Chris ABEL
School of Architecture
National University of Singapore

Ditching the Dinosaur Sanctuary: seventeen Years on

Abstract

In his paper, 'Ditching the dinosaur sanctuary' (Architectural Design, August 1969), the author brought architects' attention to the computerized, flexible production machinery then being introduced into the machine tool and other industries. Similar production technology, the author had argued, could in principle be used to revolutionize the building industry, doing away with the need for standardization, and negating many of the ideological assumptions underlying the industrialized building movement.

The author reviews his original prognosis in the light of changes in architectural theory and practise in the intervening period, and recent advances in building technology. The application of computerized machinery in the production of components for the Hongkong and Shanghai Bank headquarters is described as a major breakthrough in purpose-made industrialized building. The use of such 'smart' tools, it is claimed, heralds a new union of craft and industry.

The author concludes, nevertheless, that the potential of the new building technology may not be fulfilled unless parallel changes are undertaken in architectural practise and education, bringing both more into line with practises in industrial design.

Modernist ideology versus industrial realities

My interest in the technological developments described at this meeting is primarily that of an architectural educator and critic, and dates back to my student days in the late sixties. At that time, it may be recalled, Modern architecture, though already in doubt, was still the dominant force, both in theory and in practise. As an integral part of that force, the industrialized building (IB) movement was also still in very good shape. The collapse of the Ronan Point apartments in the U.K. and like events were yet to have their impact on either public consciousness or professional conscience, and it still seemed to most architects that the way to cope with the 'mass housing problem' - the term itself embodies the assumed solution - was through the industrialized technology of the mass production line.

However, though a devoted believer in my early student days, by the late sixties I had begun to have grave doubts about both the quality of the buildings and environment produced by systems building designers, and the claimed rationality of the IB movement itself. Serious weaknesses in architects' understanding of industrialized technique and methodology led me to believe that the basis of the IB movement lay more in architectural ideology than in any firm grasp of industrial realities (1). In particular, I could find no industrial rational for architects' attempts to promote modular co-ordination of component design, and all the attendant efforts to impose limited ranges of shapes and sizes on the building industry. I learnt, for example, that the rules of dimensional co-ordination as interpreted by the IB enthusiast, showed 'little authentic contact with engineering', that control over tolerances and '..... interchangeability has been achieved in mechanical engineering without the module' (2). Moreover, I learnt that technically and economically efficient products do not result from trying to design a component that will fit every other like component on the market, but from the integrated design of a limited family of components, such that the best performance specification for the whole may be achieved. It is a principle that Auguste Prouve, almost alone amongst architects, understood very well: 'Machines are seldom built with parts selected from various sources', he said, 'they are aggregately designed' (3).

I concluded that the root cause of all these preoccupations with standard shapes and sizes and consequent misunderstandings of the real problems of designing for industry, lay with a very architectural obsession with geometrical systems of order and proportion. The following statement typified the prevailing view:

> In a building where all the parts are of different shapes, the visual effect is one of the greatest possible disorder, indeed chaos. Order can be introduced by the repetition of similar shapes, and the highest order results when comparatively few shapes are used, repeated as often as possible.
>
> P.H. Scholfield (4)

Whether or not one shares this view of architectural aesthetics is beside the point. Unquestionably, it has a long and respectable pedigree in architectural history. What is of concern here is that such a view could be allowed to distort architects' interpretation of what is or is not possible with industrialized building technology, to the extent where the quality of their efforts was seriously impaired.

Free market myths

But if architects' obsessions with modular co-ordination was based primarily on aesthetic preferences, other manufacturing constraints on variety production were real enough. The amount of pre-planning and capital investment involved in any major industrial undertaking, such as in the automobile industry (for long the favourite model amongst Modern architects), required that the consumer had to accept a severely limited choice of product. As Kenneth Galbraith (5) has explained, in such circumstances, there can be little room for consumer preferences. The consumer oriented, free market economy was just another myth. The reality instead was that both market and consumer were, by necessity, tightly controlled, in order to make sure that consumers bought whatever was being proferred by the manufacturer.

