# CONSTRUCTION PRODUCTIVITY IMPROVEMENT

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**ABSTRACT:** Construction productivity has been on the decline in the last decade. The results are presented on a survey of the Engineering News-Record 400 largest contractors to obtain their views on where productivity improvements would most help and to compare the trends with a similar survey carried out in 1979. Data were collected on the general company characteristics of the responding contractors, and on the contractors' opinions on potential areas for productivity improvement in the office and in the field. Findings indicate that immediate research should concentrate on improving marketing practices, planning and scheduling, labor-management relations, site supervision, industrialized building systems, equipment policy and engineering design; and that governmental regulations have lost the immediate urgency attached to them in 1979. It is also recommended that similar surveys be conducted every 3 to 4 years to identify new trends and to steer research in the appropriate direction.



## INTRODUCTION

The 1970's were years of disappointment for the U.S. as far as productivity is concerned. It is not possible to explain the slowdown in U.S. productivity by using the classic excuse of the oil crisis because there is evidence that other industrialized countries did not do as poorly as the U.S. in the same period. Indeed, some of them were able to recover in a short period of time, overcoming the same energy price eruption and growing demands for government services.

Fig. 1 shows the national growth rates of some industrialized countries (22). Based upon the per capita share of gross domestic product (GDP) as an indication of national prosperity, the U.S. led other nations by a comfortable margin as it entered the 1980's. Extrapolating a 2% growth rate after the dip in 1980, GDP per person would increase to a 155.3 index rating by the end of the decade. If realistic growth rates are estimated based upon past experiences and are used to make extrapolations after 1981 (21), it is observed that West Germany and Japan will be able to catch up with the U.S. in 1989 with France coming close.

After a drop in gross national product (GNP) in 1974 and 1975, GNP per capita in the U.S. rose in real dollars for the rest of the decade at better than 3% a year. A comparable increase in GDP per capita would push the U.S. trend line to the top of the chart in 1988, effectively delaying catch-up by other nations until the mid-1990's. Just a half percentage point additional gain would secure U.S. supremacy for the rest of this century.

The U.S. productivity performance will decide the growth rate. The U.S. has neither the Japanese consolidation of labor and management, nor the German institutionalization of cooperation. Direct government intervention to allocate resources toward favored industries has been used

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Note.—Discussion open until August 1, 1985. 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 July 25, 1984. This paper is part of the *Journal of Construction Engineering and Management*, Vol. 111, No. 1, March, 1985. ©ASCE, ISSN 0733-9364/85/0001-0001/$01.00. Paper No. 19528.

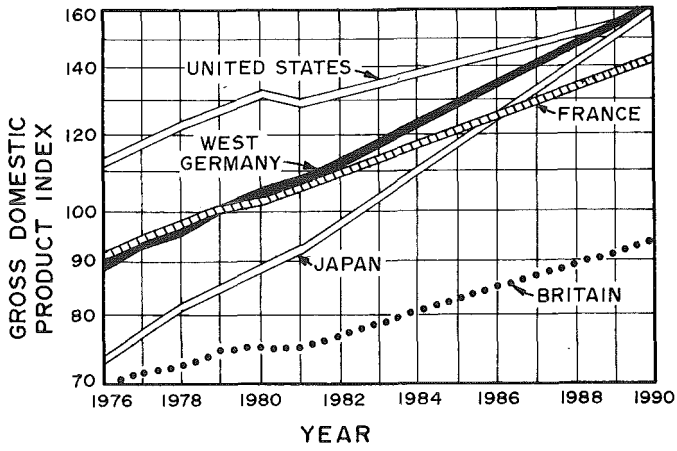


**FIG. 1.—Extrapolated Index of Real Gross Domestic Product per Capita for Selected Nations During 1980's (Base Index: United States 1967 = 100)**

sparingly in the U.S. as opposed to French and British policies. Obviously, it is important for the U.S. to clearly identify the areas for potential productivity improvement within the prevailing conditions and to concentrate research in those areas. Future action based on such research is bound to have a positive effect on productivity and consequently on national growth rates.

The construction and mining industries are the two major industries that contribute a great deal to the slowdown of the national productivity increase rates in the U.S. The construction industry is the nation's largest industry in terms of dollar volume, number of persons employed, and contributions to GNP. However, construction productivity has been on the decline for the past decade and construction labor efficiency is often cited as poor. In addition to labor, construction productivity is also influenced by other production factors, such as equipment, materials, methods of construction and management. These resources remain idle unless they are transformed into productive use by human performance. Fig. 2, prepared by the Japanese Productivity Center, is an indication of where the U.S. stands in construction productivity among other countries (20). As it can be seen, of the world's major industrial nations, only the U.S. has seen a construction productivity drop in recent years. A study made by the Business Roundtable also supports the drop in construction productivity in the U.S. (17). The study reports the belief of many authorities, such as the Department of Commerce, that the drop is about 20% at the aggregate industry level.

