A FRAMEWORK FOR THE MANAGEMENT OF CONSTRUCTION ROBOTICS AND AUTOMATION

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ABSTRACT

The management of construction automation and robotics are as important as the technological aspects for the successful implementation of the technology in the construction industry. Quality, reliability, productivity, and competitiveness are commonly advanced as the motivation for implementing robots and automation in construction operations. However, the emphasis has been mostly on technological issues with little consideration on management and human factors. Some of the technological factors have focussed on developing robots that will be conducive to the harsh environmental conditions common in construction sites, mobility of robots, and automation of construction operations. With firms embracing robots and automation an important factor that must be studied is the management of construction automation and robots. This is an exploratory paper which will present a framework for studying and implementing management of construction automation and robot. The objectives of the paper are therefore: to present a diagnostic model for managing construction robots and automation; to use expectancy theory in analyzing construction worker motivation in an automated environment; and present research needs in management of construction automation and robot. The conceptual framework developed is a proactive model and will be used in the discussion of management functions, and motivation of workers. The lessons learned from such industries like electronic, manufacturing, and automobile will be used in developing the framework and research needs.

INTRODUCTION

The manufacturing industries have enjoyed increasing benefits in economy, quality control, and workplace safety from the use of automation. The construction industry, however, because of its field orientation, frequent reconfiguration of operations and often severe environmental conditions has been slow in adopting automation or robots.

The construction of structures such as buildings, bridges, industrial process plants differ qualitatively and substantively from manufacturing. It differs in such aspects as physical scale of operations, volume of production, type of process and the distribution of workpiece and machines. Because of these differences, the automation of construction will require different engineering and management approaches from those that are applicable in factory environments.

The Construction Industry is the largest in the U.S. It contributes 10% of the GNP and employs about 5 million workers. The industry however, has been facing decline in productivity. It is estimated that the construction industry has been facing a decline in productivity of almost 3% a year since 1972 (4). To reverse this trend, the industry must explore the use of new technologies such as automation and use of robotics in the construction process. The motivation for considering automation and use of robotics can be attributed to the following:

- Shrinking pool of skilled workforce
- High cost of labor
- Hazardous and dangerous nature of construction work
- Increased cost of construction
- Enormous infrastructure refurbishment
- Increased competition by international firms
- Increased demand for quality construction by owners of construction

Because of these factors there is therefore a growing interest in the development and implementation of automation and robotics in the construction industry.

NEED FOR MANAGEMENT OF CONSTRUCTION AUTOMATION

The primary objective of this paper is to present a framework that can be used to manage construction automation and robotics. The research and Development on construction automation and robotics has focused on technology in the construction process. Little or no emphasis is placed on the management of construction with automation and robotics. During the late 70's the manufacturing industries focussed on automation and the development of the technology. They however, failed to consider the impact of management in the automation process. The consequent result was problems in the implementation of the new technology because management was not ready to deal with problems posed by automation. Another problem was the industry's failure to analyze the impact of automation on the work force and job designs. In order to avoid the mistakes made in other industries, a frame work for the management of construction automation and robotics is presented.

CONSTRUCTION AUTOMATION

Construction automation is defined as the technology concerned with the application of electronic, mechanical and computer-based systems to operate and control construction production. Construction automation therefore includes: automatic machines that assemble work; feed back control and computer process control; material handling systems; automatic inspection systems for quality control; computer systems for planning, and decision making to support construction activities and construction robotics.

Automation may be classified into three basic types (3). They are fixed automation, programmable automation and flexible automation. Fixed automation is a system in which the sequence of operation is fixed by the equipment configuration. The operations are usually simple and it is characterized by high production rates and inflexibility in product changes.

Programmable automation is designed with the capability to change the sequence of operations to accommodate different product configurations. An important feature of programmable automation is the flexibility to handle changes in product configuration. It is suitable for batch production. It may be suitable for painting and production of face bricks of varying sizes.

Flexible automation on the other hand is an extension of programmable automation. A major difference is that it is capable of change-overs from one product to the other. Typical features of flexible automation are medium production rates, flexibility to deal with product design variations and continuous production of variable mixtures of products. It may be suitable for structural steel fabrication where size, shape and dimensions may vary constantly.

