

A PROPOSED MODEL FRAMEWORK FOR THE SOCIO-ECONOMIC AND
TECHNICAL APPRAISAL OF AUTOMATION AND ROBOTIC APPLICATIONS
IN CONSTRUCTION

Dr. R. Howes, Head of Department
Dr. S. Naoum, Senior Lecturer
Mr. S. Gruneberg, Senior Lecturer

Department of Construction Management

South Bank Polytechnic,
Wandsworth Road, London SW8 2JZ

ABSTRACT

This paper describes a research proposal intended to evaluate the viability of construction automation and robotic applications by the introduction of a two component model consisting of product and automation variables which each interact with their environment. The intention is that both a qualitative and quantitative evaluation can be made to determine the most appropriate applications for construction robots. It should also be possible to measure achievement in terms of productivity as well as providing a comparative analysis between alternative applications.

The proposed hypothesis is described and the research methodology is listed with a statement of the proposed future achievement.

KEY WORDS

Construction, Robotize, Automation, Specialisation,
Standardisation, Mechanisation, Productivity, Application,
Quality, Feasibility

1. INTRODUCTION

World-wide developments in the area of construction automation and robotics are now approaching the point where it is suggested that (1) serious consideration should be given to a means of appraising the viability and practicality of various computerised applications. It is true to state that the United Kingdom is now at the threshold of deciding whether to embark on a programme of research and development on a major scale.

As with any process innovation, the new robotic technology and on-site automation provide opportunities to increase output using the same size of labour force or to produce the same output using fewer inputs, especially at a time when material prices are rising.

It may well be that skill shortages make it necessary to introduce labour saving devices. According to Construction Industry Training Board figures (2) the number of craft operatives has declined considerably over the last decade or so. Since 1978, for instance, the number of carpenters and joiners dropped from 92,900 to 54,800 in 1987. The drop in the number of bricklayers was even more dramatic, down from 47,100 in 1978 to 12,800 in 1987. Even the number of steel erectors and sheeters declined from 3,800 to 1,600. The reduction in skilled operatives is also reflected in the figures for new recruits into the industry.

Serious skill shortages using traditional materials and techniques were inevitable towards the end of the 1980s, unless the demand for building services also declined. (2) Indeed contractors' output in the 1980s did decline in the first half of the decade. Moreover, demand as measured by new orders obtained by contractors in the period from 1978 to 1988, also showed a drop, only covering in the late 1980s. The building slump in output and demand from 1980 to 1986 helped to disguise the underlying difficulties of growing skill shortages (2).

However, the longer run trend in demand shows that towards the end of the 1980s, demand was returning to the figures approached in the 1960s and early 1970s. Undoubtedly, the construction industry must improve its performance with regard to Socio-Economic aspects of robotization if it is to meet the challenge of expected demand in the 1990s with a reduced number of skilled operatives.

Hence, the intention of this paper is to describe a model capable of appraising and evaluating the feasibility of the application of construction automation and robotics.

The point of carrying out such a systematic analysis of the options is the understanding which the process of analysis provides rather than the outcome of the figures

which the method generates. The judgement of the decision makers remains of critical importance.

This study commenced by reviewing various papers published within the context of applying robots and automation in the construction industry (3&4). A number of variables have been identified and the relationship between them is postulated as in the model shown in Fig.1

The model consists of two major components, the first evaluates the product variables and the second determine the technological feasibility. Both of these components are influenced by the overall element of the environment.

2. THE PROPOSED HYPOTHESIS

'THE VIABLE APPLICATION OF ROBOTICS AND AUTOMATION TO A CONSTRUCTION OPERATION DEPENDS UPON EVALUATING THE PRODUCT VARIABLES AND THE FEASIBILITY OF THE TECHNOLOGY PROVIDED.'

