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The Causes and Effects of Design Changes

Causes et effets des modifications du projet

Gründe und Auswirkungen von Entwurfsänderungen

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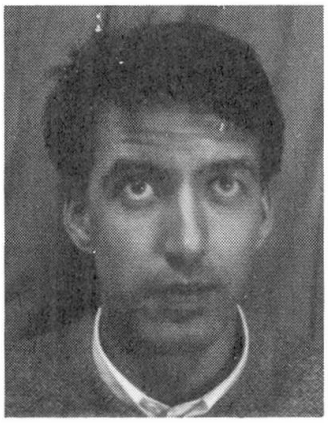

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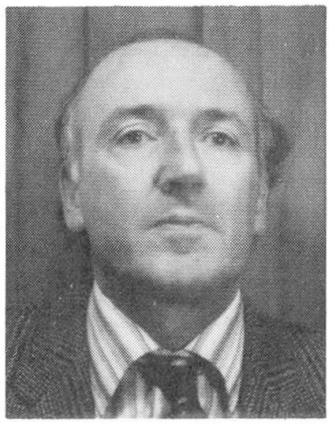

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SUMMARY

The U.K. building Industry has long expressed concern over, not only the cost and time effects of design changes during the construction stage of projects, but also the effects on the interpersonal relationships of the design team. Past research has examined such factors as the client type, the building type, the building complexity, the project team organisation, the method of contractor appointment, and the type and form of contract, in the search for the causes of these problems. This paper suggests that a more fundamental study of the communications process is more likely to lead to improved performance.

RÉSUMÉ

L'industrie du bâtiment au Royaume-Uni se préoccupe depuis longtemps non seulement des effets de coût et de durée entraînés par les modifications du projet pendant sa construction, mais aussi des effets sur les relations personnelles de l'équipe de projet. Des travaux antérieurs ont traité de facteurs tels que le type de client, le type de bâtiment, la complexité du bâtiment, l'organisation de l'équipe du projet, le choix des entrepreneurs, et le type et la forme du contrat, tout en recherchant les causes de ces problèmes. Une étude plus approfondie du processus de communication en cours de projet ménera probablement à une amélioration de la performance.

ZUSAMMENFASSUNG

Die Bauindustrie Grossbritanniens hat seit langem die Besorgnis zum Ausdruck gebracht über die Auswirkungen von Entwurfsänderungen während der Konstruktionsphase von Projekten nicht nur auf die Kosten und die zeitliche Abwicklung sondern auch auf die gegenseitigen Beziehungen im Konstruktionsteam. Die Forschung hat in der Vergangenheit auf der Suche nach den Ursachen dieser Probleme verschiedene Einflussfaktoren untersucht wie z.B. Typ des Kunden, Art des Bauwerkes, Schwierigkeitsgrad des Bauwerkes, Organisation des Projektteams, Methode der Auswahl eines Bauunternehmens und Art und Form des Vertrages. Grundlegendere Untersuchungen der Kommunikationsprozesse dürften zu verbesserten Leistungen führen.

1. INTRODUCTION

1.1 Background to the Project

For many years the U.K. building industry has been aware that post-contract design changes (i.e. variations) affect both the cost and time-performance of building projects. In 1975, the Wood Report [1] stated that '..(variations) are perhaps the most vexatious area of contractual relationships in the construction industry today, ...building projects let ostensibly on a fully planned basis... are subject to a considerable number of variations... the ease with which variations can be introduced leads to abuse... variations are too many and, it is claimed, too cheap'. Despite these findings, and the previous work of Bromilow, considered below, there has been surprisingly little study of the problem.

The incidence of both high rates of inflation and a prolonged recession in recent years has focused the attention of the building industry and its clients upon attempts to optimise value for money in building projects. Such attention has promoted investigation of building costs and time-performance but, to date, none of the studies has examined the effects of Variations in depth. A project entitled 'The Sources, Causes and Effects of Variations in Building Contracts' is currently being sponsored by the Science and Engineering Council in the U.K.

The impetus for this study emanated from the pioneering work of Bromilow [2]. He focused on the extent of variations on a sample of 248 building projects with a more detailed analysis of the sources and nature of variations on 25 of the projects. He concluded that variations are inevitable, and that the extent of variations correlates strongly with the final project cost and the incidence of variations is therefore predictable. The principal sources of the more significant variations were identified as the client, closely followed by the designers. The relationship between extensive variations and poor time performance was also established. Other research in this area has concentrated upon the effect of project factors, such as client type, building size and complexity, the project team organisation, the method of contractor appointment, and the type and form of contract, on the incidence and extent of variations.

