BARRIERS TO THE APPLICATION OF ROBOTICS AND HIGH LEVEL AUTOMATION WITHIN THE UNITED KINGDOM CONSTRUCTION INDUSTRY

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ABSTRACT

The British construction industry has scarcely begun to consider the application of robotics and advanced automation to the building process. It is both the traditional organisation and the culture of the building site which inhibit advanced technological development and its application in the UK. Organisational forms are based on separateness, in particular the separation of the responsibility for design and construction. The application of robotics, especially in its more advanced forms, requires control over design. The industry's investment in R&D has been inadequate. This paper will argue that technological push is insufficient to achieve robotic development in the UK construction industry. Many other changes will be required - organisational, managerial and cultural.

1. INTRODUCTION

In the United Kingdom, robotisation of the building process has yet to be given serious consideration by the construction industry. Few papers have been published on the subject and only a very small number of research projects have been commissioned. Why is it that Britain is lagging behind Japan, the acknowledged leaders, in the development of construction robotics, when the technological competence could easily be within her grasp?

In any situation, 'technology push' alone is insufficient to guarantee the successful implementation of a new technique. Ball (Ball) suggests that it is the organisational structure of the industry which fixes, for particular historical moments, the nature of the product and how it is produced. Other factors also influence changes in production methods, such as economic viability, the cost and availability of labour, investment strategies, and the market condition.

In Japan, the organisational structure of the industry and the economic and social environment is right for the promotion of advanced mechanisation. It is the organisation of the British construction industry that stands in the way of such development. The purpose of this paper is to identify the major barriers to the successful development of robotics in the UK

construction industry, and from that determine the changes that are necessary before the implementation of robotics can be sustained.

2. THE SEPARATION OF DESIGN FROM PRODUCTION

The contracting system that emerged in the 19th and early 20th century led to the separation of the responsibility for the design and the production of buildings. Those responsible for design - architects and engineers - were considered to be the industry's professionals, and their conduct was controlled by inherently conservative professional institutions. A class division existed between the professionals and the contractors who organised and performed the menial building tasks.

Today, that traditional contracting system is just one of a number of alternative forms of building procurement available to the client and the roles of the professional parties are becoming less rigid. However, the separation of design and production still persists.

The growth of management contracting in the seventies and eighties has reinforced the independence of design. Management contracting, with the main contractor taking on the role of a consultant, can be seen as the ultimate extension of sub-contracting, widening the gap still further between those who design and those who perform the task of building.

2.1 The Use Design and Build Contracts

Since the mid-eighties, the UK has witnessed a significant increase in use of so-called 'design and build' contracts for all kinds of building projects. Currently, design and build projects account for an estimated 20-25% of the total market for all new work. These contracts provide the building client with a single point of responsibility for design and production. Increasingly, design and build is seen to offer important commercial benefits over the discredited traditional system based on fragmented responsibility, which so often resulted in confrontational styles of management.

However, the single point of responsibility for design and production does not yet mean any integration of the two processes. In a survey of design and build contractors, carried out earlier this year by a student of the Polytechnic of Central London, only 3 of the 20 companies surveyed, offered 'pure' design and build, ie only three contractors conducted all design work in-house. The remainder, either wholly or in part, employed external design consultants. In many instances, clients still choose to nominate designers, and in some cases, design and build contractors are not engaged until the design has been well developed. Under this system, the design work is sub-let by the contractor to architectural and engineering design practices in a form not dissimilar to subcontracted work packages for the construction of the building.

2.2 Robotic Applications and the Control of Design

Within a few years, single task robots may become commercially available as an alternative to site labour or lower order mechanisation, especially if Japanese companies decide to export their hardware. We are aware that Shimizu Construction of Japan have already been using a single task robot in the UK. These machines will make only limited demands on the design of the building.

Beyond that, the development of advanced flexible robots is clearly feasible. The application of any robot directly controlled by computer-aided design and management systems, or requiring dedicated product design will not be easy in those parts of the British construction industry which maintain the separation between responsibility for design and production. If, at some point in the future, design dedicated machines, or machines requiring any level of standardisation of the product, are to be used, the building producer (as opposed to the process manager) will require control of the design. The industry as currently organised does not allow for this possibility.

3. LACK OF INVESTMENT IN R&D

3.1 Rationale for the Failure of the UK Construction Industry to Invest in R&D

Studies related to innovation in the UK construction industry are rare and one of the most significant is now over 30 years old. Marion Bowley's (1966) study of innovation in the British building industry (Bowley) determined that the separation of responsibility for design from the responsibility for production was a serious defect of the normal method of organising the building process. She argued that this not only created obstacles to the introduction of innovations, but also diminished incentives to such an extent that no party to the building process was significantly motivated to introduce any major innovations.

