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Management of construction jobsite productivity : a self assessment approach

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MANAGEMENT OF CONSTRUCTION JOBSITE PRODUCTIVITY - A SELF ASSESSMENT APPROACH

by
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ABSTRACT

Title of Thesis:	"Management of Construction Jobsite Productivity - A Self Assessment Approach"
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A critical component of construction project management is the improvement of jobsite productivity. This paper proposes a procedure for use by project managers to assess jobsite productivity performance. The methodology provides a framework which when applied will identify specific aspects of the jobsite where potential productivity improvement is possible. A major feature is its systematic approach which will direct the project manager to the specific resources which when better managed will lead to lower construction costs.

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Αφιερωμενο στην γυναικα μου
Νικολεττα
και στους γονεις μου
Πολυβιο *και* Αννα

Dedicated to my wife
Nicoletta
and to my parents
Polivios and Anna

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CHAPTER 1
INTRODUCTION

Construction is the biggest industry in the world. Perhaps no other industry promises as large a payback for performance improvement as does construction. Hundreds of billions, even trillions, of dollars are spent each year on construction. An improvement of even a fraction of a percent in performance would produce billions in savings. Yet perhaps no other industry in the world has so steadily resisted abandoning traditional, reactive management methods for performance-based management systems.(1)

Today construction is a project-oriented industry. Facilities to be constructed or objectives to be achieved are defined, and an effort is then made to achieve these within certain time and cost parameters.

Competence in the management of construction projects is a goal to which we all in the industry aspire. Bringing together the many diverse elements of construction - labor, machines, materials, and managerial talent - and successfully organizing them to bring into existence a new structure is an extremely creative and satisfying endeavor.

But management performance varies greatly. Some projects make money; others lose it. Many contractors might claim that the difference between profit and loss depends on experience and judgment. Good managers run profitable jobs. But is that all there is to it? Must every good manager be born, not made? Or is there a science of construction management to be learned, with principles that anyone can apply with an equal chance of success?

Fortunately, an emerging science of construction management holds the promise that every manager, from the weakest to the strongest, can improve jobsite performance. The principles embodied in newly developed management methods contain little that is entirely new; for the most part, the methods merely formalize exactly what good contractors have been doing intuitively for years. Formal management methods based on intuitive experience are readily understood by contractors, owners, and craftsmen anxious to improve their performance and their profitability. Competent management performance can be engineered, just as we have learned to engineer the structures we erect. And competence leads directly to larger construction savings and a bigger bottom line.

Measurment and Performance

Every construction project can be improved; however, management must know what to improve and how to improve it. This knowledge may come from unexpected sources.

Construction performance can be measured to provide management with invaluable feedback to guide daily decision making. Measurements help turn even average managers into exemplary performers by supplying them with better information.

In the best of all worlds, information would be so perfect that the right decisions and actions would follow directly. However, because information is never perfect, we depend on managers with experience, judgment, training, and natural talent to correctly interpret the confusion of jobsite information and to come up with the best possible decisions. Contractors invest large amounts of money in training managers both in classrooms and on-the-job, and in hiring and keeping people with proven managerial talent. Yet no matter how well (or how poorly) a manager performs, the quality of decision making improves if the quality of information improves. However, money invested to improve the quality of managerial information may actually do far more to boost construction performance than many times that amount spent directly on the managers themselves.

But good information requires a systematic process of collection.

This paper offers three major points:

A method for measuring construction performance

A means for using measurements to improve management

A demonstration of the method in field applications

The purpose of this paper is to improve productivity in construction and competence in construction management. The performance measurements here discussed, provide the means to reach these goals, which offer contractors larger profits.

Project and Construction Management

Perhaps the most important role in the construction process is that of the construction manager and/or the project manager.

Therefore, it is important in this introduction chapter, to define the role of construction manager, project manager and professional construction manager.

Project management in general can mean different things to different people. Quite often, executives misunderstand the concept because they have ongoing projects within their company and feel that they are using project management to control these activities. In such a case, the following might be considered as an appropriate definition:

Project management is the art of creating the illusion that any outcome is the result of a series of predetermined, deliberate acts when, in fact, it was dumb luck.

