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Autor: Griffith, Alan
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Concept of Buildability

Concept de l'aptitude à la réalisation

Das Konzept der Ausführbarkeit

Alan GRIFFITH
Dr.
Heriot-Watt University
Edinburgh, Scotland, UK

Alan Griffith, born 1958, is a lecturer and researcher in Construction Management. After qualifying as a surveyor (1974–81) he studied for a one year Master's Degree (1982), and continued study to complete his Ph. D. (1984) focusing on design/construction interaction.

SUMMARY

This paper considers the problem of Buildability – the extent which the design of a building facilitates ease of construction. It focuses upon the technological and managerial aspects of making a building more buildable following principles of design rationalisation developed in housebuilding. Illustration, through a case study, shows how these principles react to more technologically complex design types.

RÉSUMÉ

La contribution traite du concept de «l'aptitude à la réalisation», soit de l'influence du projet sur l'exécution facile de la construction. Il se concentre sur les aspects technologique et d'organisation de l'exécution d'un bâtiment facilitée par l'application de principes de la rationalisation du projet. Un cas concret montre l'application de ces principes à des constructions plus complexes.

ZUSAMMENFASSUNG

In diesem Artikel wird der Einfluss des Entwurfs eines Bauwerkes auf dessen Ausführung untersucht. Besonderes Augenmerk richtet sich auf die technologischen und organisatorischen Aspekte der Entwurfstätigkeit im Hinblick auf die einfache Bauausführung. An einem Beispiel wird aufgezeigt, wie sich diese Entwurfsprinzipien bei komplexen Bauvorhaben auswirken.

Introduction

A strong body of opinion within the U.K. construction industry suggests that the traditional separation of the design and construction phases is primarily responsible for problems of present construction projects. There is a need to gain a better understanding of the impact that the design has upon the construction process. A design that has appreciated its implications upon construction should be easier, quicker and more economic to construct.

Background - The design and construction interrelationship

The Emmerson Report (1962) [1] expressed the initial concern for the division between the design and construction processes identifying the lack of communication and co-ordination between the design team and construction team members. Emmerson attributes a number of problems, which sadly to say still prevail, as contributory factors to the inefficiency of the U.K. construction industry. The main problems were thought to include;

i Inadequate preparation of design drawings and specifications before contracts are put out to tender.

ii Pre-contract design procedures were inefficient due to their complexity.

iii Lack of communication between the architect and contractor, subcontractors and consultants.

Developing the thoughts of Emmerson, The Banwell Report (1964) [2] suggested that;

> "design and construction must be considered together and that in the traditional contracting situation, the contractor is too far removed from the design stage at which his specialist knowledge and techniques could be put to invaluable use,...the building is a member of the team and should be in it from the start."

The Report called for greater attention to pre-contract planning and design formulation, in particular to defining the user's requirements. Professionalism was criticised for being too widely perpetuated giving rise to unnecessary and efficient construction practices. Banwell highlighted the following requirements;

i The client must define his genuine requirements clearly at the start of the design formulation.

ii The complexities of modern construction design requiring specialised construction techniques demands that the design process and construction phase should not be regarded as separate fields of activity.

iii Review of traditional contractual practices, roles of the professional parties and their codes of conduct to improve interdisciplinary relationships.

The Economic Development Council (1967) [3] reported that the recommendations made in the Banwell Report had not been widely implemented within the industry. Although the professions were willing to consider the use of non-traditional contractual procedures there was considerable reluctance to involve the contractor at an earlier stage in design formulation. Flexibility in approach rather than radical change was advocated.

The problem of communication

Emphasising the apparent problems of communication and lack of co-ordination between contractual parties, the National Joint Consultative Committee, NJCC, commissioned the Tavistock Institute of Human Relations to undertake a preliminary study. [4]

Findings of the preliminary study identified and presented numerous examples of miscommunication between the contractual parties. This was attributed mainly to the pattern of relationships and division of responsibility within the building team. It was stated that;

> "effective achievement of the common design task requires full and continuous interchange of information .....there is a need for more 'carry-over' in the co-ordination function with respect to design and construction phases"

Two propositions were suggested for improving communication;

i That a co-ordinating function exercised over both design and construction functions by a single person or single group is better than one where functions have different co-ordinators.

ii That if design and construction functions must have separate co-ordinators, then the best system of this kind is one where there is an early exchange of relevant information.

