.115m	Masonry (Walls + Partitions)
012.06 Sichtmauerwerk d >= 0.24m	Facework (02)
012.07 Sichtmauerwerk d <= 0.175m	Facework
012.08 Verblendmauerwerk d <= 0.115m	Facework
013.01 Rand- und Seitenschalung	Formwork: Edges + Sides (generally) (03)
013.02 Schalung: Brüstungen, Überzüge und Attiken	Formwork: Projections, Upstands
013.03 Schalung der Wände	Formwork: Walls
013.04 Schalung der Stützen	Formwork: Columns
013.05 Schalung der Decken	Formwork: Upper Floors
013.06 Schalung der Balken und Unterzüge	Formwork: Beams, Downstands
013.11 Stabstahl	Bar Reinforcement
013.12 Mattenstahl	Fabric Reinforcement
013.21 Beton für Fundamente, Platten, Decken etc	Concrete: Foundations, Slabs, Upper Floors etc
013.22 Beton für Stützen und Wände	Concrete: Columns + Walls
014.01 Bodenbelag aus Werksteinplatten	Precast Finishes: Floors (04)
014.02 Treppenbelag aus Werksteinplatten	Precast Finishes: Stairs (04)
016.01 Kantholz liefern	Structural Timber: Supply (05)
016.02 Kantholz verzimmern	Structural Timber: Construction
016.03 Dachschalung	Roof Boarding
020.01 Dachdeckung	Tiled Roof Coverings (06)
020.02 Dachabdichtung	Sheet Roof Coverings (07)
020.03 Dachrinne / Fallrohr	Rainwater Installation

TABLE 19: LEAD POSITIONS AND THEIR UK EQUIVALENTS

"LEAD POSITIONS"	CORRESPONDING UK WORK CATEGORIES
023.01 Innenputz Wände	Plastering and Rendering to Walls: Internally
023.02 Innenputz Decken	Plastering and Rendering to Ceilings: Internally
023.03 Außenputz Wände	Plastering and Rendering to Walls: Externally
023.04 Gipskartonarbeiten	Dry Partitions + Linings
024.01 Wandfliesen	Wall Tiling: Ceramic (04)
024.02 Bodenfliesen	Floor Tiling: Ceramic (04)
025.01 Schwimmender Estrich (08)	Screeds
025.02 Verbundestrich	Screeds
027.01 Holzfenster	Timber Windows
027.02 Holztüren	Timber Doors
027.03 Holzverkleidungen	Timber Cladding + Linings: Internally
031.01 Metallfenster	Metal Windows
031.02 Metallgeländer	Metal Balustrades,Balconies,Handrails etc (04)
034.01 Anstrich auf mineralischem Untergrund	Painting: Mineral Base Surfaces
034.02 Anstrich auf Holz und Metall	Painting: Timber + Metal Surfaces
034.03 Tapezierung	Wallpapering etc
036.01 Elastischer und textiler Bodenbelag	Tile and Sheet Floor Finishings: Non-ceramic

TYPICAL COMPOSITION OF A LEAD POSITION

Table 20 shows the facility to input costs of the factors of production, if desired, into the cost centre. Alternatively, it can merely be quantified in the from of an Element Unit Quantity, in the manner of the design-based model.

TABLE 20 LEITPOSITION: 013.21: BETON FÜR ABFÜLLUNGEN, FUNDAMENTE, BÖDEN, PLATTEN, DECKEN / LEAD POSITION 013.21: CONCRETE FOR FILLING, FOUNDATIONS, GROUND FLOORS, SLABS, UPPER FLOORS

AUSFÜHRUNGSVARIANTE DESIGN AND SPECIFICATION VARIATIONS		EINHEIT UNIT/QUANTITY FACTOR	LOHNAUFWANDSWERT (LH/M2) LABOUR COSTS (HRS/M2)	MATERIAL-KOSTEN (DM/M2) MATERIAL COSTS (£/M2)
This is the basic Lead Position (Significant Cost Centre):				
013.21.01	Für alle Bauteile, B25	m3	0,6	115,00
	For all features, Grade B25	m3	0.6	
These are Z = Zulage = "extra over" cost for each stated design or specification variation:				
013.21.Z1	Zulage für B35	m3	0,6	+8,00
	Extra; Grade B35	m3	0.6	
013.21.Z2	Zulage für B35	m3	0,6	+13,00
	Extra; Grade B35	m3	0.6	
013.21.Z3	Zulage für das abreiben der Beton-oberfläche	m3	+ 0,5	
	Extra; polishing top surfaces	m3	+ 0.5	

NOTES:

(01) General site excavation and Excavation directly atrributable to the actual foundations are kept separate, which is a useful improvement on UK practice.

(02) UK *Work Categories* for Masonry are not separated by relative thickness ("d" = Dicke, "Dichte" = thickness).

(03) Formwork to edges and sides only applies to edges and sides <10 cm wide.

(04) The use of hard precast granolithic or terrazzo floor finishes, and of metal balustrading and balconies, is common in German construction and, hence, always significant in cost analyses.

(05) The supply and the installation costs of structural timbers are kept separate in German cost analyses; though it is not immediately apparent why the cost of the supply of these components, and no others, should be expressly and separately identified as a Lead Position in its own right.

(06) Costs of Pitched and Flat Roof Coverings are kept separate in the cost model under scrutiny; such sophistication is not usually seen in conventional UK Cost Analyses.

(07) The literal meaning of *Dachabdichtung* is "Roof Waterproofing". Built-up Felt Roofing, Sheet Roof Coverings and the like are the UK equivalents. The CPI Work categories (SMM7) now recognise this and classify certain roof coverings under "Waterproofing".

Annex 1:

Hypothetical Petrochemical Civil Engineering Measurement Model

(Prior to Validation Stage 1)

SECTION: CONCRETE WORK

Subsection: Insitu Concrete

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Foundations in trenches		m^3	
Isolated foundation bases Casings to steel grillages Pile caps Isolated beams Isolated beams casings Isolated columns Isolated column casings Machine bases Ground beams Casings to steel beams	...Nr	m^3	Excludes attached beams. Column length: thickness ratio=<4:1.
Beds or pavings Suspended floors or roofs Profiled soffit suspended floors or roofs Upstands or kerbs Walls Duct or channel walls Steps and staircases Tops and cheeks of dormers Filling hollow walls Mass filling Blinding		m^3	Beds and pavings include thickenings. Floors, roofs and beds exclude kerbs and upstands. Floors and roofs include attached beams and beam casings and solid margins to profiled work. Walls include projections and kickers. Walls: thickness ratio=>4:1. Steps and staircases include strings and associated landings.

Subsection: Joints in Concrete

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Designed joints	...wide	m	Includes ends, angles, intersections and the like.

Subsection: Labours on Concrete

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Treating surfaces Grinding Sand-blasting Working around heating pipes and cables	Generally Margins	m^2	
Holes <=1m girth Holes 1-2m girth Holes 2-3m girth	<=75 deep 75-150 deep 150-225 deep 225-300 deep ...deep	Nr	Includes making good concrete by specified means. If>300 deep, state depth. If >3m girth, classify in other categories elsewhere.
Channels or chases	Small Large Extra large	m	Includes making good concrete by specified means.
Mortices			Give with member for which it is provided. Otherwise measure as holes, channels and chases, or as formwork.
Anchor-bolts Fixing-devices	...diameter Serial Nr ...	Nr	Includes temporary boxings, mortices, grooves, pockets, grouting and the like. If not specified, is at contractor's discretion.

