The Business Roundtable

MODERN MANAGEMENT SYSTEMS

A CONSTRUCTION INDUSTRY COST EFFECTIVENESS PROJECT REPORT

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SUMMARY

The construction industry has been criticized, to a large extent justifiably, for its slow acceptance and use of modern management methods to plan and execute projects. Many people, both inside and outside the industry, view this as a primary cause of serious delays in schedules and large cost overruns that have plagued the industry in recent years. Yet there is no lack of modern, cost-effective management systems that provide project managers with all the controls they need.

Owners are the ultimate beneficiaries of improvements in the cost, schedule, and quality of their construction projects. But many owners do not seem to be aware of the economic payoff from the appropriate use of modern management systems, and therefore are unwilling to incur the costs of operating the systems.

Without the use of modern systems, however, owners and contractors cannot expect the workers, supervisors, or even site management to be properly motivated to achieve cost effective projects. Research by other study teams of the CICE Project has shown that ineffective project management is, in fact, a major demotivator.[1] In almost all cases, the ineffectiveness is directly traceable to the lack of modern management systems that help management to establish and achieve realistic goals for schedule, cost, and quality.

This study covered the basic management systems required for project planning and execution. The study team analyzed how well and how widely these systems are being used in the industrial, utility, and commercial segments of construction and recommends several steps to make more cost effective use of the systems. The recommendations can be used by individual owners and contractors in reviewing their current systems.

Planning and Scheduling

Construction projects are taking longer to complete than they once did for many reasons: projects are larger and involve more intricate technology; government regulations, permits and hearings impose extra delays; site productivity has declined; and material deliveries have been a recurring problem. Modern, state-of-the-art techniques of scheduling, such as the critical-path method (CPM), are available, but are not being utilized to their full potential to optimize project schedules.

[1] See Report A-2, *Construction Labor Motivation,* and Report C-6, *Absenteeism and Turnover,* The Business Roundtable, 1982.

The study team determined that there is significant potential for reduction in project schedules in general, and that modern scheduling techniques can play an important part in achieving it. However, a key factor in improvement is the relationship between the owner and the contractor, first in establishing target schedules, and then in dealing with the changes which inevitably impact their strategies.

As a part of the scheduling process, owners should consider appropriate incentives to their contractors to optimize schedules - for example, bonuses for completing work ahead of schedule.[2] They should also require that effective planning and scheduling techniques and strong project management are provided by their own organization as well as their contractors. Contractors, where necessary, should upgrade their practices to meet new higher scheduling standards.

A model planning and scheduling system, including guidelines for operation, needs to be developed as a first step in achieving industry standards. These standards should be structured to provide a level of detail and effort consistent with the size of the project.

On average, it should be possible to achieve a 10% reduction in construction time. This would result in a 3% saving to the owner, principally because he will realize an earlier return on his investment.

Cost Estimating, Budgeting, and Control Accounting

The cost of many projects is estimated and budgeted at an early stage of scope definition and design completion. Owners often assume an accuracy for these estimates which is not justified. Our research shows that early estimates have a wide range of accuracy; most often they are notoriously low.

More realistic estimates can be obtained by the proper use of risk-analysis techniques to determine appropriate contingencies, and by calculation of adequate provisions for coping with inflation, based on a schedule of expenditures.

Analysis of the results from a detailed survey of major owners and contractors led to the conclusion that large projects (i.e., costing more than $25 million) should have cost estimating and control systems which divide the project into manageable segments for improved management control.
It appears to be beyond question that the principal causes of cost overruns are poor definition of the scope of projects and loss of control over the project scope during design. The obvious message is

[2] Use of incentives is discussed in detail in Report A-7, *Contractual Arrangements,* The Business Roundtable, 1982.

that owners can and should play a significant role in controlling project costs.

Owners will benefit when they select design-construct companies and construction contractors who demonstrate that their procedures, systems and personnel capabilities meet prescribed standards for cost estimating and control. Moreover, owners should consider incentives to contractors for implementation and tangible results. More effective cost control, particularly during design, has the potential to reduce project costs significantly.

Quality Assurance

Some analysts contend that the quality of construction has declined significantly in recent years. Disputes involving liability, negligence, claims for errors and omissions and governmental citations have been increasing rapidly. Quality is becoming a subject of national public concern.

The application and benefits of a quality assurance/quality control (QA/QC) program are neither fully understood nor effectively utilized in the planning, design and construction phases of many engineered projects. Very few companies measure the cost effectiveness of their quality programs. Owners, as a group, have shown the least interest in putting formal QA/QC programs into effect, even though they stand to benefit the most from improved quality.

Owners should consider requiring designers, constructors, and vendors to have formal QA/QC programs especially on medium and large projects. The criteria for the level of intensity of these programs should be established by owners to assure a cost-effective approach toward meeting the owners' project objectives. Owners would benefit if they established an autonomous quality assurance unit within their company to monitor QA/QC programs Responsibility for quality control however, should remain with the organization performing the work.

It is difficult to estimate precisely savings resulting from an effective QA/QC program since most savings come from cost avoidance. However, there is enough experience to show that a well-planned program is cost effective. A set of guidelines for an effective QA/QC program, applicable to the construction needs of a wide range of companies is included in the Quality Assurance Subteam Report (see Appendix).

Materials Management

Materials management is the management system for planning and controlling all of the efforts necessary to ensure that the correct quality and quantity of materials and equipment are properly specified

in a timely manner, are obtained at a reasonable cost, and, most importantly, are available at the point of use when required.

This report lists the criteria for an effective materials management system. Owners can ensure that systems which meet these criteria are used for their projects, both by their own organizations and by their contractors.

