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Images of the Future Development of Automated Construction Technology

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Abstract

The purpose of this study is to indicate the future direction of automation technology as applied to the rationalization of building construction. To achieve this purpose, we administered questionnaires to building engineers who had on-site experience with advanced construction technologies. We were thus able to clarify the approach we should take to technological development and other related themes. We also received valuable suggestions on the direction of technological development in the field of construction automation. This research was carried out as part of the study activities of the Architectural Institute of Japan's Research Committee on Building Materials and Construction Procedures, and by the Committee on Technology for Robotized Building Production.

1. INTRODUCTION

In response to the strong interest within Japan concerning rationalization of building production, a variety of automation trials of building-production processes are being carried out at present. Technologies that have already been developed and their applications are discussed in detail in references 1 and 2. The purpose of this study is to explore the future requirements for automation technology as well as to indicate the direction that the development of automation technology should take.

Prior to this study, we administered questionnaires to technicians and engineers who were directly involved with advanced construction technologies. Others who responded to the questionnaires included designers and support personnel in technological control and construction control departments. Based on the results of this research, we clarified the upcoming goals for technological development and automation technology. We also obtained valuable opinions on the future direction of technological development as related to construction automation (hereafter referred to as "CA").

2. RESEARCH ITEMS AND METHODS

2.1. Research items

Our research focused on the following four items: (a) basic attitudes toward the

development of CA; (b) purposes of the development of CA and the automation of construction work; (c) technological themes proposed for future study; and (d) reasons why the proposed technological themes should be studied.

This research was conducted in September and October 1991.

2.2. Research subjects

The main subjects were construction technicians and engineers employed by major contractors in Japan and directly involved with advanced construction technologies. We also included support personnel, as shown in Table 1. Altogether, we received 262 responses, approximately 78% of which were from construction supervisors.

Table 1
Research subjects and number of responses

Correspondent's assignment	Number of replies	Response rate (%)
Field managers	173	66.0
On-site supervisors	31	11.8
Technicians in management departments	32	12.2
Technicians in CA promotion departments	3	1.1
Technicians in R&D departments	19	7.3
Technicians in design and design control departments	3	1.1
Other technicians	1	0.4
Totals	262	100

3. RESEARCH RESULTS AND ANALYSIS

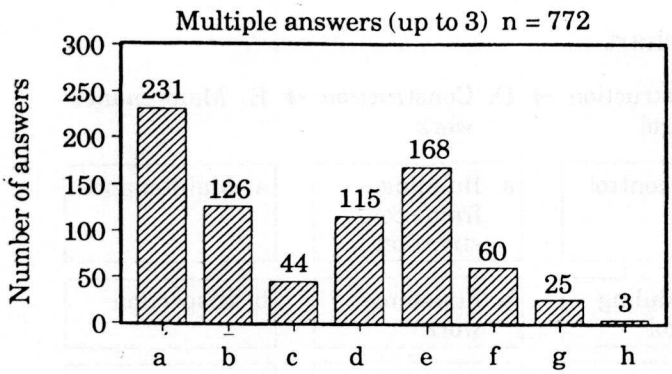
3.1. Attitudes toward the development of CA

The questionnaires addressed the topics, concerning attitudes toward the development of CA and the automation of construction work. About 70% of respondents agreeing with statement (a) thought that the development of CA and the automation of construction should be carried out more actively. When we included those agreeing with statement (b), which says that developments that are clearly advantageous should be the first to be actualized, we found that about 99% of respondents have a positive attitude toward the development of CA and the automation of construction work. These results suggest that active technological development will be necessary to achieve CA and the automation of construction work.

3.2. Purposes of developing CA

Here, we obtained responses to the seven items shown in Figure 1, relating to the goals of the development of CA. We permitted up to three answers for this question, and received a total of 772 answers.

These results show the top-ranking answer was "labor saving and energy saving," which constituted 30% of all responses, followed by "elimination of dangerous jobs" (22%), "shortening of construction terms and work hours" (16%), and "improvement of work environment" (15%). These results are essentially the same as those obtained for technologies that are applicable at present, as described in document 2, except that a slightly higher percentage mention "the elimination of dangerous jobs." On the whole, however, current and future aims do not vary significantly.



[Purposes]
a. Saving of labor, saving of energy
b. Shortening of construction terms and working hours
c. Cost reduction
d. Improvement of work environment
e. Elimination of dangerous jobs
f. Quality control
g. Improvement of worker morale
h. Other

Figure 1. Purpose of development of CA

3.3. Proposals on technology to be developed in the future

Here, we asked those respondents who made proposals on automation technology to describe which themes should be focused on. We classified the proposed technologies according to our automation technologies classification code table (see Table 2). We also asked respondents to explain why the proposed technology will be needed. Respondents were allowed to propose various technologies in up to three different fields.