Grouting under bases, grillages and the like	<=25 thick 25-50 thick ...thick	Nr	If over 50 thick, state thickness.

Subsection: Reinforcement

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Horizontal or sloping <=30° from horizontal Horizontal or sloping <=30° from horizontal, bars >12m long Vertical or sloping >30° from horizontal Vertical or sloping >30° from horizontal, bars >5m long	Foundations, bases, ground beams, pile caps and the like Beds and pavings Suspended floors and roofs Walls Columns, column casings, beams, beam casings and lintels Steps and staircases Tops and cheeks of dormers Machine bases	m^2 t	m^2 for fabric. t for bars. Classify as straight or bent, or as curved. Includes links and the like, raking and curved cutting and bending.

Subsection: Formwork

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Edges of beds, pile caps and foundations Edges of suspended floors or roofs, landings, risers and steps in floors or roofs	<=250 wide 250-500 wide >500 wide	m m m^2	Includes all cutting. Ignore Nr of surfaces. Where not plain and vertical, specify. Ignore ends of steps. No slope categories. If profile complex, specify. For tapering sections give no dimension ranges except where >500 wide to beams and beam casings.
Upper surfaces sloping >15° from horizontal	Walls, beams, beam casings, beds, suspended floors or roofs	m^2	Includes all cutting. Ignore Nr of surfaces.

Soffits of suspended floors or roofs, stairs or landings	Horizontal or sloping <15° from horizontal Sloping >15° from horizontal	m^2	Includes all cutting. Do not distinguish in measurements between flat and profiled work. Specify the profile.
Strings	<=300 wide 300-600 wide ... wide	m	Includes all cutting. State width if >600.
Attached beams and beam casings Kerbs and upstands Recesses Projecting eaves	Horizontal Sloping	m^2	Includes all cutting. Add adjacent slab edges [except recesses] to quantity. If profile complex, specify.
Walls	Vertical Sloping	m^2	Includes all cutting. Ignore Nr of surfaces and whether interrupted by projections. Add attached piers, ends of walls and pilasters to quantity. Includes kickers if not designed.
Wall projections, horizontal or sloping <=15° from horizontal Wall projections, sloping >15° from horizontal	... x ...	m	State cross-section and profile [if complex]. If vertical classify as walls.
Designed wall kickers		m	If not designed do not measure.
Holes <=1m girth Holes 1-2m girth Holes 2-3m girth	<=75 deep 75-150 deep 150-225 deep 225-300 deep ... deep	Nr	Includes making good concrete by specified means. If>300 deep, state depth. If >3m girth, classify in other categories elsewhere.

Channels or chases	Small Large Extra large	m	Includes making good concrete by specified means. —
Mortices			Give with member for which it is provided. Otherwise measure as holes, channels and chases, or as formwork.
Isolated columns and column casings Isolated beams and beam casings	...Nr	m^2	If not rectangular, describe shape.

Subsection: Precast Concrete

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Suspended floor or roof units Wall or partition units	Horizontal Sloping Vertical	m^2	Includes temporary support, joint treatments, reinforcement and surface finish, all of which must be specified. If profile unusual, specify.
Copings Kerbs Channels Lintels Beams Steps Dust covers Shelves	Straight Curved, ... radius Curved, >4m radius Reference ... BS..., Fig ...	m	Includes reinforcement, surface finish, bedding and jointing and shape of units, all of which must be specified. State radius if <=4m. Includes ends, angles, intersections and the like.
Staircases and associated landings	...size x ...rise x ... going Reference nr ... Drawing Nr ...	Nr	Includes reinforcement, surface finish, bedding and jointing and shape of units, all of which must be specified.

Subsection: Concrete Sundries

Damp-proof membranes Fibre underlay and the like		m^2	Includes turn-ups, laps and the like, the requirements for which must be specified.

SECTION: EXCAVATION AND EARTHWORK

Subsection: Site Preparation

Lifting turf and preserving		m^2	State distance to spoil heap.
Removing isolated trees	<=600 girth >600 girth	Nr	Specify ground treatment after removal.
Removing hedges		m	If >600 girth measure as trees.
Removing undergrowth		m^2	
Excavating topsoil and preserving; <=0.25m deep	... average depth	m^2	State distance to spoil heap.
Excavating topsoil and preserving; >0.25m deep		m^3	

Subsection: Excavation

Reduce level		m^3	No depth stages.
Basements Pits for foundations and bases	<=1m total depth <=2m total depth <=4m total depth <=6m total depth	m^3	Calculate total depth from reduced level. Continue depth classifications in 2m stages.
Pits for foundations and bases, each <=1m^3	... Nr	m^3	
Foundation trenches <= 300wide Foundation trenches >300 wide	<=1m total depth <=2m total depth <=4m total depth <=6m total depth	m^3	Calculate total depth from reduced level. Continue depth classifications in 2m stages.

Working space and backfill with specified material other than excavated material	<=1m total depth <=2m total depth <=4m total depth <=6m total depth	m^3	Calculate total depth from reduced level. Continue depth classifications in 2m stages. Measure only where backfill material specified is other than excavated material; otherwise the use of working space is at contractor's discretion.
Extra; breaking up pavings	... thick	m^2	Do not classify by type of excavation to which it applies. Specify type of paving. Assume thickness if unknown. Applies to all surface materials.
Extra; breaking up pavings and reinstating	... thick	m^2	Do not classify by type of excavation to which it applies. Specify type of paving and exact reinstatement materials and dimensions. Assume thickness if unknown. Applies to all surface materials.
Excavating alongside services	... deep	m	State type of service.
Excavating across services	... deep x ... long		State type of service and the length of excavation which crosses it.
Extra; excavation adjacent to roads, pavements or existing buildings	<=1m total depth <=2m total depth <=4m total depth <=6m total depth	m^2	These items are at contractor's discretion. Continue depth classifications in 2m stages.

Subsection: Earthwork Support

Generally In running sand or silt	<=1m total depth <=2m total depth <=4m total depth <=6m total depth [continuing depth classifications in 2m stages]	m^2	These two methods of classifying earthwork support are equally permitted options. Disregard type of excavation to which the items apply. Measure earthwork support to working space only if the working space is expressly required to be measured.
Generally In running sand or silt		m^2	

Subsection: Disposal of Excavated Material

Off site To Employer's tip Topsoil Multiple handling			Specify details of multiple handling. State disposal locations.

Subsection: Filling

To excavations		m^3	Include sinkings in the measured quantity.
To make up levels <=0.20m thick	... average thickness	m^2	Includes handpacking.
To make up levels >0.20m thick		m^3	Filling to working space is measured according to the Excavation Subsection. Specify details of fill materials, layers and compaction.

Subsection: Surface Treatments

To filling To excavations To excavations in hard materials		m^2	Where filling measured superficially, specify surface treatments with the filling items. Disregard slopes, but give details of unusual profiles. Specify the surface treatment [blinding is not a separate item].

Landscaping		m^2	Specify soiling, seeding, surface treatments, mulching, fertilising and the like as appropriate, using composite items to the fullest possible extent. Disregard slopes, but give details of unusual profiles.

SECTION: DRAINAGE

Subsection: Pipe Trenches

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
For pipes <=200 nominal diameter For pipes ... nominal diameter	<=2m deep [stating average depth to nearest 400mm] <=4m deep [stating average depth to nearest 400mm] <=6m deep [stating average depth to nearest 400mm]	m	Includes excavation, earthwork support, surface treatment, filling, beds, surrounds, coverings, and disposal of material [specify these]. Working space is at contractor's discretion. State pipe size if >200 nominal diameter. Continue depth classifications in 2m stages.
For pipes <=200 nominal diameter, in branches <= 3m long For pipes ... nominal diameter, in branches <=3m long		Nr	State if pipe run curved, disregarding radius. Nr of pipe bends in branches is at contractor's discretion.

