PRODUCTIVITY, BUILDABILITY AND CONSTRUCTABILITY: IS WORK STUDY THE MISSING LINK?

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Improving productivity, increasing output for the same inputs, has been a longstanding concern of the UK Construction Industry. The different approaches to improving productivity will be briefly reviewed as will the decline in awareness of classical work study and use by construction firms. Definitions of "buildability" and "constructability" will be considered and reports seeking to improve buildability reviewed. The key results of several questionnaire surveys will be presented and contractual relationships are identified both as a major deterrent to improved buildability and as the means by which buildability problems are being overcome. Suggestions are made for an expansion of the role of the Architectural Technologist.

Keywords: architecture, buildability, construction management, constructability, productivity.

INTRODUCTION

The owners of buildings, particularly when building for investment or speculative gain, invariably seek a better performing product, or larger buildings at a cheaper price. The Construction Research and Innovation Strategy Panel (CRISP 1996) asserts that "the UK construction industry has one of the highest unit output costs in Europe, despite having one of the lowest unit input costs in terms of labour and materials". While the validity of these claims cannot be verified and international comparisons of industry performance are notoriously difficult there can be no doubt that major clients are demanding improved value from construction.

The public client, a post-war socialist response to the satisfaction of society's needs, has been replaced by the private client as the transition from a command economy to a market led free enterprise economy has transformed Britain over the past half century. The Latham report (1994), written from the viewpoint that clients' needs are paramount, proposed fundamental changes to the culture and business practices of the industry. From the client viewpoint the industry comprises all the fee earning design and advisory professions as well as main, management and specialist trade contractors. "Trust and Money" was the title of the interim report and this working title snappily encompassed the concerns of the complex interrelated proposals made to changing the adversarial practices that had developed.

The headline challenge was that a 30 per cent cost reduction is possible by changing attitudes and contractual arrangements so that the effort devoted to making claims for additional payments and arguing could be devoted to reducing costs.

There has been no shortage of research into the complex contractual arrangements adopted by the industry and accepted by clients and the conflict they can generate.

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The evolution of the construction industry, development of the design professions, separation of design processes from construction processes since medieval times and the separation of building engineering from architectural practice have been thoroughly reported. The differing educational systems of the professions reflect both the need for specialist knowledge and social aspirations. Moore (1996), in a wide ranging and well referenced essay, discusses these and the crisis of identity first faced by Architects during Victoria's reign. Moore suggests that the conflict between "follower of the liberal art of design or a follower of the mechanical art of building" was resolved by the architectural profession adopting the unique position of claiming to be skilled in both technical knowledge and artistic insight. He argues these are not currently in the required balance and suggests the balance might be improved by the separation of the profession into "academic architects" and "construction architects".

Architects frequently also act as Contract Administrator, they are the client's representative and implement the procedural aspects of the client's contract with the main contractor on the client's behalf. Architectural Technologists have long been employed in Architectural Practices to work alongside Architects. Many have responsibility for the preparation of detailed assembly and component (production) drawings, which actually determine the work content and sequencing of operations on site. There has been a rapid, recent expansion in the number of undergraduate courses in Architectural Technology.

STRATEGIES FOR IMPROVING PRODUCTIVITY ON SITE

Productivity is the quantitative relationship between production and resources used. It is a concept that is difficult to measure and is often defined by reference to the basic resources used and expressed as output from labour, machinery, or capital invested. These partial expressions can be useful in that they show trends, but do not necessarily give an accurate picture of the overall position, for they do not consider the relative importance of the input resources.

Various productivity improvement strategies are discussed below:

Mechanization Use of machinery for excavation, earthmoving, materials distribution by dumper, rough ride forklift truck, crane and hoist and by specialist equipment such as concrete and screed pump. The reduction in manual effort through usage of small hand held power tools.

Prefabrication Removing the work from the site to the more controlled environment of the factory so that components and assemblies are manufactured off site or by the construction of temporary workshops or production units such as concrete precasting plant.

Improved Management Planned site layout, circulation routes and temporary access such as scaffolds, stairways and hoists can all reduce the time taken by an operative to be in a position to start productive work. Planning and programming techniques should be applied to provide continuity of work at the workplace in order to reduce time spent moving between work locations. Careful positioning of materials supplies and temporary power supplies for power tools and lighting make the workers life easier. These actions, combined with clear communications and records should lead to well-motivated personnel. Many tasks require gangs with mixed skills and team balancing can ensure that work is shared between the team with minimum idle time.