To speed gains in cost effectiveness in this area, it would be helpful if performance standards were developed for materials management.

The cost of materials and equipment usually runs about 60% of total project costs with construction labor costs at about 25%. Efficient management of this major increment can result in substantial savings in project costs. The study team, based on response to its survey among owners and contractors, concludes that an average 6% of labor costs could be saved if all materials and equipment were available at work sites when needed, thus avoiding time-wasting delays in project construction.

Linking Management Systems

Planning and scheduling, cost estimating and control, quality assurance/quality control and materials management are recognized as interrelated functions of project management. Where their use is justified by the size of the project, automatic data processing systems for these four functions should be designed so that each is self-contained and reports the data required for control of the function. At the same time the systems should be linked so that a change of data in one function will immediately show its effect on all the other functions.

A Need for the Future

It is becoming all too evident that a coordinated effort is needed by the industry to develop and promulgate standards for management systems. While some individual companies have been successful in developing and implementing new management systems, the industry as a whole is sadly lacking. Consideration should be given to the formation of a national private agency which can address the broad needs of the industry. This "national office of construction" could direct efforts to develop systems which have industry-wide application. Logical candidates for this type of research and development include not only the management systems in this report but also construction technology, productivity measurement, training and education, and additional subjects identified in other CICE Project reports.

II

INTRODUCTION

The many complexities of today's projects demand a professional, ordered approach to project management. This study suggests that owners fully recognize that modern management systems are an essential ingredient of a cost-effective project. Owners, the ultimate beneficiaries of improvement, can demonstrate their commitment to cost effectiveness by requiring the use of modern management systems on their projects.

Lack of adequate planning, scheduling, materials management, and quality assurance have been identified as demotivators for workmen that reduce the productivity of labor. Owners and contractors will have to put effective management systems in place before the industry can expect to obtain the full benefits which the labor force is capable of producing.

This study analyzes problems currently existing in the industry and recommends action that can be taken by owners and contractors to overcome the obstacles to the use of modern, cost effective management systems. There are, of course, other management systems for construction projects, but the four systems studied are considered to have the most potential for improving cost effectiveness.

It is recognized that implementation of some of the more significant recommendations of this study will take considerable time and effort to achieve. However, they are made in the belief that they are needed for the long-term health of the industry.

III

HOW STUDY WAS MADE

The systems used for project control involve all phases of a project from definition through engineering and design, procurement, and construction to the start-up of the facility. The study was subdivided into four areas:

Planning and scheduling
Cost estimating, budgeting and control accounting
Quality assurance
Materials management

A study team of experts drawn from owners and design-construct contractors was assigned to each area. The planning and scheduling team based its report on its members' extensive experience in project management, a review of a large body of literature and discussions with others involved in project planning and scheduling. The other three teams added their personal experience to results of questionnaires mailed to major owners who are members of The Business Roundtable and to the 100 largest design-construct and construction. contractors listed in the 1980-81 directories published by ***Engineering News Record***.

Texas A&M Research Foundation was retained as a consultant to help prepare the questionnaires, receive (and retain) the replies, analyze the data, and help prepare the study team reports. This procedure assured that proprietary data would be kept confidential and that individual corporate indentities would be protected.

The industrial, commercial and utility segments of construction were covered by this study. The Business Roundtable estimates that these segments accounted for $137 billion of construction put in place in 1979.[3]

This report combines the basic findings, conclusions, and recommendations of the four individual study areas under *Modern Management Systems.* Copies of the more detailed reports of the four subteams are available on written request from The Business Roundtable, Suite 2222, 200 Park Avenue, New York, NY 10166 (see Appendix for titles).

[3] The size of the Construction Industry is discussed in Report A-l, *"Measuring Productivity in Construction",* The Business Roundtable, 1982.

IV

PLANNING AND SCHEDULING

The construction industry has an extremely wide variety of organizations, contractual arrangements, and project situations. Schedules are influenced by a great number of factors, and performance can vary significantly, even under seemingly equivalent circumstances. Moreover, the industry has adopted no common means for measuring either the adequacy of schedules nor performance against them. Accordingly, these findings do not apply to all organizations or to all cases, but are matters of judgment based on the best available data.

Findings

Construction projects are taking longer to complete today than they did one or two decades ago. The reasons are too diverse to be fully quantified, but the main causes fall into five groups:

> ***Technical**:* Today's projects are generally larger, more complex, and involve more intricate technology. This has increased the amount of time required by all project phases with a high proportion of the increase required for engineering and design.
>
> ***Market Conditions:*** as industries mature, their projects become more sensitive to market conditions. Therefore, more evaluations are being made for more decisions during each step of the development process.
>
> ***Governmental and Public Involvement**:* Regulations, review boards, litigation, and other forms of public involvement have become a major source of delay in many project schedules.
>
> ***Productivity:*** The productivity of construction labor has been declining. The drop appears to be particularly significant on large projects and in geographical areas with much work underway.
>
> ***Fabrication and Construction:*** The late delivery of fabricated equipment, difficulties in procuring items such as foundry products, and problems in the constructability of large projects have also tended to prolong schedules.

During the same period, a new discipline of project management has emerged. It offers several state-of-the-art techniques, including the critical-path method of scheduling. In theory, these techniques have

all of the capabilities necessary to deal with complex projects. For some time, they have received critical acclaim throughout the industry. However, many organizations have had mixed results with them, sometimes because construction planners and schedulers do not use · the systems properly, sometimes because the computer printouts appear to be too complex for quick comprehension. Whatever the reason, the industry as a whole has not fully realized the potential of these techniques.