Subsection: Miscellaneous Drainage Items

Extra; breaking up pavings Extra; breaking up pavings and reinstating Excavating alongside services Excavating across services Extra; excavation adjacent to roads, pavements or existing buildings		Bill in Drainage section, but measure according to Excavation Subsection. Applies to work associated with pipe trenches and work associated with manholes and inspection chambers.

Subsection: Pipework

Pipework not in trenches Vertical pipework not in trenches Pipework in trenches Vertical pipework not in trenches	... nominal diameter	m	Specify supports and fixings.
Extra; pipe fittings		Nr	Specify.
Pipework accessories		Nr	Specify Gullies, rodding eyes and the like are deemed to include additional excavation, surface treatments, concrete, filling, formwork, earthwork support, rest bends and the like ; the requirements for which must be specified.

Subsection: Manholes, Inspection Chambers and the Like

Manholes Inspection Chambers Soakaways Silt Boxes Cesspits Septic tanks Petrol Interceptors Grease Traps [etc.]	... x ... internal size x ... deep to invert level ... x ... diameter x ... deep to invert level	Nr	Round depths up to nearest 500mm. Includes excavation, surface treatments, blinding, base, brick or concrete walls, concrete rings, pointing, rendering, benching, cover slab, reinforcement, formwork, filling, step irons and the like. These must be specified. Use of standard details is recommended. If shafted, state height and internal dimensions of shaft and intermediate slab. Itemise covers and frames separately following the Pipework Accessories conventions.

Subsection: Pipe Entries

Main run Branch <=3m long	... diameter	Nr	Includes building in. Nr of branch bends is at contractor's discretion.

Annex 2:

Hypothetical Petrochemical Civil Engineering Measurement Model (Prior to Validation Stage 2)

SECTION: PRELIMINARIES

Subsection: Generally

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Safety, Health and Welfare		Item	
Temporary Accommodation			
Notices and Fees to Local authorities and Public Undertakings			
Telephones			
Power for the Works			
Water for the Works			
Temporary Roads and Hardstandings			
Insurances as defined			
staff			
Plant, Tools, Scaffolding and Hoists			
Maintenance of Private and Public Roads			

SECTION: EXCAVATION AND EARTHWORK

Subsection: Site Preparation

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Lifting turf and preserving		m^2	State distance to spoil heap.
Removing isolated trees	<=600 girth >600 girth	Nr	Specify ground treatment after removal.
Removing hedges		m	If >600 girth measure as trees.
Removing undergrowth		m^2	
Excavating topsoil and preserving; <=0.25m deep	... average depth	m^2	State how and where stored.
Excavating topsoil and preserving; >0.25m deep		m^3	

Subsection: Excavation

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Reduce level		m^3	No depth stages.
Basements Pits for foundations and bases Pile caps Ground beams Working space and backfill Foundation trenches <= 300wide Foundation trenches >300 wide	<=1m total depth <=2m total depth <=4m total depth <=6m total depth	m^3	Calculate total depth from reduced level. Continue depth classifications in 2m stages. Specify fill material. Allow 600 working space from face of any work needing formwork or operatives to work from outside. Disregard type of excavation to which working space relates.
Pits for foundations and bases, each <=1m^3	... Nr	m^3	
Breaking up pavings Breaking up pavings and reinstating	... thick average ... thick	m^2	Do not classify by type of excavation to which it applies. Specify type of paving. Specify exact reinstatement materials and dimensions.
Excavating alongside services	... deep	m	Do not classify by type of excavation to which it applies. State type of service and its average depth below starting level of excavation.
Excavating across services	... deep x ... long	Nr	Do not classify by type of excavation to which it applies. State type of service, its average depth below starting level of excavation and the length of excavation which crosses it.
Excavation next roads Excavation next buildings Supporting running sand or silt	<=1m total depth <=2m total depth <=4m total depth	m^2	Continue depth classifications in 2m stages. Disregard working space when calculating quantities.

Subsection: Disposal of Excavated Material

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Off site On Site To Employer's tip Multiple handling			Specify multiple handling. State disposal locations. Topsoil not required to be preserved is classified as ordinary excavated material.

Subsection: Filling

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
To excavations To make up levels >0.20m thick		m^3	Include sinkings in quantity. Filling to working space is measured according to the Excavation Subsection. Specify details of fill materials, layers and compaction.
To make up levels <=0.20m thick	... average thickness	m^2	

Subsection: Surface Treatments

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Surfaces of filling Surfaces of excavations Surfaces of excavations in hard materials		m^2	Where filling measured superficially, specify surface treatments with the filling items. Group horizontal and sloping work together, give unusual profiles separate item; state if vertical surfaces. Specify the surface treatments.
Landscaping		m^2	Specify soiling, seeding, surface treatments, mulching, fertilising and the like as appropriate, using composite items. Group horizontal and sloping work together, but give unusual profiles a separate items; state if vertical surfaces.

SECTION: UNDERPINNING

Subsection: Excavation

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Preliminary trenches Excavating below base of existing foundation	<=1m total depth <=2m total depth <=4m total depth <=6m total depth	m^3	Continue depth classifications in 2m stages. Includes water disposal. Preparing old work to receive new deemed to be included.
Extra; excavating next existing building		m^3	Single measurement from ground level to bottom of excavation below base of existing foundation. Replaces earthwork support.
Working space and filling		m^3	Specify fill material. Allow 2m working space from face of existing wall regardless of depth.

Subsection: Surface Treatments

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Surfaces of excavations Surfaces of filling		m^2	Group together regardless of slopes etc.. State nature of surface treatment and of surface being treated

Subsection: All other Work

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
			Measure according to other Sections elsewhere in this document.

SECTION: PILING

Subsection: Piling

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Preformed concrete piles, ... Nr Preformed prestressed concrete piles, ... Nr Preformed concrete sheet piles, ... Nr Timber piles, ... Nr Isolated steel piles, ... Nr	Total completed length <=5m Total completed length 5-10m Total completed length 10-15m	m	Continue length categories in 5m stages. State whether preliminary, test, contiguous or raking piles. State angle of rake in 15° increments. Group by cross-sectional area [nominal weight/m in case of steel piles].
Preformed concrete piles, ... Nr Preformed prestressed concrete piles, ... Nr Preformed concrete sheet piles, ... Nr Timber piles, ... Nr Isolated steel piles, ... Nr	Total driven length	m	State level at which driving commences; measure driving from there to bottom of toe or driven casing. Lengths measured for preformed concrete, timber and steel piles shall be those which the contractor is instructed to provide.
Bored cast-in-place concrete piles, ... Nr Driven cast-in-place concrete piles, ... Nr	Total bored or driven depth <=5m Total bored or driven depth 5-10m Total bored or driven depth 10-15m	m	Continue length categories in 5m stages. State whether preliminary, test, contiguous or raking piles. State angle of rake in 15° increments. Group by cross-sectional area [nominal weight/m in case of steel piles].
Bored cast-in-place concrete piles, ... Nr Driven cast-in-place concrete piles, ... Nr	Total completed length of piles	m	State level at which driving commences; measure driving from there to bottom of toe. Lengths measured shall be those which the contractor is instructed to provide.