We received a total of 258 proposals on technological themes to be worked on in the future. Of these, 145 were "single proposals" involving only one of the automation technology classification codes (as shown in Table 2), 53 were "double proposals," covering two classification codes, and 60 were "triple proposals," covering three classification codes. Even if the suggested technological development was to be carried out in a single field, we found its relation to technology in other fields was also considered important.

3.3.1. Total number of technologies proposed according to automation technology classification codes

The proposed technologies were counted according to their automation technology classification codes. A single proposal counted as one case, double proposals counted as two cases, and triple proposals counted as three cases. These results were then totalled as shown in Table 3 . In Table 3, the proposed technologies are indicated in relation to the classification codes shown in Table 2. Altogether, 431 technologies were proposed. A rough classification of the responses shows that proposals regarding construction work account for 46% of the answers, making it the largest group. The next largest group of proposals, 24%, was related to preparation for construction work, followed by proposals regarding production design (15%) and control systems (14%).

In the same way, when the five top-ranked technologies proposed were considered according to their classifications, 24% of all answers referred to proposals for building frameworks in the Construction Work category, followed by proposals for finishing work (15%) and shop drawing (10%) in the same category, construction system planning the the area of Production Design (5%), and scheduling in the Construction Control category.

Based on these results, we found that many respondents considered that the automation of construction work (category D in Table 2) constituted the core of CA. We also found that many respondents had a strong interest in the automation of the "upstream" portion of the production process, which belongs to the Construction Planning (category B in Table 2).

Table 2
Automation technology classification code chart

A. Production design	B. Construction planning	C. Construction control	D. Construction work	E. Maintenance
a. Estimation	a. Project budget	a. Cost control	a. Building frame construction	a. Maintenance
b. Construction planning	b. Scheduling	b. Scheduling control	b. Finishing work	b. Inspection
c. Construction method planning	c. Construction method planning	c. Safety control	c. Electrical and mechanical installation work	c. Repair work
d. Structural planning	d. Temporary work plannning	d. Quality control	d. Others	d. Demolition work
e. Others	e. Shop drawing	e. Others		e. Others
	f. Others			

Table 3
Relationships between proposed technologies and classification codes (total number of answers)

	A: Production design	B: Construction planning	C: Construction Control	D: Construction work	E: Maintenance	Totals
a	19	7	11	103	2	
b	5	8	21	65	2	
c	15	16	9	19	0	
d	23	20	9	11	2	
e	2	42	11	—	0	
f	—	9	—	—	—	
Subtotal	64	102	61	198	6	431

3.3.2. Analysis of proposed single-coded technologies

Here, we analyzed each theme of the proposed technologies, assigning each a single-technology classification code. Altogether, 145 single technologies were proposed, as shown in Table 4, which includes the subtotals for each classification code. The largest number of proposals (94 cases) concerned Construction Work (D), followed by Construction Planning (B) (23 cases), then Construction Control (C) (18 cases). There were relatively few proposals regarding Production Design (A) or Maintenance (E).

The contents of the most frequently proposed technologies are as follows.

- Shop drawing in Construction Work (B-e): CAD technology for the preparation of shop drawings, and technology for the standardization of work planning and shop drawing

Table 4
Number of single proposals for each classification code (number of cases)

	A: Production design	B: Construction planning	C: Construction Control	D: Construction work	E: Maintenance	Totals
a	2	1	3	52	1	
b	6	2	6	31	1	
c	1	2	0	4	0	
d	3	2	1	7	2	
e	0	11	8	—	0	
f	—	5	—	—	—	
Subtotal	6	23	18	94	4	145

- Building frame construction, in Construction Work (D-a): Development of building systems and work methods suitable for automation, the integration of industrialized methods, the automation of all aspects of the building frame construction, development of all-weather roofs, and the automation of individual jobs.
- Finishing work, in Construction Work (D-b): Automation of the installation of autoclaved, lightweight concrete panels and precast concrete panels, and automation related to various types of finishing work

