The Second CIB W78 + W78 Seminar, Computer Integrated Construction - Seminar 17 - 19 1990 at AIJ in Tokyo, Japan

Title: DESIGNING FOR BUILDING PRODUCTION - An Environmental Modification Model for Computer Integrated Construction.

Authors: T. Cornick, B. Noble, University of Reading, UK

Abstract:

There is a need for equal and integrated consideration to be given to building production, as well as aesthetic, and functional design from the outset of a project proposal. Unless this occurs in practice, computer systems that just reflect current dis-integrated practice will not bring the full economic benefits that is intended.

This paper proposes how simultaneous building design and production analysis and evaluation can be made through the application of a conceptual 'environmental modification model' which ensures that equal consideration is given to all aspects of a building's design. Once "designing for production" is accepted as a design domain of knowledge that can be defined and generalised through rules it can be integrated with other design domains of building and incorporated in computer integrated construction applications.

THE NEED FOR EQUAL CONSIDERATION

In general, throughout all industries, artifacts are produced using a serial process of design and then production. The drawback with this approach is that in many cases, during production, the design as it stands fails as a "production system" and production stops until a redesign proposal is approved so that production can continue. Redesign options after work has commenced are, however, limited by features of completed building work. This means that a design change which is made to suit production not only might not satisfy the original building design's aesthetic and functional intentions but also involves a break in production - which can be costly in both time and money - as at the very worst this may mean scrapping all or a major part of the finished work.

Stopping production, changing designs and scrapping work and then making claims from the customer for "extras" becomes the ethos of an industry around which organisations are formed, business practices are developed, and forms of procurement with risk and price uncertainty are offered to the building client. Any industry adopting this "ad-hoc" approach is carrying a higher than necessary commercial and technical risk of failure through costly waste of resources and rapidly ill considered redesigns during the production process. The technical risk is open ended because the need for a design modification, during production, means that some aspect of the end product design was not thought out for production in the first instance and therefore there can
be no guarantee that its original intention can be realised and appear in the end product. It also implies that production of the whole artifact was not fully thought through and that the redesigns of other aspects may be highly desirable, to increase production efficiency, even though they are not the cause of stoppage.

The cause of the described situation in the Construction Industry in particular is because the designers - usually independent consulting architects and engineers - concentrate on spatial form and appearance and structural and services engineering, by selecting products or systems to essentially achieve their design performance standards and to suit the finished building in use. The builder - who is usually invited to tender for the production when a high degree of the end-product design has been determined - finds during production that parts of the design cannot be built because of work sequence has not been considered or that his pricing was based on incomplete information. Production of that particular element stops, effecting total production causing delay and creating claims and counter-claims for disruption, lost time and alterations. The cost of the work beyond that which was expected and, depending on the form of procurement used and who wins the claim, means that either the client has to pay more or the builder's profit margin is reduced - even to the extent that the project becomes a financial loss. Sometimes the redesign during production is incomplete in the sense that although production continues the intended functional performance is unknowingly changed to detriment of the building in use.

A good example and extreme case of this situation was the Kansas City Hotel and Conference Centre (1) whose walkway element collapsed on loading in use. This disaster, captured on film at the opening of the Centre, was a particularly tragic example of where a simple design aspect stopped production, the stoppage was overcome by redesigning the assembly of the walkway hanger system to enable production to continue, the building was finished but the walkway collapsed when loaded with people because the "rapid" redesign failed to meet the original functional performance requirements.

Events such as these indicate a lack of understanding of production performance by designers, a lack of understanding of functional performance by builders and poor communication - if any - between them during the design development of a building project. This is lack of understanding essentially stems from the fact that each is not responsible for each other's process and seldom does a single firm have total responsibility for the project as a whole. This divided responsibility was highlighted in a report for the Minister of Works (2) with a statement... "In no other important industry is the responsibility for design so far removed from the responsibility for production" as long ago in 1962 in the UK.

The report recommended the urgent examination of relationships between client professions, contractors and subcontractors directed towards improving their coordination and communication and thus economic and technical efficiency in building operations. However, it was still this mis-communication that was shown to be the root cause of the majority of quality problems.
in a recent study of U.K. construction sites (3) - and not because building projects were 'one-offs' and used technological innovation as was commonly thought - as recently as 1987.

Although many efforts have been, and are currently being, made to achieve better integration through improved forms of building procurement (4)(5) and even coordinating the drawing, specifications and bills (6), whilst the current dis-integrated process exists, unexpected design changes during production will continue to be the norm, production will be inefficient and buildings will go on not meeting the clients contractors and consultants expectations in their production cost and operation in use.

Computer system applications of themselves will not change this situation. At best they will have no effect and at worst they will just speed up the process of developing design proposals that will still require redesign during production. Effective computer systems must be based on information technology strategies that themselves based are based on conceptual models that support good communications between the participants in the process to which the computer system is to be applied. It is therefore vital that the correct conceptual model for integrating the aesthetic, functional and production design processes comes first if computer applications are to be developed that support "computer integrated construction".

THE PROPOSAL FOR A UNIFYING MODEL

If the division between design and production is to be reconciled, a view of both the product and the process of building must be developed that can be readily accepted by those responsible for the design and those responsible for production of a building. One view that cannot be disputed by either party is that both in terms of its end-product and process of production, a building is a modification of the environment. This is because building impose changes on the environment during production, as a completed physical object and in its operation in use. These changes are modifications to the environment which can be considered temporary, permanent or transient respectively. Each modification results in a new environment comprising spaces and elements - which are themselves environments - that modify building both as a "process" and a "product". For example, a structural frame "bay" helps to define an enclosed space in terms of aesthetic appearance and functional performance in the end-product of a building as well as helping to define the limitations of a working environment during building production.