Whilst recognising the merit of this approach, the current project has, in an attempt to focus more directly upon the origins of the variations, directed its efforts towards an examination of the communications process on projects. Thus, the twenty projects currently being studied have been selected on the basis of holding as many of the above factors constant as is feasible. The projects mainly involve public authority client projects in the value range of £0.5 - 1.5M with the traditional U.K. contractual approach of a lump-sum contract (bills of quantities based) and separate design and construction firms.

In conjunction with this analysis of the technical sources, causes and effects of variations, a social study involving the part-time participation of a psychologist is also being carried out. This recognises that the concern of the industry is not confined to the direct cost and time effects of variations, but also to the indirect effects upon the working efficiency of the project team.

1.2 Variations: In definition

As various contractual systems impose a range of duties upon the contractor and his sub-contractors the definition of varied work is necessarily different. The closer the client design team attempt to define the works, the greater the potential there is for change to the design and, therefore, to the

contractor's duties. Thus it might be expected that the use of bills of quantities (which "shall fully describe and accurately represent the quantity and quality of the works to be carried out")[3] where the design is purportedly complete at tender stage, would result in a greater number of variations. It is, therefore, difficult to compare different contractual systems, quantitatively, particularly across international boundaries. However, if similar methodologies are adopted it should prove possible to compare projects through the source, cause and effects of the varied work. Whatever definition of varied work is used the essential feature is, "what gets built is not what the contractor originally planned to build"[4].

Varying work means changing what the contractor has agreed to do. It is rare for built work to be varied by demolition and reconstruction; the predominant feature of variations is, therefore, that they involve changes to decisions. An examination of the factors which contributed to the original decisions should lead to the cause of the variation itself. It was this conclusion which formed the basis of the approach to the research; if the original design decisions could be traced, the causes of any changes thereto would become clear. However, first it was necessary to consider the theoretical background to the problem (i.e. the communication system) and to attempt a means of cause classification.

2. COMMUNICATIONS AND THE DESIGN PROCESS

2.1 The organisation of the construction process

Within the industry, separate firms are traditionally responsible for design, cost advice, the manufacture and supply of building components and the ultimate construction of the project. The process is further complicated by the influence of statutory authorities, and the overlap of design responsibilities with sub-contractors, contractors and suppliers.

It has been suggested that this dichotomy in design and construction may be the cause of the disparity between the rapid rate of progress in science and technology and the slow pace with which advances are applied in the building process. Further, the proliferation of roles in the industry results in a potentially confusing decision making framework, within which the sources of those decisions are hard to identify. The number of communicators involved increases the potential for error or misinterpretation of information.

2.2 The Client/Project Team Organisation

A pilot study of the role of the building client [5] found that the client system is much more complex organisationally than has been considered in the past. It was concluded that architects and other advisers were impatient of this complexity, insisting too early on dealing with a single client representative, and thereby, creating conflicts which may later prove to be the origin of variations or delays.

The report suggests that there is a growing tendency towards the re-integration of the design/construct team, and a possible simplification of the dividing lines of responsibility. However, the traditional roles are kept and the stereotyped images prevail as a bulwark against too rapid rates of change and levels of uncertainty. These images illustrated below hinder rather than help effective teamwork.

Architects are seen as "creative designers, wilful, arrogant but possibly feckless when the spending of other people's money interferes with the vision he wants to build" [6]. On the other hand, the surveyor is seen as a "sober citizen, honest, reliable, upright and trustworthy, who injects reality and economics to curb the architect's wilder flights of fancy". Contractors in

their turn have an image of hardnosed, hardfaced practicality, machismo and of being obsessed with time and money.

Such viewpoints can lead to misunderstandings and devaluations of the other's contributions to the building process and the instability leads to anxiety and strains relationships. If these tensions increase there is either considerable defensiveness or a "formal amiability which denies the underlying tensions" [7]. This report concluded by highlighting the key problem as being one of conflict between a chain of technically interdependent operations and resources and organisationally independent people or resource controllers. Cherns [5] went on to describe the project team in terms of a "temporary multi-organisation" or TMO, i.e. a team whose members are drawn from representatives of many different organisations for a short-term, for the purpose of one project. These team members are differentiated by their specialist skills and their allegiances, whether to profession or firm. Thus, we have a picture of a complex system of relationships between organisations (inter-corporate aspects) and within orgnisations (intra-corporate aspects. It is not surprising, therefore, for such a system to often subject to communication problems.