3. COMPONENTS OF THE PROPOSED MODEL

A. THE PRODUCT VARIABLES

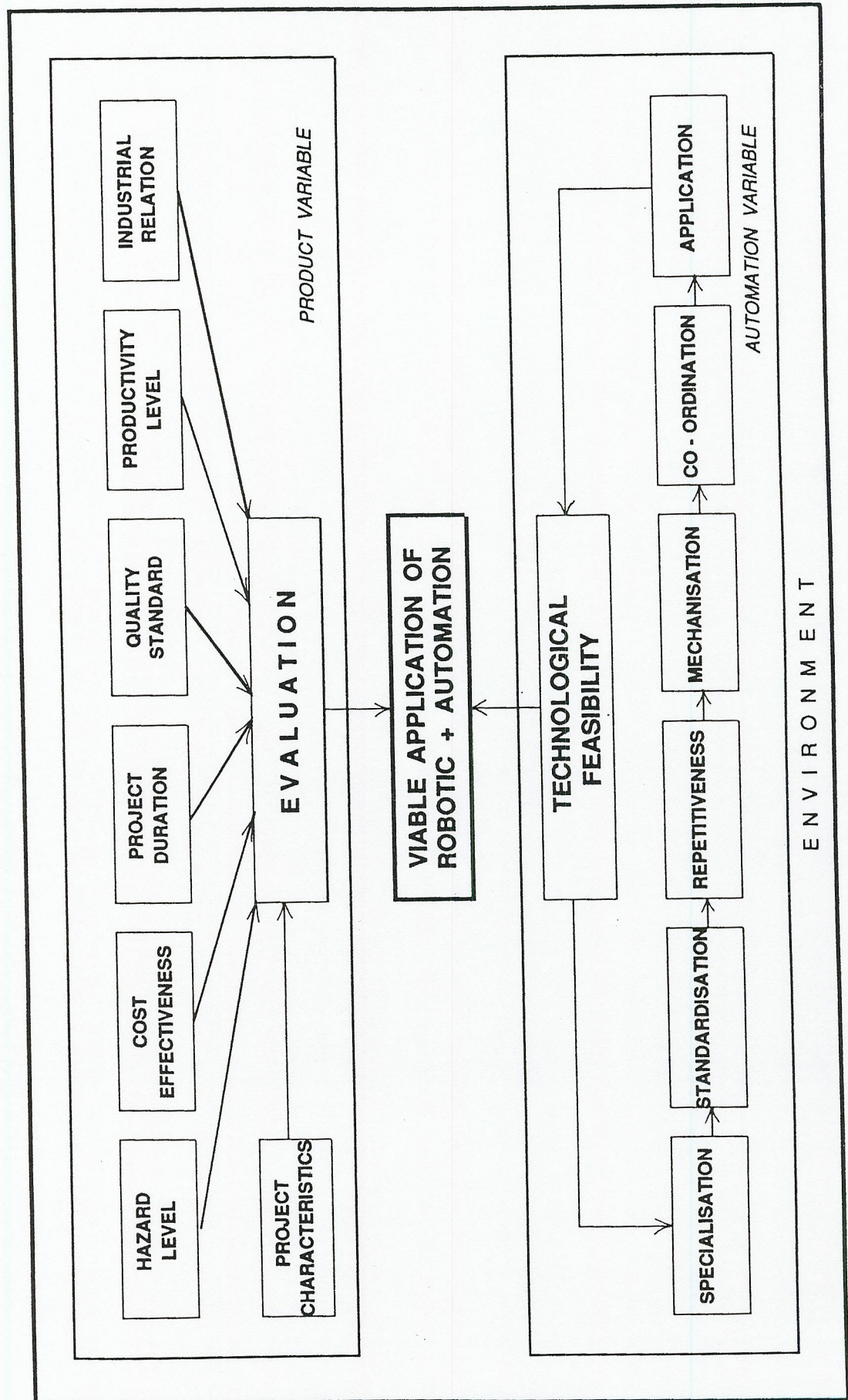
Project Characteristics

The characteristics of a project are its physical form, together with the social, economic and environmental conditions which affect its nature and performance.

The physical form will arise from the needs of the client which in turn will be derived from market demand and the scope which this offers in terms of function and performance. Urban planning considerations include siting, plot density and aesthetic appearance and harmony with surroundings. Other social matters will also have an influence depending on their relative significance.

For the developer a financial appraisal will relate to the gross development value of the project and matters concerning life cycle factors. To the contractor, the major consideration will be the minimisation of costs and the maximisation of profit. The nature and quality of the building will be highly dependent upon these and other financial factors.

Economic models of the comparison of building methods will include social costs and benefits, which developers and contractors would not normally feel were directly relevant for their own investment and management decisions.



Clearly, the factors included in any model will depend on for whom an appraisal is written and the user's requirements. By stating some of the factors from which a selection might be taken in any given instance, the authors hope to have provided a starting point for such appraisals, especially where robots and automation are being considered.

Safety and hazard

The construction site can be regarded as dangerous and operating under difficult environmental conditions. In this respect, safety on site is now becoming of great concern to those involved in it as a result of a continuous rise in accidents over the past years. Accidents could be due to operatives' fault, either through carelessness or by the misuse of equipment, as well as mismanagement. In other cases there are some construction operations that expose the operatives to a hazardous environment such as radiation, temperature and noise. Therefore it has been suggested that the robot is able, if feasible and practical, to react safely with its environment without human intervention.

Cost effectiveness

Robotics and automation can be considered as a piece of public and private investment and involve great capital expenditure. Such an investment can be regarded as worthwhile if there is an acceptable return on the capital employed. Firms investing in robotic systems would need to consider the degree of plant dedication and the level of their own specialisation, since investment returns can only be maximised if the plant approaches full utilisation over its useful life, perhaps on several projects of differing natures.

