Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 53 (1986)

Artikel: Modelling information transfer during design production

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DOI: https://doi.org/10.5169/seals-41110

Modelling Information Transfer during Design Production

Modèle de transfert d'informations lors de l'étude d'un projet

Die Modellierung des Informationsaustausches im Entwurfsprozess

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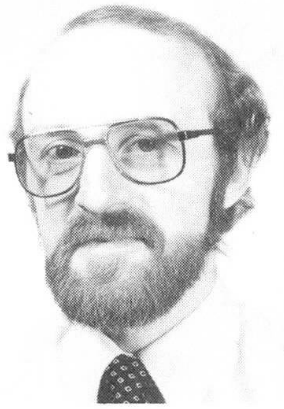

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SUMMARY
This paper describes the principles of a research project which will investigate the process of producing the design information required for a UK building project. It is anticipated that the design process can be modelled by identifying each step the designer takes to design each significant piece of the structure and the sources of data he uses. The network of information interchanges between the designer and his sources will be used to form the model.

RÉSUMÉ
Cette communication traite d'un projet de recherche qui examinera le processus produisant les informations nécessaires à un projet de construction en Grande-Bretagne. Il semble que le processus de projet puisse être modelé en identifiant chaque phase de calcul de parties majeures de la structure, ainsi que les sources de données disponibles. Le réseau d'échanges d'informations entre le projeteur et ses sources servira à la construction du modèle.

ZUSAMMENFASSUNG
Dieser Beitrag beschreibt ein Forschungsprojekt, welches den Prozess der Beschaffung von Entwurfsinformationen für ein Bauvorhaben in England zum Gegenstand hat. Dabei wird davon ausgegangen, dass der Entwurfsprozess modelliert werden kann, indem jeder Entwurfsschritt und die entsprechenden Informationsquellen definiert und durch das dazwischenliegende Beziehungsnetz miteinander verknüpft werden.

1. INTRODUCTION

1.1 The UK building industry's design production problem

In the UK building industry there is a growing awareness that the production of design information is becoming increasingly complex and that it has to be managed in a better way than it has up until now, (Faster Building for Industry, 1983). The responsibility for managing the construction information is retained by the lead designer, who is usually the Architect. What is unusual about the practice of UK design teams compared to European and American practice is that they are responsible and active in the production of the detailed working drawings. This is evident from the number of drawings produced by the design team on a typical UK building project of between 500 and 5000 to that on a comparable US Project of between 50 and 100. (The shop drawings produced by the specialist contractors have been excluded from these figures.) Even under normal circumstances to produce such a large number of items would require considerable management ability but the problem is invariably compounded by the need to start on site quickly leaving inadequate time for the design information to be prepared. Because of this the information production process often fails to deliver the information when it is required (Davies, 1984) through a failing to understand the complexity and requirements of the process (Gray, 1981).

1.2 The research project

This paper describes the background to a research project, which has just commenced, that has the object of predicting the sequence of the design process for any building. Once the sequence has been predicted the work volume can be calculated to give a sound basis for the effective management of the design production process.

2. THE CHARACTERISTICS OF THE DESIGN PRODUCTION PROCESS

2.1 Design is a complex iterative process

Nearly every piece of design information is produced as a result of an initial concept which is refined by the iterative cycle of analysis, synthesis and evaluation. The number of iterations is a function of the designer's knowledge, his experience and the need to interface with others. Each refinement is as a result of new knowledge being added to the problem. In some cases the designer may undertake his own research and continually evolve the solution but in many cases others have to work on the problem in a substantial manner to apply their own knowledge and develop their contribution to the problem. There appears to be two levels of iteration and refinement. First, the iteration within the designer's domain and secondly, the iterations which occur between designer's domains.

2.1.1

The iterations within the designer's domain involve him in proposing a solution to a problem from his own knowledge and challenging that solution to obtain improvement. He may seek additional knowledge by referring to libraries of product and technical data or by discussion with other members of the design team to add their knowledge to the problem. The solution is refined until the answer is available in its completed form either in a drawing, a set of drawings, a specification or other written material. It is implicit within this definition that the knowledge gathering and consequent iterations are performed by the designer to form a complete stage in the generation of the final data.

2.1.2

Most buildings are too complex to enable the single designer to collect and collate all the information for the complete design and others are involved to perform sections of the design, either within the primary design, eg, architecture, or within the secondary design, eg, structural engineering. It is still the role of the primary designer to be responsible for the whole design but he has to obtain considerable sections of it from the others. However, as the others contribution is secondary to his own they must wait for information from the primary designer. When sufficient information is available from the primary designer it is transferred to the domain of the secondary designer who goes through his own iterative process to develop the design. Once he has achieved his design task the information is transferred from the secondary domain back to the primary domain or it becomes the primary domain for another subsequent secondary domain.