2.3 Variations: A Means of Communication

The communications problem has been succinctly set in terms of "How simply and completely can the needs of the building authority be identified, interpreted, notified and transmitted to those who have to submit offers and in due course execute building work"?[8].

This necessarily involves technical considerations of how best to structure and co-ordinate the documentation which has traditionally been used for this purpose. Thus, the Co-ordinating Committee for Project Information (CCPI) was established by its constituent bodies (the RIBA, RICS, NFBTE, and ACE) in 1981 with the objective of improving the quality and collective usefulness of the means of communication, i.e. the drawings, specifications and bills of quantities.

These existing models of the design process, whereby the decisions made by the design team are to be transferred to the construction team, are inefficient due to their static nature. Design, and indeed construction, are iterative processes involving feedback between the research identified phases of analysis-synthesis-evaluation.

In terms of design -

a) analysis is the phase in which all the design requirements are listed and reduced to a set of logically related performance specifications,

b) synthesis is the phase in which solutions are found for individual performance specifications and then built up to form complete designs,

c) evaluation is the phase in which alternative designs are tested against performance specifications.

It is suggested that there will always be conflict between the creative process outlined, and the practical requirements of project progress. Therefore any model or plan should be capable, if its objective of defining the reality is to be achieved, of facilitating change; any that do not, are limited in their use, and are unrealistic. Crichton [9] stated the case as follows; "each time a design decision was taken it set in train a chain of consequences which could and did cause the initial decision to be changed.... Since the full implications of any decision or action can seldom if ever be forecast with absolute accuracy, a communications system which assumes that they can will simply not work".

Although the requirements of the documentation system are strict it has long been recognised that the construction project organisations, like most other organisations, have some form of underlying control mechanism. The distinction between these formal and informal systems is most apparent, according to Higgin [7], in the pretence surrounding the completeness of design at contract stage. The report suggests that the design team, aware of the realities of uncertainty on which they have based their decisions, proceed to contract on behalf of their client, behaving as if the requirements of the formal system have been met. "They, and the builder in collusion with them, will agree a bargain as if the priced bills, drawings and other contract documents contained full and feasible information...."

Variations, in this context, can be seen to be the means whereby the formal system recognises that changes to the contracted model are inevitable.

2.4 Research method - The Classification of the Sources and Causes of Variations

The complexity, in organisation, of the construction process extends the potential source (that is, the person or body responsible for originating a variation) of a variation to any party who has influenced the original design decisions, or, who has contributed to the production of the project documentation. Thus, not only the clients' project team of designers, surveyors and contractors (i.e. those internal to the project organisation), but also, those external authorities such as fire and building control, etc. (see Figure 1.1), whose decisions and information are relied upon, need to be considered. Contractors with no contractual design responsibility can contribute to the process through informal suggestions to the design team.

A classification system of the potential causes (that is, the events which precipitated the variation) of variations has been derived from the study of communications, and, consideration of the factors influencing design decisions, (see Figure 1.2).

Research conducted by Mackinder and Marvin, [10] to examines the routes taken to reach design decisions, and how they vary from project to project, revealed the major influences on design decisions; influences which are either brought to the design by the designer or, those which are imposed on him by the particular project constraints.

This research confirmed many of the general impressions of the problems associated with design progression: In most of the case studies the initial concept formed the general basis of the final design, only undergoing minor changes. Time constraints restricted the exploration of alternatives, while the few major changes to design were generally due to compliance with the requirement of statutory undertakers.

Individual designers brought three major sources of influence to the design process; experience (the most often quoted), personal choice and tradition, and their preferred recorded design data (e.g. British Standards, trade literature, etc).