The study team investigated the reasons for this situation attempting to determine where the industry could do better. It studied several systems in an effort to pick characteristics most likely to be helpful and looked for justification which would support recommendations for change.

Conclusions

1. Most of the forces that delay construction schedules can respond to improved methods of project management. There is an industry-wide consensus that the time has come for concerted action, and that it can be effective. Efforts are justified by the potential return: a 10% reduction in the schedule for a typical project should result in a 3% cost saving to the owner of the project. The principal saving comes from the earlier date at which his investment begins to earn money; smaller savings result from shortening the period when the owner must pay for insurance and other overhead costs.

   The duration of projects can be shortened if:

   - Schedule reduction is made a specific objective by project personnel.
   - The owner provides appropriate incentives.
   - All participants, including owners, adopt effective planning and scheduling techniques.
   - Construction site productivity can be increased.[4]

2. Owners and contractors need to take additional steps to improve the external environment of their construction projects. The external environment includes involvement of governmental bodies, vendors and suppliers, subcontractors and labor organizations. Project managers have recognized their responsibilities in this area, but they have often been unable to predetermine the true impact of these external influences on project schedules. Use of sound planning and

[4] Means of measuring site productivity are discussed in detail in Report A-1, *"Measuring Productivity in Construction".* The Business Roundtable. 1952.

scheduling techniques can minimize the negative impact of these external factors.

3. The big financial stakes involved in a typical large construction project demand and justify strong project management. This management should be based, in turn, on well established principles such as clearly expressed plans, a minimum of unknowns, control of logistics, and management of resources. Project managers need sound planning and scheduling techniques at their disposal to adhere to these principles and to adequately address the many complexities of today's projects.

4. Today, planning and scheduling techniques are adopted or rejected by owners, construction managers, or contractors based on their own assessments of their utility and value. In some cases, owners or managers make the installation of a CPM-type technique a condition of the contract. In others no requirement is made by the owner, thus a clear indication of the lack of understanding of the value of these techniques.

Although most techniques have much in common, industry standards are needed. This will increase the applicability and, therefore, the acceptability of proven systems with desirable features. Owners have the most at stake because over time they stand to become the principal beneficiaries; they also have the most financial incentive. Larger projects have the greatest need for these industry standards but they should be structured for use on other projects also.

Recommendations

1. To meet the need for industry standards, a mode/planning and scheduling system needs to be developed.

- Be based on network theory embodied in the critical-path method which shows the time needed for each step of the project, and also the steps that must be taken in sequence. This would provide a means for analysis and evaluation of alternatives.
- Provide the flexibility to permit its use on a wide range of project sizes and complexities.
- Provide realistic resource allocation and definition of responsibilities.
- Set project timing and note key points.
- Establish target dates and progress milestones.
- Isolate those activities which must precisely meet target times to avoid slowing the entire project, and those which have a degree of flexibility for their completion.

- Measure progress and assist in the calculation of completion dates.
- Incorporate change efficiently and calculate its impact.
- Define the effort required to maintain intended rates of progress.
- Provide clear reports which are vital to the organization's management procedures, to illustrate decision points, and to assist review meetings.
- Provide a mechanism for calculating cost justification for specific management actions.
- Mesh with a unified system of budgeting, control and progress measurement for project management.
- Be retrievable for historical comparisons and planning of future projects.

The most advance systems will also incorporate these features:

- Time/cost trade-offs.
- Probabilistic calculations.
- A project scheduling model, with "what if" capabilities.
- Risk analyses.
- Cash flow and cost modeling.
- Audit.

2. A model set of operating guidelines also needs to be developed. It should adhere to these principles:

- Project networks will cover all stages of the project from initial studies through operation.
- The management systems are supported by sufficient numbers of personnel, fully trained and adequately funded.
- All parties in the project have taken part in developing the strategy to the greatest practical extent; they share the project's goals, and are committed to meeting them.
- The division of work between the owner and contractor is clear and straightforward.
- Special-purpose schedules can be used to pinpoint special conditions, such as a "60-day get started" schedule, or a concrete-placement schedule.
- Schedules are revised and brought up-to-date on a timely basis.

3. To help the industry implement better and more standardized methods of planning and scheduling these steps need to be taken:

- Owners need to be more active in exercising their responsibilities and prerogatives in all aspects of scheduling. For example, they should:
    - Advise the construction manager as to the goals and the economic stake of the project so that he has a

better informed basis for giving advice about strategic decisions.
    - Delegate appropriate authority to the construction manager so that he can manage effectively.
    - Require clear lines of communications and methods of reporting.
    - Ask the construction manager to develop challenging strategies, alternatives, and goals.
    - Provide the construction manager all the data, including decisions, when required in the project.
- Model clauses covering planning and scheduling systems should be developed for inclusions in contracts.
- Evaluations should be made of systems being used or proposed by construction managers and contractors, as well as scheduling packages offered by software vendors.
- Standard measures of scheduling performance need to be devised for a variety of types of projects.
- It would be helpful if a central body kept records of scheduling performance by project type and made this information available to owners and contractors.
- Criteria need to be developed for the certification of personnel-training programs.
- Model incentive arrangements should be devised for possible inclusion in contracts.

Clearly the intent of improving the planning and scheduling process in the construction industry is to reduce schedules and commensurately the cost of projects. There is persuasive evidence, particularly in the area of post analysis, that a 10% reduction in average project duration is an achievable goal for owners and contractors to expect.

V

COST ESTIMATING, BUDGETING, AND CONTROL ACCOUNTING

The construction, industry is often criticized for poor performance in delivering major projects within the original cost estimate. With the predominant use of fast-track design and construction and the attendant uncertainties of project schedules, a negotiated contract is increasingly common on major projects, thus eliminating the historic incentive to meet cost estimates that is inherent in competitive bidding. This statement is not intended as condemnation of the fast-track process since it is often more crucial for owners to meet market conditions than to reach for maximum efficiency in design and construction.

