HUMAN FACTORS IN INTRODUCING ON-SITE CONSTRUCTION AUTOMATION

By Ronie Navon,[1] Member, ASCE, Paul W. Kelly,[2] and David W. Johnston,[3] Fellow, ASCE

ABSTRACT: Implementation of automation and robotics is being considered by segments of the construction industry as part of an overall program to increase productivity, safety, and quality, and to remain competitive in the face of growing global competition. The limited experience of applying robots to construction, together with conclusions drawn on the basis of robotic applications in related areas, show that developing efficient robotic systems alone will not ensure successful implementation. Significant resistance was observed in the manufacturing industry, which seriously impeded successful implementation. In addition to this, the conservative nature of the construction industry suggests potentially significant levels of resistance to the introduction of project-level automation and robotics. The present paper reviews several limited introductions of automation into the construction industry and finds evidence of resistance. The sources and the causes of resistance to the introduction of automation and robotics, as experienced in selected manufacturing industries, are summarized, followed by an exploration of their applicability to construction. A strategy for the implementation of an automated system is developed, relating to resistance to automation elements and successful reduction actions in manufacturing.

INTRODUCTION

Automation and robotics is gradually receiving more attention in the construction industry as a promising means to solve, or facilitate, some of the major problems the industry is facing (Paulson 1988). It is believed that automation will contribute to increased productivity and improved quality and safety (Tatum 1989). This belief has led both practitioners and especially researchers to develop automated systems for well over a decade, yielding results that can eventually be implemented in the field. The success level of the field implementations will depend on numerous technological and human factors (Neil et al. 1991; Warszawski 1991). This article addresses some of the human factors influencing the successful implementation of on-site automation at the project level.

Experience accumulated in various manufacturing industries shows that resistance can seriously impede successful implementation of advanced technologies in general, and automation and robotics in particular (Chao and Kozlowski 1986; Majchrzak 1988). The construction industry, which is well known for its conservatism in adopting new technologies, can expect even more extreme resistance. The following statistics illustrate the conservative nature of the construction industry. It takes approximately 17 years from

[1]Lect., Fac. of Civ. Engrg. and National Building Research Inst., Technion City, 32000 Haifa, Israel; formerly, Visiting Asst. Prof., Dept. of Civ. Engrg., North Carolina State Univ., Raleigh, NC.

[2]Capt., U.S. Army Corps of Engineers, Huntington, WV 25701; formerly, Grad. Student, Dept. of Civ. Engrg., North Carolina State Univ., Raleigh, NC.

[3]Prof., Dept. of Civ. Engrg., North Carolina State Univ., Raleigh, NC 27695-7908.

Note. Discussion open until May 1, 1994. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on November 9, 1992. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 119, No. 4, December, 1993. ©ASCE, ISSN 0733-9364/93/0004-0801/$1.00 + $.15 per page. Paper No. 5081.

the proof-of-feasibility to the adoption of a new technology in the construction industry, while other industries advance much faster (Fenves 1990).

Resistance to new technologies in the construction industry has both subjective and objective origins. Because of the volatile and unpredictable nature of the environment within which the construction industry operates, the management tends to avoid changes and recourses to the old and proven methods and technologies (Warszawski and Sangrey 1985). Field studies on construction sites have shown that lower-level resistance to changes also exists. Workers, foremen, and superintendents offer strong resistance to change due to the fact that they are busy and under pressure—they are reluctant to try new methods even if they know that it would cut cost (Oglesby et al. 1989).

The inevitable conclusion of the preceding observations is that the development of sophisticated and efficient automated systems alone will not guarantee their successful implementation. Despite the high technological level of these systems, the construction industry might find itself facing a large implementation failure if it does not anticipate and reduce potential resistance. Consequently, there is an immediate need to develop a management strategy model for anticipating and reducing resistance to automation.

The present paper describes research (Kelly 1990) undertaken to analyze the human resistance problems and to develop a management strategy for facilitating implementation of automation and robotics. Major sections describe the research methodology details, identify resistance elements to automation and robotics in manufacturing, and investigates their applicability to construction. Finally, a detailed implementation strategy is proposed that is based on the identified resistance elements and construction-relatable successful cases in manufacturing.