The framework of an "environmental modification model" - which has many similarities with that proposed by Broadbent (7) for Computer-Aided-Design in the 1970s - is therefore proposed as a unifying conceptual structure for giving equal consideration to production factors, as well as aesthetic/functional factors, during the design development of a building project right from its initial conception. The "model" sets levels of simultaneous consideration for both aspects of design in an integrated an orderly manner and in a progression from outline concept to detailed assembly of the building. This encourages the user to
ask and answer questions about on- or off-site production processes, every time an end-product modification is proposed to suit aesthetic/functional design. For example if a brickwork elevation is proposed to suit aesthetic proportion and material colour and texture in appearance and achieve structural functional performance based on certain "rules" of design, "rules" for production could be added for simultaneous consideration at any level from an outline building form to particular detailed brickwork elements using special-shaped brick components with specific material characteristics. It is now possible to encapsulate such rules for this or any other elemental part of a building in computer-based expert systems with a graphical interface to the user (8).

The "model" proposes five levels of "environmental modification", each nested to the one above so that the outcome of simultaneously considering design to meet production requirements as well as aesthetic/functional requirements creates a framework for simultaneous consideration at the next level of detail down. From top to bottom the levels progress in detail from the "widest" of environments - the natural and built environment to the "narrowest" - the chemical/physical characteristics of individual materials and components assembled in a constructed element.

The Environmental Modification Model

1
natural /built environment

2
building configuration

3
element

4
component

5
material

---

FIG 1 The Environmental Modification Model

The essential simultaneous consideration given at Level 1 is - surrounding buildings and land, climatic and sensory conditions, site topography, geology and natural (or built) features, access and proposed outline building form, location and site layout.

The essential simultaneous consideration given at Level 2 is - size, shape and arrangement of spaces and their
enclosing, dividing and servicing elements,

The information to be processed at these Levels 2 and 3 will be particular to the building project...

The essential simultaneous consideration given at Level 3 is -
- detailed size, shape and arrangement of the enclosing, dividing and servicing elements and elements within elements,

The information to be processed at Level 3 will be particular to the building project and specific to general building standards requirements and characteristics of building components and materials...

The essential simultaneous consideration given at Levels 4 and 5 is -
- detailed size, shape and physical/chemical characteristics of assembled materials/components and plant movement and assembly.

The information to be processed at Levels 4 and 5 will be specific to general building materials, component and plant and their physical/chemical characteristics.

It can be seen therefore that when information is to be processed - either manually or by computer - it is extremely important at Level 3 to manage the integration of general specific data about building, materials and plant with particular project data about the building site, location and orientation, material finish and form (10). Unless this can be effectively carried out, the chances of reducing - and even eliminating - "quality problems" in construction are remote (11).

However, even if the information throughout the building project process is effectively managed to achieve "general" and "particular" data integration, "quality problems" in, or caused through, production will continue to occur unless "production" as a process is considered as part of building design. Production as a "design domain" is part of a proposal for a European study for computer integrated construction (12)

**Designing for Production using the Environmental Modification Model**

Designing for production means considering a building as not only a "system of many systems" of a finished end product (13) - an approach already being proposed for the computer modelling of building (14) - but also as a "system of a changing production facility" and taking the view of "process" rather than "product" about a building. Designing for production in building is therefore concerned with the analysis, synthesis and evaluation of the proposition of an emerging building - from clear site to commissioning - and requires the following steps to be taken -

**Step 1 -**
- identification of the building site features that are significant for production, in terms of topography, geology, surrounding natural and built features, and access, in Level 1,
- identification of the building configuration features that are significant for production, in terms of material finish and content, spatial arrangement and location, in Level 2,
identification of the detailed building elements, and elements within elements, that are significant for production, in terms of position and fix of materials and components, in Level 3,
identification of the detailed materials and components and plant that are significant for production, in terms of size, shape, weight and physical/chemical characteristics, in Levels 4 and 5.

Step 2 -
define, drawing upon information at all Levels but giving emphasis at each Level according to project phase, the requirements for man and machine to produce a building taking account of such general things as mobility, geometry, power, resistivity and pollution control.

Step 3 -
describe, concurrently with the propositions emanating from other design domains such "functional spatial arrangement" - the means of transportation/access; material and component storage/flow; element to element, component to component/material assembly sequence, fixing and sealing; and element protection/commissioning.

Step 4 -
assess the proposed changing production facility design, at any project phase and to any degree of detail, against the proposed project cost, time and aesthetic/functional requirements.

Step 5 -
iterate through Steps 2, 3 and 4 until all project requirements can be fully met.

In conclusion

Computer integrated construction requires that the information from different design domains can be interrelated in a systematic manner. Unless one of those domains - whether represented by data-bases or expert systems or both - concerns "designing for production", the computer applications will be incomplete as an aid in solving modern building "quality problems" in production. A common conceptual model that embraces the general production process in construction is required before meaningful computer integrated applications can be formulated. This paper has proposed what needs to be considered in designing for production and, of equal importance, how that consideration can be made simultaneously with designing for aesthetic and functional performance in building.

References

1 Disasters, UK BBC Horizon Programme

Construction Management Forum Final Report, University of Reading, November 1990 (forthcoming)

Coordinated Project Information for Building Works, UK Coordinating Committee 1987.