From the public point of view, the analysis might be to investigate if there is a benefit or a loss to the community. To determine whether a robot is economically and socially feasible, given that, cost benefit analysis should be carried out.

Project duration

The employment of robotic devices for manipulating components designed for automation would lead to a higher level of speed and substantially reduce the construction time due to mitigating a number of outside factors such as working hours and weather conditions. Of course, full advantage of the new technology can only be achieved if

management is in a position to fully utilise the shorter period of erection time. 'Just in time' and 'right first time' management techniques would have to be adopted in conjunction with the robotised methods. Otherwise, many of the potential advantages of the new systems would be lost.

Quality standard

One of the major benefits of robotic and automated construction operation is the accuracy in production which will consequently improve the quality standard. However, there is a direct correlation between the cost of robotised operation and the level of quality achieved. Quality in this context refers to a finished building meeting its technical specifications to the satisfaction of the client and professionals involved. Quality of a construction product can be measured by according to the initial performance and appearance of the building. However the definitive test of quality will manifest itself according to time. Consequently, conformance and dimensional tolerance control can be instituted relatively easily when compared with that achieved by the integrating of the design of the product. This implies that adequate research, development and testing should be undertaken to validate the performance of the design.

Productivity

It is essential that a bench mark for measuring productivity is established. Only in this manner will it be possible to measure any advantage gained by investment and the introduction of robotic process.

One problem which arises here is that the measure of productivity used may not always reflect increased productivity on site. Productivity might be measured by the value of the finished building divided by the number of people directly employed on the project. Gross output may be said to be the value or price of the finished building. Net output is the value of gross output less the value of prefabricated components. In other words, net output is a measure of the value the contractors and sub-contractors add to components by assembling them on site.

Productivity on site is measured by dividing net output by the number of operatives and management directly employed. It is this process which robots and automation would be designed to improve. Although it may be possible to raise productivity on site, it may nevertheless be cheaper to bring onto a site highly finished prefabricated components which then produce a high value completed product.

Industrial relations

Innovative methods using new technology can be used to produce the same output with fewer inputs, including less labour. There would therefore be a threat to jobs, if demand for construction work were not rising. A risk to job security would understandably be resisted. However, because of the casualisation of the labour force, piece rate working and low levels of union participation resulting in weak union representation on many sites, resistance would tend to be minimised.

Nevertheless, investment in new technology would tend to increase the degree of dependency on labour. Expensive machinery needs to be combined with reliable and skilled labour. Indeed, new skills would be required. Obtaining trained labour is an investment which would demand improved working conditions and terms of employment. Otherwise a newly trained worker would tend to leave. As a consequence of the introduction of expensive robotic equipment on site, the amount of directly employed labour would be expected to increase, while the need for casual labour would be reduced, reversing current trends and reducing contractors' flexibility. The introduction of robots needs to be planned with the labour process in mind or the introduction will be at best costly and at worst unacceptable.

B. AUTOMATION VARIABLES

Specialisation

In order to achieve optimum performance it is necessary to confine the operation of robots to specific related functions. This will enable the cost of the robots to be more strictly controlled whilst permitting higher levels of productivity due to concentration on a limited number of tasks. A further factor relates to the need to co-ordinate the performance of robots undertaking such specialised functions.

Due recognition should be given to the need design component products, assemblies and fabrications to permit appropriate specialists to be incorporated in the automated process to be adopted.

Standardisation and repetitiveness

Standardisation and repetitiveness are the two major variables that contribute to the feasible application of robots. The amount and type of repetition for each

construction operation has to be analysed and the decision is to be made upon the cycle of operations in each work. Moreover, there is a minimum number of production units that can optimise the success of implementing a robot. Otherwise some form of mechanised system would be more appropriate. Standardisation may include shape, size and function of the components.

Mechanisation

The variable concerned with mechanisation will establish the viability of utilising mechanised processes as opposed to the adoption of manual or semi-mechanised production. Criteria will need to be established which will be able to evaluate the gain which can be achieved by the introduction of machinery and equipment to undertake specialist processes which have been, to a greater or lesser extent, standardised to form a repetitive process. The ability to introduce greater sophistication and versatility are important and crucial factors. This may be achieved by the incorporation of on board intelligence and efficient drive mechanisms of sufficient capability to achieve stated performance objectives.

However, it has been pointed out (1), point out that the history of building production has not followed the same path as industry into mass production and automation, partly because much of the building process is carried out on changing sites. A further reason they give for the difficulty of using computer aided manufacturing, (CAM) techniques in the building industry, is the strong client influence over one-off production in construction.

The philosophy relating to the production process will also need to be assessed with regard to components and the degree of fabrication necessary. Another consideration will be the production flow process and the question as to whether the product moves or alternatively the machine moves and the product remains static. There may be some instances where a combination of these circumstances is necessary.