Improved labour efficiency Generally results from management actions and initiatives such as creating a safe, well lit, working environment and appropriate work places with safe access routes and temporary support, providing the most appropriate tools and equipment for the tasks, providing shelter from the climate and good welfare facilities. The level of skill and ability possessed by each individual operative can be enhanced by task specific training, prompt provision of information, and by taking advantage of the "learning curve" by arranging work so that operatives repeat tasks.

There are disincentives to training operatives in improved working methods in an industry where casual, short term, employment is commonplace. The benefits of training are lost at the end of the contract when the operatives leave to work for another firm. The rival contractors, particularly specialist subcontractors, will probably be competing for work with the firm that has incurred the cost of the training.

Improving productivity through design

The scope for improving productivity through improved product design has long been recognized in manufacturing industries. However, improving productivity through architectural design is more difficult. There is the separation of responsibility for design from production with all the inherent disincentives for contractors to share production expertise with designers, for both are competing with commercial and professional rivals to sell their different services to clients.

Bishop (1966) reported the results of studies undertaken to improve site productivity by changes in design. He drew attention to the frequent failures to achieve the anticipated benefits of innovation, particularly of introducing prefabricated components and mechanization, such as spray plastering. The anticipated time savings were not achieved because the irreducible, non-productive time of setting up and clearing away remained as did some of the awkward and incidental tasks associated with preparing for following trades. Frequently the changes imposed unanticipated requirements for accuracy and special fixings in and protection of the preceding work and greater need for frequent "making good" of work damaged by other trades.

Many of the detailed work study investigations undertaken by the UK Building Research Establishment commented on the lack of thought given to the production implications of many designs. The interrelationship of trades often causes problems because each separate activity requires the tradesperson to transport themselves and their tools to the place of work and then away again afterwards. The less work there is involved in each activity, the greater will be the ratio of productive to non- productive time. Furthermore, the greater the number of operations to be performed, the greater the probability of delays, since many of the operations are directly dependent upon the completion of previous activities. Architects were asked to produce designs that: reduced the number of separate operations; provided continuity of work at a workplace; reduced the frequent need for operatives to return to a work place and reduced the need for "making good".

These ideas were further developed by the BRE (See for instance Forbes and Stjernstedt 1972 and Stevens 1987). The BRE teams made extensive use of Work Study techniques and developed computer character reading and analysis of data gained by activity sampling. One of the most extensively reported studies of design rationalization to improve on site productivity was that of the Scottish Development

Department (Anderson and Bailey 1981), which adopted the designed strategies in Table 1, below.

Table 1: Design Strategies Adopted to Improve Productivity

1.	Same building sequence for all houses, despite variations in type, size and layout.
2.	Standardization of details.
3.	Simplified "traditional" construction using readily available materials and components. This reduced the operatives' learning curve that would be associated with new techniques.
4.	Fewer and larger on-site operations; the aim was for each trade to only visit a house once, eliminate return visits and minimize the interdependence of different trades, particularly when installing services.
5.	Dimensional Co-ordination, by restricting the range of sizes to be used cutting and waste was reduced and the fit between components improved.

The designers considered the operational consequences of their designs and modified detail design so as to apply the results of the earlier research.

BUILDABILITY

This word appears to have first entered the English language in the late nineteen seventies, the Construction Industry Research and Information Association (CIRIA 1983) attributes the term, or more correctly, the lack of buildability, to building contractors' complaints about the designs produced by architectural designers for the clients of the industry. The contractors asserted that it was the fault of designers that the cost of building work and new buildings were high and that "building designers were not enabling the industry's clients to obtain the best possible value for their money in terms of the efficiency with which building was carried out" This refusal to accept that building might be expensive led to the contractor's assertion and attempt to blame the other group. Architects equally tell their clients, not surprisingly the same people, that the industry is inefficient because it cannot realize their designs cheaply. This conflict encouraged a major, though largely misguided, research effort into approaches to improving a vaguely defined term. The study group established by CIRIA adopted an apparently simple definition:

> *Buildability is the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building.*

The study was undertaken by interviewing site managers and contractors' quantity surveyors in medium and large general contracting firms and sought to establish general principles for designers.

The view of the study group was that good buildability depends upon both designers and builders being able to see the whole building process through each others eyes, though at no time did the study seek to obtain the views of architectural or other designers involved with the design of buildings. A further study attempted to develop the above guidelines into a coherent set of design principles, Adams (1989).