The need for collaboration

> "Collaboration is essential if satisfactory results are to be achieved......modern construction requires a wider variety of skills instilling the need for greater co-operation and closer co-ordination of the people and processes involved." Smith (1967) [5]

Smith noted that, on most occasions the contractor met completion dates but these dates were generally un-realistic in the first place. He said, realistic dates could be specified through closer liaison between the owner, architect, surveyor and contractor.

Nasmith (1967) [6] cites professional demarcation as the fundamental barrier to collaboration commenting that the professions view collaboration as;

> "a sort of take-over bid by other professions."

This attitude can be attributed to the nature of the construction process itself as Cowan (1967) [7] points out;

> "in practice the engineer and consultant will stand divided in the same way as architect and contractor and the division will become more marked as each, albeit blamelessly, produces problems which the other must solve."

The traditional building process separates design from construction through professionalisation demanded by contractual forms. It creates an environment in which the parties must defend and uphold their respective rights, concentrating upon apportioning blame for deficiencies rather than encouraging teamwork.

Improvement......but the problem exists

The Wood Report (1975) [8] recognised improvement in the design- construction interrelationship within the decade following the Banwell Report. It was stated that;

> "The traditional separation between design and construction was found to have diminished with consequent advantages all round.... contractors have much to offer at the design stage, especially by way of advice on constructional implications of design solutions and decisions...yet, methods of procurement are still such that they are brought in too late for their advice and experience to be of practical use.....the original problems still exist."

Re-defining the problem - The concept of Buildability

In 1979, The Construction Industry Research and Information Association (CIRIA) [9] embarked upon a research programme aimed at investigating the major problems of current U.K. construction practice. This renewed interest in the recurrent concern for the interrelationship between design and construction which had followed the Emmerson and Banwell Reports of the early 1960's. Interest focused upon the concept of buildability and suggestions that present designs were not providing value for money in terms of the efficiency with which the building process is executed. The principle consideration was promoting awareness amongst designers of those aspects of design which would enable the building contractor to give the client better value for money.

Buildability defined

Buildability is defined by CIRIA as;

> "The extent to which the design of the building facilitates ease of construction, subject to the overall requirements for the completed building"

CIRIA's somewhat simplistic definition inherently suggests careful consideration of design detailing to present a design solution assisting the construction phase whilst meeting desired performance and quality requirements within planned cost parameters. Whilst CIRIA appreciates that ease of construction may be influenced by many organisational, technical, managerial and environmental considerations, the major contribution was thought to lie in those factors which fall within the influence or control of the design team.

It is, however, a misnomer to associate buildability purely with the aspect of design, as there is increasing recognition for the contractors role and contribution of other parties in promoting ease of construction.

CIRIA suggest that the problem of buildability exists;

> "probably because of the comparative isolation of many designers from the practical construction process. The shortcomings as seen by the builders were not the personal shortcomings of particular people, but of the separation of the design and construction functions which has characterised the U.K. building industry over the last century or so."

The concept of buildability as a development of productivity and design orientated research

Consideration towards improving ease of construction has been practiced by a number of exponents over the last twenty years. Within the U.K. the Building Research Establishment (BRE), National Building Agency (NBA) and Scottish Development Department (SDD) have investigated methods of improving levels of site productivity in traditional house-building through implementing 'design rationalisation'. Whilst design rationalisation probably maintains greatest affiliation to productivity orientated analyses rather than explicit investigations of buildability, they have nonetheless provided a sound base upon which buildability ideas can be developed.