The challenge to the industry becomes one of *managing* to maximize the efficiency of the design and construction process particularly where fast track schedules and negotiated contracts are used. Application of modern techniques and systems is critical to such a management process, since appropriate and timely decisions are essential to control project costs.

The study team recognized that there are major problems in the use of available modern management systems. The following basic questions were considered:

- If there is a general consensus of control-system requirements in the community of professional estimating and cost scheduling personnel; and, if presently available systems have developed around this consensus, why are such a variety of methods used from project to project?

- If top management of owners and contractors agree that projects require discipline and careful management to assure proper budgeting and control throughout the execution, why does the process fail so often?

Findings

In design and construction of major projects in recent years, there has been a trend toward starting field construction with a lower percentage of design definition and completion than in the past. Such practice has become predominant on large, complex, long-duration projects. Small projects tend to have more definition and higher percentages of design completed prior to the actual start of construction, thus providing a more traditional approach to contracting and management.

The amount of lump-sum contracting for construction decreases as the size and complexity of projects increase; and, correspondingly, the amount of cost-plus contracting increases. This is primarily because of the lesser degree of definition and design completion at the time of initial contracting.[5]

A lack of consistent, industry-recognized terminology covering estimating, budgeting, and cost control exists because owners and design-construct and construction contractors operate from different perspectives. The resulting communication gap has retarded the development of a widely accepted process for controls over estimating, budgets, and costs.

The owner's budget for a project is often set during the early stages of project definition, a point at which the figures are often crude estimates. Survey results indicate that owners often have unrealistic expectations for accuracy of these figures.

There is little sharing of actual, reliable cost data within the construction industry. Most published cost data are viewed as lacking credibility in the real world. Even within companies, a feedback of actual costs is not consistently used to review and adjust the basis for estimating future projects.

Computerized-estimating techniques are not fully used in the industry. Commercially available estimating systems and services are seldom used. Many estimates are prepared without using state-of-the-art techniques for risk analysis. Budgets for many long-duration projects have been hit hard by cost escalation not foreseen in estimates. The techniques of applying escalation estimates at intervals along the time span of the project have not been used effectively. An allowance for escalation is often applied as a bottom-line percentage, thus missing the compounding effect of inflation over several years.

A major deficiency in the industry, which often defeats efforts to control costs all the way to completion of construction, is inadequate documentation of the project's scope when original cost estimates are made. Another deficient area is lack of cost control during the design phase. Much attention is devoted to collecting field production data, but insufficient attention is normally paid to quantity growth of the project during design. Most respondents to the survey among owners and engineering firms report that cost control procedures for design exist, but work effectively only "sometimes.'

Poor scope definition at the estimate (budget) stage and ***loss of control of project scope*** rank as the most frequent contributing factors to cost overruns.

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[5] The subject of contracting strategy is discussed in detail in Report A-7, *"Contractual Arrangements",* The Business Roundtable, 1982.

Survey respondents report that computers are commonly used to help control costs in the field, but that management needs to give more attention to control data systems to improve the effectiveness of these control efforts.

The weighted average expenditure for estimating and budgeting for a typical, medium-sized project, the survey showed, is approximately 0.65% of the project's cost. The reported expenditure for cost accounting and cost control is some 0.75%. Most respondents indicated that outlays for these activities should be increased to achieve cost-effective programs.

Before picking design-construct and/or construction contractors, owners have not always thoroughly investigated their systems, procedures, and personnel capabilities for estimating and cost control. Relatively few contracts require qualification and implementation standards for assigned estimating, budget, cost accounting, and cost control functions.

Conclusions

Both the risk of and exposure to cost overruns are greater in large projects with long durations than in smaller or briefer ones. Yet it is mainly the large projects that are budgeted so early, generally before the scope of the project is fully defined and long before architectural and engineering design is finished. Risk analysis and evaluation techniques are available for use during the budgeting process and offer management the opportunity to make decisions based on improved data.

Regardless of the means of construction, whether by owner management with contractors, general contractors, or construction manager control, the total project must be set up in manageable segments to ensure control. The precise scope of these segments is easier to define and communicate to all project participants, thus improving their ability to control the design and construction process. As a result, budgeting, cost control, and decision making are greatly simplified. Moreover, scheduling for the project can be aligned with cost modules for additional management control.

All project participants should realize that the accuracy of cost estimating depends not only on a clear definition of the project, but also on:

- Knowledge of costs associated with various elements of the project.
- Accuracy of historical data.
- Accurate prediction of the schedule.
- Assumptions concerning changing regulations.

- Evaluations of escalation and risks associated with design evolution in areas where the scope definition may not be clear.
- Achievable productivity.
- Start-up procedures.
- Management skills.

The estimator should not be expected to reach cost conclusions without consulting representatives of all participating parties, particularly the management charged with responsibility for the actual construction.

The construction industry historically has had difficulty in sharing cost-experience data. The amount of detail in shared data varies with the requirements, or perspective, of the participants. As an example, owners do not need large volume of detailed productivity data from contractors. But owners *do* need accurate summary data for future estimating. Cost module planning at the beginning of a project can provide valuable information on which a data base may be built for future use in making estimates.

The industry should expand its use of computer-aided estimating for efficiency, speed, and cost-reduction. But the effective use of computerized estimating hinges on developing a reliable data base of information and careful training of personnel. Computers cannot eliminate the need for experienced estimators and management involvement.