Indeed, a mechanised process will already have been applied in the manufacture of prefabricated components and it might be easier in many cases to increase the amount of prefabrication off-site as an alternative to robotization on site.

Co-ordination

The variable measuring the degree of co-ordination will be concerned with the various processes which are necessary to complete the project. Some processes may take place at

remote sites before they are brought together for assembly. Others will occur entirely on the project construction site.

Clearly there must be a smooth and co-ordinated production flow from one process to another concerned with the assembly of the total project. The need for compatibility relating to fit and fixture will require careful appraisal in association with a balanced production flow intended to avoid unnecessary bottlenecks and delays.

In cases where production is a highly automated flow process co-ordination of the sub processes involved will be predetermined in the design of the flow line. Hence the output will be at a consistent rate and productivity will be set by the speed of the line. Under these circumstances the robots will either be static or will follow set transportation paths.

Production involving the use of single or multi function robots on site will require considerable planning and scheduling to achieve the potential offered by automated processes (5). The co-ordination necessary will involve other robots and/or manual processes which must be geared to smooth and balanced production.

The purpose of this variable is to measure the requirement to co-ordinate automated production given the nature and size of the project(s) under consideration.

Application

The application of an automated process will be evaluated by the variables contained within the model in order to achieve an assessment of performance. This process will be set within the context of the product characteristics and its technological feasibility. Consideration will need to be given to performance in accordance with particular demands relating to product specification, quality, output and cost. Further the application must be practically feasible in terms of investment and return and it should be sufficiently developed to be reliable and consistent.

The above requirements imply a full understanding of the manner in which it is proposed to apply the robotic or automated process. This demands knowledge of both the product and the technology and the operating specification of the robot.

The object of the application variable will be to assess the integrity of the robotic in terms of its practicality and performance.

Technological feasibility

The consideration of the above automated variables results in developing a technology that is feasibly applicable. If this is not the case, then no further action need be taken since the whole operation can not be achieved ie. the existing technology can not invent a machine that is feasible to operate.

4. METHODOLOGY

Choice is an essential feature of any decision. To appraise the economic viability of robotic applications in the construction process, a comparison between the new technological possibilities and traditional methods is required. Clearly, a systematic approach to the problem involves stating desired outcomes and selecting options for consideration. These options may be defined in terms of construction materials and methods as well as the degree of prefabrication. Having defined the alternatives, a method of assessing the performance of each option needs to be constructed.

Each of the above variables represents an issue of varying importance in the decision making process. By describing the more relevant variables, a checklist of factors might be developed and later refined. The choice of variables is an iterative process, the first set of variables suggested in this paper being of general application. Versions of the proposed model might be applied to the industry as a whole or to specific projects. The variables included in a model will themselves tend to vary depending on the size and scope of the model, the circumstances of each case and the questions posed.

5. PROPOSED RESEARCH ACHIEVEMENT

The intention of this research proposal is to develop a model for the evaluation of automation and robotic applications in the construction process. Technological feasibility will be assessed by the consideration of automation variables which will be interrelated both quantitatively and qualitatively in order to make judgements against predetermined criteria.

The product variables will input directly into an evaluation of the nature and performance requirements of the product. The performance standards will be set by the demands made upon the product which will also be related in both a qualitative and quantitative manner.

The result of this dual appraisal will be a definitive analysis relating to the feasibility of a particular automated process or robotic application.

It is intended that this model will provide a basis on which to assess all potential applications and it will have the ability to make comparisons. This aspect is seen to be particularly suitable to a comparative analysis of alternative proposals, as well as having the ability to measure improvements to existing robotics.

6. REFERENCES

1. Bonke, S., Pedersen, E.F., and Jensen, N.A. (1986) 'Consequences for the working conditions on site with increased use of CAD/CAM in construction' in Proceedings of the Bartlett International Summer School, pp 142-50.
2. Ball, M., (1989) 'Rebuilding Construction' Dept. of the Environment, Housing and Construction Statistic 1978-1988, HMSO
3. Benes, J., DIEPEVEEN, W.J., Wissema, J.G., (1984) 'The process of Innovation in the Building Industry CIB conference, Waterloo, Canada
4. Rozbeh Kangari (1986), 'Socio-Economic Aspects of Robotization' CIB Conference, Washington, USA
5. Brown, M.A., (1989) 'Barriers to the Application of Robotics and High Level Automation within the UK Construction Industry' 6th International ISARC Symposium on Automation and Robotics in Construction. San Francisco.
6. Cusack M.M., and Earl C.F. (1989), 'Automation and Robotics: the Design and Operational Planning of Construction Robots' 6th International ISARC Symposium on Automation and Robotics in Construction, San Francisco USA