INFRASTRUCTURES AND SUPERSTRUCTURES; ACCOMMODATING ROBOTICS IN CONSTRUCTION

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SUMMARY

Automation and robotics in construction are integral to the techno-economic paradigm founded on the developments in microelectronics and telecommunications. Technological change is not uniquely a technical phenomena, it also requires a complex of social and institutional factors to be satisfied for its effective implementation. There has to be a synergy between the technical, social and institutional. The role of social factors in conditioning and constraining technical change in construction is self evident, but there is a certain confusion as to the nature of the technology choice function. Construction technology is usually conceived as relating to either the construction 'product' in itself or to the methods of production. Choice of technique in construction can be seen as a function of one or more of the 'actors' engaged in the construction process. Within the presently dominant paradigm the choice function is biased towards the 'product', but innovations in automation and robotics will effectively restructure the construction process and effect a shift in the centre of gravity of the choice function towards production.

SOME REFLECTIONS ON TECHNOLOGICAL INNOVATION

Technological innovation and the consequent technical changes are a prerequisite of economic growth however, as yet, we have only a limited understanding of the mechanisms through which these changes are effected. It is argued that micro-economic theory does not address the problem of technical change and as such it is not adequately integrated into the theory.

These analysts start from the proposition that:

> "Technical change is a fundamental force in shaping the patterns of transformation of the economic system.
>
> There are some mechanisms of dynamic adjustment which are radically different in nature from those allocative mechanisms postulated by traditional theory.

These mechanisms have to do with technical change and institutional change, or the lack of it.

The socio-institutional framework always influences and may sometimes facilitate and sometimes retard processes of technical and structural change, coordination and dynamic adjustment."

(Freeman et al 1988)

Technological and technical changes are not discrete but are grouped into "technological regimes which dominate engineering and management decisions for several decades;" these have been termed techno-economic paradigms. (Nelson and Winters and Perez 1988) 'Techno-economic' paradigms are a cluster of interrelated technical, organisational and managerial innovations, whose advantages are to be found not only in a new range of products and systems, but most of all in the dynamics of the relative cost structure of all possible inputs into production.

In this context automation and robotics are part of the contemporary techno-economic paradigm, which Freeman has defined as:

"Predominantly based upon cheap inputs of information derived from advances in microelectronic and telecommunication technology." (Freeman 1988)

Using Vernon's model of the 'product cycle', automation has, at the present levels of technology, achieved the status of product maturity: a significant degree of standardisation and concern with costs of production superseding concern with product characteristics. Robotics however is in the earliest stages of the product cycle and subject to little standardisation of product, a comparatively low price elasticity of demand and uncertainty with respect to the main characteristics and dimensions of the ultimate market. (Vernon 1966)

If innovations are to be conceived as integral to a specific techno-economic paradigm they must be seen as process centred rather than product centred. Thus, Husband argues that ".... the accepted wisdom is now to look to advanced technology only after the savings from good management have been achieved and the bottlenecks identified."(Husband 1989) As a salutary warning he continues "industrial robots have proved to be a commercial disaster for virtually all western robot builders."

In a state of the art review of robotics in construction Wing argues that "the introduction of robotics technology into the building construction industry will be influenced primarily by cultural and financial considerations, and to a lesser extent by technical capability."(Wing 1989) While in a study of the international construction system, Drewer has concluded that, "there is a tendency to equalise the level of technologies between sectors consequent on the 'pull effect' of the dominant advanced technology sectors. Modern industry requires a modern construction sector to satisfy it's requirements."(Drewer 1989)

The relevance of the socio-economic dimension to technological innovation in construction is not surprising. The construction sector services rather than dominates the economy, as such it is, to some extent, passive with respect to the broad structure of the economy, systems of regulation, client requirements and fashions. Consequently the sector can be considered as reactive rather than pro-active with respect to technological change.

Given this, construction has been subject to and integrated within, the dominant techno-economic paradigms of the last fifty years. This raises some interesting issues, for example 'Fordism' in construction was not limited to the production of building materials and components off site, it's all pervasive effects were manifest on site through industrialised systems, modular coordination and management procedures. The currently dominant microelectronic and telecommunications based techno-economic paradigm is already reflected in many aspects of the design and production of modern buildings and civils works.