RESEARCH METHODOLOGY

The problem of new-technology implementation resistance in general, and construction automation and robotics in particular, is very wide in scope. Among the many obstacles to successful implementation are technical, economic, institutional, organizational, social, and human barriers. The present paper focuses on the human aspects of obstacles to the successful implementation of construction automation. The main objective of the paper is to identify some possible causes for, and sources of, resistance to implement construction automation and indicate possible solutions to deal with the human aspects of successful construction-automation application. Second, but no less important, the paper tries to shed some light on the need to refer to the human aspects, even at this early stage of development of automation in construction.

The emphasis of the research is on project-level acceptance. For the purpose of this research, project level refers to the on-site personnel, namely workers, foremen, superintendents, and project managers. An implicit assumption pertaining to other elements of the industry, such as company management, suppliers, subcontractors, owners and/or clients, federal or local agencies, etc., is made. This assumption is that all the aforementioned fully accept construction automation and pose no obstacles to its successful implementation. This assumption, however, utopian as it may be, is necessary to isolate the problem in question.

Because present construction-automation applications are mainly limited to prototypes employed in pilot efforts, it is not possible to utilize experience from the construction industry. Consequently, to avoid unnecessary delays in pursuing the objective, an indirect methodology had to be employed. The methodology studied the obstacles to automation in other industries, as well as the barriers to the introduction of other advanced technologies in construction. Consequently, based on that information together with common implementation strategies, a management tool for resistance identification and reduction is suggested. More specifically, the methodology consists of the following stages:

Literature Survey

A literature review was conducted, the results of which are presented later in the section on resistance in the manufacturing industry.

Analysis and Compilation of Literature-Survey Results

The analysis consolidates the information gained in the previous stage to indicate three issues: Who is expected to resist the introduction of automation and robotics; the major reasons for such resistance; the main elements of common models for implementation of new technologies and/or robotics?

Implementation Strategy and/or Introduction-Model Development

As mentioned before, direct knowledge of how to overcome resistance to construction automation does not exist. Consequently, an indirect approach is used. It is indirect because it looks either at methods in construction that do not relate to automation, or at methods relating to automation in manufacturing industries. The development process takes each of the elements found previously and adapts them to the specific conditions prevailing in construction.

Model and Strategy Testing

At this stage, attitudes toward automation in construction sites will be measured before and after applying the model. The experiment can be performed in various ways. The exact way will have to be decided upon in accordance with the characteristics of the actual project and site. In any case, the proposed testing stages will consist of:

1. Project selection—an appropriate project including the target population (one or more groups) is selected.
2. Attitude assessment—the attitudes of the target population, and possibly other directly or indirectly involved personnel, should be assessed before any strategy is applied. These attitudes will be used as reference lines to evaluate the suitability and efficiency of the strategy/model application.
3. Strategy/model application—the procedures of the strategy or the model will be carried out in part or fully. It must be remembered that skillful application has to take into account the strengths and limitations of the manager who applies it. Unskillful application of the strategy may cause its failure and subsequently affect prospects of future applications.
4. Construction-automation application—this should preferably be done by actually applying an automated system in the selected project. Other methods, such as simulation, could be conceived, but will not be discussed here.
5. Strategy or model evaluation—this stage will include an attitude-as-

J. Constr. Eng. Manage., 1993, 119(4): 801-812

sessment survey, similar to the one carried out at the attitude-assessment stage. The new attitudes and the way they relate to the previous ones will be the basis for the evaluation of the model and its usefulness.

The whole process of the strategy/model and construction-automation application stages is cyclic and iterative, and should be carried out on a regular basis. This way the strategy can be both improved with time and adapted to specific cases on a regular basis.

The present paper reports research results concerning the first three methodology stages—the literature survey, its analysis, and the implementation strategy. The fourth stage is a subject for separate research.

RESISTANCE TO AUTOMATION AND ROBOTICS IN MANUFACTURING

The literature covering causes of resistance to change in general, automation included, does not lend itself to simple analysis. None of the studies measures exactly the same resistance variables and each organization and every change being introduced is unique. However, despite these differences, there are some definite trends.