Drawing upon this work the potential variations arising from unforeseen changes in design constraints or circumstances have been classified into six subsets:-

Budget
Technology
Time
Site
Legal
Social (see Figure 1.2A)

FIGURE 1.1

POTENTIAL SOURCES OF VARIATIONS

Internal:

1. Client
2. Architect
3. Structural Engineer
4. Mech. and Elect. Engineer
5. Quantity Surveyor
6. Contractors (with design responsibility)

External:

1. Fire Authority
2. Planning Authority
3. Building Control Authority
4. Statutory Authority (water, gas, electricity)
5. Manufacturer/Supplier

Informal:

1. Contractor
2. Sub-contractor

FIGURE 1.2

POTENTIAL CASES OF VARIATIONS

A. Change in Original Design Constraint.

Budget	Technology	Time	Site	Legal	Social

B. Communication of information in the design decision process.

Stage in Communication of Information	Error	Inadequate
Briefing		
Sketch Plan		
Working Drawings		
Site Feedback		

The second part of the classification (see Figure 1.2B) recognises that the cause of variations may lie in earlier stages of the process than when the effects are felt; it is based on the Royal Institution of British Architects Plan of Work. In addition, distinction is drawn between errors in the production of information and simply inadequate information, the latter giving an indication of the extent of design completion at tender stage.

The data presented in this context was collected by interviews with the key project personnel, and through detailed study of the project documentation (i.e. instructions, drawings, bills, letters etc).

2.5 Research Method - The Social Study Approach

A dual approach was adopted to this aspect of the research incorporating a semi-structured interview session, and the use of the Schutz FIRO-B [11] measure of interpersonal relationship styles on construction personnel. The Schutz FIRO-B, first developed in 1958, is a brief inventory of 54 questions, taking only 10 - 15 minutes to complete, so avoiding fatigue and decreased motivation. Scoring the form, is straight-forward arithmetical with no need for lengthy and costly computerised analysis. It is not proposed to enter here into a detailed discussion of the necessary psychometric properties of the test but sufficient to say that FIRO-B is a reasonably consistent measure from test to test.

The psychology of interpersonal behaviour, relationships and groups of people are very wide fields; here the concern is with working groups, which in common with other groups develop norms i.e. shared patterns of perceiving, thinking and behaviour, have a leader or leaders and "arise to satisfy two basic human motivations, to carry out a task and to enjoy social interaction"[12]. Which of these motivations predominates is subject to debate.

Argyris [13] argues that emphasis on rationality in working relationships leads to the suppression of emotional aspects and to interpersonal difficulties which still emerge, though disguised as technical, rational matters. He found that in engineering, people develop strong emotional attachments to technical issues which block rational discussion and make the solving of complex problems more difficult because the emotion has been displaced on to technical subjects. In the construction industry variations could provide one of the technical displacement areas for these emotions, leading to similar problems.

The FIRO-B measures three areas or needs of interpersonal behaviour which are as follows:-

1) Inclusion (I) - the need to establish and maintain a satisfactory relationship with people with respect to interaction and association, i.e. moving towards or away from people.

2) Control (C) - to establish and maintain a satisfactory relationship with others with respect to control and power, i.e. the assumption of responsibility, decision-making and domination.

3) Affection (A) - to establish and maintain a satisfactory relationship with others with respect to love and affection, and becoming involved with others, i.e. a need for deep rather than superficial relationships.

For each of these three dimensions there are two scores, symbolised by the letters 'e' and 'w'; 'e' represents what is EXPRESSED or manifestly observable on each of the three dimensions and 'w' represents what is WANTED by the person from others and is less observable.

The FIRO-B also measures the degree of compatibility or incompatibility between pairs of individuals as a function of needs to give or receive in

each of the three areas. Preliminary results are stated later.

3. THE RESULTS OF A PILOT STUDY OF FIVE PROJECTS

3.1 Technical Aspects

The potential effects of variations in terms of cost and time performance, and hence the occurrence of disruption and claims, has been well documented elsewhere. Many of the project case studies were still in the course of construction or at the final account stage when the data was being collected. Although these are subsequently being monitored, the design team's perceived "significance" of the variations was recorded in order to allow interim analysis.

The interim results which are reported here are based upon five completed analyses.

An analysis of the sources of variations for the five projects revealed the proportionate breakdown as Column A, Figure 2.1. It is clear that the architect as the major decision maker and co-ordinator in the design stages is the major source of variations as measured by number. However, if the "significant" variations alone are considered the picture changes considerably, as shown by Column B above.

The architect as a source of variations drops from 37 to 6%. This shows that the majority of the variations originating from the architect were "insignificant".

The variations originated by the client were predominantly significant. These two conclusions were supported by additional data where the sources of variations on four projects were analysed by number and by value (i.e. value is used as the indicator of significance), with the architect responsible for 37% by number, but 19% by value, and the client responsible for 32% by number and 45% by value.