Although this might be the way that some companies are running their projects, this is not project management. Project management is designed to make better use of existing resources by getting work to flow horizontally as well as vertically within the company. This approach does not really destroy the vertical, bureaucratic flow of work, but simply requires that line organizations talk to one another horizontally so work will be accomplished more smoothly thoughtout the organization. The vertical flow of work is still the responsibility of the line managers. The horizontal flow of work is the responsibility of the project managers, and their primary effort is to communicate and coordinate activities horizontally betwen the line organizations. The following would be an overview definition of project management:

Project management is the planning, organizing, directing, and controlling of company resources for a relatively short-term objective that has been established to complete specific goals and objectives. Furthermore, project management utilizes the systems approach to management by having funcitonal personnel (the vertical hierarchy) assigned to a specific project (the horizontal hierarchy).(2)

The above definition requires further comment. Classical management is usually considered to have five functions or principles:

. *Planning*

. *Organizing*

. *Staffing*

. *Controlling*

. *Directing*

You will notice that, in the above definition, the staffing function has been omitted. This was intentional, because the project manager does not staff the project. Staffing is a line responsibility. The project manager has the right to request specific resources, but the final decision of what resources will be committed rests with the line managers.

Construction management is the composite of all modern project management methodologies having as their objectives the control of time, cost, and quality in the design and construction of a new facility. Project management in construction is the term by which this process is more frequently referrred to abroad, in order to emphasize that the conceptual planning, predesign, and design phases may be of equal or greater importance to the control process as compared with the field, or construction, phase.(3) Therefore, in this paper the acronym CM includes both philosophies of management.

The Advantage of CM

CM can have many forms, but successful systems have common characteristics:

1. The CM is retained as a professional, respected for his knowledge of the constructionprocess. He has a systematic approach to developing estimates and schedules. He is assigned the responsibility of watching the process throughout to control costs and schedule (not just report them). For this purpose he participates in the decision process with the owner and architect. He will perform the tasks listed above of a General Contractor (GC) in a professional manner, committed as an advocate to the objectives of the owner and the intent of the designers. While the bids and adversary relationship of the trade contractors remain, good project management helps them do their work efficiently; it gains their commitment to the owner's and designer's objectives. As the CM does no direct work, he devotes his full attention to effective management.

2. The CM helps the owner and architect perform their roles more effectively by providing unbiased advice on cost and constructability. Whether his rank be superior, subordinate, or equal to that of the architect, he respects the professional skill and objectives of the designers; he must help them, not merely police them. He advises the

owner on risks inherent in the construction process and tries to reduce the exposure and consequences. He may be given specific early asignment such as arranging for borings or investigating site restraints. He is a team player, minimizing conflicts between organizations to encourage effective contributions by all.

3. The CM provides reasonable estimates from incomplete preliminary information to guide the owner and architect in planning and design. He updates the estimates at each major checkpoint, and parts of them as information is available. He helps the designers find the most cost-effective solutions. This process includes procurement to gain a guarantee of the cost from trade contractors. The techniques used in preliminary estimating and procurement are sophisticated to imporve accuracy. For changes in the work, the CM negotiates as an agent of the owner to obtain a proper price. Although he does not have the final say on design, he has the responsibility to control cost; thus he is a frequent adviser as the design develops.

4. The CM provides early schedules of the whole project, with emphasis on early tasks, then updates this with expanded detail as more input is available. By regular review, he identifies early potential delays and seeks ways to avoid them. The network schedules are planned to identify the strategic element at each step and are comprehensive enough to include those items which need attention. This scheduling role is particulary important in the off-site coordination and synchronization of on-site activities.

5. The CM acts as communicator. He establishes the communication channels for the whole project, often acting as facilitator in meetings, helping each specialist understand the other organizations. Most important is his role of explaining the limits and opportunities of the local marketplace to the owner and designers. Much of this is oral, as letters and reports can be of more cost than value, but there is enough formal documentation to inform all involed, to serve as a forcing device by identifying action expected, and to provide a record.