"Productivity" is the amount of goods and services produced by a productive factor in a unit of time; a "productivity index" is the ratio between input and output of a productive factor (11). High productivity is the intensive use of scarce resources converting input into output. Productivity is a complex issue in construction where even labor productivity, let alone capital, materials, or total factor productivity, is extremely difficult to measure due to the heterogeneity of the industry's

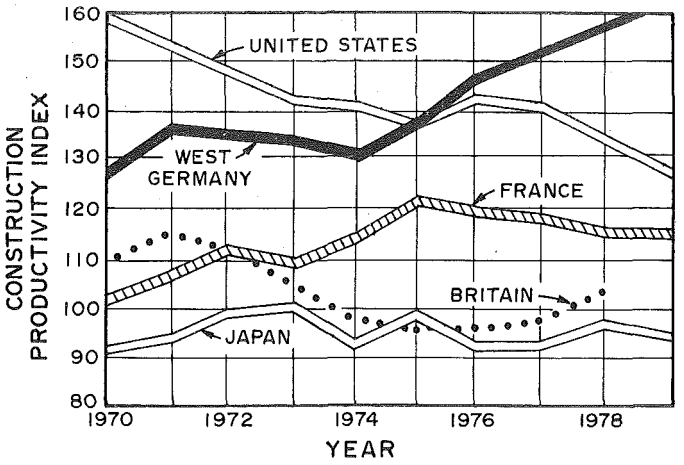


**FIG. 2.—U.S. and Foreign Construction Productivity (Percent 1976 = 100 in Japan)**

products as well as of its inputs (14). This paper reports the findings of a survey of large construction companies conducted in 1983, where no attempt is made to measure any type of productivity but where companies are asked to express their opinions as to what aspects are likely to contribute best to productivity increases in their activities; a comparison of the findings with those obtained in a duplicate survey conducted in 1979 is made.

## Methodology

Choromokos & McKee conducted a survey of the top 400 Engineering News-Record contractors in 1979 to identify the areas perceived by construction executives as having greatest potential for productivity improvement (4). They were able to get a rate of response of 25% to their mail survey and a great deal of interest was expressed by the respondents. A careful review of the literature and the realization that conditions had changed considerably since 1979, constituted enough justification for the decision to duplicate the same survey in 1983. It was believed that the duplication of such a survey would be helpful in identifying new trends and would result in valuable comparative information between 1979 and 1983.

The productivity model used in the study is given in Fig. 3. Construction tasks have been divided into headquarter-type functions, and site-type functions. It can be observed that there are overlaps among the functions such as the "Procurement" function in headquarters and the "Materials" and "Equipment" functions in sites. Some functions such as "Labor" problems cited as a site function, could also be cited as a headquarter function, and vice versa. Finally, a few other factors such as capital availability, inflation, and taxation could also be included in the model. However, since one of the objectives of the study was to

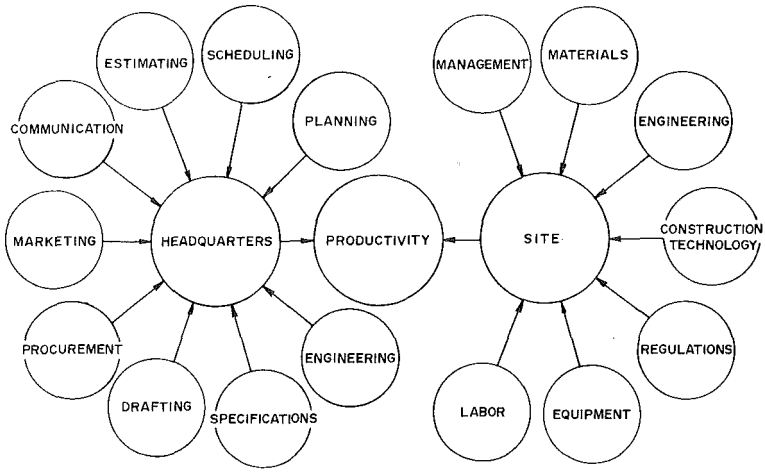


**FIG. 3.—Productivity Factors**

compare the trends in 1979 and 1983, the approach originally developed by Choromokos and McKee was preserved with no modifications.

Similarly, the questionnaire that was originally used by Choromokos and McKee in their 1979 survey was duplicated and mailed again to the top 400 construction contractors cited by Engineering News-Record in 1983 (12). Obviously, a few firms dropped out from the 1979 top 400 list and were replaced by new companies in the 1983 list. Despite this minor change in the study population, it was believed that a comparison of surveys made in 1979 and 1983 would reasonably reflect the differences in opinion that took place in this period in large American contracting organizations, since Engineering News-Record's selection criteria of the top 400 firms remained unchanged in these four years.

A copy of the questionnaire is presented in Appendix I. It consists basically of four parts. The first part was designed to collect contextual information on participating companies, such as type of jobs generally undertaken, size of company in terms of dollar turnover and number of persons employed, amount of work subcontracted, equipment usage policy and geographical dispersion of activities.

The second part was designed to record respondents' perceptions of potential for productivity improvement in headquarter functions. Similarly, the third part recorded respondents' perceptions of productivity improvement potential in site functions. The respondent was asked in the second and third parts to rate the functions as high, medium and low for potential with respect to opportunity in productivity improvement.

Finally, the fourth part investigated the respondents' interest in actively taking part in various types of activities specifically designed to improve productivity.