Interlocking steel piles, ... total driven area	Total completed area of piles of length <=5m Total completed area of piles of length 5-10m Total completed area of piles of length 10-15m	m	Continue length categories in 5m stages. State whether preliminary, test, contiguous or raking piles. State angle of rake in 15° increments. Group by section modulus State level at which driving commences; measure driving from there to bottom of toe or driven casing. Lengths measured shall be those which the contractor is instructed to provide.

Subsection: Extras on Piling

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Extra; corner piles Extra; junction piles Extra; closure piles Extra; taper piles Extra; boring through rock Extra; permanent pile casings Extra; placing concrete by tremie pipe Expressly required pre-boring Backfilling empty bores Expressly required jetting Filling hollow piles with concrete Pile extensions; ... Nr Cutting tops off interlocking piles		m	State anticipated rock strata. Specify types of pile casings. Specify backfill material. Specify mix of concrete filling. tremie placing includes adjustment of mix proportions. Measure pile cutting horizontally.

Cutting tops off isolated piles Preparing concrete pile heads and reinforcement for capping Forming enlarged bases Heads Shoes Cutting interlocking piles to form holes		Nr	Continue length classifications in 5m stages. State size and type of piles.
Removing piles	Pile length <=5m Pile length 5-10m Pile length 10-15m	m^3	State type and size of piles.
Disposal of excavated material arising from piling operations			State how and where disposed. Calculate from bored length and nominal cross-section size. Deduct amounts backfilled. Do not measure in case of displacement piles.
Authorised standing time for pile rigs and associated labour Boring through artificial obstructions		Hr	Do not classify by type of obstruction.

Subsection: Pile Testing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Testing piles			Specify full particulars of tests.

SECTION: CONCRETE WORK

Subsection: Insitu Concrete

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Foundations in trenches		m^3	

Isolated foundation bases Casings to steel grillages Pile caps Isolated beams and beam casings Isolated columns Isolated column casings Machine bases Ground beams Casings to steel beams	...Nr	m^3	Column length: thickness ratio=<4:1. No size or thickness categories.
Beds or pavings Suspended floors or roofs Profiled soffit suspended floors or roofs Upstands or kerbs Walls Duct or channel walls Steps and staircases Tops and cheeks of dormers Fillling hollow walls Mass filling Blinding		m^3	Beds and pavings include thickenings. Floors, roofs and beds exclude kerbs and upstands. Floors and roofs include attached beams and beam casings and solid margins to profiled work. Walls include projections and kickers. Walls: thickness ratio=>4:1. Steps and staircases include strings and associated landings. No thickness or size categories.

Subsection: Joints in Concrete

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Designed joints	...wide	m	Includes ends, angles, intersections and the like. State if vertical. Group horizontal and sloping work together. Applies to plain joints with no dowels, sealant or the like.

Subsection: Sundries on Concrete

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Treating surfaces	Generally Margins	m^2	Covers trowelled additives, floating, screeding, grinding, blasting and the like. Do not differentiate between horizontal and sloping work. State if vertical. No narrow widths.
Holes, mortices, pockets and the like <=1m girth Holes, mortices, pockets and the like 1-2m girth Holes, mortices, pockets and the like 2-3m girth	<=75 deep 75-150 deep 150-225 deep 225-300 deep ...deep	Nr	If>300 deep, state depth. If >3m girth, classify in other categories elsewhere. State if sides not vertical. State if non-rectangular. State if cut, formed or drilled. Holes, mortices, pockets and the like associated with a component should be given with the item for that component. Give details of grouting and the like, failing which it (and the fixing of any component) is at the discretion of the contractor.
Channels, chases, grooves and the like	<=0.05m^2 sectional area 0.05-0.10m^2 sectional area 0.10-0.25m^2 sectional area ... x ...		If >0.25m^2, state size. State if sides not vertical, or if non-rectangular. State if cut or formed. Group horizontal or sloping work together. State if vertical. Channels, chases, grooves and the like associated with a component should be given with the item for that component. Includes grouting and the like, which,if not specified, is at the discretion of the contractor.

Anchor-bolts Fixing-devices	...diameter Serial Nr ...	Nr	Includes temporary boxings, mortices, grooves, pockets, grouting and the like. If not specified, is at contractor's discretion.
Grouting under bases, grillages and the like	<=25 thick 25-50 thick ...thick	Nr	If over 50 thick, state thickness.
Damp-proof membranes Fibre underlay and the like		m^2	Includes turn-ups, laps and the like, the requirements for which must be specified. Measure net.

Subsection: Reinforcement

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Bars Bars >12m long Fabric	[Classifications as for Insitu Concrete Subsection]	m^2 t	m^2 for fabric. t for bars. Classify as straight or bent, or as curved. Includes links and the like, raking and. curved cutting and bending. Group horizontal and sloping fabric together. State if vertical.

Subsection: Formwork

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Edges of beds, pile caps and foundations Edges of suspended floors or roofs, landings, risers and steps in floors or roofs Upper surfaces sloping >15° from horizontal Sloping upper surfaces of walls, beams, beam casings and the like	<=250 wide <=250 wide, tapering 250-500 wide 250-500 wide, tapering >500 wide >500 wide, tapering from ... to ...	m m m^2	Includes all cutting. No slope categories. Ignore Nr of surfaces. Where not plain and vertical, specify. If profile complex, specify. Ignore ends of steps abutting walls etc. For tapering sections give no dimension ranges except where >500 wide to beams and beam casings.

Soffits of suspended floors or roofs, stairs or landings	Horizontal or sloping <15° from horizontal Sloping >15° from horizontal	m²	Includes all cutting. Do not distinguish between flat and profiled work. Specify the profile.
Strings	<=300 wide 300-600 wide ... wide	m	Includes all cutting. State width if >600. If not plain and vertical, state. Specify if profile complex.
Attached beams and beam casings Kerbs and upstands Recesses Projecting eaves	Horizontal Sloping	m²	Includes all cutting. If profile complex, specify. Add adjacent slab edges [except recesses] to quantity. State set-back of recesses.
Walls	Vertical Sloping	m²	Includes all cutting and kickers [if not designed]. Ignore Nr of surfaces and interruptions by projections. Add attached piers, ends of walls and pilasters to quantity.
Wall projections, horizontal or sloping <=15° from horizontal Wall projections, sloping >15° from horizontal	... x ...	m	State cross-section and profile [if complex]. If vertical classify as walls.
Designed wall kickers Isolated columns and column casings Isolated beams and beam casings	...Nr	m m²	If not designed do not measure. If not rectangular, describe shape. No size categories.

Subsection: Precast Concrete

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Suspended floor or roof units Wall or partition units	Horizontal or sloping <=15° from horizontal Sloping .15° from horizontal Vertical	m²	Includes temporary support, joint treatments, reinforcement and surface finish, all of which must be specified. If profile unusual, specify.

Copings Kerbs Channels Lintels Beams Steps	Straight Curved, ... radius Curved, >4m radius	m	Includes reinforcement, surface finish, bedding and jointing, all of which must be specified. State radius if <=4m. Includes ends, angles, intersections and the like. Specify shape of units.
Duct covers Shelves	... x ... x ... Proprietary Reference Nr ...	Nr	
Staircases and associated landings	...size x ...rise x ... going Reference nr ... Drawing Nr ...	Nr	Includes reinforcement, surface finish, bedding and jointing, all of which must be specified. Specify shape of units.

SECTION: BRICKWORK AND BLOCKWORK

Subsection: Generally

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Projections of attached piers, plinths, bands, oversailing courses and the like Isolated columns, piers, casings and the like	... x ...	m	Projections of attached piers, plinths, bands, oversailing courses and the like are defined by length: thickness ratio <=4:1. All cutting, fair returns and and margins are deemed included. Specify materials and workmanship. No separate rules for brickwork, blockwork, facing brickwork and facing blockwork. State if built overhand.