However, in the late sixties, there began to emerge signs of a new kind of manufacturing technology which promised not only to upturn Galbraith's thesis, but also to pull the rug out from under the IB movement. The impetus behind the new technology was the need to meet increasing demands for small batches of components, demands that the fixed, one product mass-production line could not meet.

At that time, robots were already being introduced into several manufacturing industries, and were even handling bricks in one case (6). But it was not so much the glamorous robots, with their human-like movements, that represented the most significant advances in automated production. The reprogrammable robots introduced a new kind of flexibility into the production line, but their impact on the total production process was limited. The most important advances at that time were to be found in the machine tool industry. Numerically controlled machining centers capable of machining operations of variable complexity were making dramatic increases in the speed and flexibility of small batch production of metal components. But it was even then not until a number of such machines were strung together in a fully automated production line, as in the Molins System 24 example (7), that the full potential of high volume, variable automated production was realised. Metal parts could now be shuttled more efficiently between a group of machine tools of differing capabilities, all under computer control, the whole process continually changing according to what the market required.

Toward the Cybernetic factory

Exciting as these innovations were, there was much more in store. Such flexible systems of automated production were only the first essential rung in what Stafford Beer (8) described as the 'cybernetic factory' to come. the complete cybernetic factory comprised a hierarchy of increasingly complex levels of automated control, reaching up from the factory floor, through the levels of production design, management and marketing, to create a sensitive industrial organism capable of adapting to the vagaries of a free market-oriented economy, and of improving its performance along the way (9). At that time, it was a remarkable vision by any measure, and as remote from the conventional model of industrial production assumed, but misunderstood by IB enthusiasts, as it was possible to be.

Beer forsaw that that same conventional model had had its day, and, like Galbraith, understood that 'such industries could only survive by companies paying publicity men enormous sums to make less mutable an environment to which the (industrial) organism cannot adapt. If the dinosaur can no longer live in the world, the world must be turned into a dinosaur sanctuary' (10). But whereas Galbraith could only call attention to the lie behind so-called market economies, Beer showed the way to a viable alternative.

It seemed to me then that it would not be many years before such developments found their way into the building industry. As it was, I underestimated the length of time required by more than a decade, such is the relative slowness of that industry to respond to technological innovations. Even now, it appears that a complete cybernetic factory for the building industry is not yet at hand. But the gains made are significant ones, and the implications far reaching.

To recap, efficient product design and manufacture requires the integration of components so as to meet the highest possible performance specification for the whole. This in itself suggests that performance specifications cannot be too generalized, but should meet a limited range of particular user needs. Conventional mass-production methods also impose their own technological and economic limitations, with the result that the consumer has to accept a limited choice of product. In contrast to this conventional model of industry, the flexible nature of the computer-controlled production machinery now available means that 'the manufacturer need no longer rely on a passive market to ensure justification for an efficient production line ..... Instead of tuning the consumer to the machine, we can now tune the machine to the consumer' (11).

Union of craft and industry

But if the IB movement was always founded on shaky grounds, it must also now be recognised that the architectural issues of the mid-eighties are not the same issues as those that dominated the late sixties. Belated recognition amongst architects of the poor quality of system building, as well as amongst the unfortunate users, has been one of the contributing factors in the demise of the Modern Movement itself. In the age of Post-Modernism, the number of architects laying claim to a belief in a universal architecture of standard forms appropriate to standard human needs, has, fortunately, considerably diminished, if by no means altogether vanished, and the implications of the post-industrial revolution before us have consequently also to be rethought.