2.2 Transfers between design domains is a linear process

It is a characterstic of the design process that time is expended between each transfer between the designer's domain. This is to allow the information to be assimilated into the recipients own design generation process. The time taken to incorporate it will depend on the information and its importance to the generation of the total design. In most instances design work in each domain can be done in parallel but because the design is to achieve a single integrated objective - the building - there must be substantial cross reference between design domains. The work content within the domains will be different as will the resources so each set of work within the domain will take a varying amount of time. The design process is, therefore, a complex exchange of design information between design domains which is essential to the development of the total set of design information.

2.3 The characteristics of the design domain within the construction process

There are five general groupings of knowledge and expertise that are used during the design proces. Each is used creatively to generate information as well as being used to appraise the work of the others at each stage in the development of the design. The groups of knowledge are:

2.3.1 Technical knowledge

Given the nature of construction, its long life, the need for structural stability and safety of the occupants, the technical knowledge assumes great importance. Once the concept has been created, the designer is attempting to use the technology of the components available to him to the best advantage in satisfying the concept design. His predominant concern is with the performance of the component given its technical specification. Each designer in the primary domain has available to him a range of components of which he may have a specific knowledge in certain cases but generally he will have a broader knowledge of the market place. His skill is more concerned with establishing a specification of his requirements by combining the knowledge of the progress of the final design, his general awareness of the market and the specific nature of the performance he is seeking. This may be simply stated using a drawing or may require an extensive specification in addition. Eventually the knowledge domain of the component manufacturer will be required.

2.3.2 Manufacturing knowledge

It is a feature of the UK's component supply industry that it offers a capability to supply a range of components. Its capability lies within the knowledge of the manufacturing process, how the process can be used to manipulate the basic materials and the limits to which the product can be extended.

The manufacturer reviews the specification from the primary domain and assesses whether he can manufacture his specific product to meet the requirements. This process involves an interaction between the manufacturers own design and production staff to resolve the technical problems in meeting the specification. It is probably unlikely that the problems of assembling the component into the building will be considered by the component manufacturer. But in the context of erecting the final building the way the component is to be incorporated into the building must be considered.

2.3.3 Component assembly knowledge

This knowledge is not confined to knowledge held by the contractor about the problems to be faced on site. Obviously this forms a large knowledge area about the practice of assembly but other knowledge is required during the design process. It must be an integral part of the design that the assembly interfaces are considered in practical terms during each process in the development of the design. Building is a process of joining components together and the jointing techniques must be understood and be capable of being executed given all of the location of the component and the need to fulfil the designer's aesthetic requirements.

2.3.4 Financial knowledge

Whilst the foregoing are predominant considerations, each solution is balanced against the cost of satisfying the specification established by the primary design domain. In some cases the demands placed on the technology of the material or component may be excessive, thus forcing the costs beyond an acceptable boundary. If this occurs then the iteration within the primary domain will be repeated to derive an alternative specification to be evaluated by the secondary design domain until an acceptable solution is found.

2.3.5 Management knowledge

The process of design relies on an ability to identify the primary and secondary design domains and their boundaries. Once identified the development of the specification by the primary design domain must be achieved. The identification of the secondary design domain must be made and its willingness to participate established. These are the actions of managing the interfaces between the design domains. The process within the domain must also be managed to establish the point at which an acceptable solution has been reached so that the iterative process does not endlessly cycle seeking the ultimate refinement.

3. ESTABLISHING A MODEL OF THE DESIGN PROCESS

3.1 Design and manufacture of component assemblies establish the design model

The identification, procurement and application of knowledge domains forms the basic design process. Each contribution of knowledge is used to identify the specification of the materials, components and component assemblies to be used to build the final building. Therefore, once the components have been identified the linear sequence for obtaining the knowledge can be established. The sequence must recognize the ability of each knowledge domain to contribute to the design solution and how the specification will be established to obtain any additional information it may require from the secondary domain. It has been observed on many building projects that each component and assembly carries with it a standard sequence of activities for this process. The content of the design activity will vary from project to project because the problem is varied by the conceptual design requirements.

3.2 Identification of the interfaces between the knowledge domains

If the design process for a building was a series of sequential operations functioning in parallel then the management of the whole process would be relatively simple. However, because each component is fixed to another there is interaction between the design process of each component to ensure that the knowledge of the fixing and support provisions is compatible from one component to another. This is particularly relevant when one component contains an element of the fixing for another component. For example, a bracket may be welded to a steel beam in the fabrication shop because on-site welding is not allowed. The bracket will be used to receive a bolt from a cladding panel to secure the panel to the building. To achieve the correct location of the bracket to receive the bolt, the location of the bolt will have to be transferred to the steel fabricator from the cladding specialist.