Innovation involves risk and there needs to be a sufficient incentive to undertake risk (for example, to gain competitive advantage over another contractor). Innovation also needs organisations with sufficient financial resources to undertake the development work.

Bowley argued that designers do not have the resources to invest in serious research and development. Contractors have the resources but, without control of the design process, do not generally have much incentive.

In a critique of Bowley's work, Ball (Ball) emphasises that while she presents her arguments in an empirical and pragmatic way and there is no explanation of the reasons why design and

production have remained as rigidly separate as she argues they are. This is an area where serious research still needs to be conducted.

3.2 R&D Funding

Thirty years on from Bowley's work, construction research and development remains at a low level and the proportion targeted at mechanising the building process is minimal. Total UK expenditure on construction R&D in 1985 was estimated at £146 million (including materials and components). This was approximately 0.7% of construction turnover. The equivalent figure for all industries in the UK was 2.3% (NEDO).

Construction industry research in the UK is both publicly and privately funded. In 1985 the private sector contribution was estimated at £90 million. Of this, £80 million was invested by the manufacturers of materials and components. £6 million was expended by contractors (part of this was contracted work and not direct R&D), and the remaining £4 million by private laboratories and consultancies (NEDO).

This expenditure has to be contrasted with Japan, where the contractors invest heavily in R&D. Just one of the Big 6 Japanese contractors will commit over three times the investment of all the UK contractors combined.

3.3 NEDO Report - A Strategy for Construction R&D

In 1985, the National Economic Development Office produced a Strategy for Construction R&D (NEDO). This report stated that construction R&D in the UK is inadequate, with minimal coordination of funding, activities and facilities, and poor dissemination of information. Existing knowledge is frequently not applied. In recent years research has been concerned with matters of organisation and structure of the industry, and increasingly preoccupied with construction failures and the growing demands on repair and maintenance.

3.4 The Need for Commercial Advantage

Many companies and practices in the industry do not participate in R&D. Research and development does not appeal to contractors if they find it difficult to take commercial advantage of their own innovations. It remains to be seen whether the recent trends towards the use of design and build contracts will enable contractors to exploit some of the commercial benefits accruing from R&D.

4. THE NEED TO UPGRADE SITE CONDITIONS

The construction industry in the United Kingdom has a poor public image. It is seen as being technologically backward, labour intensive, and the building site is renowned for its

hostile environment. Construction is considered a hard and unattractive industry in which to earn a living. Conditions are improving, but the 'culture' of the UK industry is not generally attuned to the need for an ordered, controlled environment in the building workplace, a prerequisite for any significant introduction of high level automation. The expectation, even of the workers, is that the building site will always be a dirty, uncomfortable place to work.

The Japanese industry has proved conclusively that building operations can be carried out in conditions more akin to a well run factory. A frequent response from managers in the UK industry when introduced to Japanese style site organisation is that the British client would not be prepared to pay the additional cost necessary to achieve the higher standards. To what extent these additional costs would be off-set by more efficient working is not known, but this should be secondary to achieving an environment conducive to high production standards and safer working.

The creation of a building 'factory' as opposed to the building 'site' is a further prerequisite for the introduction of higher levels of automation in the industry.

5. THE IMPLICATIONS OF LABOUR DISPLACEMENT

As soon as the first robot is deployed, labour is replaced by a machine and its minder. The construction industry has encouraged the casualisation of labour through the system of labour-only subcontracting, and this was legitimised by the 1974-9 Labour government through the introduction of the P714 tax-certification scheme. This enables employers to reduce their workforce without negotiation and without incurring penalties.

The pathway to high technology mechanisation in the construction industry is, therefore, relatively clear of obstacles arising from the labour market. Labour unions lack strength and do not have a clear policy with respect to mechanisation of the construction process.

Casualisation of the construction industry may ease the path to robotisation, but a fully integrated and automated design, management and production system would be very finely tuned and require loyal and dependable staff to operate it. It is probable that this new workforce would need to be permanent and directly employed.

6. NOTES ON THE APPLICATION OF ROBOTICS WITHIN THE BRITISH CONSTRUCTION INDUSTRY

There are many parties to a construction contract in the UK - the client, the designers, the contractor, the subcontractor, the supplier, plant hire specialists, etc - and each in different circumstances might become interested in robotics. The question

must be asked, 'Who will invest in construction robotics, and the development of robotic methods, and who will benefit from any productivity advantages accruing?'.