A key issue confronting architects today is the drastic change in the relation between the design and manufacturing processes which the new computerized technology is bring about. Ever since the nineteenth century, when mechanization began to have a serious impact on the building industry, the architect has been increasingly distanced from the processes by which the parts of buildings are made. The English Arts and Crafts Movement was a nostalgic reaction to this trend, which was recognised by William Morris and others as symptomatic of the more general trend towards human alienation in an industrialised society (12). Walter Gropius later saw it differently, and tried for a more construction adjustment in the Bauhaus School. However, Gropius's approach was based in part on expediency, having to reconcile the early craft orientation of Bauhaus teaching with the emphasis on industrial design which the School later came to represent (13). In a deft sleight of hand, he described the continuing need for craft training as follows:

> The teaching of a craft is meant to prepare for designing for mass-production. Starting with the simplest tools and least complicated jobs, he gradually acquires ability to master more intricate problems and to work with machines, while at the same time he keeps in touch with the entire process of production from start to finish.
>
> Walter Gropius (14)

The implication is that both craft and industrialized production methods belong together on the same scale, ranging from simple to complex tools of production. I accept the basic idea for what it promised, but of course at the time the statement was made it glossed over some enormous differences, not just in the scale of production, but in the degree of human control the designer has over the production process, and not least, in the degree of individuality that can be achieved in the end product.

Now the extraordinary thing about the new flexible, computer controlled tools of production, is that these incongruities tend to disappear, and the scale from craft tools to automated tools reflects a true continuum. For now we can produce factory-made components that are also tailor-made - a previous contradiction in terms - according to specific designs for specific buildings. in other words, the potential is there for the designer to regain a level of control over the industrialized building process previously thought possible only with craft building techniques.

I say the potential is there, for it is far from clear that the architectural profession, and the schools of architecture, are currently in any position to take advantage of the tremendous opportunities ahead. We have already noted that even when architects have sought to harness conventional industrial power to the production of system building, with rare exception, they failed to grasp the essentials of manufacturing. The relative success of Auguste Prouve's work has a great deal to do with that architect's early personal experience on the shop floor. More generally, architects have come to accept an increasingly circumscribed role as form makers, the design of the building components they use being left to others, to the point where the selection of components from a catalogue is all that is left of most architects' contact with the building industry. Where architects do get involved at all in the making of new components, it is now usually in the writing of performance specifications, an understandable limitation in the light of previous excursions into industrialized building, but a sad reflection on the current state of affairs.

The architect as industrial designer

A notable exception is the practise of Foster Associates, and I should like to take the work of this outstanding team of architects as a relevant case study in what can be achieved in the use of the new production technology, given the right approach.

Norman Foster has achieved justified world-wide recognition for his willingness to push building technology to its limits. Nevertheless, till recently, he and his team also confined themselves to making the most out of ready-made components, though put together with an imaginative understanding of the industrialized materials at their disposal, and rare attention to detail.

However, with his commission for the Hongkong and Shanghai Bank headquarters, Foster and his team have produced a very different kind of building, requiring an entirely new approach to the design and production process (15). What distinguishes the new approach, which Foster refers to as 'design development', is its similarity to industrial design rather than to conventional architectural practise. Almost all of the components used in the Bank building were designed by the Foster team itself in close collaboration with the manufacturers' own design and shop floor people, an exhaustive process which included the making and testing of full prototypes (16).

But it was in the design and making of the special aluminium cladding for the steel structure, that the Foster team achieved what is, especially for this gathering, their most important breakthrough in industrialised building technology. The masts, trusses, suspension rods and cross bracing of the Bank's suspension structure required layers of corrosion protection and fire-proofing materials, which in turn required some kind of maintenance-free cover. In order that the structure underneath should be still expressed as directly as possible, it was necessary that the finished aluminium cladding should follow the complex geometry of the structural members as closely as possible, necessitating the design and production of thousands of separate pieces of cladding, with enormous variations in shape and size. The complexity of the geometry in some cases was difficult enough to even visualize, let alone manufacture.