CONSTRUCTION TECHNOLOGY IN CONTEXT

Given the ambiguity in meaning of 'technology' as generally interpreted by the 'lay' observer and when used in the particular context of intellectual enquiry, some clarification is required:

> "Regarding technology, ... we follow the tradition of using it in a more vague and comprehensive sense, including, besides techniques, also immaterial aspects, such as technical know-how, management, organisation of work, etc." (Edqvist and Edquist 1979)

Construction technology can be classified as 'hard', related to the product and production as physical entities and 'soft', related to systems and processes. Thus 'hard' construction technology is about the construction product, the associated materials and components and the techniques of production, while 'soft' technology is concerned with the wider environment which conditions and constrains the construction process.

In the 'ideal type' situation, the choice of 'product technologies' is determined during the briefing and design stage of the construction process. This involves an iterative process where the designer's technology enters into a dialogue with the client's criteria with respect to performance, function and budget and the production possibilities available to achieve the product. These 'product technologies', having been defined, limit and constrain the choice of 'production technologies'.

The distinction between product and production technologies is fundamental to an understanding of the technology choice function. Although they have an obvious symbiosis, they do not necessarily have a congruence in the hierarchy of technological sophistication. Many sophisticated 'product technologies' can be achieved using relatively unsophisticated production methods, while many apparently unsophisticated 'product technologies' imply the use of relatively sophisticated production methods.

"Choice of techniques is not the primary choice. Techniques are the means to reach certain goals. Usually the choice of product comes first; the choice of goal or results." (Edqvist and Edquist op cit)

A number of conditions must be satisfied for a technique to be chosen and implemented in a specific context or situation:

> the technique must actually exist somewhere in the world,
>
> a social entity must exist that has an interest in choosing and implementing the technique,
>
> this entity must be organised to be able to make a decision,
>
> it (the social carrier) must have the necessary social, economic and political power to be able to implement the technique chosen,
>
> the social entity must have information about the existence of the technique,
>
> it (the social carrier) must have access to the technique in question,
>
> the social entity must have, or be able to acquire, the needed knowledge about how to handle the technique."

Sometimes a technique is carried by different 'actors' through different stages of the process of technical change; 'linked carriers' of techniques.

An examination of the building process suggests that discrete 'social carriers' are rare. Designers work within the constraints of planning regulations, building codes and regulations and client budgets. Contractors are constrained by the design. Materials producers manufacture to externally established performance specifications. Each becomes an agent for choice of technique, through a process of accommodation and adjustment.

Although 'linked carriers'might be the expected, the various 'actors' will, within each combination, have different weightings. The role of 'leader' changing as the process moves through its various stages. Consequently the client, designer, materials producer and contractor have 'leader'roles in the process, which are defined by their legal responsibilities. Thus, although we do not have autonomous 'social carriers' in construction, the legal system, in defining de jure responsibilities, also defines the de facto 'social carriers'.

ROBOTISATION IN CONSTRUCTION AND THE NEW PARADIGM

Accepting that robotics is integral to the new techno-economic paradigm, a profound impact on the structure and organisation of the construction process might be expected. In the context of construction, robotics has been defined as, "the endowing of machines especially designed for this purpose, with a capacity to execute in an intelligent manner, complex and ill structured tasks based upon signals and images received from the work environment."(Warszawski 1987)

The implication being that the robot or advanced 'device' must accommodate the work environment. Wing however argues that, ".... there are few instances where robots may be quickly and efficiently applied to an existing situation, the bricklaying robot may be a fascinating challenge and is certainly technically feasible, but only if the whole process is rethought could a cost effective system be approached."(Wing 1989)

The dispute is not between an atomistic or holistic perspective, but rather the issue is the need to identify agreed functions, which a robot can perform, that will enhance either the function and quality of the 'product' or facilitate more effective and efficient methods of production. The introduction of all innovatory building technologies requires a dialogue between product and production of this type. The problem with robotisation is one of the scale of accommodation that is required in terms of function, design and the ordering of the construction process.

It has been argued that production technologies in construction are conditioned and constrained by the design function, consequently good design is effected when the designer is sensitive to the problems of production.

Robotisation however, will require that the product be designed to accommodate the use of a particular production technology; robotics. Hence, the extensive use of robots in construction will not simply redefine roles among the various actors in the construction process, it will also significantly shift the centre of gravity of the construction process from product to production. In manufacturing this is the norm, a fact which makes it difficult to compare product standards through time, however construction has still to enter the era of production led product design.