Categories of Resistance

The general categories of resistance, identified in the literature survey, provide a starting point for identifying those trends and for further analyzing the data. These categories are (Kotter and Schlesinger 1979; Majchrzak 1988):

- Fear of unknown changes or uncertainty—people tend to resist something that they cannot predict or do not understand.
- Desire not to lose something of value—people tend to resist something they perceive as a threat to what they value.
- Fear of personal inability to handle new requirements—people who feel they cannot meet challenges of change tend to resist it.
- Inadequate understanding of need for the change—people tend to resist change if they perceive the cost outweighs the benefits.
- Poor implementation efforts—inadequate planning of the implementation process itself, including inappropriate user involvement and insufficient training, results in resistance by intended users.
- Labor-management relations—an atmosphere of openness and trust between labor and management is crucial for successful implementation of automation. Lack of such an atmosphere will cause the workers to resist, based on their obstructed concerns.

The first two categories end up being combined into one category in this analysis, because the things people desire not to lose—jobs, skills, etc.—are the same things in which they fear unknown changes. The following summarizes the specific causes of resistance to the introduction of automation for different levels of employees in manufacturing.

Manufacturing Workers

For general workers, resistance results from fear of unknown changes in and/or desire not to lose employment; extrinsic rewards such as pay, bonuses, promotion opportunities, and seniority; intrinsic rewards such as pride in work, job satisfaction, autonomy, and challenge; and their social and interpersonal relationships at work. Further, workers fear they will be unable to handle the requirements of training/retraining, new work methods and skills required for new technology, and new challenges.

Lower- and Middle-Level Managers in Manufacturing

Lower- and middle-level managers also have resistance. The managers' resistance, however results from fears of unknown changes in and/or desire not to lose control/power, authority, their acquired level of competence; status; and career/promotion opportunities. Lower- and middle-level managers fear of their inability to handle changes, also, specifically new ways of doing business, or learning to use new tools or technology.

Shared Worker/Manager Concerns in Manufacturing

Both workers and lower- and middle-level managers share the following resistance causes: Lack of any perceived personal benefit or the perception that the negatives outweigh the positives; inadequate understanding of the need for change; poor implementation efforts (inadequate planning, inadequate user involvement, and inadequate training); poor labor-management relations.

The applicability of the resistance elements shown in the preceding paragraphs to construction can be questioned due to the differing characteristics between construction and other manufacturing industries. The following explores this applicability.

APPLICABILITY TO CONSTRUCTION INDUSTRY

Construction Workers' Employment Concerns

Fear of employment instability is the most common reason for resistance in manufacturing (Majchrzak 1988). In spite of the fact that construction is a project-oriented industry, workers have relatively continuous employment with one contractor or another, and foresee a reasonable chance that it will continue (Oglesby et al. 1989). Consequently, construction workers can be expected to fear job loss for reasons such as follow.

First, automation in construction is justified economically, among various factors, by its labor-cost savings. Knowing this, workers may consequently fear that this savings may be at the expense of their jobs.

Second, the expected reduction of preexisting construction jobs (one part of direct labor costs) is even greater than the overall savings anticipated in direct labor. Not all positions will be redundant; some of the labor force will have to be reskilled, but not all will be able to cope with it. The ones who are not reskilled will essentially find their way out of the system.

Third, if automation lives up to its expectation to shorten construction time at each job site (Arditi et al. 1990; Paulson 1988; Tatum 1988; Warszawski and Sangrey 1985), it will cause workers to be confronted with all the disruptions associated with changing sites, disruptions such as looking for a new job earlier than planned had automation not occurred. The result may be that they find themselves temporarily in between jobs, or even lose their positions at the construction company altogether.

Extrinsic Rewards (Pay, Bonuses, etc.)

This concern is linked closely to the fear of job loss or displacement. Hourly pay for construction workers has been higher than that in other

J. Constr. Eng. Manage., 1993, 119(4): 801-812

industries based on the argument that employment is not continuous and higher wages are often offset because of: (1) Loss of pay during severe weather; (2) shifts between different job sites that involve interruptions in pay; and (3) the possible necessity of moving one's home—with the accompanying personal and family disruptions (Oglesby et al. 1989). Consequently, construction workers may fear the loss of their present pay level more than their manufacturing counterparts. They may fear that this current pay-level asset might be lost due to relinquishing their craft skills to an automated system.

Intrinsic Rewards (Job Satisfaction, Skills, Status, etc.)

Construction workers take pride in their work, among other reasons, because it is very diversified and specialized. They often have a high degree of skill and exercise a good deal of autonomy on the job, giving them a sense of power and self-esteem (Hodson 1990). Consequently, construction workers can be expected to fear the loss of, or change in, these elements of job satisfaction caused by the introduction of automation.