The study group, of which the principal author was a member, asserted that good buildability leads to major benefits for clients, designers and builders, it may reduce tender prices, increase profits, reduce contact administration duties for architects or

variations or ensure completion to time or improve quality, though no evidence was offered. Not surprisingly some architects found the guidance insulting, platitudinous and unnecessary, for they considered that they had always considered these when developing concept/sketch designs to working drawings.

Typical of the poorly focused debate at that time was a series of articles in the Architects Journal. The architect argues for design to be complete before work commences on site. The structural engineer for architects to spend substantial periods of time on site during their training, The quantity surveyor justifies that profession's role in the UK procurement system, while the contractor complains at being excluded from design input and being provided with poor tendering information. The teacher-researchers attempt to define buildability by extending the scope of the initiative.

The problem is that neither CIRIA or any of the other authors on the subject suggest how the "buildability" of a project might be measured, consequently all suggestions for improvement are exhortations of common sense and good practice, often obtained using "Delphic research methods"- a group of self defined experts sit around and share their extensive experience, again undefined, and pontificate how matters might be improved. A total negation of the scientific method which requires facts to be recorded and measured

CONSTRUCTABILITY

Constructability has been widely adopted in the United States and Australia as an means of increasing cost efficiency. While it has similar intentions to the UK Buildability initiative it has placed emphasis on the development of a management system rather than on techniques and detail of site productivity by design rationalization. It is defined by the Construction Industry Institute (1993) as:

> *Constructability is a system for achieving optimum integration of construction knowledge in the project delivery process and balancing the various project and environmental constraints to achieve maximization of project goals and building performance*

It developed in the very different social and legal structures of the USA where Construction Management is a more commonly used procurement route, architects do not undertake a contract administration role and often limit their design role to concept design, and specialist trade contractors undertake detail design and production of shop drawings. Clearly the emphasis is on the development of management systems and subsystems which enable construction knowledge to be brought further forward in the project delivery process, even including initial consideration by the clients. This overcomes the possible disadvantage of lack clients' knowledge of construction at the early stages, while safeguarding the competitive advantages inherent in the traditional process.

This approach was developed in the totally different culture of the USA for use on all types of construction project, by persons educated in a different manner and familiar with construction management as the method of organizing and procuring specialist trade contractors. Also, in the USA, contractors often have direct links with clients and provide cost advice at an early stage in the design as there are no quantity surveyors in private practice.

WORK STUDY AS A MANAGEMENT SERVICE

The 20th century saw the evolution, development and widespread application of work measurement and method study to all industries. The peak was reached around the middle of the century followed by decline in the extent of the use of work study and the development of the more generic management services function. Currie (1977) contains a highly readable overview of the evolution of work study. The adoption of the techniques was not without difficulty and sometimes resistance was encountered from those whose daily work activities were being monitored. More rigorously referenced accounts of the development of the techniques in Britain and America are available (Shaw (1960) and Barnes (1966)).

The widespread introduction of incentive payment schemes required the foundation knowledge of optimized production methods (equipment and machines, work place arrangement, operative body motions, lighting and temperature control) so that standard outputs could be determined and payment schemes agreed that were satisfactory to both individual operatives and their trades union representatives.