Problems such as these called for a major retooling by Cupples, the U.S. firm selected for the job, which included the acquisition of computerized, variable presses, as well as a number of robot welders. The benefits accrued from this massive investment in new technology included months of labour saved in drawing board work and the rejigging that conventional presses would have required, as well as distortion-free welds - no 'heat sinks' - in assembly. More than that, given the nature of the task and the constraints of the 'fast track' programme into which the whole operation had to be fitted, it is doubtful that this unique job could have been completed satisfactorily at all without the help of these 'smart' tools.

It is, I believe, the largest application to date of computerized production machinery to a single building project. But it is in the relation between the method of design used by the Foster team and the use of these smart tools that the real significance of this case study lies, and on which I should like to focus your attention. For here we have one of the first true examples of the unification of craft and industrial processes, which Gropius alluded to, but which is only now made possible by the new technology at our disposal.

Note again, all that this case study involves: Architects working in close collaboration with industry to design, test, produce and assemble an enormously varied range of building components, for one building project only, using fully automated but flexible tools of production. What all this adds up to is craftsmanship on a mega-scale, and it completely reverses those industrial developments which underpinned Modern Movement dogma, and which have led to architects' alienation from the tools and products of the building industry upon which they rely.

CAD + CAM = Craftsmanship

The question that naturally arises is, given the amount of time and care Foster and his team were willing, and able to give to this project, is the design development process replicable by less committed architects, perhaps working for less committed clients and with less adventurous manufacturers? I believe that it is, but that we shall have to await further advances in computer-aided design, as well as in the manufacturing technology itself, before we see the model accepted as normal practise. Some portion, possibly a large portion at that, of the unique expertise the Foster team, as well as the manufacturers, brought to bear on the project, will have to be taken up by automated 'expert systems' and other advances in artificial intelligence (17), if the approach is to become more widely available.

It might be asked if this further degree of computerization represents a loss of human control, and thus a regression from the craft-oriented model of design and production just described, but I do not think that it does. I prefer to think of such aids in the same way Stafford Beer described the computers helping to keep his cybernetic factory running smoothly, as 'intelligence amplification' (18). Just as we recognise true craftsmanship when we see it, as the result of a combination of artistic intelligence and technical dexterity, then so is it also possible to represent both developments in CAD and CAM as extensions of the same human facilities of control over the quality of the end product.

Robots on site

To these innovations we can now add the more recent encroachment of computerized automation onto the building site itself. The first robot to be used for on-site construction purposes in Japan was put to work only three years ago, but already, several types of robots have been developed to deal with different construction tasks. They range from assembly robots which help to put building structures together, reinforcement and concrete laying robots, interior finishing robots, including robots for concrete slab finishing and spraying fire-proofing materials, and exterior finishing robots, as well as drilling and cutting robots used for heavy excavation and engineering works (19).

The movement of robots from the relatively safe and predictable environment of the factory floor to the more rigorous and constantly changing environment of a construction site, represents a considerable increase in demands on the technology, especially on the sensory capacity and durability of robots, over that needed for their industrial cousins. The reasons cited to justify their use in these more strenuous conditions, which will inevitably entail the replacement of large numbers of construction workers, include savings in human accidents and improvements in working conditions, increases in productivity and sometimes in the quality of the work carried out, and in Japan, the need to overcome a shortage of skilled manual labour (20). Preliminary studies suggest that widespread use of construction robots in most areas of the construction sequence is not only technically feasible, but economically desirable (21).

There is little question that the prospect of a fully integrated, computerized design, manufacturing and construction process summons up an intellectually thrilling vision, in which, at its ultimate, on-site robots complete the reinforcement of human intelligence and craft skills described earlier. Making the construction process more amenable to the use of such robots can also be expected to have significant repercussions on the design and manufacturing processes themselves, until such time as all three levels of operation are brought into line with each other.

Pandora's box

At this point, though, I must confess to some doubts. Aside from the economics of the issue, there has always been a reasonable, though not indisputable case, for replacing human workers on the assembly line, by robots and other machines, on the grounds that neither the nature nor the conditions of the work involved afford much in the way of human satisfaction. But can this be said of the work involved in getting a building up? I am not so sure. Dirty work it usually is, often hazardous too, but hardly boring. Each job is never quite the same, and the problems which place extra demands on construction robots' intelligence and sensory capacity also place stimulating demands on the intelligence and sensory capacities of the human workers who have so far carried out such jobs.