Social and Interpersonal Relationships

A significant amount of the construction work is performed by crews, thereby making social work relationships an important element of job satisfaction (Borcherding 1980; Maloney and McFillen 1987). Consequently, construction workers are expected to fear the loss of, or change in, these relationships due to the introduction of automation since automated systems are expected to reduce crew sizes, possibly even to one person (the system's operator).

Fear of New Work Methods and Retraining

Construction workers are typically trained in a single craft and have spent many years learning it, mostly by on-the-job training. The new job will most probably require higher education, in addition to retraining, which the construction worker might not have. Consequently, construction workers may well doubt their ability to make the necessary adjustments required for automation.

The preceding partial analysis indicates that similar resistance sources to the introduction of automation apply to construction, as they do to manufacturing. It can be concluded, therefore, that the development of a resistance-reduction strategy can be accomplished by referring to those elements.

RESISTANCE TO AUTOMATION AND ROBOTICS IN CONSTRUCTION

As mentioned before, the information about resistance to automation and robotics in construction is based mostly on indirect data. This section examines an automation and robotics survey and three case studies. Resistance was not the primary focus of the studies—however, they do cite information concerning actual resistance to the introduction of automation in its broader sense in construction. This section also looks into the Japanese experience.

A survey was conducted of the top 400 *Engineering News-Record* contractors to investigate their reactions to automation and robotics in construction operations (Arditi et al. 1990). The majority of respondents believed that automation and robotics would improve productivity (95%), speed (91%), and quality, safety, and competition (77–79%). However,

J. Constr. Eng. Manage., 1993, 119(4): 801-812

only 15% felt that labor-management relations would improve. In fact, the majority felt they would be worsened. While 84% of the respondents expected mechanization to increase, only 38% expected advancement in robotization. The survey concluded that several changes were necessary to implement the use of robots; an important one was that construction-contractor attitudes regarding advanced technologies must be changed toward the positive (Arditi et al. 1990).

The first case study describes a construction company that moved from manual methods to extensive computerized operations (Rounds and Warning 1987). The company—a midsize company specializing in commercial buildings—had a variety of microcomputers, some for field, but mostly for headquarters applications. The case study focuses on the company's transition to microcomputer use and the effects of that transition on various company personnel.

Midlevel managers' attitudes toward the microcomputers spanned from fear to total lack of interest to curiosity to excitement to obsession. Negative attitudes developed when nonusers were not open to seeing how microcomputer applications could benefit them. Some midlevel managers even became hostile toward the "company computer nut," which resulted from the managers' lack of confidence in their own abilities to learn to use computers, or from fear that computers would eventually replace them on the job. Some employees never adjusted to microcomputer use—they were transferred to a noncomputer area, and some of them had to be dismissed altogether.

Field use of the microcomputer was limited to inventory, project cost accounting, job logs, and word processing. The case study observed that field employees were divided between those who were anxious to have a microcomputer on the job and those who might conveniently "lose" a microcomputer if it appeared on the job site.

Another case study is based on the first writer's experience as the head of the construction planning department in one of the leading Israeli construction companies at the beginning of the 1980s. A computerized critical path method (CPM) plan was developed for a specific project with the involvement of the project manager, who was a civil engineer holding a Bachelor of Science degree, and the superintendent. When completed, the output was brought to the site. After he received a negative answer to his question–"is the output able to hammer nails?" the project manager said, "Put it anywhere you want, just don't bother me with it." This type of reaction was typical and portrayed hostility toward the computer. The educational aspects of resistance reduction at the project managers' level is discussed in Navon and Demsetz (1991).

The third case study is the introduction of the partial automation of grading equipment using laser alignment system (Tatum and Funke 1988). The traditional method of grading requires skilled operators. It takes approximately eight years of training and practice to develop the highest level of expertise. The laser-aided grading technology provides assistance to the operator in controlling the blade to cut the soil. This system would require a less-skilled operator but would achieve similar or better results to that obtained by the most experienced operator, as well as a meaningfully higher productivity.

The contractor, who implemented the system, experienced many technical problems in the development of the system. However, one nontechnical problem cited was the strong resistance from the experienced operators.