Walls and partitions Filling existing openings Skins of hollow walls Dwarf support walls Projections of footings and chimney stacks Backing to masonry or the like Flue linings	straight curved, ... radius curved, >4m radius	m^2	Work assumed vertical. State whether battering [uniform thickness] or tapering [varying thickness, stating mean thickness or range]. Group together all work >4m radius. State radius if <=4m. For work bonded to dissimilar work specify how bonded. State if used as formwork; temporary strutting deemed included. State if work is in raising existing structures, staing starting level above ground level. State if work is in thickening existing work. All cutting, fair returns and and margins are deemed included. Specify materials and workmanship. No separate rules for brickwork, blockwork, facing brickwork and facing blockwork.

Subsection: Brickwork and Blockwork Features

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Plain or ornamental bands <= 300 wide	Horizontal Raking Vertical Curved	m	State whether flush, recessed, or projecting. State set-back or projection. Specify materials, bonding and workmanship if dissimilar to the surrounding general work. All ends, angles, fair returns, margins and cutting are deemed included. If >300 wide measure as general brickwork and blockwork.

Brick-on-edge bands brick-on-end bands Plinth cappings Moulded string courses Cornices		m	State width, and any set-back or projection. Specify materials, bonding and workmanship if dissimilar to the surrounding general work. All ends, angles, fair returns, margins and cutting are deemed included.
Extra; quoins, angles or the like	Flush Sunk Projecting	m	Measure according to this classification if bricks or blocks differ in size and/or specification to the surrounding general work.
Sills Thresholds Copings Steps	Horizontal Raking Vertical Curved	m	State size and shape. All ends, angles, fair returns, margins and cutting are deemed included.
Boiler seatings, plinths, pipe supports and the like		Nr	State size.

Subsection: Brickwork and Blockwork Sundries

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Forming cavities		m^2	State width. Specify ties and their spacing.
Closing cavities		m^2	Group work to heads, jambs, wall ends, sills and the like together. Specify materials and method. Give precise cavity closer dimensions where expressly required.
Raking out joints		m	If associated with some linear feature [e.g. skirtings, coverings or finishings] give with that feature.
Weather and angle fillets	... wide	m	Group together. Ends, angles and the like are deemed included.

Hacking or keying		m^2	Specify method.
Cut angles on brickwork or blockwork Cut chases, grooves, channels and the like on brickwork or blockwork	Horizontal Raking Vertical Curved	m	State shape and size [if expressly required] of angle. Ends, angles, intersections, mitres and the like deemed included. Chases, channels, grooves and the like associated with some component should be given with that component, failing which they are deemed to be at the contractor's discretion.
Damp-proof courses Cavity trays	Horizontal Stepped Vertical Horizontal, ... wide Stepped, ... wide Vertical, ... wide	m^2 m	m^2 if >225 wide. m if <=225 wide. State width if <=225 wide. Ends, angles, intersections, mitres, laps and the like deemed included. Specify laps.
Brick or block reinforcement		m	If associated with a linear feature of brickwork or blockwork give with that item. If a regularly occurring feature in a superficial item of brickwork or blockwork give with that item. If an isolated or irregularly occurring feature measure here. Specify laps, which are deemed included.
Wedging and pinning to underside of existing work where loads transferred to new work		m	State thickness. Specify materials.
Bedding plates, frames, sills, profiled sheets and the like	... wide	m	Group together. State if pointed on one or both sides.

Designed joints		m	State size. Specify materials. Ends, angles and the like are deemed included.
Building in ends of pipes, steel sections, bars, tubes, rails, lintels, brackets, steps and the like			Deemed included in rates for other items.
Holes for pipes, bars, tubes, cables, conduit and the like	<=110 nominal diameter >110 nominal diameter	Nr	Specify and include sleeves if expressly required, otherwise deemed to be at contractor's discretion. Do not discern between brickwork and blockwork.
Holes for gratings, ducting, trunking, trays and the like	<=0.15m² sectional area 0.15-0.30m² sectional area		Continue hole size classifications in 0.15m² stages. State depth or thickness.
Air bricks and the like		Nr	State size. Building in is deemed included. Specify and include lintels and the like if expressly required, otherwise deemed to be at contractor's discretion.

SECTION: **ROOFING**

Subsection: **Profiled Sheet Roofing**

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Coverings	Horizontal or sloping <=50° from horizontal Vertical or sloping >50° from horizontal	m²	Specify any underlinings. All square cutting deemed included.
Extra; cranks Extra; upstands		m	State girth.
Holes for pipes, standards and the like		Nr	Classify irrespective of size.

Raking cutting Curved cutting		m	Classify irrespective of radius. Do not classify separately by location.
Forming openings <=1m^2		Nr	State shape if non-rectangular. Associated cutting, filler pieces, flashings, framing and the like should be specified, failing which they are deemed to be at contractor's discretion. For openings >1m^2 associated components should be measured according to the conventions elsewhere in this and in other Subsections.
Filler pieces	Eaves Jambs Above or under roof glazing and the like Over lintels		Specify bedding and pointing, which are deemed to be included.
Cappings	Ridge Hip Vertical angle	m	All ends, angles and intersections are deemed included.
Vent units		Nr	Associated labour and materials should be specified, failing which they are deemed to be at contractor's discretion.
Extra; rooflights Extra; translucent or transparent sheets Extra; ventilator sheets Extra; louvre units Extra; sheets with soaker flanges Roof ventilators	size... Reference Nr ...	Nr	Specify glazing where appropriate [deemed included]. Associated labour and materials should be specified, failing which they are deemed to be at contractor's discretion.

Barge boards Corner pieces Flashings Expansion joints		m	Associated labour and materials should be specified, failing which they are deemed to be at contractor's discretion.

Subsection: Roof Decking

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Coverings	Horizontal or sloping <=50° from horizontal Vertical or sloping >50° from horizontal	m^2	Specify fixing blocks and the like, which are deemed included. All cutting deemed included.
Bearings Eaves Kerbs Flashings		m	State sizes and girths, where applicable.
Holes for pipes, standards and the like		Nr	Classify irrespective of size.

Subsection: Felt Roofing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Coverings	Horizontal or sloping <=50° from horizontal Vertical or sloping >50° from horizontal	m^2	Specify laps, which are deemed included. All cutting, notching, bending, turning into grooves, wedging, angles, ends and the like are deemed included.
Skirtings and kerb coverings	Total length ....m	m^2	State total length for each different specification. State if stepped or raking [group together]. All raking out joints, cutting, fair edges, dressing over fillets, notching, bending, turning into grooves, wedging, angles, ends, intersections, laps and the like are deemed included.

Linings	Gutter Valley Channels Extra; working coverings into channels	m	State girth. All raking out joints, cutting, fair edges, dressing over fillets, notching, bending, turning into grooves, wedging, angles, ends, intersections, laps and the like are deemed included.
	To cesspools, sumps and the like	Nr	State size. State outlets if applicable.
Collars to pipes, standards and the like		Nr	State size.

Subsection: Sheet Metal Roofing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Coverings	Horizontal or sloping <=50° from horizontal Vertical or sloping >50° from horizontal	m^2	Add small areas to general quantity. Specify method of fixing. Specify laps, which are deemed included. Cutting , notching, bending, dressing over drips and rolls and dressing into outlets and gullies are deemed included.
Welted edges Beaded edges Wedging into grooves Burned or brazed angles Welted seams Burned or brazed seams		m	Give raking out grooves etc. with specification; otherwise they are deemed to be at contractor's discretion. Extra material and workmanship for drips, seams, welts, rolls, upstands and laps are deemed included with the respective items.
Dressing over profiled roofing Dressing over glazing bars		m	State type of units over which dressed, stating relative direction of such units or bars. Dressing over drips and rolls deemed included.
Nailing			Deemed included with the respective items.