No doubt, there will be strong economic arguments in favour of displacing manual workers in this area, as in other industries. But we should be careful to distinguish, for example, between cases where there is a genuine shortage of skilled labour, or the work involves levels of danger or some other conditions which are humanly unacceptable, from those where the social costs outweigh the economic gains.

Clearly, this is a Pandora's Box, and part of a much larger group of social problems and issues which have to do with the impact of automation on society as a whole (22). But better that we should open it now, while there is still time to contemplate what we find there, than later, when it might be too late to influence events.

Which brings me back to another pressing social issue of the same order, that is, the impact all this is going to have on the future role of the architect. The difficulties of adjustment with which the architect is now faced cannot be overestimated. It is going to take an equivalent revolution in architectural and educational practises for architects to come to grips with the post-industrial age these technological advances represent. I have described the practise of Foster Associates as a plausible model for the sort of approach needed by architects if they are to take advantage of the new technology. But given the widespread lack of concern with even conventional technology, typical of so many schools of architecture, it is hard to be confident about the future. Foster and his team had to educate themselves for the new role they invented, and no doubt other architects wishing to follow suit will likewise have to learn their new skills on the job, after they have put their formal education behind them. Gropius's ideal of educating architects and others to design in partnership with industry, despite all the wrong turnings since taken by Modernists, was never more relevant than today.

A concluding note on aesthetics

I began by pointing to the importance of architects' aesthetic preferences in shaping their attitudes towards industrialized methods of production, and I should like to end on an aesthetic note.

I have already remarked that not so many architects today are hung up on standard forms as they were seventeen years ago. As a so-called 'High-Tech' architect, Norman Foster is widely assumed to be still clinging to those Modernist preferences that Post-Modernists now eshew. But the observation is only true of his earlier work, and it would be a mistake to view the Hongkong and Shanghai Bank headquarters in the same terms. As I have explained elsewhere, the design of the Bank incorporates significant regional attributes of space and form (23). And while such attributes cannot be connected directly to the use of the advanced production methods involved, they are certainly an outcome of Foster's general shift from the use of ready-made components towards a craft oriented approach. This shift can in turn be interpreted, at a higher level, as a part of a new, more balanced architectural philosophy which allows the architect to pay due respect to what is particular to a place and regional culture, as well as make the most of the universal, technological culture we all now share.

Foster's latest work therefore suggests a convincing resolution of what are usually considered to be opposing architectural tendencies. And while the increase in variety which the new production technology makes possible does not in itself guarantee high quality design, or respect for cultural and place identities, it will certainly facilitate those architects capable of responding to the unique demands and characteristics of specific building programmes and environments.

Finally, I predict that such developments in CAD/CAM as have been discussed here will eventually also lead to a resurgence in the use of ornament in buildings. Generations of architects have been so brainwashed into thinking of ornament as something superfluous, of quaint historical interest only, that it is still beyond most architects' capabilities to even consider the use of ornament in architectural design. But there has never been any human culture without some form of ornamental art to embellish its artifacts and buildings (24), excluding, of course, that restricted, puritanical culture invented by early twentieth century architects. And even here, there were exceptions, notably Frank Lloyd Wright, who, for good reason, never considered himself to belong to that culture.

Aside from a dubious ideology which equated the use of ornament with committing a 'crime', it was also taken for granted that ornament was a craft production, and that contemporary economics and technology forbade it. But, given the new production technology, is there any good reason now to pretend that ornament has no place in contemporary architecture? I believe not, and that if suitable computerized craft tools are put to the task, the technological and economic problems can be overcome, leaving the ideological excuses exposed for the fraud that they always were. Make no mistake, this is no trivial or secondary issue. If architects can grasp this opportunity, along with the others, they will have regained some very potent means of humanizing their buildings.