It is most unlikely that the client and the design consultants will directly invest in advanced robotics, except in very special circumstances. The traditional contractor and the management contractor are also unlikely contenders, the first having no control over design, and the latter no responsibility for design or production other than as a consultant.

6.1 International Contractors

The large UK conglomerate and international contractors clearly have the resources, the curiosity, and the competitive instinct to want to investigate and develop robotics further. There is already some evidence that this is the case. British contractors are clearly behind their Japanese counterparts, but if they are to re-establish their share of the international market, in competition with the new low cost contractors, they will be targeting more sophisticated projects and must demonstrate the very latest technological know-how.

6.2 Design and Build Contractors

Design and build contractors would appear to be in an ideal position to develop robotics methods within construction. Indeed, Japanese contractors work within a design/build culture. As stated above some changes will still be required with respect to the design component. However, since the 1960's many UK contractors have ceased to employ labour directly and have moved to wholesale subcontracting. By subcontracting the site construction work, contractors have relieved themselves of the incentive to replace labour by enhanced mechanisation.

If current practice persists, there must be some doubt as to whether design and build contractors will move into robotics. We must wait to see if these contractors will depart from tradition and begin to see the need for expenditure on R&D. Many of the criteria for process innovation are met, and minimal organisational adaptation may again provide the incentive to invest in new forms of site mechanisation.

6.3 Speculative Builders

Speculative builders, especially the major speculative house builders, appear to have the incentive and the resources required to stimulate investment in robotics. Speculative contractors also have control over design and the casual labour employed is easily replaced. However, technical change and methods of organisation tend to be adopted in speculative building once they have proved their worth for contractors (Ball).

As land speculation and development profits currently outweigh production profits, the incentive to invest in advanced mechanisation is diluted. However, the house building market will become increasingly competitive over the next decade with the decline in first time buyers, and productivity advantages gained through robotisation may become more significant in providing a competitive edge.

6.4 Specialist Subcontractors

Many specialist subcontractors are large commercial organisations with sufficient resources to invest in robotics. Further, many carry out partial design of the project within their specialist competence. These subcontractors are frequently in competition with similar organisations and a higher level of productivity on site would give a competitive advantage when tendering for work. Many subcontractors engage in similar work from project to project thus increasing the potential for standardisation and repetition.

If such a company has a sufficiently well developed management team, the potential for investment in robotics would be present.

6.5 Materials and Components Suppliers

Much of the recent product innovation stems from the materials and components industry. By their very nature, component manufacturers are contributing to the design of the final product and, through standardisation and modularisation, they are providing increased opportunity for mechanisation.

Further, an increasing number of manufacturers are diversifying into specialist subcontracting. Manufacturers have demonstrated that they have the resources and incentive required to invest in innovation. As with specialist subcontractors, a competitive edge with respect to productivity is of utmost importance but in this case it has to be achieved alongside continual product enhancement.

Powerful materials and component suppliers may well contemplate robotic applications to production on site, as well as in the factory. The structural steel industry could possibly be the first. By providing the material or component as well as the high technology system for incorporating them into the building, the manufacturer sells his product and increases his market share either by becoming the specialist subcontractor or eliminating the need for one. Through the use of robotics and other forms of high technology automation, it is possible that the manufacturer may play a much more prominent role in the construction process (Brown).

6.6 Plant Hire Specialists

Construction has always been beset by fluctuations in demand, and one solution to the problem of over capacity during troughs in the construction cycle is to hire plant and equipment rather than to have fixed capital tied up in non-productive machines. The plant hire industry accounts for more than half of the total construction plant investment in Britain. When half of this investment is made by non-producers, the coercive force of competition is further weakened, and technical innovation is divorced from the production process as a whole (Ball).

The future role of the plant-hire industry in higher levels of automation and robotics is open for speculation. With the increasing dedication of machinery to the design process, investment in construction equipment may need to take new and longer term forms.

7. CONCLUSIONS

'Technology push' alone is insufficient to establish robotics within the construction industry. A set of conditions must exist before new robotic technologies can be adopted. This will involve changes to the structure and the 'culture' of the British industry.

The British construction industry has traditionally separated the responsibility for design and production. Process innovation in general and the application of robotics in particular require the integration of design and production.

Construction R&D in the UK is inadequate with many companies and practices failing to participate because they find it difficult to gain any commercial advantage from their innovations.

Materials and component manufacturers and many specialist subcontractors have sufficient resources to invest in robotisation. Many carry out specialist design work. These companies may recognise productivity advantages by robotising their site installations.

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