3.3.3. Analysis of proposed double-coded technologies

Figure 2 shows the distribution of technological proposals extending over two classification codes. This diagram shows that the greatest number of proposals (10) were related to building frame construction (D-a) and finishing work (D-b) in Construction Work. Next were the six proposals related to both temporary work planning (B-d) and shop drawing (B-e) in Construction Planning; and the six related to both estimation (A-a) in Production Design and shop drawing (B-e) in Construction Planning. As mentioned above, we found that Construction Work proposals separated into two types. One consisted of proposals that integrated past work with subsequent work within the same technological classification, and the other proposed the integration of two forms of work belonging to different technological classifications. The contents of the technologies mentioned most frequently are summarized in the following:

- Proposals concerning building frame construction (D-a) and finishing work in Construction Work: Automation of work related to both building construction work and finishing work
- Proposals concerning temporary work planning (B-d) and shop drawing (B-e) in Construction Work: Proposals suggesting comprehensive handling of two types of business functions—planning and shop drawing preparation—in a comprehensive shop drawing preparation system
- Proposals concerning estimation (A-a) in Production Design, and shop drawing (B-e) in Construction Planning: Proposals for the unification of business functions (e.g., a CAD system for the continuous operation of design and construction work) in a comprehensive shop drawing system (including design)

3.3.4. Analysis of proposed triple-coded technologies

There were 60 proposals concerning technologies that encompassed three classification codes. We concentrated mainly on analyzing relationships between technological

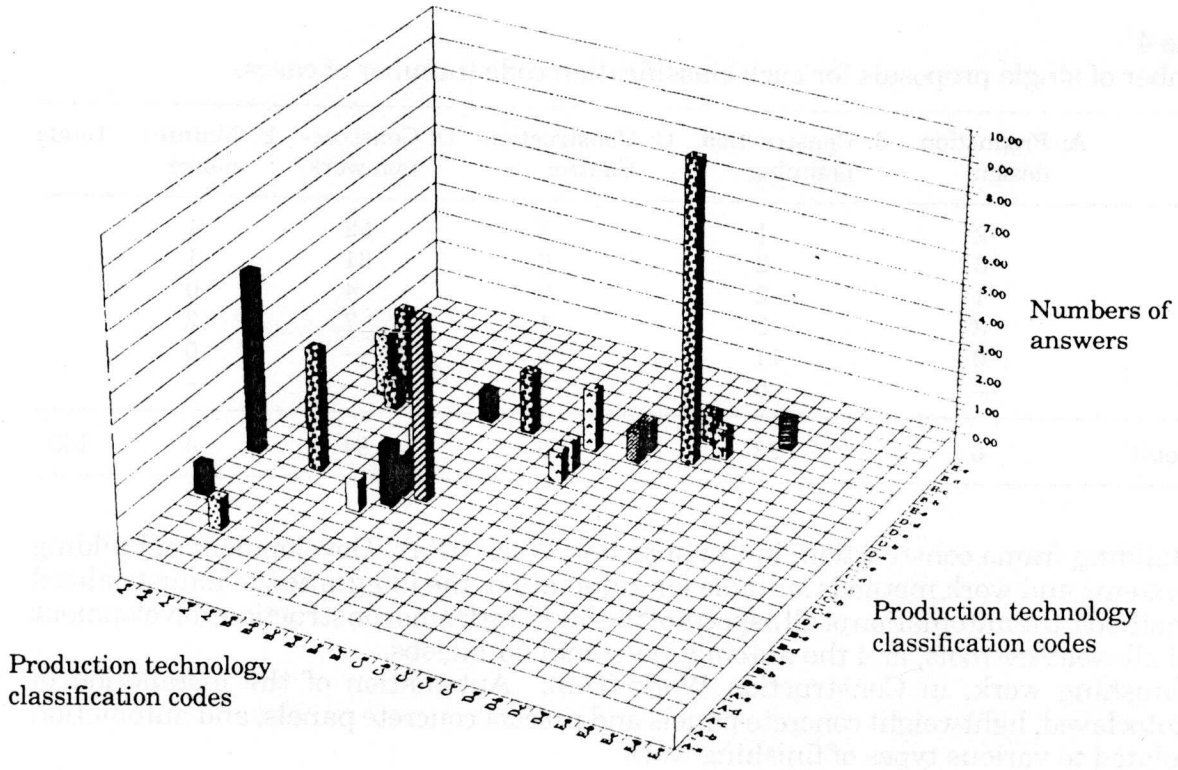


Figure 2. Numbers of proposed technologies covering two production technology classification codes

fields. When we began this analysis, we examined the relationships between different technological areas roughly based on the classification shown in Table 2. Figure 3 summarizes the study results for the relationships between Construction Work and each work subcategory.