Scope of the investigations

Studies relate primarily to the early 1970's when following the Sidwell Report (1970) [10], a programme of research was initiated by the Scottish Housing Research and Development Committee. Investigation originated from the general concern that Scottish houses, built to traditional designs, had cost more to build than comparable houses constructed in England. Lower levels of productivity was cited as the main cause.

Following early productivity studies in England, attention focused upon a number of applications of design rationalisation in Scotland. Practice concentrated on low-rise housing developments based on a two-storey design using traditional construction methods prevalent in Scotland.

Scottish application

Blantyre [11], the first Scottish study observed the construction of 132 traditionally built houses over an eighteen month period between January 1971 and June 1972. The contract was let by competitive tender with the contractor employing his own labour and sub-contractors following traditional U.K. contractual procedures.

The dwellings were one and two-storey house types built from one generic design using common shell dimensions of 6.6 x 6.0 metres and 6.0 x 7.5 metres for a four-person and five-person house respectively. The design retained flexibility by being able to turn through ninety degrees to create alternative house types each with a different aspect. Rationalistion of the design involved the modular co-ordination of external components, sub-structure elements and superstructure construction were designed with the co-ordination of materials and reducing material waste in mind. Construction detail was based upon traditional building practice with in-situ concrete strip foundations, suspended timber ground floor, brick-block cavity wall and timber roof structure with felt and tiled covering.

The second Scottish application at Greenfield [12], in 1972 involved 131 houses and 218 flats and differed from Blantyre in that construction followed a design and build service provided by the main contractor although the form of contract remained competitive through a package deal approach. The dwellings comprised five-person and seven-person two-storey houses to modular co-ordinated plans provided by the Scottish Local Authority Special Housing Group (SLASH). Construction differed from Blantyre as an in-situ concrete raft was used with brickwork up to d.p.c. supporting a suspended timber ground floor. External enclosure comprised prefabricated timber panels faced with brickwork.

These studies were followed by a two-phase application at Pitcoudie [13] in 1974. Pitcoudie Phase I comprised 112 dwellings of two-person to seven-person accommodation in a range of six house types and Pitcoudie Phase II involved 283 dwellings. Plans followed those developed at Greenfield but were modified as repetition of elements was a priority. Through the introduction of only two distinct plan areas, the rationalisation of many construction elements became possible.

Main objective

The main objective of design rationalisation is to make more effective the labour resource on site by making the on-site tasks easier to perform by considering the construction procedures during the design stage. In explicit terms, reductions in manhour expenditure are expected.

Principles of design rationalisation

The Scottish applications have suggested that buildability may be improved by implementing five principles of design rationalisation during the design stage;

i Building to the same construction sequence
ii Reducing the number of building operations
iii Simplification of design elements
iv Standardisation of building components
v Dimensional co-ordination of materials

Although the design of each dwelling varied to provide a range of house types, the sequence for construction operations was similar for each house. The number of operations required by each trade was reduced where possible and the number of visits by that trade to any one dwelling was minimised to avoid disruption to other trades. Design elements were simplified to reduce technical complexity of the on-site task and thought was given to designing a dimensionally co-ordinated grid to reduce waste incurred in cutting components to fit on-site. Building components were standardised throughout each dwelling, irrespective of the house type or its aspect.

Analysis

Analysis focuses upon levels of average manhour expenditure per dwelling. Figure (1) depicts average manhour expenditure for housing sites in England and Scotland, five of traditional construction design and three prefabricated timber construction. Of those projects illustrated, only sites numbered 3, 4 and 5 are directly comparable. It can be observed that manhours expended in constructing a dwelling has reduced from 1292 in the earliest study to 1023 in the most recent application. In isolating the studies which involved the implementation of design rationalisation, there is very little difference between the 1064 manhours per dwelling expended at Blantyre and 1032 and 1023 manhours expended at Pitcoudie I and II. This represents an average saving per dwelling of only 3.00% to 3.85% of total manhours. When viewed in this way, data reflecting reductions in manhour expenditure for similar building types does little to suggest that design rationalisation has really been successful.