One area offering great potential for cost savings is control of scope during project design.[6] Based on responses to our survey, a saving of 2 to 4% of total project cost appears to be a conservative estimate of the potential for cost reduction through the use of scope control procedures.

Poor scope definition, limited use of risk evaluation techniques, poor documentation of the basis for estimates, loss of control of scope during design, and lack of management involvement are problems that can be corrected if owners and contractors adopt and actively use available procedures and systems.

Outlays for effective budgeting and estimating programs should generally be increased. Effective project cost control systems will also require some increased expenditures for medium-to-large projects. However, with timely and effective action by management, the increased expenditures in these areas should provide savings well in excess of their cost.

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[6] This subject is discussed in a separate Report B-1. *"Integrating Construction Resources and Technology Into Engineering",* The Business Roundtable, 1982.

Owners have much to gain by choosing contractors who can demonstrate full capability in estimating and cost control. Incentives in contracts, if properly structured, can be positive motivators for improving the industry's commitment to the use of these systems.

Recommendations

Owners are urged to

1. Recognize that it is extremely risky to budget projects - especially large ones - on the basis of conceptual estimates made with a low percentage of project definition and design completion.

2. Use risk-analysis techniques to evaluate undefined areas, scope growth potential, process and design status, schedules, regulation changes, procurement, productivity, start-up and management skill. Be prepared to accept contingency factors appropriate to the risk evaluation in order to get a more accurate estimate of final cost.

3. Require that escalation of costs be calculated on the basis of a realistic schedule of expenditures for labor, equipment, and materials. Escalation for materials should be by commodity classification.

4. Make sure that project managers have adequate training and experience to make estimating and cost control decisions, and are fully involved in the development of estimates and in cost control efforts.

5. Require that medium and large projects be subdivided at an early stage into smaller, more easily managed segments for *estimating/budgeting,* and cost control purposes.

6. Require that cost modules be tied to schedule modules to assure cost and schedule control and integration of each project segment.

7. Require that the basis for cost estimates be documented and used as a communication and control device.

8. Promote the use of computerized estimating techniques where the size of the project justifies their use.

9. Require that cost estimates be brought up-to-date, at planned intervals as the design of a project proceeds. Documentation of changes at this stage is critical to project cost control efforts.

10. Plan the cost control program to provide actual cost feedback to be used for management decisions on a timely basis and to, provide a historical record for future estimating.

11. Choose design-construct contractors and/or construction contractors who demonstrate that their procedures, systems and personnel capabilities meet prescribed criteria for cost estimating and control.

12. Consider contractual incentives to help assure implementation and tangible results in estimating and cost control.

13. Commit to an adequate outlay for estimating and cost control.

14. Require a post-project review of actual costs vs estimated costs to determine areas where the estimating data base should be modified.

VI

QUALITY ASSURANCE

There are at least three major concerns involving quality in the construction industry. First is the idea, perhaps perceived or perhaps real, that the quality of engineered construction in the United States has declined significantly. Second, construction-related disputes involving legal liability, negligence, errors and omissions claims, and governmental citations and fines have been increasing at a rapid rate. Third, and perhaps most important, there is a growing public awareness that major construction projects impinge in a substantial way on society and the environment. Thus quality is becoming a national public concern.

To set the stage for a meaningful study of quality in construction, the study team established definitions for quality assurance and for quality control:

> ***Quality Assurance*** **(QA):** a planned and systematic pattern of all actions necessary to provide adequate confidence that a product will conform to established requirements.
>
> ***Quality Control (QC):*** implements the quality plan by actions necessary for conformance to established requirements.

The study team was unable to find any published literature or existing groups which had focused on quality assurance or quality control in construction. As a result, the study team prepared a comprehensive questionnaire to survey QA/QC practices in certain segments of the construction industry. Supplementing the questionnaire, the study team conducted selected interviews with company representatives whose expertise could aid the study.

Findings

Formalized quality-assurance/quality-control programs have really evolved rather than been planned on a sound engineering basis. Quality problems arose and quality procedures were instituted or refined to prevent future occurrences. The application and benefits of a quality assurance/quality control program are neither fully understood nor effectively utilized in the planning, design and construction phases of most projects. Only a very few firms were found that indicated they were attempting to measure the cost effectiveness of their quality programs. These measurements were mainly by comparing costs of rework and downtime (as a percentage of total project costs) with identifiable QA/QC costs.

Of the three types of companies queried, owners exhibited the *least* interest in establishing formal QA/QC programs, even though they

stand to benefit the most because they must live with any poor quality construction that is accepted. There is no question that increased attention to quality by owners would bring them tangible benefits - in costs, productivity, and in the use of their facilities over time.

Confusion exists about the differences between quality assurance and quality control, as well as the best organizational structure to handle these two functions. Organizational structure must clearly define the functional, administrative, and communication lines between quality assurance and quality control units and other groups in the company or project.

In nuclear power plant design and construction the amount of money budgeted as a percent of project cost for QA/QC is several fold more than in other types of design and construction. All reporting firms indicated their nuclear QA/QC budgets were overspent (usually by a large amount). Most companies question the cost effectiveness of the QA/QC efforts as now required in nuclear power plant projects. They cite redundancy, massive paperwork, confusion, unnecessary delays, and skyrocketing costs. The amount of money budgeted for QA/QC on projects other than nuclear power plants varies widely. No trends or norms appear evident. Most respondents indicated a strong interest in finding out how much others were spending to this end.

Personnel problems in quality assurance and quality control revolve around high turnover and a chronic shortage of qualified personnel. There appears to be a lack of well defined career paths in quality assurance and quality control for all types of companies. Information about training programs is generally lacking; indeed, a number of companies ***requested*** such information. A number of national professional organizations focus on certain aspects of quality assurance and quality control, but the study team found no organization focused on QA/QC in construction.