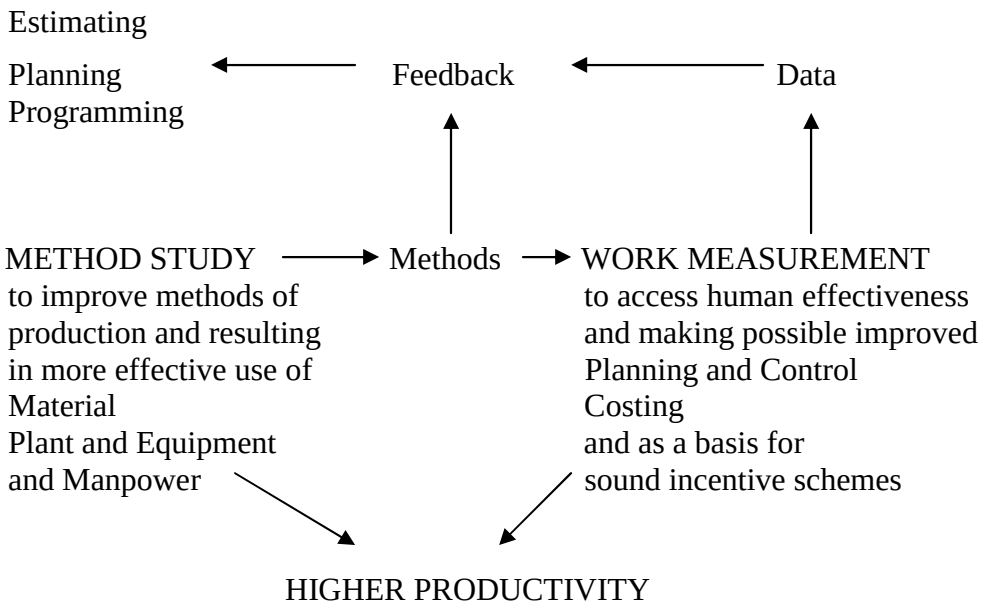

Figure 1: The Ideal Cycle in application of Work Study techniques

The decline of traditional manufacturing industry has been matched by the evolution of the "Work Study" department into the "Management Services" department and the development and use of a broader range of planning and control techniques. This change of name reflected developments in information systems and management control systems made possible by the widespread use of computers and the introduction of quality management systems to improve product quality. The careers aspirations of those specializing in the techniques encouraged them to offer this wider range of tools as a service to their employers. The Institute of Work Study initially changed its name to Institute of Work Study Practitioners and finally to the Institute of Management Services between 1960 and 1980.

Building, under the influence of Frank Bunker Gilbreth, was one of the first industries to be consciously studied in an attempt to improve productivity, yet work study has had a chequered history in the industry. The adoption of "payment by results"

schemes and the concern during the existence of the Prices and Incomes Boards, led to a need for employers to at least pay lip service to the benefits of work study.

Whitehead (1970) observed "it would seem that some firms who nominally practice work study, in fact largely confine their activities to work measurement for bonus schemes". Most textbooks frequently used by students of construction management contain chapters on work study which both describe the techniques and provide examples of their application.

USE AND KNOWLEDGE OF WORK STUDY AMONG CONTRACTORS' MANAGEMENT STAFF

Questionnaire surveys

In recent years, under the supervision of the principal author, two surveys, one in the Birmingham area (Brennan (1995)) and the other on Merseyside (McEvoy (1996)), have been carried out.

Brennan sought to investigate the reluctance of the industry to use work study and repeated the questions posed by Whitehead some 25 years earlier, but achieved a poorer response rate and failed to identify any firms with either management services or work study departments. The replies to the questionnaires returned and a limited number of interviews revealed the same objections as earlier: small size of firms; production subject to the weather; workplace not fixed; would not gain sufficient benefit from investment/could not afford another overhead to the business; each new contract involving a fresh set of problems and a new team; casual labour; no benefit from training; operative resentment at being observed; variation in buildings produced and lack of repetition. Additionally it pointed to the growth of subcontracting of trades that 20 years earlier would have been employed by the main contractor.

McEvoy sought to investigate knowledge and usage of the many techniques of method study and work measurement. Again, no head or regional office management services or work study departments could be located, the study was extended to the automobile and utilities industries. The Management Services departments of these more stable organizations were found to use work study techniques.

Questionnaires returned by managers with HND, degree and CIOB qualifications reported knowledge of: Flow Process Charts; Multiple Activity Charts; String Diagrams; Critical Examination Forms; Activity Sampling; Time Study Recording and Work Rating and Analytical Estimating. They thought the introduction to the concepts they had received as part of their studies had helped them to think about their sites and act in a logical and constructive manner. Some expressed the view that with the decline of trade union influence, direct employment and the recession had removed the need for justification of output targets for bonus payments and their job has become one of negotiation as to the lowest piecework rates acceptable to a highly flexible labour force. Some mentioned that the Critical Examination Technique had been adopted by those practising Value Engineering and Business Process Re-engineering. One reported that he had trained with John Laing and during that time they had closed their Head Office Production Control and Management Services departments.

Interviews with CIOB Candidates preparing for the DMX Examinations.

The principal author served as one of three members of a Chartered Institute of Building panel interviewing candidates on their management experience and level of

responsibility for corporate membership. Interviews were conducted with twelve men, ages ranging from 35 to52. Their job titles included: Contracts Director, Contracts Manager, Site Manager, Contract Surveyor, Site Engineer and Managing Director. They provided access to the experience of ten firms in the North West of England. All the candidates claimed either to be attending a course or undertaking a correspondence course that prepared them for the written examinations.