Automation has been successfully applied to some aspects of construction operation. For example the Army Corps of Engineers at its construction engineering research laboratory in Illinois has developed a continuous weld quality control system (7). Some heavy constructors are now using lasers in excavation and grading. There has also been some progress in automation in on-site plant for batching concrete, bending reinforcing steel and pre-cast elements. As an illustration a computer system can control the selection, transportation, mixing of concrete (cement, sand, aggregates, water and admixtures) for a batch that meets specified design criteria. The same system can also be used for reporting such information as cost and quality control of the batch produced.

ROBOTICS IN CONSTRUCTION

Robotics in construction represents one of a group of related applications for robotics in unstructured environments such as agriculture, mining and undersea operations. The application of robotics in these unstructured environments pose different problems from those encountered in such structured environments as manufacturing. Some of these problems are: mobility, unstructured work tasks and harsh work environment.

The application of robotics to construction has been receiving growing attention over the last few years. There are now some discussions on robots that have been developed and successfully applied on construction sites. Some of these discussions can be found in (9,11) and other sources. There has also been an increase in research on the development of robotics and their applications in the industry.

Some of the attributes that will motivate the use of robots and increase its utilization in the construction industry are safety and hazardous working environment (such as dust, radiation and heat). Labor unions may likely oppose the introduction of robots on construction sites. However, because of the dangers workers face due to exposure to such hazards like toxic substances on soils, tedious and dangerous tasks (underground construction) labor unions will likely favor the introduction of robots on sites. Other factors that may likely motivate the introduction of robotics on construction sites are, increased demand on product quality, liability, and need to increase productivity. Because robots are numerically controlled, the quality of tasks computed by robots will be more consistent than those done by workers. As an illustration, robots will likely finish a concrete floor more precisely to the finished grade than workers (concrete finishers).

Contractors may be interested in construction robots because its utilization will reduce their liabilities. For example, in excavation there are always the danger of soils collapsing with the result of injuries or loss of life by workers. These injuries increase the liabilities of constructors. With robots however, there may be reduced liabilities. Robots can be worked continuously for shifts and hence the output in a given shift will be greater than that of workers. This increase in production will ultimately lead to a reduction in the cost of construction.

MANAGEMENT PROCESS

The construction of any project can be viewed as transformation of resources (manpower, machinery, material, and money) into a given product. The process is illustrated in figure 1.

Resource inputs ⟹ Transformation ⟹ Construction product

Resource inputs	Transformation	Construction product
Material Machinery Manpower Money	Physical resource Human resource	Buildings Highway Industrial plants

Figure 1. Construction Transformation Processes

From figure 1, it can be seen that the construction process involves the transformation of physical (machinery, material, and money) and human resources into construction products.

Because we view the construction of a product as transformation of resources to produce a product, we define management as working with and through individuals and groups to accomplish organizational goals. Consequently, management functions include planning, organizing, motivating and controlling. This is shown in figure 2.

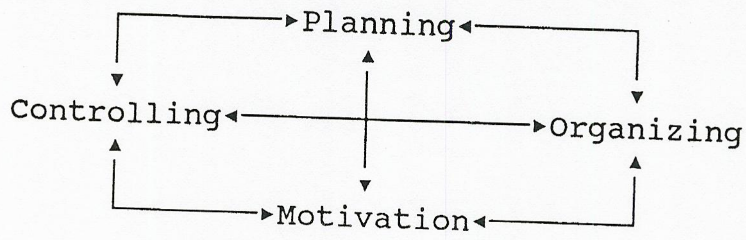

Figure 2. Management Functions.

Planning involves setting organizational goals and objectives for the organization and developing strategies that show how these goals and objectives are to be accomplished. Once the firm has made its plans, then organizing becomes meaningful. This is essentially the integration of resources (machinery, material, manpower and money) in the most efficient way to accomplish its goals.

Motivating plays a significant part in determining the level of performance of employees. The construction industry is a labor intensive industry and hence with automation and robotics, there will still be a need to have motivated labor force. Of all the resources used in the transformation process, manpower is the only one that has "will". Consequently, management must be skilled in motivating workers in its transformation process. Because of the importance of workers, the implication of automation and robotics in construction is presented.