Among owners, the lack of formal manuals and procedures covering QA/QC methods and procedures is surprisingly high. It appears that many owners do not require contractors, subcontractors, or vendors to have approved QA/QC manuals and procedures. In many cases where manuals and procedures exist, the construction specification portions are out-of-date and largely irrelevant.

Another disturbing finding was the lack of statistical methods and the infrequent use of automatic data processing (ADP) in construction quality assurance and quality control. Statistical analysis is a powerful tool to disclose the cost effectiveness of QA/QC efforts. Its use does require ADP equipment but such equipment has become relatively inexpensive and easy to use.

From the respondents' viewpoint, the most troubling quality problems were those involving on-site construction, as contrasted with shop-

fabricated items. This response supports the basic premise that quality control must be exercised directly by the craft performing the work, or quality will suffer.

Owner companies that consistently seem to obtain the highest quality construction have adopted several innovative management techniques. First, they have a separate quality group at corporate headquarters. Second, they have a formal, documented QA/QC program. Third, they carefully-rate and qualify potential contractors, and as part of this rating they do rather extensive planning. Fourth, they often have formal post-project evaluations, including a review of QA/QC efforts during construction. Guidelines for a cost effective QA/QC program are shown in the Quality Assurance Subteam Report (see Appendix).

Recommendations

1. General

- More effective quality assurance and quality control programs are needed throughout the industry.
- Methods for measuring quantitatively, to the extent practical, both the additional costs and the benefits of formal QA/QC programs in the design and construction of engineered projects are also needed.
- An existing or, if necessary, a new professional organization is needed to focus on the problems of QA/QC in the design and construction of engineered projects.

2. Owners should strongly consider:

- Clearly defining the level of quality assurance required on their projects.
- Requiring designers, constructors, and vendors to have formal QA/QC programs and procedures as one prequalification for bidding or negotiating work.
- Requiring pre-job meetings to review and clarify all QA/QC requirements and define how they will be monitored.
- Having the operational executive (preferably the plant manager) become more active in the planning and execution of the QA/QC efforts.
- Establishing an autonomous quality assurance group within the company to 1) analyze and approve programs and procedures that are submitted, and 2) assure that the programs are in fact put to use during design and construction.
- Placing the responsibility for the control of quality directly upon the organization performing the work and under the day-to-day direction of the manager responsible for the execution of the work.

- Establishing a regular post-project quality review to assess the effectiveness of the QA/QC effort. The results of the review should be documented for use in future project planning.
- Tracking the cost of critical items over the entire life of the facility built, in order to get a more precise reading on the results of the quality level achieved during design and construction.

3. Owners and contractors should:
- Establish definitive career paths for QA/QC personnel within their organization.
- Have current, relevant QA/QC manuals and procedures.
- Use automatic data processing more extensively for statistical analysis and to create data for historic comparisons in future years.
- Fully explore the many ideas and modern methods now being proposed for improving the quality of engineered construction through motivational techniques. They include quality circles, innovative labor relations, personnel motivation, and participative decision making.[7]

4. Both design-construct and construction companies should develop a well defined QA/QC organizational structure. This structure should clearly delineate the quality assurance and quality control groups and establish administrative, functional and communication links between these groups and both the project management and home-office management.

[7] These subjects are discussed in a separate Report A-2, *"Construction Labor Motivation",* The Business Roundtable, 1982.

VII

MATERIALS MANAGEMENT

Materials management is the management system for planning and controlling all necessary efforts to make certain that the right quality and quantity of materials and equipment are appropriately specified in a timely manner, are obtained at a reasonable cost, and are available at the point of use when needed. It should be noted that materials management is a system, not the organization responsible for performing these tasks. However, it does affect activities traditionally performed by engineering, purchasing and construction departments.

Findings

The cost of the materials and equipment put in place in industrial, commercial, and power plant construction in 1979 amounted to approximately 60% of the total cost of the projects, or about $82 billion. The report concludes that more than 6% of construction labor cost could have been saved if these materials and equipment had been available at the work site when needed.

Many firms in the construction industry have sophisticated and computerized control systems for materials and equipment. But questionnaire responses clearly indicate that these systems are often deficient in meeting the materials management goal. The construction industry lags far behind the manufacturing industry in applying the concepts of materials management.

Three major weaknesses must be overcome before any appreciable improvement can be expected in the cost effectiveness of materials management systems as used in the construction industry.

- Senior management of firms in the construction industry has not always recognized the significant contribution that materials management can make to the cost effectiveness of projects. Too little attention has been given to controlling the largest single element of project cost.
- When top executives lack appreciation of the importance of materials management systems, the personnel performing the related functions have not been properly selected or trained.
- Even the sophisticated and computerized systems for materials and equipment now being used were often not properly selected or designed, or are being misused. As a result, they do not provide the needed information to let management control what happens.

The lack of management direction to carry out the concept of materials management is evident when:

- Management of project work is complicated by inconsistent and/or illogical assignment of responsibility for materials management activities among project-support groups.
- Personnel, both in project offices and at job sites, are not appropriately trained to perform their assigned tasks, and lack full understanding of the interdependency of their own work and that of related work performed by other organizations.
- Integration of materials management into project planning is noticeably lacking.
- Systems used to support materials management are generally not effectively meshed with the overall project management system.
- Existing control information is poorly used to monitor performance against plans, to forecast all the impacts of design changes and to adjust the total project plan in response to change.
- Little work has been done to develop effective standards of performance for materials management. This contrasts strikingly with the large amount of work done to develop performance standards for measuring both engineering and construction tasks.