When we observed the relationships between the work in each subcategory of D and other work in Figure 3, we found that D-a: building frame construction; D-b: finishing work; and C-c: electrical and mechanical installation work were the most closely related. D-a: building frame construction was closely related to A-d: building system planning, C-a: cost control, and C-c: safety control. In Category D, the actual names of the proposed technologies related to classification items a, b, and c were as follows: fully automatic building-construction systems, robotic technology, measuring systems, and material transportation technology.

As mentioned above, the main trend in technological development has been a concentration on individual technologies. We found, however, that there is currently great demand for systematic technological development both within and across various technological fields, as outlined above.

4. PURPOSES OF DEVELOPING PROPOSED TECHNOLOGICAL THEMES

Here, we asked the respondents to cite one or more of the reasons shown in Table 5 to explain why each of the proposed technologies would require future development. We

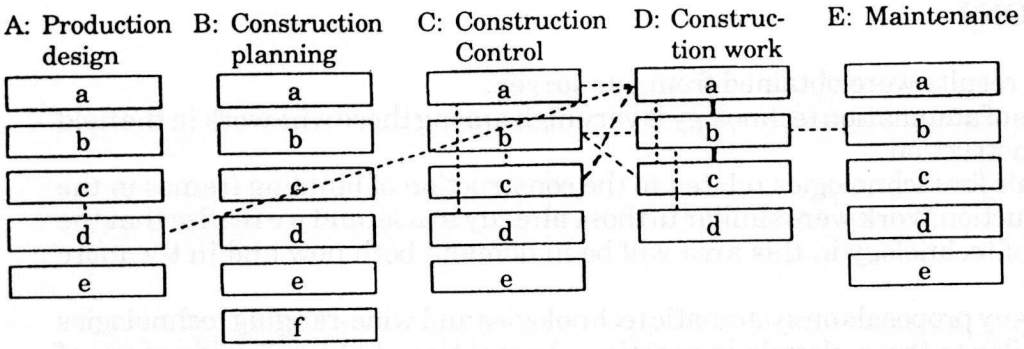


Figure 3. Relationships among triple proposal technologies (classified on the basis of Construction Work-D)

classified the reasons into four categories: "general proposals," "single proposals," "double proposals," and "triple proposals," in the same way that the proposed technologies themselves were classified. We then totalled the answers for each response.

As shown in Table 6, 42.6% of the answers cited "a", saying that the proposed technology was needed as a basic technology; 18.6% cited "b", that the proposed technology was needed in order to integrate existing technologies; and 36.8% chose "c".

The following are the characteristics of the technologies proposed for each reason:

i. The answers citing reason "a", that the proposed technology is needed as a basic technology, mainly concentrated on shop drawing in the category of Construction Planning, as well as on building frame construction, finishing work, and electrical and mechanical installation work in the category of Construction Work.
ii. The answers citing reason "b", that the proposed technology will be needed to integrate existing technologies, centered on estimation and building system planning in the category of Production Design, construction planning and shop drawing in the category of Construction Planning, and cost control in the field of Construction Control.
iii. Answers citing reason "c", that the proposed technology will be needed to expand the applicable range of existing technologies, placed priority on construction system planning and building system planning in Production Design; shop drawing in Construction Planning; and building frame construction, finishing work, and electrical and mechanical installation work in Construction Work.

Table 5
Proposed technologies and reasons why they are required

Reason why technology is required	a	b	c	Unknown	Totals
Single proposals	71	21	50	3	145
Double proposals	17	9	27	0	53
Triple proposals	22	18	18	2	60
Totals	110	48	95	5	258

Notes: a: The proposed technology is needed as a basic technology.
b: The proposed technology is needed to integrate existing technologies (e.g., by providing access to information).
c: The proposed technology is needed to expand the applications of existing technologies.

5. CONCLUSIONS

The following results were obtained from our survey:

a. Consciousness of automation technology is very high among those who work in the field of building construction.
b. Many proposals for technologies related to the construction of building frames in the field of Construction Work were similar to those already in use, and we realize that the development of technology in this area will be in demand both now and in the more distant future.
c. There were many proposals on systematic technologies and wide-ranging technologies that were similar to those already in practice. As mentioned above, a wide range of technological development leading to the use of CA systems has been proposed, and we have obtained valuable suggestions on the future course that development should take. We need to evaluate the automation technology related to CA on the basis of these research results, and we must create an appropriate system in order to develop future CA systems.

6. ACKNOWLEDGEMENTS

We wish to express our sincere gratitude to all persons associated with the eight general contractors that we surveyed as part of our research.

7. REFERENCES

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