## RESULTS

Out of the 400 questionnaires, 61 or slightly more than 15% were re-

TABLE 1.—Company Organization/Structure

| Variable (1) | Respondents, as a percentage 1979 (2) | 1983 (3) |
|---|---|---|
| Type of contractor[a] | | |
| All three types | 15 | 15 |
| Two types | 20 | 18 |
| One type | 62 | 65 |
| Other construction | 3 | 2 |
| Annual sales, in millions of dollars | | |
| 10–50 | 30 | 20 |
| 50–100 | 40 | 36 |
| 100–500 | 20 | 38 |
| Greater than 500 | 10 | 6 |
| Number of permanent employees | | |
| Less than 100 | 15 | 22 |
| 100–500 | 55 | 62 |
| 500–5,000 | 17 | 13 |
| Greater than 5,000 | 3 | 3 |
| Number of temporary employees | | |
| Less than 100 | 18 | 20 |
| 100–500 | 33 | 47 |
| 500–1,000 | 26 | 18 |
| 1,000–5,000 | 13 | 8 |
| Greater than 5,000 | 10 | 7 |
| Type of computer facility | | |
| On-site | 23 | 56 |
| Centralized | 60 | 72 |
| Terminal | 19 | 16 |
| Dollar value of construction equipment in millions of dollars | | |
| Less than 5 | 52 | 52 |
| 5–25 | 28 | 28 |
| 25–50 | 15 | 8 |
| 50–200 | 2.5 | 10 |
| Greater than 200 | 2.5 | 2 |
| Percentage of construction equipment leased or rented | | |
| 0 | 11 | 16 |
| Less than 25 | 44 | 44 |
| 25–50 | 22 | 12 |
| 50–75 | 8 | 13 |
| 75–100 | 15 | 15 |
| Percentage of work subcontracted on average job | | |
| Less than 25 | 31 | 28 |
| 25–50 | 27 | 31 |
| 50–75 | 31 | 23 |
| 75–100 | 11 | 18 |
| Geographic location of projects | | |
| Northeastern states | 36 | 28 |

TABLE 1.—*Continued*

| (1) | (2) | (3) |
|---|---|---|
| Mid-Atlantic states | 15 | 30 |
| Southern states | 11 | 51 |
| Southwestern states | 10 | 44 |
| Central states | 5 | 34 |
| Western and northwestern states | 4 | 51 |
| Outside continental United States | 15 | 15 |

[a]Choices given: building (educational, commercial, etc.); engineering (highway, heavy, etc.); and industrial (power plants, refineries, etc.).

turned in the 1983 survey, as opposed to 25% in the 1979 survey. No follow-up was conducted to enhance the returns. Either the company president or the chairman of the board answered 44% of the questionnaires. Vice presidents answered 33%. The respective percentages in the 1979 survey were 59% and 28%.

Table 1 gives the information collected in the first part of the questionnaire, namely, general characteristics of the respondent companies. The effect of the computerization movement in the last few years is reflected in the answers, with many more companies using on-site and centralized computer facilities. Also the effect of the hard economic times is seen on the geographical dispersion of projects with companies undertaking jobs in many more locations than in 1979. On the whole, however, there seems to be no significant difference in the size (expressed in terms of annual sales, and number of permanent and temporary employees) of the companies, their job diversification characteristics, equipment usage policy, and amount of work subcontracted.

25% of the firms that responded to the 1983 survey were the same firms that responded to the 1979 survey. The writer had no control over the firms that responded since the information was collected through regular mail surveys. Despite the limited overlapping, it is believed that these two random samples that had such similar characteristics (Table 1) and which were part of the top 400 company population in both cases, could safely be used for comparison purposes.

Table 2 gives the respondents' perception of potential in headquarter-type functions with respect to opportunity for productivity improvement in 1979 and in 1983. The percentages indicate that "Marketing" which was marked in 1979 by the majority of the respondents to have medium potential was marked by the majority in 1983 to have high potential. The increase in the percentage of respondents that viewed "Marketing" as a high priority area is statistically significant at 1%. This upward trend in marketing can be explained easily; the reduction in public and private construction investments in the last few years have resulted in record bankrupcy rates in the construction industry (13). It is obvious that those companies that stayed in business had to take aggressive action to find work. This seems to have led to a review of their marketing policy and to the discovery that marketing as used by manufacturing industries is seldom practiced in the construction industry. This in turn seems to have led to a search for better marketing practices in the construction industry.

TABLE 2.—Potential for Productivity Improvement in Headquarters

| Variables (1) | High, as a Percentage 1979 (2) | High, as a Percentage 1983 (3) | Medium, as a Percentage 1979 (4) | Medium, as a Percentage 1983 (5) | Low, as a Percentage 1979 (6) | Low, as a Percentage 1983 (7) | No Comment, as a Percentage 1979 (8) | No Comment, as a Percentage 1983 (9) |
|---|---|---|---|---|---|---|---|---|
| Planning | 55 | 48 | 37 | 41 | 8 | 11 | — | — |
| Scheduling | 46 | 41 | 41 | 46 | 13 | 13 | — | — |
| Estimating | 34 | 33 | 40 | 56[a] | 26 | 11[a] | — | — |
| Communication | 35 | 43 | 50 | 46 | 15 | 9 | — | 2 |
| Marketing | 26 | 38[a] | 41 | 33 | 33 | 29 | — | — |
| Procurement | 18 | 21 | 55 | 44 | 27 | 33 | — | 2 |
| Drafting | 15 | 10 | 41 | 39 | 39 | 33 | 5 | 18 |
| Specifications | 21 | 15 | 43 | 36 | 32 | 31 | 4 | 18 |
| Engineering | 24 | 26 | 46 | 39 | 28 | 17 | 2 | 18 |

[a]Changes that are statistically significant at 1%.