The transition of buildability concepts from domestic dwellings to more complex design types

The principles of design rationalisation developed through the housebuilding applications have been extended to the construction of a more complex design type [14,15]. The project, a Local Authority medical centre was designed to traditional construction following design elements developed in the housing studies. Whilst a number of aspects to the design are obviously different and cannot therefore be a subject for comparison, other common elements are. The building, with superficial floor area of 950 square metres incorporates main

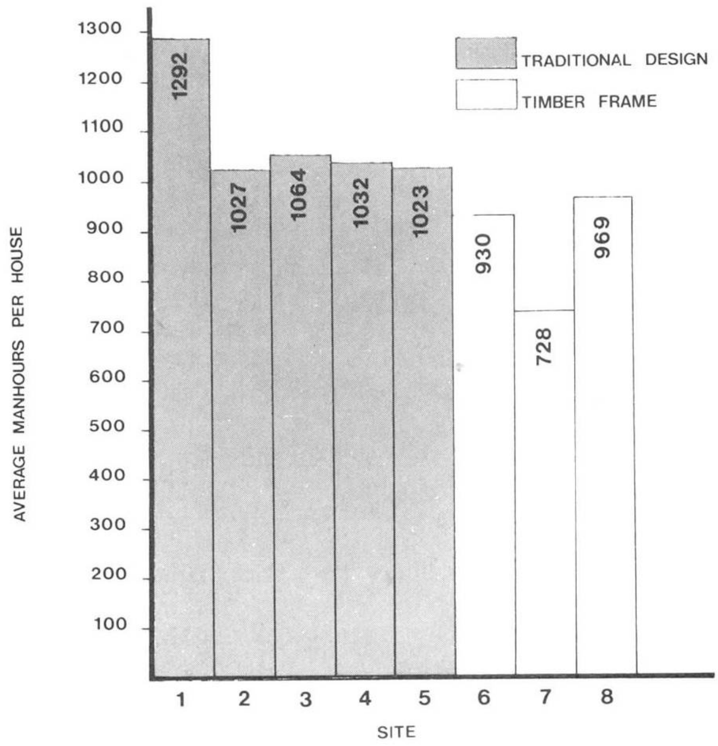

FIGURE 1

AVERAGE MANHOURS EXPENDED PER DWELLING ON EIGHT U.K. HOUSEBUILDING SITES

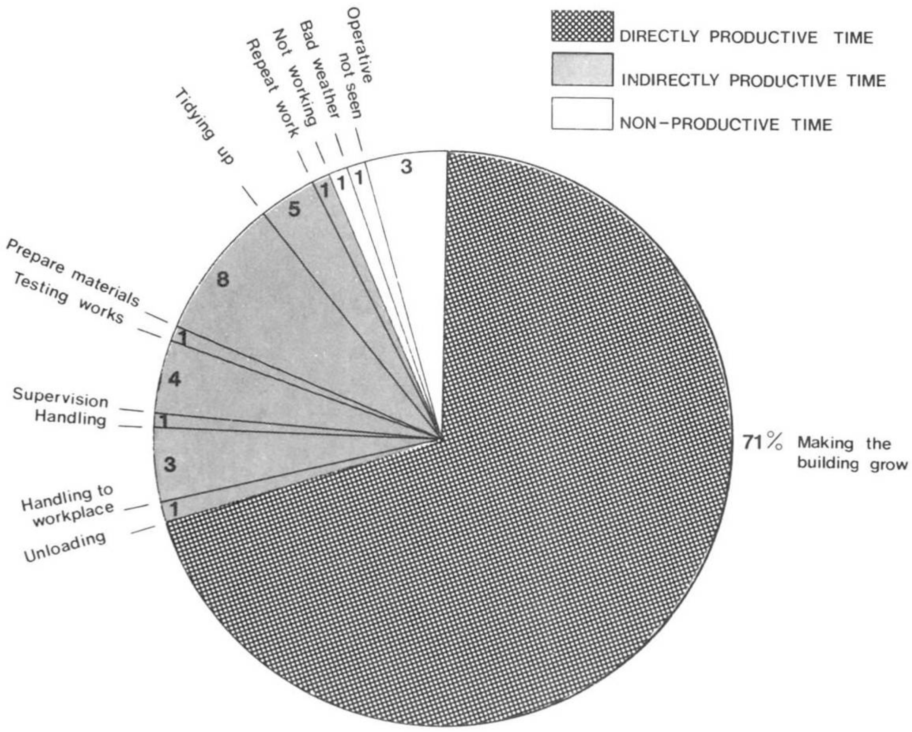

FIGURE 2

MANHOUR EXPENDITURE BY ACTIVITY

accommodation on the ground floor with a small upper storey section. The project was bid in selected competition under the Joint Contracts Tribunal - JCT 80 Standard Form of Building Contract with Scottish amendment and involved a duration of fifteen months to a completion date in August 1983.

Methodological approach

The research approach adopted for the project utilised the Site Monitoring Analysis Package developed by the BRE [16]. Sampling in this way consists of observing a small proportion of a construction projects total activity and, providing this sample is representative and sufficiently large to maintain statistical validity, it is possible to derive estimates of the level of activity of the whole project or any part of it.

Conscious implementation of design rationalisation

Design rationalisation has two main interests;

i Analysis of individual work tasks with the intention of simplifying the design detail and examining the practicalities of task dependence and methods by which the different trades interrelate. These are aimed at influencing the productive element or 'increasing the time spent making the building grow'.

ii Impact of standardisation and required building and trade tolerances. These interests are directed towards 'reducing the time spent between construction operations'.

Design rationalisation was implemented using the following methods;

i Organisation of design and construction drawings in a location, assembly and component hierarchy with each being cross referenced.

ii 'A4' size assembly drawings which could be used directly at the workplace by the operatives.

iii Use of a referenced planning grid to locate construction elements and components on site.

iv Ground and first floor concrete slabs designed to final level without wet screeds.

v Design of a single leaf lightweight concrete block external wall.

vi Rationalisation of blockwork to co-ordinated dimensions and specific coursings and minimisation of blockwork cutting.

vii Use of an independent internal dry lining wall finish.