Professional Construction Management

Professional construction management is one effective method of satisfying an owner's construction needs, and often providing the technical expertise that is needed. It treats the project planning, design, and construction phases as integrated tasks. Tasks are asigned to a project management team consisting of the owner, the professional construction manager, and the design organization. A prime construction contractor and/or funding agency may also be part of the team. The team works together from the beginning of design to project completion, with the common objective of best serving the owner's interests. Contractual relationships among members of the team are intended to minimize adversary relationships and contribute to greater responsiveness within the management group. Interactions relating to construction cost, environmental impact, quality, and completion schedule are carefully examined by the team so that a project of maximum value to the owner is realized in the most economical time frame.(4)

Professional Construction Manager

A professional construction manager is a firm or an organization specializing in the practice of professional construction management, or practicing it in a particular project, as a part of a project management team. As the primary construction professional on the team, the professional construction manager provides the following services, or such portion thereof, as may be appropriate to the specific project in question.

1. The professional construction manager works with the owner and the design organization from the beginnning of design through completion of construction, providing leadership to the construction team on all matters relating to construction, keeping the project management team informed, and making recommendations on design improvements, construction technology, schedules, and construction economies.

2. The professional construction manager proposes construction and design alternatives to be studied by the project management team during the planning phase, and analyzes the effects of these alternatives on the project cost and schedule.

3. Once the project budget, schedule, and quality requirements have been established, the professional construction manager monitors subsequent development of the project in order that these targets are not exceeded without the knowledge of the owner.

4. The professional construction manager advises on and coordinates procurement of material and equipment and the work of all construction contractors; the firm may monitor payments to contractors, changes, claims, and inspection for conformance to design requirements; it provides current cost and progress information as the work proceeds; and it performs other construction-related services as required by the owner.

In keeping with the nonadversary relationship of the team members, the professional construction manager does not normally perform significant design or construction work with its own forces, although it may provide the general conditions of the site.

CHAPTER 2
PRE-CONSTRUCTION

The Life Cycle of a Construction Project

Six basic phases contribute to developing a project from an idea to reality:

Concept and feasibility studies

Engineering and design

Procurement

Construction

Start-up and implementation

Operation or utilization

In practice, of course, the degree of overlap among phases, in both time and operations performed, varies widely from one project to another, as does the distribution of responsibilities.

Concept and Feasibility Studies

Most construction projects begin with recognition of a need for a new facility. Long before designers start preparing drawings, and certainly well before field construction can commence, considerable thought must go into broad-scale planning. Elements of this phase include conceptual analyses, technical and economic feasibility studies, and environmental impact reports.

For example, location is fundamental to planning for a new industrial plant. Where can the plant be located to provide desirable, nearby employment for an adequate supply of skilled, productive workers? What are the present and projected costs and customs associated with the labor force? Depending on the nature of its raw-materials input and its products, will the plant have access to the most appropriate and economical forms of transportation, be they air, water, highway, rail, or pipeline? Does the location provide access to raw materials and to markets? Are there adequate sources for energy, including gas, oil, and electricity; and are there convenient communication facilities? What political or institutional factors may ease or impede the development and operation of the facility? What will be the sociological and economic impact of this plant on the community? What will be the environmental impact? What do all these factors, taken as a whole, mean for the technical and economic feasibility of the project?

To illustrate, one might wonder why there is a large aluminum plant on the north shore of Norway's Hardanger Fjord. Norway does not produce the raw material; rather, bauxite comes from Africa, Jamaica, or elsewhere. Nor does this country of 4 million people provide a large market. The location nonethless makes technical and economic sense. Technically, the production of aluminum requires vast amounts of electric energy. The west coast of Norway is mountainous and has one of the highest average annual rainfalls in the world. When these facts are taken together, it is no coincidence that a hydroelectric power station sits adjacent to the aluminum plant. For transportation, once the bauxite is loaded into ocean freighters, the cheapest form of long-distance transport for bulk materials, the geologic nature of a fjord provides for an ideal receiving harbor that requires no expensive dredging and only minimal berthing structures, thus making transshipment an economical proposition. Although Norway's population is small, it is highly educated and productive, thus providing an excellent skilled labor pool for a technologically complex facility. Finally, the nearby European industrial populations to the south provide a vast market for the plant's output.(5)