IMPLICATION OF AUTOMATION AND ROBOTICS FOR MANAGEMENT

The basic question on worker behavior is the ability of management to understand and direct worker behavior so that both organizational and individual goals can be achieved. To help management motivate workers, the expectancy theory is presented as a framework that can be used in motivating workers. The basic motivation -behavior sequence is shown in figure 3.

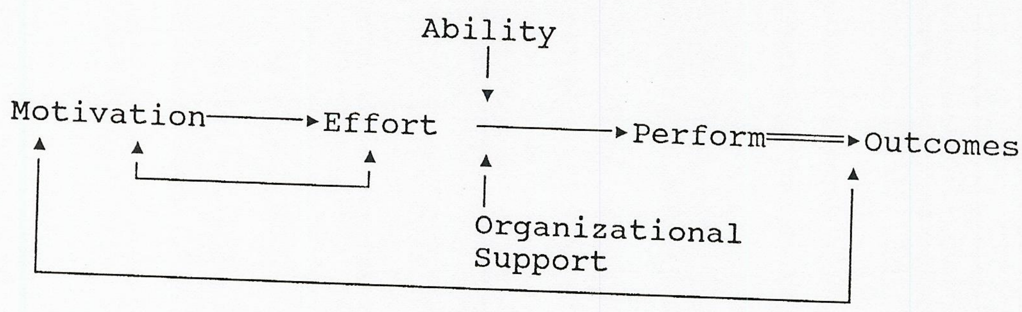

Figure 3. Basic Motivating Behavior Sequence

Expectancy theory states that work motivation is determined by individual beliefs regarding effort-performance relationships and desirabilities of various work outcomes that are associated with different performance level. From managerial perspective expectancy theory states that people exert work effort to achieve a given task and hence receive work related outcomes. However, workers performance depends also on organizational support. The result is that if a technology is available and workers do not know how to use them or do not feel comfortable working with such technology then, the firms performance will suffer. As a result of this, management must pay attention to how it adopts new technologies.

The implication of using this model from a managerial stand point in introducing automation and robotics are:

1. The design of tasks, jobs and rules: The expectancy theory model supports job enrichment. Therefore, with implementation of robotics and automation, repetitive, boring and hazardous tasks are eliminated. The consequence of this is that management must redesign current work tasks so as to enrich job and provide task variety for workers. The expectancy theory suggests that work enrichment will motivate workers to perform and hence make it possible to achieve its organizational goals.

2. Supervisory role: Immediate supervision has an important role in creating, monitoring, and maintaining the expectations and reward structures which will lead to better performance level. Consequently, management must provide clear goals, clear reward expectations, nature of motivation and how to create positive motivation.

3. Implementation of automation and robotics: Because of the expectancy theory, management must include workers during the development, planning and implementation of robotics and automation in the workplace. This will foster positive attitude and workers hopefully will be motivated to perform.

4. Training: Expectancy theory suggests that a worker will perform if he believes he has the know-how and skills. Consequently, management must provide workers with adequate training and education so as to work effectively with automation and robotics. Some workers may have to be retrained so as to be effective in the workplace.

RESEARCH NEEDS

Strategic issues may be the most serious issue facing the construction industry. If construction automation and robotics is perceived as a solely technical (engineering) problem then automation will not pay off. The benefits of automation lie in their potential to significantly increase management's effectiveness in being a competitive force in the market. Research is therefore needed into the process of adopting automation and robotics in the construction process.

There is also the issue of manpower. Although certain skills may not longer be needed, the skills that will be left will have greater power over construction process. In particular, operations, maintenance workers, and inspectors will be utilized more frequently. Research is therefore needed on leadership and motivation due to automation and robotics. It is also necessary to research current construction methods and how it can be redesigned because of automation.

CONCLUSIONS

The potential for using automation and robotics have been demonstrated in other industries. What the construction industry needs is an in-depth study on techniques for adopting new technologies (such as automation and robotics) and the management implication of such technologies once adopted in the workplace. The industry should learn from the mistakes from other industries. Perhaps that may be our biggest benefit in lagging behind in adopting new technologies.

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