The only other statistically significant change at 1% has occurred in the area of "Estimating." Although the majority still marked medium priority in 1983, this percentage is significantly larger than what it was in 1979. Similarly, there is a significant drop in the number of respondents who marked "Estimating" as having low priority. There is therefore more interest in 1983 in improving estimating practices than there was in 1979. This finding can be attributed mainly to the computerization movement that took place in the last few years. Surveys indicate that computerized estimating is being used by some contractors and that those who do not use it yet express their high current priority for it (6,7). Although contractors who use computerized estimating report substantial economies over time (15), the problems of integrating the estimating process with the other computerized operations still exist. Furthermore, potential users are undecided as to whether they should modify their estimating practices to suit package requirements or whether they should design individualized programs to suit their estimating practices (6,7). Another possible area of improvement lies in the practice of probabilistic estimating. Probabilistic cost assessment is well developed in terms of its mathematics but its use is still in its infancy (10,15).

The third point that seems to be of importance in Table 2 is that "Planning" is still marked by the majority of respondents as having high potential but the figures indicate that there is a trend towards lower potential. "Scheduling" on the other hand, has been marked in 1983 by the majority of respondents as having medium potential whereas this was high potential in 1979. However, none of these changes are statistically significant, implying that implementation (1,2) and diffusion (3) problems in modern planning and scheduling techniques continue to affect performance as they did before.

The other variables in Table 2 have remained approximately the same with all of them being viewed by the majority of the respondents in 1979 as well as in 1983 as having medium potential for productivity improvement. None of the changes are statistically significant.

Respondents' perceptions of potential in site type functions with re-

**TABLE 3.—Potential for Productivity Improvement at Job Site**

| Variables (1) | High, as a Percentage 1979 (2) | High, as a Percentage 1983 (3) | Medium, as a Percentage 1979 (4) | Medium, as a Percentage 1983 (5) | Low, as a Percentage 1979 (6) | Low, as a Percentage 1983 (7) | No Comment, as a Percentage 1979 (8) | No Comment, as a Percentage 1983 (9) |
|---|---|---|---|---|---|---|---|---|
| Management | | | | | | | | |
| Labor relations | 35 | 41 | 41 | 28 | 23 | 25 | 1 | 6 |
| Cost control | 49 | 38 | 41 | 44 | 9 | 13 | 1 | 5 |
| Supervision | 53 | 48 | 35 | 29 | 11 | 18 | 1 | 5 |
| Materials | | | | | | | | |
| Delivery | 30 | 25 | 51 | 51 | 12 | 18 | 2 | 6 |
| Storage | 10 | 15 | 53 | 49 | 32 | 28 | 5 | 8 |
| Packaging | 3 | 7 | 42 | 39 | 45 | 36 | 10 | 18 |
| Prefabrication | 34 | 35 | 45 | 35 | 14 | 18 | 7 | 13 |
| Standardization | 39 | 36 | 47 | 41 | 9 | 13 | 5 | 10 |
| Product availability | 31 | 23 | 44 | 38 | 20 | 26 | 5 | 13 |
| New products | 21 | 20 | 53 | 44 | 20 | 20 | 6 | 16 |
| Engineering | | | | | | | | |
| Design standards | 33 | 31 | 44 | 44 | 16 | 10 | 2 | 15 |
| Design improvements | 46 | 44 | 39 | 36 | 9 | 5 | 6 | 15 |
| Systems engineering | 31 | 28 | 45 | 44 | 17 | 13 | 7 | 15 |
| Standard speficiations | 31 | 31 | 50 | 46 | 14 | 10 | 5 | 13 |
| Construction Techniques | | | | | | | | |
| Precast elements | 20 | 28 | 58 | 50 | 16 | 13 | 6 | 9 |
| Preassemble | 24 | 36 | 51 | 35[a] | 19 | 16 | 6 | 13 |
| Foreign developments | 8 | 10 | 32 | 38 | 46 | 31[a] | 14 | 21 |
| Regulations | | | | | | | | |
| EPA | 41 | 23[a] | 31 | 35 | 25 | 35 | 3 | 8 |
| OSHA | 41 | 25[a] | 40 | 41 | 14 | 26[a] | 5 | 8 |
| EEO | 43 | 26[a] | 32 | 36 | 19 | 28 | 6 | 10 |
| Local codes | 32 | 28 | 34 | 36 | 30 | 23 | 4 | 13 |
| Labor | | | | | | | | |
| Contract agreement | 40 | 48 | 32 | 28 | 18 | 16 | 10 | 8 |
| Training | 48 | 54 | 38 | 36 | 12 | 5[a] | 2 | 5 |
| Quality control | 30 | 43 | 55 | 47 | 13 | 3 | 2 | 7 |
| Turnover | 29 | 29 | 41 | 46 | 28 | 15 | 2 | 10 |
| Availability | 25 | 16 | 59 | 48 | 14 | 25[a] | 2 | 11 |
| Equipment | | | | | | | | |
| Capacity | 9 | 15 | 50 | 49 | 37 | 28 | 4 | 8 |
| Simplicity | 18 | 26 | 58 | 44 | 21 | 22 | 4 | 8 |
| Maintainability | 20 | 33[a] | 66 | 47[a] | 8 | 13 | 5 | 7 |
| Utilization | 25 | 39[a] | 60 | 43[a] | 13 | 10 | 2 | 8 |