Many of them considered the new technology a slap in the face and refused to use it. In fact, four of the top operators left the company to protest the new development. On the other hand, the system gained acceptance among the younger operators once the technical bugs were resolved, and particularly after the apprentice operators achieved production rates of up to four times those of highly skilled operators.

Because many variables are involved in each of the studies, there is insufficient evidence to make any hard conclusions regarding project-level resistance to the introduction of automation. However, both from the case studies and the surveys, there appear to be strong indications that construction automation can be expected to meet significant resistance from some project level employees.

The Japanese have developed quite a few prototypes of construction automation systems. It is intriguing to look at the attitude of their construction workers toward automation. The limited literature implies a significantly lower resistance at the project level, than the one indicated before (Muro and Arai 1990; "Report" 1989).

Results of a comprehensive survey on construction automation, conducted among subcontracting companies covering six categories of work (earthmoving, scaffolding, concrete reinforcement, framing, plastering, and painting), has been reported in "Report" (1989) and Muro and Arai (1990). The survey was conducted by sending questioners to 552 foremen and workers, covering many construction-automation–related topics. The response rate was about 44% (245 individuals—155 foremen, 22 assistant foremen, and 68 workers, at an average age of 45). The survey results indicated a generally positive workers' attitude toward automation. For example, about 50–80% of the respondents said that they have no particular objection to automation (50% of earthmoving and scaffolding workers, 80% of painting workers). Less than 10% of the respondents feared losing their jobs, and about 70–90% said that they would definitely like to use automated systems "if introduced in a positive way." Another interesting question referred to the level of automation that workers would like to see on construction sites. About 30% of the workers wanted to see a robot that only assists the worker, who does most of the work; about 70% of them would like to see the robot do most of the work, and a negligible number were prepared to have a fully autonomous robot. Wage concern was one of the lowest concerns of the workers (7.5% of the respondents).

Experience also shows that the Japanese manufacturing industry suffered a meaningfully lower resistance to automation than the one experienced in Western manufacturing industries (Huang and Sakurai 1990). The comparison has to take into account cultural differences. One reason for a relatively low resistance level in Japan is credited to their "lifetime employment" system, which is used by many companies (Huang and Sakurai 1990). Another reason is a "wage guarantee" policy maintained by most companies (Bednarzik 1985).

Western industries cannot expect reduced resistance such as experienced in Japan, because of these previously mentioned cultural differences. On the other hand, the Japanese experience supports the findings of the previous chapter and the analysis of their applicability to construction. It also supports the forthcoming analysis, which will lead to development of the model.

IMPLEMENTATION STRATEGY

The findings presented in the previous sections indicate that meaningful resistance to the introduction of automated systems can be expected in

J. Constr. Eng. Manage., 1993, 119(4): 801-812

construction, which might be a barrier to successful implementation (Paulson 1986; Warszawski 1989). Moreover, it revealed that the manufacturing industry also experienced resistance to the implementation of automated systems. On the other hand, it is quite clear that in cases where an implementation strategy was used that took the human aspects into account, the rate of success increased.

This section suggests a strategy for a project level on-site implementation of an automated system. The strategy was developed on the basis of the resistance elements presented before and the recommended resistance-reduction actions, such as the ones suggested in Argote and Goodman (1986). The basic assumptions have to be borne in mind, namely that the automated system is both economically and technologically feasible, and that other participants of the construction process accept the new technology.

The strategy has four phases. The first phase assesses the feasibility of the actual implementation's conditions and produces a go/no-go recommendation. If it is decided to go ahead with the implementation, an announcement to employees is made, based on a set of decisions pertaining to the implementation (second stage). The third stage develops a detailed plan of actions that will enhance the acceptance of using the automated system. The last phase is the actual implementation. The four stages are presented below.

Phase I—Assessment

In the first phase, senior-level management assesses the human, social, and organizational impacts of introducing automated system to the construction environment.

To accurately assess the feasibility of automation, an assessment must be made of current operations, organization, and personnel. Based on this information, senior-level management can conduct an assessment of impacts/effects of introducing new system on the organizational structure, functional responsibilities, decision-making authority, labor-management relations, and the potential concerns of employees such as:

- Job security
- Extrinsic rewards
- Intrinsic rewards
- Control/power
- Career/promotion opportunities
- New requirements

Finally in this phase of the strategy, senior-level management must conduct an assessment of resources (time, money, and personnel) available for improving acceptance of the new system.