The Production Management section of the CIOB Direct Membership Examination syllabus for Construction Management includes "The practical application of work study techniques as aids to a managers' decision-making and problem solving exercises" and "Payment systems: Relationship between incentive payments and standard wages, non-financial and financial aids to production, target setting and agreement of savings allocation, advantages and disadvantages of incentive scheme operation." Though the candidates had not completed their courses of study at the time of the interview the panel agreed to these topics being explored for it was likely that the answers would permit discussion of their management roles, experience and levels of responsibility.

Candidates were asked about the use of financial incentives to motivate site operatives. Questions about their knowledge and experience of Work Study techniques based on the questionnaire developed by McEvoy were also planned. Another member of the panel posed questions about the management of safety and the application of the Construction, Design and Management Regulations. All interviewees were aware of the CDM Regulations and some volunteered detailed information about their firms' risk assessment procedures and the development of pre-tender method statements into health and safety plans. None had any familiarity with incentive payment schemes and all responded that all site works were undertaken by sub-contractors working on measured rates. None had any familiarity with method statements obtained by detailed time study observation or experience of the use of work study. When the words "work study" were mentioned two volunteered that they knew people with expertise in it. Such was the ignorance of the topic that it was not possible to explore any of the planned more detailed questions.

Interviews with Site Managers, Site Engineers and Foremen

The opportunity to further explore knowledge and use of work study techniques was taken when visiting Construction Management students on one year work placements on five Merseyside sites. The questions were introduced when the opportunity arose during reviews of the student's progress and walks around the sites. None of the firms directly employed the labour undertaking site work, some even employed freelance setting-out engineers. Again, while a few respondents recalled knowledge from their studies, none had used the techniques, nor had access to specialists within their firms. Their concern was for the sub-contactors to maintain the agreed rate of production and keep to program. They regarded their prime task as being co-ordination between trades and the interpretation of drawings and resolution of conflicts between drawings from different sources. They were not concerned with productivity, only production. It was a matter for the employer of the various trades to ensure the individual operatives were working profitably. All payments to operatives appeared to be either at agreed hourly rates or at measured rates for work completed. Two of the older site managers reminisced about union militancy on Merseyside and the battles bonus clerks fought over standard output rates when incentive payment schemes were introduced during the nineteen sixties. They lamented their current lack of control

over labour and the easy going, late start, early finish adopted by some, particularly when their football teams are playing!

CONCLUSIONS

Productivity is simply not an issue to those managing sites and the many specialist trade contractors actually employing labour are too small to be able to support specialists who advise on training and working methods. There is no interest in the application of work study and no construction firms now appear to employ specialists in the field. More attention is given to pre-tender Health and Safety Plans and their requirements for method statements to ensure safe working are considered and priced. There are no methods of measuring buildability, though with great effort the labour content of alternative designs might be estimated using work study generated synthetics data rather than estimators' rates. No contractors bidding for work in competition can devote the resources to such detailed and expensive a task.

The role of the architectural technologist might be developed to include a work study synthesis and evaluation of time and manpower content of alternative designs. It is only by making a detailed analysis of the likely effects on production that the "buildability" of alternative designs might be appraised. Such evaluation may well be part of the role of a new specialist, the "construction architect" who extends the current role of the Architectural Technologist when developing concept sketches into working drawings. It will probably be necessary for these specialists to undertake site activity sampling studies to fully evaluate the effects of changes made to enhance buildability, and for systematic production development to become a recognized part of the design service offered by architectural practices to clients.

The immediate problem is who pays for such activities when Architectural practices gain new commissions as a result of competitive fee bidding and are concerned to create sufficient profit to remain in business. Ideally the increased ease of construction following rigorous consideration of production development would result in lower tender prices and cost incurred by clients in paying larger design fees be recovered in lower construction cost. Such a trend might be seen to reinforce the need for contractors, offering buildings and their facilities, under the Private Finance Initiative, to be concerned to reduce variability and risk in the initial construction costs as well as ongoing operating costs.

Alternatively, the adoption of Constructability Principles and a trend towards American style management contracting, separate trade contracting and construction management will improve buildability for design with production in mind must be increased if specialist trade contractors are undertaking detailed design. This approach though will also result in Architects losing their role as Contract Administrators and the associated powers under commonly used UK contracts. This will probably be resisted by those architects who are often the first to be approached by occasional clients. Major clients with on-going programs might, however, be able to appoint architects solely as scheme or concept designers and encourage specialist trades to produce drawings for the work they will undertake. These specialists would then compete on both design proposals and price. These specialist trade designers will need to have an awareness of work study techniques for productivity improvement if their firms are to prosper in the long term.

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