[a]Changes that are statistically significant at 1%.

spect to opportunity for productivity improvement in 1979 and in 1983 are given in Table 3. Percentages indicate that there have been small changes of insignificant magnitude in the first three general categories of "Management," "Materials," and "Engineering." Management supervision in sites, and engineering design improvements are still regarded as areas with high potential for productivity improvement, whereas all the remaining factors in these categories are rated as having medium potential.

As far as changes in the remaining categories are concerned, a shift is observed in the field of industrialized building processes. One of the

reasons why industrialized building techniques are not used in the U.S. as extensively as in Western European countries is because of the opposition of the trade unions which are trying to prevent the shift of labor from the site to the factory, for fear of losing jurisdiction over it. In accordance with a U.S. supreme court decision made in 1967, construction unions may legally obtain labor agreements to bar the use of prefabricated products in construction in order to preserve their customary on-site work, and can enforce them by strikes and picketing (5). Commonly called "work preservation clauses" or "prefabrication clauses," these provisions ban the use of prefabricated construction products manufactured off the site provided that these were not specified by the designer. It seems that with the trend towards open shop practices, the possibility of using more productive industrialized building processes is again on the agenda. This is supported by the statistically significant increase in the interest in the use of preassembled modules as an alternative construction technique. Furthermore, while most respondents in 1979 did not think it worthwhile to look into foreign developments in construction technology, the majority of the respondents in 1983 seemed to believe that this had higher potential for productivity improvements. Indeed, Japan and west European countries like France and Germany are not only well equiped in industrialized building technology but also in sophisticated construction methods, tunneling, highway construction, and bridge building.

Construction companies have traditionally complained a great deal about the negative effect of governmental regulations on productivity in general. More than 236 departments, agencies, bureaus, and commissions were created in the past two decades while only about 20 were eliminated (25). A single project may require several years to obtain all the required permits. Many large corporations have found it necessary to develop an in-house staff whose purpose is to cope with the regulation process and to obtain the necessary permits. This staff can be expensive, and so is the time required to obtain the necessary permits. Another significant difference between the 1979 and 1983 surveys is in the potential attached by the majority of the respondents to the implementation of legislation regulating Occupational Safety and Health, Environmental Protection, and Equal Employment Opportunity. These regulations are not viewed as high priority areas any more in 1983. A speculative explanation may lie in the more relaxed implementation of this legislation by the present administration which favors for example the use of voluntary inspection for OSHA implementation (26), and also in the loss of interest in 1983 of the population at large in environmental aspects, when compared to the strong mass reactions of the 1970's.

Most of the changes in the "Labor" category are not statistically significant but systematically indicate that most labor related aspects have gained in importance between 1979 and 1983. There are indications in the construction business that there is a trend among construction companies toward open-shop practices (18,19,24) especially in parts of the country where union-shop practices have ceased to be competitive. A Business Roundtable report (8) indicates that there exist major problems in this area, and these problems are bound to be accentuated by the economic crisis of the last few years. On the other hand, the high level

of unemployment (9) seems to be reflected in the statistically significant finding that more contractors regard labor availability as a lesser problem in 1983.

Finally, in the category "Equipment," contractors in 1983 are looking for better maintainability and utilization characteristics than they were in 1979. A survey of equipment practices in medium size construction firms indicates that the large majority of the firms (78% all the time, and 17% sometimes) use maintenance costs in making replacement decisions; and that 67% of the companies track machine utilization time and repair data regularly (23). In other words, especially larger contractors are beginning to collect equipment utilization and cost data as part of their equipment management policy, and to regard this function as having higher potential for improvement.

Table 4 shows how much the respondents are willing to get involved in various activities designed to improve productivity in the construction industry. It will be noticed that all the 1983 percentages are equal to or slightly lower than their respective 1979 percentages. It seems therefore that interest has slightly fallen off since 1979. This observation can also be supported by the lower rate of return of the questionnaires (15% in 1983 as opposed to 25% in 1979), by the systematically larger number of respondents in 1983 having no comments on many questions (as tabulated in the last column of Tables 3 and 4), and finally by the fewer number of top executives who answered the questionaire (presidents, vice presidents, and chairmen of the board answered 77% of the returned questionnaires in 1983 whereas this was 87% in 1979). However, all the indications point to the fact that this is not a drastic fall, but a slight decrease in interest.