As a result of the information gathered in phase I, a decision must be made to either move ahead, research more, or abandon the proposed new system.

Phase II—Decision

During the second phase, senior-level management makes the appropriate decisions based on the phase I assessment. First, the overall objectives of resistance-reduction program must be derived. Second, resource allocation to implement the program must be formulated, including the selection of key personnel to include a "champion," the setting of an initial timetable, and provision for funding. Third, the type and level of participation must be decided, whether consensus, consultative, or representative. Finally, a decision on employment and wage-security policies must be made.

Upon completion of this phase, an announcement is made to all employees concerning the introduction of the new system, to include a summary of the company's employment and wage-security policy.

Phase III—Participative Assessment and Planning

As a minimum, a representative from each affected group within the organization should be part of this phase (i.e. workers, supervisors, managers, support personnel, senior-level managers, labor unions, and so forth). Together, the representatives first assess key concerns of workers. How will each of the following aspects be affected by the introduction of automation:

- Skills, job satisfaction, autonomy, status, pride in work
- Bonuses and promotion opportunities
- Social and interpersonal work relationships

The group also assesses what the requirements of training will be and what other changes can be expected on the workers' level.

Second, the representatives assess key concerns of low- to middle-level managers. How will the introduction affect their control/power, authority, and career/promotion opportunities? Also, how will the current way of doing business be affected and what new skills will be required for these levels of management?

Third, the representatives must assess key concerns shared by both groups such as why the system must be implemented and how it will be introduced. Fourth, any other concerns about the new system should be addressed.

Next, based on assessment results, input from group representatives, and available resources, senior-level management develops a plan for introducing the new system. The following communication and education techniques, among others, may be implemented to reduce resistance:

- Training for operators and other involved personnel
- Resistance-reduction education for managers
- Feedback mechanisms/two-way communication
- Orientation programs, explaining the need for the new system
- Demonstrations, followed by discussions of the system's capabilities and limitations to reduce fear and anxiety
- Meetings (both formal and informal)

Include in the plan financial arrangements that directly involve personnel, making sure their incomes do not decrease. Communicate the investment in training, which increases employee security by enhancing skills. Develop a financial incentive program (FIP) if the automated system is successfully implemented. Such a program is especially important when the justification of the automated system is economic.

Negotiate with the union to ensure its cooperation. The union can be offered job security, increased rates, etc.

The result of this phase of introduction of an automation system is a specific plan and set of actions for enhancing acceptance of the new system.

Phase IV—Implementation and Monitoring

Finally, implement plan and monitor continuously, making necessary adjustments as appropriate. The outcome of the four-phase program should be increased employee acceptance of new system.

This strategy is generic and by no means attempts to cover the whole spectrum of resistance reduction actions—rather, it should serve as a guideline. As in many organizational-change efforts, successful application is characterized by using a number of the approaches, often in very different combinations. However, successful applications share two characteristics: managers employ the approaches with sensitivity to their strengths and limitations, and appraise the situation realistically. Consequently, a more detailed program will be developed for the last stage of testing the model, after selecting the project, in accordance with its characteristics.

CONCLUSIONS

Automation and robotics is receiving increasing attention as one of the means for solving some of the serious problems faced by the construction industry today. Successful application of automated systems into the construction environment requires that potential users overcome various technical, economic, institutional, organizational, social, and human barriers. This paper has explored expected aspects of the human barriers with the following results:

1. The expected human resistance, unless properly dealt with, might hinder the application of automated systems to construction. Since the barriers are mostly emotional, it is feared that the application of even the most efficient and economical robotic systems might fail due to those reasons.
2. Potential sources of resistance (who might resist and for what reasons?) were identified.
3. Human-resistance–reduction strategies, used by the manufacturing industry, were summarized.
4. A human-resistance–reduction strategy for the construction project level was proposed.

ACKNOWLEDGMENT

The writers wish to thank W. DeLuca for all his help toward the successful completion of the thesis that was the basis of this article.

APPENDIX. REFERENCES

Arditi, D., Sundareswaran, S., and Gutierrez, A. E. (1990). "The future of automation and robotics in construction activities." *Proc., 7th Int. Symp. on Automation and Robotics in Constr.*, Bristol Polytechnic, Bristol, England, 447–454.