Similar forethought must go into the planning for any new project. Transportation facilities, such as highways, bridges, airports, and rapid transit systems, need not only forecasts of future demands, but also analyses of how the existence or nonexistence of these structures will actually afect social, economic, and demographic patterns and thus influence the demands the structures are intended to create or fulfill. The same applies to water supply systems, wastewater treatment plants, and new or more economical sources of energy.

Traditionally, these early stages are handled by the owner alone, or by the owner working with consultants knowledgeable of the most important factors affecting the situation. Considerable amounts of "free" information are available from, or offered by, public and private organizations that may benefit from, or be adversely impacted by, a new facility. To some extent, architect/engineer consultants, design-constructors, orprofessional construction managers can become involved in this early activity, but normally they are not brought in at least until the latter stages, if at all.

Engineering and Design

Engineering and design have two main phases: (a) preliminary engineering and design; and (b) detailed engineering and design. These phases are traditionally the domain of architects and design-oriented engineers. Increasingly, however, the owner's operations and utilization knowledge and the field constructor's experience are being more strongly injected at this stage through both direct participation and stringent review procedures. This involvement should be the case especially with construction management, and it is one of the strong points of the approach.

Preliminary Engineering and Design Preliminary engineering and design stress architectural concepts, evaluation of technological process alternatives, size and capacity decisions, and comparative economic studies. To a great extent, these steps evolve directly from the concept and feasibility stage, and it is sometimes difficult to see where one leaves off and the other begins.

To illustrate, in a high-rise building the preliminary design determines the number and spacing of the stories, the general layout of the service and occupied floor spaces, general functional allocations (parking, retail, office space, etc.), and the overall design approach. The last-mentioned factor involves decisions such as the choice between a bolted structural-steel frame or a reinforced-concrete structure. Further refinements determine whether the structure will be precast or cast-in-place concrete. In building construction, the architect has the primary responsibility for preliminary design.

In heavy construction, engineers are responsible for the preliminary design, but they often need substantial input from geologists, hydrologists, and increasingly from ecologists and other professionals in the natural sciences. For example, in designing a dam for flood control, hydroelectric power, recreation, or water storage for agricultural, domestic, or industrial uses or for regulating water quality, preliminary design requires analysis of the water-shed's hydrologic characteristics as they relate to the purpose of the structure to determine the necessary reservoir storage characteristics; the geologic nature of the foundation and abutments determines the precise location of the dam on its site; the geology, size, shape, and availability of materials influence the choice among basic structural types, such as concrete, earth-fill, or earth-rock. A concrete structure might be further specified to be a gravity, arch, or buttress design, and an earth-fill might require decisions on the type of impermeable barrier, filters, and foundation cutoffs. These and succeeding decisions result in a set of preliminary plans and specifications that are first subject to review and refinement, and then serve as the departure point for the detailed engineering and design process.

Preliminary engineering and design in industrial construction involve input and output capacity decisions, choices between basic process alternatives, general site layout, and often the preparation of overall process flowsheets. In a mining and ore-processing operation, engineers and geologists work out the mine development scheme, choose between alternative ore benefication methods, and specify other related processes. In a nuclear power plant, it is necessary to decide between the types of reactor, such as a two-cycle boiling water reactor or a three-cycle pressure water reactor. An oil refinery or petrochemical plant often involves decisions between licensing several alternative patented processes. These decisions demand close cooparation among specialists from several engineering disciplines, and they require considerable interaction between the owner's staff and the design-constructor's personnel.