Another important finding that seems to be apparent in Table 4 and that is common to the 1979 and 1983 data is that respondents generally do not wish to take active part in developing, funding, and conducting research in productivity related problems. About half of them, however, indicate that they would like to attend conferences and meetings where these issues are discussed and to make their own evaluations where the

**TABLE 4.—Willingness to Participate in Improving Productivity**

| Characteristic (1) | Result as a percentage | |
|---|---|---|
| | 1979 (2) | 1983 (3) |
| Serve as a member of a group that identifies productivity problems | 43 | 39 |
| Contribute funds to support programs aimed at improving construction | 26 | 18 |
| Develop project aimed at improving construction productivity | 26 | 26 |
| Conduct projects aimed at improving construction productivity | 40 | 38 |
| Evaluate results of projects aimed at improving construction productivity | 54 | 54 |
| Attend conference and meeting on construction productivity | 55 | 49 |
| Subscribe to a construction productivity information service | 41 | 36 |

results of such projects are made available to them. The dilemma remains that in times of crisis, the parties involved in the construction activity have limited resources to invest in such research, whereas in times of boom, few are interested in productivity improvements and therefore in contributing funds and expertise to support research for higher productivity.

## Conclusions

Two surveys of the top 400 construction contractors listed by Engineering News-Record in 1979 and in 1983 indicate that contractors' perception of some aspects related to productivity improvement has changed in the last 4 years. Apart from labor availability and EPA/OSHA/EED regulations where higher satisfaction is expressed in 1983 when compared to 1979, all the other statistically significant changes that occurred in the period 1979–1983 (Tables 2 and 3) indicate a higher need for improvement in a number of functions. Marketing has become a new area that is regarded by most contractors to have high potential with respect to productivity improvement. It seems that most contractors in 1983 need to abandon their traditional "production oriented" policies and become actively "market oriented" to ensure their survival. More productive construction technology such as industrialized building processes, and techniques developed by other industrialized nations seem to have gained importance in achieving higher productivity. Also, a revision of some labor and equipment related aspects seems to be necessary for the survival of many contractors whereas governmental regulations on Occupational Safety and Health, Environmental Protection, and Equal Employment Opportunity seem to have lost the urgency that was attached to them by most respondents in 1979.

According to the same surveys, there seems to be consensus among 1979 and 1983 respondents that effort should primarily be concentrated in planning and scheduling, site supervision, and engineering design improvements. Finally, a general observation is that interest in productivity related issues has slightly fallen off since 1979.

Based on the outcome of these studies, it is recommended that immediate research concentrate on improving marketing practices, planning and scheduling, labor-management relations, site supervision, industrialized building systems, and engineering design. It is also recommended that similar surveys be conducted every 3 to 4 years to observe and identify new trends in the industry and to steer research in the appropriate direction. Such research should be efficiently coordinated and the results speedily communicated to all the parties involved in the construction activity.

## Acknowledgments

The writer wishes to thank Habib Nicolas Nasra, a graduate student at Illinois Institute of Technology, Department of Civil Engineering for helping collect and compile the data used in this study, and the respondents in the many construction firms who spent their valuable time to answer the questionnaire.

## APPENDIX I.—QUESTIONNAIRE

CONSTRUCTION PRODUCTIVITY QUESTIONNAIRE

COMPANY

NAME _____

TITLE _____

1. TYPE OF CONTRACTOR
   - BUILDING (EDUCATIONAL, COMMERCIAL, ETC.) ☐
   - ENGINEERING (HIGHWAY, HEAVY) ☐
   - INDUSTRIAL (POWER PLANTS, REFINERIES, ETC.) ☐

2. ANNUAL SALES
   UNDER 10 ☐ 10–50 ☐ 50–100 ☐ 100–500 ☐ OVER 500 ☐

3. NUMBER OF PERMANENT EMPLOYEES
   UNDER 100 ☐ 100–500 ☐ 500–1,000 ☐ 1,000–5,000 ☐ OVER 5,000 ☐

4. NUMBER OF TEMPORARY EMPLOYEES
   UNDER 100 ☐ 100–500 ☐ 500–1,000 ☐ 1,000–5,000 ☐ OVER 5,000 ☐

5. TYPE OF COMPUTER USAGE
   ON SITE ☐ CENTRALIZED CONTROL ☐ TERMINAL TO OUTSIDE SERVICE ☐

6. DOLLAR VALUE OF CONSTRUCTION EQUIPMENT (MILLIONS OF DOLLARS)
   UNDER 5 ☐ 5–25 ☐ 25–50 ☐ 50–200 ☐ OVER 200 ☐

7. PERCENTAGE OF CONSTRUCTION EQUIPMENT LEASED OR RENTED
   NONE ☐ LESS THAN 25% ☐ 25%–50% ☐ 50%–75% ☐ 75%–100% ☐

8. AMOUNT OF WORK (BY DOLLAR VALUE) SUBCONTRACTED ON AVERAGE JOB
   LESS THAN 25% ☐ 25%–50% ☐ 50%–75% ☐ 75%–100% ☐

9. GEOGRAPHIC LOCATION OF PROJECTS

| | | | | | |
|---|---|---|---|---|---|
| NORTHEASTERN U.S. | ☐ | CENTRAL U.S. | ☐ | CENTRAL AMERICA | ☐ |
| MID ATLANTIC U.S. | ☐ | EUROPE | ☐ | ALASKA | ☐ |
| SOUTHERN U.S. | ☐ | AFRICA | ☐ | HAWAII | ☐ |
| SOUTHWESTERN U.S. | ☐ | ASIA | ☐ | OTHER (SPECIFY) | ☐ |
| WESTERN U.S. | ☐ | AUSTRALIA | ☐ | _____ | |
| NORTHWESTERN U.S. | ☐ | SOUTH AMERICA | ☐ | _____ | |