Underlay			Follow the conventions in Slate and Tile Roofing Subsection.
Dressing into hollows Dressing into condensation channels Dresing over mouldings Dressing over rolls		m	All ends, angles and intersections are deemed included. Extra material and labour are deemed included.
Collars to pipes, standards and the like		Nr	Group together. Specify types of joints. Extra labour and material deemed included. State sizes.
Linings to cesspools, sumps and the like		Nr	Group together. State sizes, outlets and type of angles.

Subsection: Slate and Tile Roofing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Coverings		m^2	State pitch. State if vertical. Specify battens, which are deemed indcluded. All cutting and 1.1/2 width units are deemed included.
Extra; forming eaves Extra; forming verges Extra; forming ridges Extra; forming hips Extra; forming valleys Extra; forming ertical angles	Straight Curved Raking	m	Give all labour, materials, cutting, special units and components, undercloaks, bedding and pointing as a composite item; these are all deemed included in the rates.

Ventilating units Finials Purpose-made units			Give all labour, materials, cutting and components as a composite item; these are all deemed included in the rates. Any such feature not specified is deemed to be at the contractor's discretion.
Tile slips and the like		m	Bedding and pointing deemed included.
Hip-irons		Nr	
Fix only; components supplied by other trades	Slates Saddles Soakers	Nr	Specify. Do not differentiate by size.
Extra; transparent or translucent components	Slates Tiles	Nr	Specify and state how fixed.
Counter-battens		m^2	State general spacing and how fixed.
Underlay		m^2	State laps, which are deemed included. All cutting is deemed included. State how fixed. Do not deduct openings <=1m^2.

Subsection: Flashings and Gutters

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Flashings Stepped flashings Aprons Cornice-weatherings Hip-cappings Ridge-cappings Kerb-cappings		m	State girth, profile, and how fixed and jointed. Specify shaped edges, wedging into grooves, dressing into or over fillets, hollows, channels , mouldings, glazing bars and profiled roofing units [stating general direction], which are all deemed included in the rates. Ends, angles, intersections, hollows, condensation channels and mouldings are deemed included.

Parapet and flat gutter linings Sloping gutter linings	... girth, profile ...	m	State girth and profile. Specify dressing over fillets, wedging into grooves etc, which are deemed included. Dressing into outlets, rainwater hheads and the like are deemed included.
Preformed flashings	... girth, profile ... Reference Nr ...	m	State girth and profile, or give proprietary reference Nr if appropriate.
Supplying soakers Supplying metal slates Saddles		Nr	State size and shape. State how saddles are dressed and fixed.

SECTION: METALWORK

Subsection: Composite Items

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Roller shutters	... x ... Reference Nr ...	Nr	State size and proprietary reference Nr if appropriate. Specify associated fittings, frames, guides, tracks and fastenings. The use of standard drawings and specifications is recommended. Sundry packing pieces, holes, mortices, pockets and the like should be specified, failing which they are at the contractor's discretion.
Duct covers and frames	... x ... x ... Reference Nr ...	m	State size, thickness and proprietary reference Nr if appropriate. Ends, angles, intersections and the like are deemed included, but should be specified if formed from special units

Windows Doors Opening gear Window assemblies Door frames not integral with door Rooflights Staircases and associated landings Isolated balustrades and newels Cloakroom fittings Cycle racks Storage racks Grilles Matwells Ladders Tanks	Size ... Reference Nr ... Drawing Nr ...	Nr	State size. State reference Nr if appropriate. The use of standard drawn details is recommended; in which case give drawing Nr. All associated brackets, fixing devices, labours, holes, fastenings, mortices, pockets and the like shall be specified and are deemed included; failing which they are at the contractor's deiscretion. Specify frames, sub-sills, sills, window boards, window surrounds and the like with the appropriate measured items. Ends, bends, wreaths, intersections, angles and the like on handrails and balustrades are deemed included.
Extra; opening portions on balustrades	... x ...	Nr	State size and associated ironmongery.

Subsection: Plates, Bars, Sections and the Like

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Frames Arch-bars Bearers Stays Toe boards Skirtings and the like	... x ... Reference Nr	m	Stae sizes and reference Nrs as appropriate. Ends, angles, intersections and the like are deemed included. Specify associated lugs, tangs, fixing devices and the like, which are deemed included.

Straps Collars Hangers Brackets Corbels	... x ... x ... Reference Nr	Nr	State sizes and reference Nrs as appropriate. —

Subsection: Sheet Metal, Mesh and Expanded Metal

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Coverings	Walls and partitions Floors	m^2	State gauge and/or reference Nr as appropriate. No separate category for narrow widths. Do not deduct voids <=m^2. All cutting, screwing and nailing deemed included.
Welted edges Beaded edges Welted seams		m	
Angles	Burned Brazed Welded	m	Angles, intersections and the like on these features are deemed included.
Dressing into hollows or over kerbs	... girth	m	
Holes, bolts and rivets		[Nr] [m]	Where possible give holes with their associated components and bolts, rivets and the like with associated measured items. Otherwise enumerate or give in m stating spacing. Where shown on a drawing or specification to which an item measured elsewhere in this document refers, they shall be deemed included with that item.

SECTION: GLAZING

Subsection: Glass in Openings

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Glazing associated with doors, doorsets, casements, windows, screens and the like			Specify with those items; do not measure here. Specify bedding; otherwise at contractor's discretion. All cutting and bending of materials deemed included.
Items involving specialist work	Grinding Sandblasting Embossing Acid etching	PC Sum	Issue drawings and specifications.
Hacking out glass and preparing to receive new work		m	State extent to which beads and the like are to be reused, e.g. by %.

Subsection: Glass in Mirrors

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Mirrors	... x ... x .... thick	Nr	Specify materials and components.

Subsection: Patent Glazing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Roofs Skylights Lantern lights Vertical surfaces		m^2	State length of and spacing of glazing bars, nature of bearing and span between bearings. Do not state Nr of separate surfaces. Square and raking cutting deemed included.
Curved cutting		m	
Extra; opening portions		Nr	State size. Specify opening gear.

Subsection: Domelights

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Domelights	Size ...	Nr	Specify type, size, method of fixing [including fixing components] and shape. The use of standard drawings and specifications is recommended.

SECTION: PAINTING AND DECORATING

Subsection: Painting and Polishing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Walls and associated projections Ceilings and attached beams, cornices and mouldings Floors Doors Windows, casements and the like Radiators Structural steelwork or metalwork Open-type fencing and gates Close-type fencing and gates Structural steelwork or structural metalwork members in roofs	Generally Corrugated Fluted Carved Profiled	m^2	Add narrow widths and small areas to general quantities. Measure all work flat, but state if profiled, corrugated and the like. Windows and casements are deemed to include work to opening edges. Keep steelwork and metalwork roof members separate. Measure work to fencing from finished ground level. Fencing includes balustrading.
Glazed doors	Average pane size <=0.50m^2 Average pane size 0.50-1.00m^2 Average pane size >1m^2	m^2	

Gratings Rainwater heads Flushing-cisterns		Nr	Classify irrespective of size.
Valley- or parapet-gutters Eaves-gutters Pipes, lagged pipes, cables, ducting, trunking, standards, bars, handrails and the like Frames, linings and associated mouldings Skirtings, rails and the like Mouldings or bands picked out in different colours from surrounding work	<= 150 girth 150-300 girth >300 girth	m m m^2	Work to brackets, clips, baseplates, fittings and the like are deemed included.
Colour coded bands on service pipes	For pipes <=200 nominal diameter For pipes ... nominal diameter	Nr	State Nr of coded colours. State nominal pipe diameter if >200.
Individual cartoons or motifs		Nr	Provide drawing or catalogue reference.