These, then, as I see it, are some of the more significant implications and opportunities which the current technological revolution presents us with. Certainly, they all represent a direct challenge to accepted architectural and educational practises. It is going to be a very long haul indeed before we see the full potential before us realized. When we do, I suggest that that earlier revolution trumpeted by the Heroes of the Modern Movement will have to be re-evaluated for the very misleading event it is. For all the rational and scientific trimmings that went with it, the ideal of mechanization at the heart of Modern architecture has turned out to be just another dinosaur, destined for extinction, and to be superceded by a more adaptable species.

Notes

1 This and the following earlier viewpoints expressed by the author are abstracted from, Chris Abel, 'Ditching the dinosaur sanctuary', Architectural Design, August 1969. Many key arguments from that paper, relating to ideological and practical flaws in the industrialized building movement, have since been elaborated and verified in: Barry Russell, Building Systems: Industrialization and Architecture, John Wiley and Sons, 1982.

2 J.F. Eden, 'Metrology and the module', Architectural Design, March 1967.

3 Auguste Prouve, UIA Symposium address, Delft, 6 - 17 September 1964, reproduced in: Towards Industrialized Building - Proceedings of the Third CIB Congress, Copenhagen, 1965, Elsevier, 1966.

4 P.H. Scholfield, The Theory of Proportion in Architecture, Cambridge University Press, 1958.

5 John Kenneth Galbraith, 'The new industrial estate', The Reith Lectures - 1, The Listener, Thursday, November 17th, 1966.

6 H.A. Ballinger, 'Machines with arms', Science Journal, October 1968.

7 D.T.N. Williamson, 'A new way of making things', Science Journal, June 1968.

8 Stafford Beer, 'Towards the cybernetic factory', in H. Von Foester and G.W. Zopf, eds., Principles of Self-Organization, Pergamon Press, 1962.

9 Stafford Beer, 'Machines that control machines', Science Journal, October 1968.

10 Stafford Beer, 'Toward the cybernetic factory', ibid.

11 Chris Abel, ibid.

12 Kenneth Frampton, Modern Architecture, Oxford University Press, 1980.

13 Reynar Banham, Theory and Design in the Machine Age, The Architectural Press, 1960.

14 Reynar Banham, ibid.

15 Chris Abel, 'A building for the Pacific century', Architectural Review, April 1986.

16 Colin Davies, 'Building the Bank', Architectural Review, April 1986.

17 Lionel Feigenbaum, 'Advances in computer science and technology', lectures delivered at the National University of Singapore, 24 - 25 March 1986. See also Rienk Schijf, 'Expert computer systems in architecture', Singapore Institute of Architects Journal, April 1986.

18 Stafford Beer, Cybernetics and Management, The English Universities Press, 1967.

19 Seishi Suzuki, Tetsuji Yoshida, Takatoshi Veno, 'Construction robots in Japan', paper at The Second Century of the Skyscraper, Third International Conference of the Council on Tall Buildings and Urban Habitat, Chicago, 6 - 10 January, 1986.

20 Seishi Suzuki, et al, ibid.

21 A. Warszawski, 'Analysis of building construction for robotization', and Irving J. Oppenheim, 'Research activities in construction robotics', papers at The Second Century of the Skyscraper, ibid.

22 For a broad accound of the pros and cons of using robots in industry, see Leopold Froehlich, 'Robots to the rescue?', Datamation, January 1981.

23 Chris Abel, 'A building for the Pacific century', ibid.

24 Ernst Gombrich, A Sense of Order, Phaidon Press, 1982.

Chris Abel

School of Architecture
National University of Singapore
Kent Ridge
Singapore 0511

Phone: 7723454
Telex: NUSPER RS5111

The Hongkong and Shanghai Bank headquarters, Designed by Foster Associates. State of the art computerized presses and robot welders were used in the manufacture and assembly of the aluminium cladding, made up of thousands of separate pieces of different size and shape.