10. RATE THE FOLLOWING "HEADQUARTERS-TYPE" FUNCTIONS FOR POTENTIAL WITH RESPECT TO OPPORTUNITY FOR PRODUCTIVITY IMPROVEMENT (H = HIGH M = MEDIUM L = LOW)

| | H | M | L | | H | M | L | | H | M | L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANNING | ☐ | ☐ | ☐ | COMMUNICATIONS | ☐ | ☐ | ☐ | DRAFTING | ☐ | ☐ | ☐ |
| SCHEDULING | ☐ | ☐ | ☐ | MARKETING | ☐ | ☐ | ☐ | SPECIFICATIONS | ☐ | ☐ | ☐ |
| ESTIMATING | ☐ | ☐ | ☐ | PROCUREMENT | ☐ | ☐ | ☐ | ENGINEERING | ☐ | ☐ | ☐ |
| OTHERS (SPECIFY) | | | | _____ | ☐ | ☐ | ☐ | _____ | ☐ | ☐ | ☐ |

11. RATE THE FOLLOWING AREAS FOR THEIR POTENTIAL WITH RESPECT TO OPPORTUNITY FOR PRODUCTIVITY IMPROVEMENT ON CONSTRUCTION SITES. (H = HIGH M = MEDIUM L = LOW)

| | H | M | L | | H | M | L |
|---|---|---|---|---|---|---|---|
| MANAGEMENT | | | | REGULATIONS | | | |
| LABOR RELATIONS | ☐ | ☐ | ☐ | EPA | ☐ | ☐ | ☐ |
| COST CONTROL | ☐ | ☐ | ☐ | OSHA | ☐ | ☐ | ☐ |
| SUPERVISION | ☐ | ☐ | ☐ | EEO | ☐ | ☐ | ☐ |
| | | | | LOCAL CODES | ☐ | ☐ | ☐ |
| MATERIALS | | | | OTHER (SPECIFY) | | | |
| DELIVERY | ☐ | ☐ | ☐ | _____ | ☐ | ☐ | ☐ |
| STORAGE | ☐ | ☐ | ☐ | | | | |
| PACKAGING | ☐ | ☐ | ☐ | LABOR | | | |
| PREFABRICATION | ☐ | ☐ | ☐ | CONTRACT AGREEMENTS | ☐ | ☐ | ☐ |
| STANDARDIZATION | ☐ | ☐ | ☐ | TRAINING | ☐ | ☐ | ☐ |
| PRODUCT AVAILABILITY | ☐ | ☐ | ☐ | QUALITY CONTROL | ☐ | ☐ | ☐ |
| NEW PRODUCTS | ☐ | ☐ | ☐ | TURNOVER | ☐ | ☐ | ☐ |
| | | | | AVAILABILITY | ☐ | ☐ | ☐ |
| ENGINEERING | | | | EQUIPMENT | | | |
| DESIGN STANDARDS | ☐ | ☐ | ☐ | CAPACITY | ☐ | ☐ | ☐ |
| DESIGN IMPROVEMENT | ☐ | ☐ | ☐ | SIMPLICITY | ☐ | ☐ | ☐ |
| SYSTEMS ENGINEERING | ☐ | ☐ | ☐ | MAINTAINABILITY | ☐ | ☐ | ☐ |
| STANDARD SPECIFICATIONS | ☐ | ☐ | ☐ | UTILIZATION | ☐ | ☐ | ☐ |

CONSTRUCTION TECHNIQUES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PRE-CAST ELEMENTS | ☐ | ☐ | ☐ | OTHER (SPECIFY) | | | |
| PRE-ASSEMBLE MODULARS | ☐ | ☐ | ☐ | _____ | ☐ | ☐ | ☐ |
| FOREIGN DEVELOPMENTS | ☐ | ☐ | ☐ | _____ | ☐ | ☐ | ☐ |

12. INDICATE THE TYPES OF ACTION YOUR ORGANIZATION WOULD TAKE IN THE INTEREST OF IMPROVING PRODUCTIVITY

- SERVE AS A MEMBER OF A GROUP THAT IDENTIFIES PRODUCTIVITY PROBLEMS ☐
- CONTRIBUTE FUNDS (TOGETHER WITH OTHER COMPANIES) TO SUPPORT PROGRAMS AIMED AT IMPROVING CONSTRUCTION ☐
- HELP DEVELOP A PROJECT AIMED AT IMPROVING CONSTRUCTION PRODUCTIVITY ☐
- CONDUCT (OR PARTICIPATE IN) A PROJECT AIMED AT IMPROVING CONSTRUCTION PRODUCTIVITY ☐
- EVALUATE THE RESULTS OF A PROJECT AIMED AT IMPROVING CONSTRUCTION PRODUCTIVITY ☐
- ATTEND CONSTRUCTION PRODUCTIVITY CONFERENCES AND MEETINGS ☐
- SUBSCRIBE TO A CONSTRUCTION PRODUCTIVITY INFORMATION SERVICE ☐
- OTHER (SPECIFY) _____ ☐