Subsection: Signwriting

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Signwriting		[Prov or PC Sum]	Provide drawings and specifications.

Subsection: Paperhanging, Sheet Plastic and the Like

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Walls and associated projections Ceilings and beams Columns		m^2	Specify materials and workmanship; give PC Sum for supply if desired, but clearly state type of materials. Add small areas and narrow widths to general quantity. Do not state Nr of pieces. All cutting deemed included.

Motifs		Nr	Specify materials and workmanship; or give PC Sum for supply.
Border strips		m	Specify materials and workmanship; or give PC Sum for supply. Add small areas and narrow widths to general quantity. Do not state Nr of pieces. All cuttting, ends, angle and intersections deemed included.

SECTION: FENCING AND GATES

Subsection: Fencing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Post and wire Post and rail Chain link Wire mesh Cleft pale Pallisade Metal bar Close boarded Open boarded ...	Straight Curved, ... radius Straight, designed for sloping ground Curved, ... radius, designed for sloping ground	m	State height [measure from finished ground level to top of filling, top rail, top wire or top bar]. State if designed for sloping ground. State radius if curved. State making and filling of post holes in specification. Specify method of fixing filling, rails, wires, straining wires or bars to posts. State spacing of posts, filling members, rails, wires, straining wires or bars.
Extra; filling post holes with material other than in general specification Extra; end posts Extra; angle posts Extra; straining posts Extra; posts differing from general specification		Nr	Specify construction, materials and workmanship

Subsection: Gates

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Gates	... x ...	Nr	State size and specify materials and workmanship including hinges, locks, fastenings, gate posts, post holes and filling, gate stops, gate catches, gate stays and the like, all of which are deemed included.

Subsection: Sundries

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Concrete spurs for timber posts	size ... x ... x ...	Nr	State size and how fixed. Specify bolts and holes, which are deemed included.

SECTION: BUILDER'S WORK IN CONNECTION WITH SERVICES

Subsection: Service Trenches

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
For drain pipes <=200 nominal diameter	Average 500 deep	m	Includes excavation, earthwork support, surface treatment, filling, beds, surrounds, coverings, and disposal of material [specify these].
For drain pipes ... nominal diameter	Average 1000 deep		
For groups of drain pipes	Average 1500 deep		
For pipes or cable ducts <=55 nominal size	Average 2000 deep		Excavation, surface treatments, earthwork support and all necessary formwork are all deemed included.
For pipes or cable ducts ... nominal size			Working space is at contractor's discretion.
For groups of pipes or cable ducts			State drain pipe size if >200 nominal diameter.
			State pipe or cable duct size if >55 nominal diameter
			Continue depth classifications in 500 stages.

Subsection: Pipework

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Pipework not in trenches Vertical pipework not in trenches Pipework in trenches Vertical pipework not in trenches	... nominal diameter	m	Specify supports and fixings. Applies to all types of pipework.
Extra; pipe fittings	... nominal diameter ... x .... x ... x ... ... · ... , reducing	Nr	Specify. Use reference Nrs if appropriate.
Pipes in trenches; in branches <= 3m long	nominal diameter <= 200 .. nominal diameter	m	State nominal diameter if >200. Do not separate vertical pipework in branches. Coonections to gullies and the like, and the contractor's assessment of pipe bends and fittings are deemed included.

Subsection: Pipework Accessories

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Gullies Shoes Outlets Flaps Traps --	... nominal diameter.	Nr	Specify. State nominal diameter. Gullies, rodding eyes and the like are deemed to include additional excavation, surface treatments, concrete, filling, formwork, earthwork support, rest bends and the like ; the requirements for which must be specified. Give gratings, raising pieces and the like with the appropriate accessory.

Subsection: Appliances

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Sinks Baths WC Suites Water heaters Cookers Taps Shower trays ...	Size ... Reference Nr ...	Nr	Specify. State sizes. Give reference Nrs if appropriate. Specify all accessories, fixing devices and the like, which are deemed included. All connections to pipe work are deemed included.

Subsection: Gutters, Channels and the Like

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Rainwater gutters Proprietary drainage channels	... nominal size Reference Nr ...	m	Specify. State size. State reference Nr if appropriate. Where excavation and the like for channels is required specify filling, beds, surrounds, haunching and spoil disposal, which are deemed included. Where excavation and the like for channels is required excavation, earthwork support, surface treatments and any necessary formwork are deemed included. Ends, angles, intersections and the like are deemed included.
Fittings Silt boxes Rainwater heads ...	... nominal size ... x ... x ... deep to invert Reference Nr ...	Nr	Specify. State sizes. State reference Nr if appropriate.

Subsection: Miscellaneous Drainage Items

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Extra; breaking up pavings Extra; breaking up pavings and reinstating Excavating alongside services Excavating across services Extra; excavation adjacent to roads, pavements or existing buildings		m^2	Bill in BWIC Services Section, but measure according to Excavation Subsection. Applies to work associated with pipe trenches and work associated with manholes and inspection chambers.
Building in pipe ends to chambers and the like	... nominal size	Nr	State nominal size.

Subsection: Manholes, Inspection Chambers and the Like

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Manholes Inspection Chambers Silt Boxes Petrol Interceptors Telecom joint boxes Stop cock pits --	500 deep maximum 1000 deep maximum 1500 deep maximum 2000 deep maximum	Nr	Round depths up to nearest 500mm. Continue depth classifications in 500 stages. Depths are to invert. State excavation depth if partially in fill. If wholly in fill area, so state. Includes disposal of excavated material, blinding, base, brick or concrete walls, concrete rings, pointing, rendering, benching, cover slab, reinforcement, formwork, filling, step irons and the like. These must be specified. Use of standard details is recommended. Excavation and earthwork support are deemed included. If shafted, state height and internal dimensions of shaft and intermediate slab. Itemise covers and frames separately following the Pipework Accessories conventions.

SECTION: FINISHINGS

Subsection: Generally

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
To or forming	Walls or partitions and associated projections Isolated columns and the like Ceilings and attached beams Ceilings and attached beams, sloping >15° from horizontal Floors or pavings Treads, total length ... Risers, total length ... Strings Aprons Treads and risers on carpet work Skirtings, total length ... Kerbs, total length ... Isolated beams and the like Isolated beams and the like, sloping >15° from horizontal Sides of openings	m^2	Do not separately classify Insitu Finishings, Beds and Backings, Tile, Slab and Block Finishings, Dry Linings, Partition Systems, Suspended Ceiling Systems, Fibrous Plaster and Fitted Carpets. Specify the Finishings system: materials, workmanship, Nr of coats of insitu work, method of fixing or application, associated components and fixing devices and their spacings, associtied filling and insulation mateials and preparation work to surfaces to which fixed or applied. These are all deemed included. Do not deduct voids <= $1m^2$. The following are deemed included: cutting, fair edges, abutments to other finishings, working or cutting around pipes, bars, ducting, trunking, cables, steel sections, brackets, sanitary *appliances and the like*, notching, and cutting and fitting into recessed covers and the like. Add small areas and narrow widths into the general quantities. State thickness [and the thicknesses of the various coats, layers and units].
	Architraves, profile ... Mouldings, profile ... Ceiling ribs, profile ... Cornices, profile ...	m	State background to which applied or fixed.