viii Co-ordinated timber roof joists and joist hangers.

ix Minimisation of cutting to co-ordinated decking system in roof structure.

x Prefabricated timber panels and cladding sheets in upper floor super-structure enclosure.

Analysis

Figure (2) indicates the manhour expenditure by construction activity recorded for the project. Separating productive and non-productive activity reveals that 71% of total manhour expenditure involved 'making the building grow' with a further 24% expended in direct and in-directly productive tasks. Only 5% of total manhour expenditure is associated with completely non-productive activity. The 71% level of totally productive manhour expenditure is considerably higher than the most successful of the housebuilding applications where in traditional construction the highest level was 53% and in timber design dwellings 58% was recorded.

Methodological error

The data was checked at this stage of analysis to ensure the high level of totally productive manhour expenditure was not the product of statistical or observational error. Accuracy was upheld as the degree of error generated in the sixty thousand individual observations was less than 1.5%.

Influence of other factors

Whilst design rationalisation had played a part in the design formulation, like the preceding housebuilding projects, it was questionable whether it had any substantial effect. When the total manhour expenditure is converted to manhour expenditure per square metre of floor area for each building element and construction operation, there is no evidence to suggest that manhour expenditure had been reduced as a result of the rationalisations consciously implemented.

Attention focused upon other factors of potential influence which can be broadly categorised as 'managerial and project orientated factors'. These are listed as follows;

i Client
ii Contractor
iii Form of contract
iv Site organisational structure (autonomous or organic)
v Client-contractor relationship (parties resident on site)
vi Managerial style (formal, hierarchical, participative etc)
vii Labour resource level (workforce number, trade gang distribution)
viii Size of site
ix Supervisory style (informal or formal)
x Locational aspect (geographical position)
xi Control of site by contractor (off-site control, feedback mechanisms)
xii Methods of material procurement (site or area office)
xiii Methods of material handling (single, double handling)
xiv Planning approaches (short-term planning and resource assessment)
xv Site conditions

When these factors are considered, the medical centre project differs considerably from all the preceding housebuilding studies. Sufficient clear difference exists to suggest that it is the combined effect of these factors, rather than the implementation of design rationalisation, which has been influential in achieving the high level of productive manhour expenditure on the medical centre project.