Criteria for Effective Materials Management Systems

The criteria for organization, planning, execution and capture and use of data can be used in at least three ways:

1. To test the effectiveness of existing materials management systems.
2. To develop systems where none exist.
3. By owners to evaluate the capabilities of prospective contractors.

Organization

- Organizational responsibilities for all materials management activities, including those at job sites, must be fully defined, logically and consistently assigned, and understood by all personnel involved.
- Detailed written procedures should be published covering the performance of all materials management activities and the monitoring of that performance against plans. The procedures must be consistent with the assignment of organizational responsibility.
- Standards should be used to establish staffing levels for each activity. There should be procedures to keep track

of staff levels and make adjustments to suit changed requirements.

Planning

- Detailed plans and schedules should be prepared covering all the materials management activities. These must properly reflect the interdependence of related project activities. They must be regularly updated to take account of changes in project requirements and market conditions.
- All activities should be tested for their cost effectiveness before being included in detailed plans.
- Performance standards should be used to develop man-hour/cost budgets for materials management activities. Budgets should be structured so that they can be used to compare actual performance with the budget.
- Plans and budgets should be developed early in the project, with the advice and concurrence of all managers charged with execution of the plans.
- Schedules for activities to be performed by outside firms should be realistic, reflect anticipated market conditions, and be based on adequate information from outside firms as well as in-house experience.
- An effective procedure should be established for incorporating changes, for assessing the impact and for communicating changes throughout the project organization.
- An ongoing system should be used for advance planning to ensure that required craft materials are at specific work areas of the. job site.

Execution

- Early take offs and purchases of bulk materials should be made consistent with the timing of construction needs, with provisions for adjusting final quantities from later takeoffs.
- Effective use should be made of computer aided systems for schedule preparation, material take off and purchasing documents in conjunction with design and drafting efforts.
- Well defined systems should be used for pre qualifying bidders. They should include maximum use of in house information on the bidder's past performance.
- Expediting and inspection personnel should participate in the selection of suppliers, and in pre award meetings to help assure that delivery promises and quality requirements can be met by the supplier.
- The plan for issuance of requisitions and purchase orders should be monitored against actual issuance to make

sure that prompt corrective steps are taken if requisitions or purchase orders are issued tardily.

- Expediting plans should be prepared for every order based on the complexity of the product's production, the project schedule requirements, and the known performance capability of the supplier.
- On critical orders, the supplier's total production schedule should be obtained. Thereafter, the supplier's performance, and that of subsuppliers, should be monitored by shop visits. The purpose of these inspections is to make sure that a supplier's design effort, purchasing, production, and testing do not fall behind schedule.
- Quality assurance and quality control requirements which identify in shop inspection needs should be documented.
- Inspection plans should be prepared for each order based on the complexity of the product, the known performance of the supplier, and the requirements of the QA/QC documents.
- Sufficient monitoring and inspection of a supplier's performance and that of sub suppliers should be done by preplanned shop visits to assure that the supplier's materials, production processes, workmanship, and finished product as prepared for shipment will meet specified quality requirements.
- Plans should be made and monitored as executed for the expeditious and economical transport of materials and equipment to the job site. The plans should also provide for adequate protection against damage in transit.
- Procedures for handling and storage of materials and equipment at the job site should be developed to minimize handling.

Capture and Use of Data

- Project and materials management systems and procedures should be designed recognizing the interdependent relationships of all materials management activities, regardless of what organization is performing the activity.
- The systems and procedures, both manual and automated, should be so designed that data developed or used for one activity are readily available for other activities when and if needed.
- Exception reports based on timely, consistent and correct data should be used by appropriate managers to monitor progress against materials management plans and schedules, and to start corrective action when required.

Recommendations

Owners should consider:

1. Requiring that materials management systems meeting the above criteria are used for their projects both by their own organizations and by their contractors.

2. The adverse impact on cost and schedule of proposed changes to drawings and specifications and fully evaluate their effect before making changes. Incomplete drawings and specifications should not be issued for procurement, unless the owner fully accepts the probable large increase in costs that will ensue in return for minor savings of time.

Owners and Contractors should;

1. Develop standards of performance for materials management activities.

2. Select materials management personnel carefully, provide adequate training and career progression plans. Increased attention should be given to providing training for any local hire personnel performing materials management activities at the job site.

3. Use automatic data processing more extensively for materials management, especially for large projects and for job site activities where it can be most effective at eliminating waste of time and money.

4. Expedite placement of purchase orders by techniques, varied to suit the dollar amount and conditions of orders, such as a form of proposal to encourage technical uniformity in bids, price agreements, requirements orders, small dollar value orders, and petty cash fund purchases for small items.

5. Improve job site inventory control by broader use of coding systems and of re-order points for commonly stocked materials. Satellite warehouses close to work areas should be established for large projects.

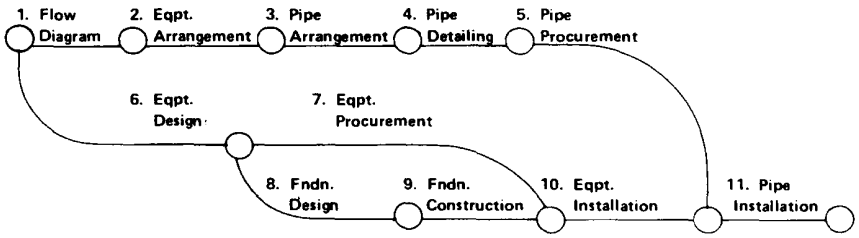
VIII

MESHING ALL THE MANAGEMENT SYSTEMS

Planning and scheduling, cost estimating and control, quality assurance/quality control and materials management are interrelated functions of project management. They fit together into a whole. Piecemeal use of one part or another will yield minimal results. Figure 1 is a diagram of this network interrelationship.