13. YOUR COMMENTS RELATIVE TO PROBLEMS OR SOLUTION DIRECTIONS FOR CONSTRUCTION PRODUCTIVITY, WOULD BE APPRECIATED. PLEASE MAKE THESE COMMENTS ON A SEPARATE PIECE OF PAPER AND ENCLOSE IN THE ENCLOSED POSTAGE PAID ENVELOPE AND RETURN WITH YOUR COMPLETED QUESTIONNAIRE

## APPENDIX II.—REFERENCES


1. Arditi, D., "Problems in the Process of Introducing Network Analysis," *Proceedings of the Fifth INTERNET World Congress on Project Implementation and Management—Bridging the Gap*, Birmingham, United Kingdom, 1976.
2. Arditi, D., "Organizational and Contextual Characteristics Affecting the Use of Network Analysis Techniques in the Construction Industry," *Proceedings of the International Council for Building Research and Documentation (CIB) W-65 Second Symposium on Organization and Management of Construction*, Haifa, Israel, 1981.
3. Arditi, D., "Diffusion of Network Planning in Construction," *Journal of Construction Engineering and Management*, ASCE, Vol. 109, No. 1, Proc. Paper 17763, Mar., 1983, pp.1–12.
4. Choromokos, J., and McKee, K. E., "Construction Productivity Improvement," *Journal of the Construction Division*, ASCE, Vol. 107, No. CO1, Proc. Paper 16105, Mar., 1981, pp. 35–47.
5. Clough, R. H., *Construction Contracting*, Fourth Edition, John Wiley & Sons, Inc., New York, N.Y., 1981.
6. "Computer Estimating—Individualized Methods Require Custom Programs," *Engineering News-Record*, Vol. 210, No. 25, June 23, 1983, p. 27.
7. "Computer Estimating—Status Report," *Inside Contracting*, Vol. 28, No. 2, Feb.–Mar., 1984, pp. 22–24.
8. "Constraints Imposed by Collective Bargaining Agreements," *A Construction Industry Cost Effectiveness Project Report No. C-4*, The Business Roundtable, New York, N.Y., Sept., 1982.
9. "Construction Jobless Rate at All-Time High," *Engineering News-Record*, Vol. 209, No. 16, Oct. 14, 1982, p. 5.
10. Dickmann, J. E., "Probabilistic Estimating: Mathematics and Applications," *Journal of Construction Engineering and Management*, ASCE, Vol. 109, No. 3, Sept., 1983, pp. 297–308.
11. Drewin, F. J., *Construction Productivity*, Elsevier, New York, N.Y., 1982.
12. "The ENR 400," *Engineering News-Record*, Vol. 210, No. 18, Apr. 28, 1983, pp. 69–95.
13. "Failures Hit 50 Year High," *Engineering News Record*, Vol. 209, No. 11, Sept. 9, 1982, p. 68.

14. Loch, J. A., and Moavenzadeh, F., "Productivity and Technology in Construction," *Journal of the Construction Division*, ASCE, Vol. 105, No. CO4, Dec., 1979, pp. 351–366.
15. Lichtenberg, S., "Project Management Systems—Monsters or Assistants to the Managers," *Proceedings of the Eighth Annual Symposium of the Project Management Institute*, PMI, Montreal, Canada, Oct., 1976, pp. 152–158.
16. Llewellyn, G., "Computer Estimating and Job Management," *Concrete Construction*, Vol. 29, No. 2, Feb., 1984, pp. 163–165.
17. "Measuring Productivity in Construction," *A Construction Industry Cost Effectiveness Project Report No. A-1*, The Business Roundtable, New York, N.Y., Sept., 1982.
18. "Open Shop Grabs Mechanical Work, "*Engineering News-Record*, Vol. 212, No. 1, Jan. 5, 1984, p. 74.
19. "Open Shop and Unions Toe to Toe, "*Engineering News-Record*, Vol. 212, No. 18, May 3, 1984, p. 52.
20. "Productivity in Civil Engineering and Construction," *Civil Engineering*, Vol. 53, No. 2, Feb., 1983, pp. 60–63.
21. *The Productivity Slowdown: Causes and Policy Responses*, Congressional Budget Office, Washington, D.C., Sept., 1982.
22. Riggs, J., and Felix, G. H., *Productivity by Objectives*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1983.
23. Schexnayder, C. J., Jr., and Hancher, D. E., "Contractor Equipment-Management Practices," *Journal of the Construction Division*, ASCE, Vol. 107, No. CO4, Dec., 1981, pp. 619–626.
24. "Subjourneymen in Union Construction," *A Construction Industry Cost Effectiveness Project Report, No. D-1*, The Business Roundtable, New York, N.Y., Feb., 1982.
25. Turner, J. C., "The Effect of Regulations on Productivity," *Proceedings of the Conference on the Civil Engineer's Role in Productivity in the Construction Industry*, Lincolnshire, Ill., ASCE, New York, N.Y., Aug., 1976, pp. 60–63.
26. "Voluntary Safety Plans Outlined," *Engineering News-Record*, Vol. 208, No. 3, Jan. 21, 1982, p. 184.