Conclusions

The conclusions of this study may be summarised as follows;

1. There is little evidence to suggest that design rationalisation is influential in reducing total manhour expenditure on site.

2. There is little or no evidence to suggest that the principles of design rationalisation developed in the housebuilding studies can be applied to more complex building types.

3. Twenty years research into traditional housebuilding has focused upon investigating manhour expenditure as a result of design orientated influences when other factors of influence appear to be of greater importance.

4. There is evidence to suggest, although it is arguable, that practical buildability is more likely to follow sound site-managerial practices than be attributed to buildability criteria consciously drawn into the design.

5. Buildability is a concept impinging upon the total building process and as such, if its principles are not carried through from design to construction, the concept becomes a totally worthless pursuit.

Principal areas requiring further study

From recent study conducted at Heriot-Watt University (1985) [17] two critical aspects of buildability have been identified for continued investigation;

i Analysis of architect's design details
ii Communication of the design to the operative at the workplace.

It would appear that the major problem associated with buildability during the construction phase is essentially one of inaccurate detailing of design information. Problems occur mainly due to inaccurate provision of design information through inaccurate working drawings or inadequate specifications.

It is also evident that even if the architects design details are accurately represented, their effect is often rendered useless through the innability to convey this information accurately and effectively to the operative directly at the workplace. Communication between the drawing board and the man-at-work is therefore paramount.

Current state of the art

A number of studies reporting findings in the recent period 1983 to 1985 [18,19,20,21] have examined the disparity between design and construction phases highlighting the requirement for; the early involvement of the contractor in the procurement process, the overlapping of design and construction functions using 'fast-tracking' techniques, and more radically, the adoption of non-traditional contractual approaches. Of recent studies, the Building Economic Development Council Report, 'Faster Building for Industry' (1983) [22] summarises the main problems and identifies the needs for bridging the divide between design and construction;

1. The general belief that speed costs money is quite unfounded, fast building is possible without either penalty to cost or quality. Responsibilities within the team must be clearly defined and in particular, the client must know who is the team leader.

2. Organisation of the contractor under traditional procurement procedures can create unnecessary complexity for the client.

3. Whilst traditional methods of design and tendering can give good results, on average non-traditional techniques tend to be quicker, and within the traditional approach, both tendering on bills of approximate quantities and choosing the contractor through a negotiated tender leads to faster progress.

4. Preparation of the design must be directed toward facilitating progress on site.

5. The design must take account of buildability, allowing the procurement of materials and the performance of the different building operations to be planned and organised as straightforwardly as possible within the scope of minimised disruption.

6. Contributions from specialist consultants, the contractor, sub-contractors and suppliers must be obtained within sufficient time for effective co-ordination and input to the design function.

7. Contractors should not be selected on the basis of price alone, the contractor's ability should be assessed also. Early recruitment of the contractor, before the design is finalised, may assist in programming, the anticipation of site problems and produce a more economic and more buildable design.

8. Efficient progress on site requires effective site management, clear communication between the client, architect and contractor and detailed feedback mechanisms to control progress.

9. The form of contract is not the determining factor to meeting requirements of the construction process, it is the attitude of the parties. The Standard Form of Building Contract invokes penalties for delays and no incentives for efficiency. Industry must look for ways of sharing the benefits accrued from improved performance.

Whilst buildability is looked upon as being purely a design orientated activity, it should be emphasised that buildability involves the total building process from the design itself through to the on-site construction process. It is an inherent aspect of construction impinging upon every aspect and all contractual parties. If its principles are not carried through from design to construction and beyond, then buildability becomes a totally worthless pursuit.

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