Argote, L., and Goodman, P. S. (1986). "Investigating the implementation of robotics." *Managing technological innovation: organizational strategies for implementing advanced manufacturing technologies*, D. Davis, ed., Jossey-Bass, San Francisco, Calif.

Borcherding, J. D. (1980). "Improving motivation and productivity on large projects." *J. Constr. Div.*, ASCE, 106(1), 73–89.

Bednarzik, R. W. (1985). "The impact of microelectronics in employment: Japan's experience." *Monthly Labor Rev.*, 108(9), 45–48.

Chao, G. T., and Kozlowski, S. W. (1986). "Employee perceptions on the imple-

mentation of robotics manufacturing technology." *J. Appl. Psychology*, 71, 70–76.
Fenves, S. (1990). "The potentials of computer-based technologies in civil engineering." *29th Henry M. Shaw Lect. in Civ. Engrg.*, North Carolina State Univ., Raleigh, N.C.
Hodson, R. (1990). *The social organization of work.* Wadsworth Publishing Co., Belmont, Calif.
Huang, P., and Sakurai, M. (1990). "Factory automation: the Japanese experience." *IEEE Trans. on Engrg. Mgmt.*, 37(2), 102–108.
Kelly, P. (1990). "Development of a strategy for introducing on-site construction automation: the human aspects." M.S. thesis, North Carolina State Univ., Raleigh, N.C.
Kotter, J., and Schlesinger, L. (1979). "Choosing strategies for change." *Harvard Business Rev.*, 57(2), 106–114.
Majchrzak, A. (1988). *The human side of factory automation.* Jossey-Bass Publishers, San Francisco, Calif.
Maloney, W. F., and McFillen, J. M. (1987). "Motivational impact of work crews." *J. Constr. Engrg. and Mgmt.*, Vol. 113, pp. 208–221.
Muro, E., and Arai, K. (1990). "Analysis of construction works for robotization." *Proc., 7th Int. Symp. on Automation and Robotics in Constr.* Bristol Polytechnic, Bristol, England, 483–490.
Navon, R., and Demsetz, L. (1991). "Survey and further issues in construction automation education." *Proc., 8th Int. Symp. on Automation and Robotics in Constr.*, 327–332.
Neil, C., Solomonsson, G., and Sharpe, R. (1991). "The short-term social implications for construction workers of introducing robotics onto Australian building sites." *Proc., 8th Int. Symp. on Automation and Robotics in Constr.*, Verein zur Förderungproductionstechnischer, forschung, Stuttgart, Germany, 317–326.
Oglesby, C., Parker, H., and Howell, G. (1989). *Productivity improvement in construction.* McGraw-Hill, New York, N.Y.
Paulson, B. C. (1986). "Anticipating technology's impact on construction." *23rd Henry M. Shaw Lect. in Civ. Engrg.*, North Carolina State Univ., Raleigh, N.C.
Paulson, B. C. Jr., Boyer, L. T., Ibbs, C. W., Koehn, E., Nunnally, S. W., Quinn, S. B., and Tatum, C. B. (1988). "Construction division input to ASCE conference on civil engineering in the 21st century." *J. Profl. Issues in Engrg.*, 114(3), 317–326.
"Report on research on automation in construction work." (1989). *Survey of Professional Constructors, Japan*, Part 1, Constructors Association, (Dec.) (in Japanese, partial translation to English).
Rounds, J. L., and Warning, G. (1987). "Impact of computerizing midsized construction companies." *J. Constr. Engrg. and Mgmt.*, 113(2), 183–190.
Tatum, C. B. (1989). "Design and construction automation: competitive advantages and management challenges." *Proc., 6th Int. Symp. on Automation and Robotics in Constr.*, Construction Industry Institute, Austin, Tex., 332–339.
Tatum, C. B., and Funke, A. T. (1988). "Partially automated grading: construction process innovation." *J. Constr. Engrg. and Mgmt.*, ASCE, 114(1), 19–35.
Warszawski, A. (1989). *Industrialization and robotics in building.* Harper and Row, New York, N.Y.
Warszawski, A. (1991). "Implementation of research in building." *Proc., 2nd Rinker Int. Conf. of Building Constr.*, Univ. of Florida, Gainesville, Fla.
Warszawski, A., and Sangrey, D. A. (1985). "Robotics in building construction." *J. Constr. Engrg. and Mgmt.*, ASCE, 111(3), 260, 280.