An analysis of the causes of variations for the five projects revealed the proportionate breakdown as Column A, Figure 2.2. This highlights the production information stage as the critical point in the communication process. It is at this stage that the co-ordination of the designs of the respective specialisms appears to be faltering; this is supported by the high proportion of variations whose source was attributed to the specialist designers in the previous section.

If "significant" variations alone are considered, the emphasis is re-directed towards variations due to changes in the original design constraints. Such variations may by definition, be considered as fundamental changes. The reason for the high proportion in this category, is the number of significant variations due to problems of site or ground conditions which resulted in extensive re-design.

Site Operations accounted for a high proportion of the significant variations (11%). These can be attributed to feedback of information from the site, resulting in redesigns to incorporate "buildability" suggestions. The sources of these latter variations was great. Often they were problems anticipated in advance by the architect/designer. However, it is at this stage that the contractor has the opportunity to contribute his expertise towards reducing the costs or time of the project design although the traditional procurement system offers no incentive. It was noted during the case studies that the extent of contractor saving - suggestions varied greatly from project to project. Where it did occur, it proceeded on an informal basis, indicating that this is a role which is developed from the goodwill of the participants. No formal Value Incentive Clauses operate in these U.K.

FIGURE 2

The Sources and Causes of Variations for Five Projects Tabulated.

2.1 SOURCES

Source	Col.A %age of all Variations	Col.B %age of significant variations
Architects	37	6
Clients	11	11
Consultant Engineers) Quantity Surveyors)	19	34
Contractors/Subcontractors	5	6
External bodies	14	12
Unallocatable	14	31

2.2 CAUSES

Cause	Col.A %age of all Variations	Col.B %age of significant variations
Change in design constraints	19	38
Briefing	5	5
Sketch Plan	10	11
Production Information)	37	27
Bill of Quantities)	10	8
Site Operations	19	11

contracts, as may do elsewhere.

External bodies, such as planning authorities or services boards, were responsible for few variations, but those that were initiated were significant. This confirms the oft quoted necessity that no decisions concerning outstanding statutory requirements or regulations should be allowed to carry over in to the contract stage.

The high proportion of significant variations attributable to the consultant engineers and quantity surveyors would suggest that the co-ordination of the designs and documentation of the respective disciplines was inadequate.

3.2 Social Aspects

The preliminary findings from this element of the research, which used three of the technical case studies, were as follows:

1) That relationships between members of the project team do NOT have an influence on the incidence or genesis of variations. Variations primarily arise from circumstances beyond the control of the project team (i.e. 'unavoidable' variations). Those which do arise have a strong basis in the technical performance of the participants but

2) relationships between members of the project team WILL affect how variations are dealt with when they do arise. If relationships are good, variations will be dealt with informally, quickly and efficiently. If relationships are bad there will be delays, pedantry and haggling over costs and responsibilities.

3) Good project relations are founded on trust, honesty, mutual respect and professional integrity. Major variations could impair these qualities.

4) Variations are seen as inevitable and affecting the time and cost performance of projects.

5) Close project supervision lessened the incidence and disruptive effect of variations.

6) FIRO-B Profiles on project team members indicated that several of them were highly autonomous and individualistic, if they were sociable, it was because of the demands of the job and they disliked being controlled or having to control others EXCEPT for the contracts managers who wish to control. This was expected as was the introvert, solitary nature of the architects.

7) With regard to 6 above, personal relations could affect how variations were dealt with, not so much because of clashes between differing types but because of a lack of interaction leading to wrong, incomplete or erroneous information. BUT the project team members appeared to be aware of this and allowed for and dealt with it accordingly.

8) Architects were more likely to consider the human relations aspects of variations than contractors' teams who saw them in economic terms.

9) New technology was seen as increasing the incidence of variations and complexity of personal relationships.

3.3 Continuing Work

The results published here are the results of a twelve month pilot study. Ultimately twenty projects will have been studied in depth and data, as to the source, cause and effects of all variations, recorded. In addition the life-cycle of those variations identified as significant will be traced, in order to develop a genesis-development-implementation-settlement profile.

In conjunction with this technical analysis of the projects, a social science researcher is investigating the influence of the occurrence of contentious variations on people's roles and behaviour during the course of the building projects concerned.

3.4 Future Work

This project is envisaged as a first step towards the establishment of a variation data base for a whole range of project factors (i.e. client-type, building size, etc.). Such a tool would act as a warning to clients and design teams of the possible effects of variations, and, as a predictive model for the occurrence of variations.

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