For example, consider, the development of a robot to inspect the vertical surfaces of buildings. At present the major problem is not the technology of inspection, rather it is that of access. The direct costs involved in using a robotic device have to be compared with that of providing access using existing technologies.(Ndekugri and Cusack 1990) However, the existing access equipment does not appear to be excessively costly and it is versatile and multi-functional. Using existing technologies, it is possible to inspect, maintain and repair most buildings and structures.

Assuming that the technology is available, or can be developed, the main factors conditioning the economic viability of a robotic device are:

a market for the product;

a mechanism to supply the device;

a mechanism to supply the product;

the facility to move the device between product delivery locations;

the human resources required to support the use of the device;

the 'infrastructure' necessary to alow the use of the device in a commercial context;

a legal framework which would allow the device and its 'products' to be traded in the formal economy.

The existing 'inspection product' is supported by a well established supply mechanism, proven technologies and an acceptable product standard, it is also delivered at a price which the market can accommodate. An innovative robotic device, assuming that it could did not have a significant cost advantage, would have to offer a qualitatively different 'product' for it to be accepted by the market.

It has been argued that:

> "In market research on new products, early attitudes or behaviour of consumers are assumed to be valid predictors of adoption behaviour. For innovative products, this assumption may be invalid." (Tauber 1979)

Therefore, accepting the plausibility of this argument, the economic viability of the device is a function of the new innovative inspection 'products' it can deliver and not it's capacity to outperform existing technologies. However, even this presupposes a 'total system' which can accommodate the broader requirements for the satisfactory introduction of the innovation.

CONCLUSIONS

Shifts in the techno-economic paradigm are infrequent in fact Robertson has argued that:

> "Most innovation in the American economy is of a continuous nature and, especially in the consumer sector, is the result of an attempt to differentiate products in order to increase market share. Few and far between are innovations of a discontinuous nature which significantly alter or create new consumption patterns."(Robertson 1971)

A paradigm shift not only requires a complete re-evaluation of product design and mode of production it also involves the creation of an infrastructure to support the culture of the new technology. In spite of the claim that construction technology has been integral with previous techno-economic paradigms, there is a sense in which this culture is traditional. The itinerant construction worker and the formal and informal organisation of sub-contract gangs, have many of the attributes of peasant communities.

The accommodation of these rather unique characteristics have been central to the successful introduction of new production technologies in construction. It may be a coincidence, but many of the most successful production technologies introduced in construction have been shared with the agricultural sector: specialist earth moving machinery.

However, the paradigm shift associated with automation and robotics is of a different order of magnitude. It will require a significant modification in the manner in which buildings and civils works are produced and changes in the design of the 'product' to accommodate these new and assertive production technologies.

REFERENCES

Freeman et al — Technical Change and Economic Theory, Pinter Publishers, London, 1988.

Nelson & Winter — An Evolutionary Theory of Economic Change, Harvard University Press, Cambridge, 1982.

Freeman & Perez — "Structural Crisis of Adjustment: Business Cycles and Investment Behaviour", in Technical Change and Economic Theory, op cit.

Vernon R — "International and International Trade in the Product Cycle", The Quarterly Journal of Economics, May 1966.

Husband T — Review of "Industrial Robotics" by G Mair, Times Higher Educational Supplement, July 29th 1989.

Wing R D — "Robotics in Construction: A State of the Art Review," Proceedings of the Institution of Civil Engineers, Part 1, October, 1989.

Drewer S — Construction and Development: A Study From Two Perspectives, University of Lund, 1989.

Edqvist & Edquist — Social Carriers of Techniques for Development, SAREC, Stockholm, 1979.

Warszawski — "The Potential Contribution of Novel Information-Automation Technologies to the Construction Process, Proceedings of the Fourth International Symposium on Robotics and Artificial Intelligence in Building Construction, Haifa, Israel, 1987.

Ndekugri & Cusack — "The Economics of Building Inspection and Testing by a Robotics Device", paper to be presented to the Seventh International Symposium on Automation and Robotics in Construction, Bristol, June 1990.

Tauber E — "How Market Research Discourages Major Innovation," in Readings in the Management of Innovation, ed Tushman and Moore, Pitman Books, Boston, 1982.

Robertson T — Innovative Behaviour and Communication, Holt, Rinehart and Winston, New York, 1971.