3.3 Design is a series of interlinked sequences between knowledge domains

The sequences and interfaces form a network of design activity using the knowledge within the domains. Each activity is established by the components being used to satisfy the requirements of the concept of the building. The components have physical attributes and can be identified, thus the network of the design activity which precedes the construction activity can be established. This is the theory. In practice it is difficult to identify the network as design is perceived as being satisfied by two extremes. The first is that the process of acquiring knowledge is satisfied when the designer, in the corporate sense, ie, the architectural or engineering practice, is employed. The second is that the design process is satisfied when the drawings are produced. These two extremes are unsuitable for control as the first is too coarse for any method of control and the second is impossibly detailed (Farrell, 1968). An intermediate stage between the two extremes must be achieved to obtain a realistic assessment of the network of interchanges and to provide a level of detail upon which it is possible to realistically assess progress.

4. CONFIRMATION OF THE MODEL USING CASE STUDIES

4.1 Network of design interchange

A method of management of the design process which has been tried in practice, with some degree of success, is to examine the most mechanistic aspect of the design process. Instead of attempting to monitor the production of each drawing a more appropriate method is to partition the information into sets of information which are transferred between knowledge domains. The sets comprise drawings, sketches, specifications and text to describe the design. It is the role of the recipient design domain to establish the context of the information which will satisfy his needs. The content is obviously related to the task he will perform once the information is available.

4.2 The design process involves multiple contributions

Associated with each component is a three stage process for the production of the information: the general design information, the working drawings and the shop drawings. There is, therefore, an interchange between the lead designer, the associated consultant designers, the manufacturers designers and his production team. These interchanges must be included in the network of design activity.

4.3 The timing of the design contribution

An additional problem is that the sequence of construction activity on the site is often used to generate the programme for the information production whereas the information interchange requirements demand a different sequence to be established. It was particularly noticeable that there was considerable interchange between the specialist contractors to resolve details at the junctions between components. The need to bring this information into the process often required that the specialist contractors were appointed in a different sequence to their normal pattern of site work because of the importance of their special knowledge. The interchange between specialist contractors must also be included in the network of design activity.

4.4 The apparent isolation of designers

Perhaps due to the size of the project or the pressure to complete their own section of the design, individual designers found it extremely difficult to perceive the importance of their contribution to the whole project. They became very self-centred. This often produces a very high technical standard but fails to appreciate the implications of the time that is taken to resolve the problem. Because, the design process is a complex interlinked network of activity each failure is magnified such that the whole process quickly becomes unmanaged and chaotic (Bennett, 1985). Bennett has identified the important characteristics of construction projects from a management point of view. They can be used equally to describe the management characteristics of the design process. Size is the number of separately identifiable design domains. Complexity is the number of stages of work between interchanges from one design domain to another. Repetition is the number of iterations within each domain. Speed is the number of stages completed per time period. Variability is the range of output around a standard level of productivity. These characteristics combine such that simple designs involving few design domains, with few iterations and little variability are predictable in terms of predicting the production time with little variability and high confidence. Whilst the combination of; large, highly complex, repetitious, innovative, high variable designs under pressures of time are highly variable with little confidence in the outcome. One way to overcome this is for each designer to clearly state why the information to be supplied to him is important and what he will do with it and what will be the consequences of failure. This has the very powerful effect of increasing everybody's awareness of the importance of their role in the whole process.

4.5 Simplified design management systems

The attempts at managing the design process on a variety of building projects has enabled the simplified form shown in Figure 1 to be evolved. This shows two components of the system: the programme on the left and the explanation of the significance of each activity on the right. A programme sheet is developed for each designer and contributor to the design process which includes: the client, contractor, project manager and financial controller. Each sheet is bound into a report which includes a statement of the policy on the project and any decisions which affect particular methods of design or procurement which are in any way unorthodox. Whilst each sheet gives a complete view of the specific tasks and their relevance and importance, by reading the other sheets, the designer can very rapidly gain a comprehensive understanding of the project.

5. CURRENT RESEARCH PROGRAMME

5.1 The objectives

The case studies have shown that it is possible to manage the design process once the network of the interchange of the sets of information between design domains is understood. They have also shown that there is a common procedure associated with each building component or building system which is applicable whoever is the supplier. The first objective is to understand the sequence associated with the principle components used in buildings.

The information interchange will depend on the way the components are used in the building but generally they will form a consistent pattern because of the nature of the fixing system and support requirements. The second objective is to establish the principles of each fixing system which control the knowledge transfer.

The third objective is to define the parameters which establish the design work-load in each set of information.

Finally, the design production network must be interfaced with an analysis of the construction process. This is essential because the design process must eventually supply the information to the constructor in the correct sequence. However, because the interchange between design domains requires a different sequence the consequences of failure in the process must be demonstrated to change traditional attitudes.