FIGURE 1
Interrelationships of Modern Management Systems

NETWORK DIAGRAM
(ILLUSTRATING ELEVEN ACTIVITIES)



MODERN MANAGEMENT SYSTEMS
(ILLUSTRATING THEIR COVERAGE OF ACTIVITIES)

ACTIVITIES

ACT NO.	DESCRIPTION	PLANNING & SCHEDULING	MATERIALS MANAGEMENT	QA/QC.	COST EST. & CONTROL
1	Flow Diagram		BTO	QA	D
2	Eqpt. Arrangement				D
3	Pipe Arrangement				D
4	Pipe Detailing	Covers	G	QC	D
5	Pipe Procurement		P	QC	P
6	Eqpt. Design	All	G	QC	D
7	Eqpt. Procurement	Activities	P	QCP	
8	Fndn'. Design		G	QC	D
9	Fndn. Construction		P, U	QC	P, D
10	Eqpt. Installation		U	QC	C
11	Pipe Installation		U	QC	C

LEGEND

QA/QC	MATERIALS MANAGEMENT	COST EST. + CONTROL
QA = Concurrent Activity	G = Matis. Generated	D = Design Cost
BTO = Bulk Takeoff		
QC = Involved in Activity	P = Marls. Procured	P = Procurement Cost
	U = Marls. Used	C = Construction Cost

Costs and schedules should be considered together in the planning and estimating of a project, and trade-offs should be calculated. The most cost effective project to an owner is the one that achieves the ultimate balance of schedule and cost considerations.

Materials management should be integrated fully into the planning process to obtain a realistic schedule.

Quality assurance and quality control, if not planned and executed properly, can have an adverse impact on both costs and schedule.

IX

GENERAL RECOMMENDATIONS

Many owners and contractors have not yet recognized the major role that modern management systems can play in the achievement of cost effective projects. Today's projects are becoming more complex in nature, often because of external influences beyond the control of the owner or contractor. Most of the old tried and tested systems of yesteryear can no longer handle the complexity and volume of data confronting today's project and construction managers. Action is needed to put in place modern management systems which will provide effective project controls. Specific recommendations have been made in sections IV through VII of this report. They can be used as a checklist for evaluation of the adequacy of existing systems. The following general recommendations concern the overall development and implementation of modern management systems.

Owners should consider:

- The need for modern, cost effective, management systems to plan, execute, and control their projects.

- Their responsibilities and prerogatives as related to the use of management systems. In this regard, they should formally establish their specific scheduling, cost control, quality assurance and materials management objectives prior to requesting bids for a construction project.

- The selection of design-construct and construction contractors who can demonstrate that their procedures, systems, and personnel capabilities meet prescribed standards for control of schedule, cost, quality assurance, and materials management.

- The possible use of incentives to contractors to achieve project objectives, whether they be schedule, cost, or quality assurance.

Owners and Contractors:

- Can assist in the development of industry guidelines for the four management system functions (planning and scheduling, cost, quality assurance, and materials management. These guidelines should include model clauses for inclusion in construction contracts.

- Should recognize that these four functions are integrated. Accordingly, automatic data processing systems for the four functions should be designed so each system is self-contained and reports data required for control of that function, but the

systems should be tied together so that a change of data in one system will be reflected immediately in the other related systems.

X

APPENDIX

LIST OF SUBTEAM REPORTS

A-6.1 PLANNING AND SCHEDULING

A-6.2 COST ESTIMATING, BUDGETING AND CONTROL ACCOUNTING

A-6.4 QUALITY ASSURANCE

A-6.5 MATERIALS MANAGEMENT

Copies of the above reports are available on written request from The Business Roundtable, Suite 2222, 200 Park Avenue, New York, NY 10166.

CICE REPORTS

The Findings and Recommendations of The Business Roundtable's Construction Industry Cost Effectiveness project are included in the Reports listed below. Copies may be obtained at no cost by writing to The Business Roundtable, ATTN: CICE, 200 Park Avenue, New York, NY 10166.

Project Management -- Study Area A

- A-1 Measuring Productivity in Construction
- A-2 Construction Labor Motivation
- A-3 Improving Construction Safety Performance
- A-4 First and Second Level Supervisory Training
- A-5 Management Education and Academic Relations
- A-6 Modern Management Systems
- A-7 Contractual Arrangements

Construction Technology -- Study Area B

- B-1 Integrating Construction Resources and Technology into Engineering
- B-2 Technological Progress in the Construction Industry
- B-3 Construction Technology Needs and Priorities

Labor Effectiveness -- Study Area C

- C-1 Exclusive Jurisdiction in Construction
- C-2 Scheduled Overtime Effect on Construction Projects
- C-3 Contractor Supervision in Unionized Construction
- C-4 Constraints Imposed by Collective Bargaining Agreements
- C-5 Local Labor Practices
- C-6 Absenteeism and Turnover
- C-7 The Impact of Local Union Politics

Labor Supply and Training -- Study Area D

- D-1 Subjourneymen in Union Construction
- D-2 Government Limitations on Training Innovations
- D-3 Construction Training Through Vocational Education
- D-4 Training Problems in Open Shop Construction
- D-5 Labor Supply Information

Regulations and Codes -- Study Area E

- E-1 Administration and Enforcement of Building Codes and Regulations

Summaries - More Construction For The Money
- CICE: The Next Five Years and Beyond

Supplements - The Workers' Compensation Crisis…Safety
- Excellence Will Make A Difference (A-3)