Subsection: Sundries on Insitu Work

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Working into shallow channels	...x...x...	Nr	State girth or profile. Plain rectangular angles are not measurable.
	... girth	m	
Worked or formed internal angles Worked or formed external angles	Walls or columns Ceilings, beams or beam casings Floors, pavings, stairs, strings and the like	m	The use of standard drawings and specifications is recommended. Nosings, and angles associated with channels, areclassified here.

Subsection: Sundries on Tile, Slab or Block Work

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Extra; special units Extra; angle units Extra; corner piece units Extra; access units		Nr	Specify. State size and thickness of units. Where units conform to a regular or fixed pattern, specify pattern. Do not measure separate items.

Subsection: Sundries on Fitted Carpet Work

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Forming openings <=1m^2 each		Nr	State shape if non-rectangular.
Fair sewn heading joints in openings or doorways Perimeter fixing		m	State method of perimeter fixing.

Subsection: Sundries on Dry Lining or Partition Work

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Intersections Angles Internal angles External angles		m	Angles are deemed 90° and intersections 3-way unless otherwise stated. Specify materials and workmanship, which are deemed included; otherwise deemed to be at contractor's discretion.

Cutting to profile of openings	<=1m girth 1-2m girth 2-3m girth 3-4m girth 4-5m girth	Nr	Not classified as openings if >6m girth. Materials and workmanship are deemed included and should be specified; otherwise deemed to be at contractor's discretion. State shape if openings non-rectangular.
Extra; access panels	.. x ..		State size of access panels.

Subsection: Sundries on Suspended Ceiling and Lining Work

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Forming openings Forming openings Forming openings	<=1m girth 1-2m girth 2-3m girth	Nr	Not classified as openings if >3m girth; incorporate in general quantities. State shape if openings non-rectangular. Materials and workmanship are deemed included and should be specified; otherwise deemed to be at contractor's discretion.
Forming access panels	.. x ..		State size.

SECTION: WOODWORK

Subsection: Carcassing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Members in floors Members in partitions Members in flat roofs Members in pitched roofs	.. x ..	m	Specify materials and workmanship. State if members wrought, regularised or sawn. State sizes of members.
Strutting and bridging Kerbs, bearers and the like		m	Add trimming around openings to general quantities. Measure strutting flat over joists.
Cleats, sprockets and the like Ornamental ends		Nr	State shape of ornamental ends.

Subsection: First Fixing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Boarding	Floors Roofs, flat or sloping <= 15° from horizontal Roofs, sloping >15° from horizontal or vertical Walls, vertical Walls, sloping Ceilings and beams, flat or sloping <= 15° from horizontal Ceilings and beams, sloping >15° from horizontal or vertical Tops and cheeks of dormers Gutters and sides Eaves, verges, fascias, barge-boarding and the like	m^2	Specify materials and workmanship, otherwise deemed to be at contractor's discretion. Do not deduct for voids <= $1m^2$. Add small areas and narrow widths to general quantities. No separate items for short lengths. All notches, rounded corners, cutting, scribing and stops on labours are deemed included. State laps, which are deemed included.
Sinkings	... x ... x ...	Nr	State size.
Tongued edges		m	Measure here only if tonguing is not the general jointing method.
Firrings Drips and nosings Margins and the like Angle- or tilting-fillets Rolls Grounds Battens and bearers	... x ... ... x ... (average)	m	State size or average size. No separate items for short lengths.

Subsection: Second Fixing

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Skirtings, rails and the like Architraves, cover fillets, stops, glazing beads and the like Shelves, worktops, seats and the like Window boards, nosings, bed moulds and the like Handrails	... x ... ... x ... (average)	m	State continuous labours, which are deemed included. For built-up members, state sizes of,and labours on, each component. State if components are tongued or otherwise jointed. Specify applied coverings, which are deemed included.
Backboards, plinth blocks and the like	... x ... x ...	Nr	
Sinkings on second fix items		Nr	State size and to which item.
Sheet linings and casings	Walls and attached projections Ceilings and attached beams Isolated columns, sides of openings, pipe casings and the like	Nr	Specify materials and workmanship. State thickness and how jointed and fixed. Include framing in specification. Add narrow widths and small areas to general quantities. All cutting, labours, stops on labours, notches and rounded corners are deemed included. Do not deduct for voids <=1m^2.
Rounded angles on sheet linings or casings Coved angles on sheet linings or casings	... x ... ... girth	m	
Forming openings in sheet linings or casings <=1m^2.		Nr	Specify materials and workmanship, which are deemed included
Forming access panels in sheet linings or casings	... x ...	Nr	Specify materials and workmanship, which are deemed included. State size, dimensions.

Subsection: Composite Items

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Trussed rafters Roof trusses Doors Door, frame and lining sets Casements and frames Windows and surrounds Lantern lights Skylights Screens Borrowed lights Staircases and the like Balustrades Fittings	... x ... x ... Size ... ... wide x ... rise x ... going	Nr	State dimensions, sizes and / or reference Nrs as appropriate. Specify materials and workmanship, which are deemed included. Specify associated packing pieces, fixing devices and the like, which are deemed included; otherwise they are deemed to be at the contractor's discretion. Give associated labours, lippings and the like with doors and doorsets. Where doors not in sets, measure each leaf as a door. Do not measure frames and linings to doorsets as separate items. Doors integral with screens and the like should be specified with screens. Balustrades integral with staircases and the like should be specified with staircases. Identify types of fittings as separate items. No separate items for supply and fix. Cutting and fitting around obstructions, notching and the like are deemed included. Specify associated glazing with the composite items measured.

Subsection: Sundries

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	COVERAGE
Plugging		[m] [m²]	May be specified with the components to which they relate.

Holes for bolts and the like			Specify with associated component; they are deemed included therewith.
Holes for pipes, bars, cables and the like	<= 110 diameter > 110 diameter	Nr	State depth. State shape if sides not vertical. Where a drawing or specification relating to an item measured elsewhere in this document indicates such a hole, it is deemed included with that item.
Holes for ducting, trunking and the like	<= 0.15m^2 0.15-0.30m^2 0.30-0.45m^2		Continue classifications for ducting, trunking and the like in stages of 0.15m^2.
Insulation	... thick	m^2	State thickness and whether across or between members. State laps, which are deemed included. Stae how and to what fixed. All cutting deemed included.

Subsection: Metalwork

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Bolts Joist hangers	... diameter x ... long Reference Nr x ... long Size .... x .... To suit ... x ... timber	Nr	State sizes and/or reference Nrs, where appropriate. Where a drawing or specification relating to an item measured elsewhere in this document indicates such a bolt, it is deemed included with that item. State background to which joist hangers fixed, and how fixed. Building in is deemed included.

Subsection: Ironmongery

ITEM FAMILY	MEASUREMENT CATEGORY	UNIT	
Ironmongery scheduled in combinations or sets		Nr	Issue such schedules. Reference and enumerate these sets according to the schedule. State background to which fixed, and how fixed. All mortices, labours, sinkings in structure or finishes, making good and the like are deemed included.
Individual ironmongery items			Enumerate individually. State background to which fixed, and how fixed. All mortices, labours, sinkings in structure or finishes, making good and the like are deemed included.

Thesis Font Specifications:
Font: Clarendon Light DTC
General Font Size: 11
Table Font Size: 9
Character Compression: 0.5