5.2 Research schedule

The project commenced in January 1986 with a 2 year schedule. Initially the work will establish a model of the design process which will be used to evaluate further case studies.

6. CONCLUSIONS

Management of the design process is an emotive issue because it involves intense personal endeavour. However, it is anticipated that, by concentrating on the mechanistic aspects of design, a method can be proposed which does not inhibit design freedom, but does allow the process to be managed to satisfy the demands of the construction process.

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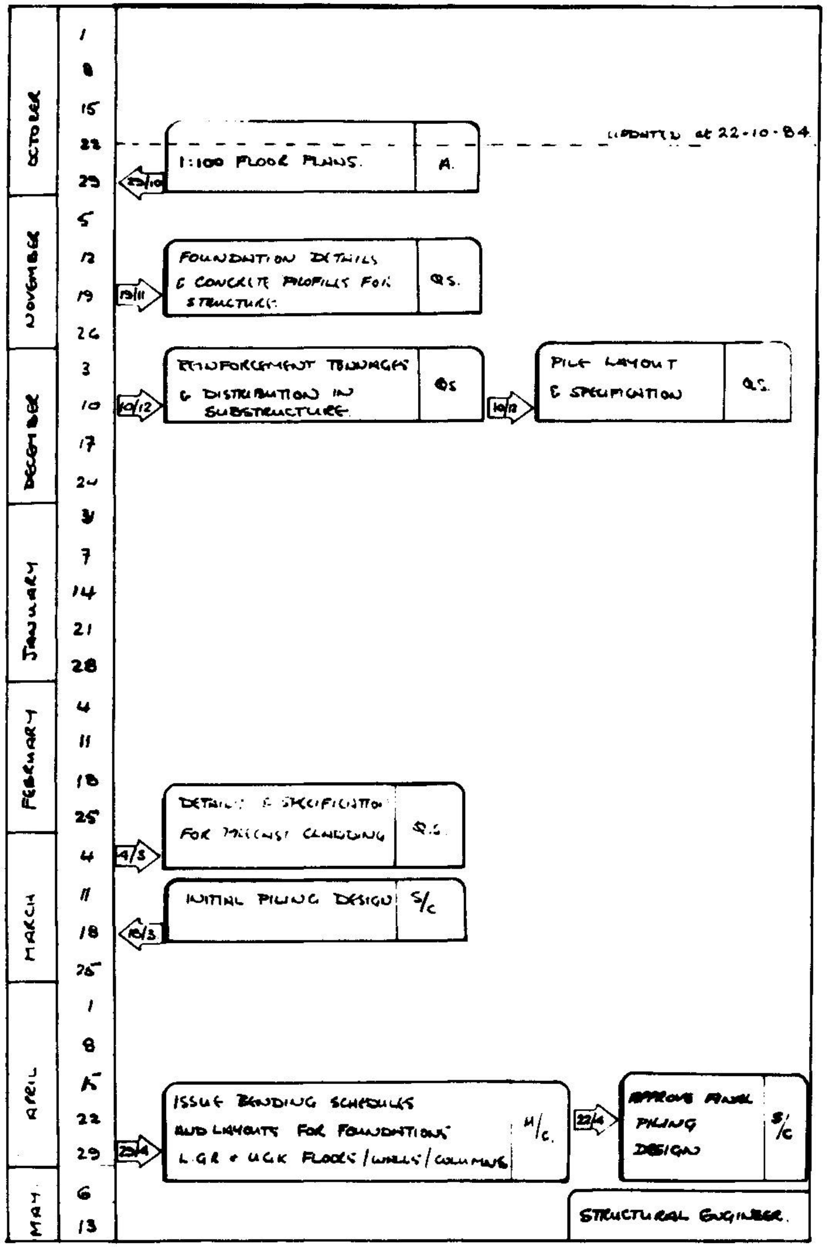

STRUCTURAL ENGINEER

REQUIREMENTS AND PROVISIONS

29 October 1984

Final floor layouts required to enable resolution of location of structural members before detail design can commence.

19 November 1984

To allow the QS to prepare the Stage I tender documents based on the complete measure of the structure, all floor plans/sections showing concrete profiles to be complete.

10 December 1984

(a) Supply the bulk reinforcement requirements in terms of tonnage per bar size and location.

(b) The piling will still be let separately to enable a test pile to be driven and the final design by the subcontractor to be completed to enable piling to commence on 29 April 1985.

4 March 1985

All precast cladding details, fixings and specifications to enable bid document preparation.

22 April 1985

Approve final piling design.

29 April 1985

Issue first of bar schedules and layouts for ordering by main contractor (12 week procurement and bending period allowed).