Once preliminary engineering and design are essentially complete, there is generally an extensive review process before detailed work is allowed to proceed. In private work, such as industrial construction and commercial building, the review focuses mainly on seeking approval from higher levels of management and from sources of external financing, where required. But increasingly this review involves regulatory bodies that look for compliance with zoning regulations, building codes, licensing procedures, safety standards, environmental impact, etc. In public works, agencies are providing more and more opportunities for direct involvement of the general public. There are also complicated funding cycles in legislative and executive bodies, and most of the constraints from regulatory bodies and others also apply much as they do in private construction.

Detailed Engineering and Design Detailed engineering and design involve the process of successively breaking down, analyzing, and designing the structure and its elements so that it complies with recognized standards of safety and performance while rendering the design in the form of a set of explicit drawings and specifications that will tell the constructors exactly how to build the structure in the field.

This detailed phase is the traditional realm of design professionals, including architects, interior designers, landscape architects, and several engineering disciplines, including chemical, civil, electrical, mechanical, and other engineers as needed. The types of design professionals involved vary by type of work (building, heavy, or industrial) and are much the same as in the preliminary design phase, but the staffs become much larger and are generally augmented by various people at the technician and technology level, such as draftsmen and soils testers. In addition to designing the structure itself, the design professional often conducts detailed field studies to get good engineering information on foundation conditions, slope stability, and structural properties of natural materials. Such studies can require further input from experts in other disciplines, such as geologists, economists, and environmental scientists.

Again, it is becoming increasingly common for field construction methods and cost knowledge to be injected into the detailed engineering and design process. This is especially true in the design-construct and professional construction management approaches.

Procurement

Procurement involvs two major types of activities. One is contracting and subcontracting for services of general and specialty construction contractors. The other is obtaining materials and equipment required to construct the project. Allocation of responsibilities for these two functions varies widely, and it is especially dependent on the contractual approach taken for a particular project.

The traditional form for procuring construction services as well as most of the materials and equipment required for a project is to solicit competitive bids for a single general contract. This takes place soon after the detailed engineering and design phase has produced a comprehensive set of plans and specifications. The general contractor then handles all subcontracting, plus the procurement of materials and equipment. In design-construct projects, the contractor also handles all these services, but awarding of subcontracts and procurement of major equipment and materials items can proceed incrementally and can considerably overlap the design phase. In professional construction management, the professional construction manager often coordinates all these functions, including the letting of several prime contracts instead of subcontracts, while acting as the agent of the owner.

Construction

Construction is the process whereby designers' plans and specifications are converted into physical structures and facilities. It involves the organization and coordination of all the resources for the project - labor, construction equipment, permanent and temporary materials, supplies and utilities, money, technology and methods, and time - to complete the project on schedule, within the budget, and according to the standards of quality and performance specified by the designer.(6)

Start-up and Implementation

Most structures and facilities of any significance involve a start-up and implementation phase. In both simple and complex cases, much testing of componenets is done while the project is underway. Nevertheless, as the project nears completion, it is important to be sure that all components function well together as a total system. In some cases, this mainly involves testing, adjusting, and correcting the major electrical and mechanical systems so that they perform at their optimum level. Often this phase also involves a warranty period during which the designer and the contractors can be called back to correct problems that were not immediately evident upon initial testing and to make adjustments to better suit the facility to the owner's needs after he has had a chance to try it out.

In many projects, especially large industrial facilities such as power plants, refineries, and factors, start-up is a highly complex process that pushes the facility to its technological limits, as well as seeing that it operates efficiently under "normal" conditions. In this case, start-up is a project in its own right; it requires months of careful advance planning and demands good coordination and supervision, once underway. Often, spares for critical components will be kept on hand just in case something goes wrong.

Operation and Utilization

The functional value of the project will depend upon the decisions and implementation of the objectives developed during the preceding phases. With a projected operational life of 20 to 25 years or more, it is evident that the overall cost and value to the owner throughout the operating life are determined largely during the period from conception through start-up.(7)

Parties involved at this stage range from homeowners doing weekend maintenance, through janitors and equipment specialists in buildings, to public works staffs maintaining highways and operating dams and bridges, and on to the skilled engineers and technicians who operate factories, refineries, power plants, and mines. In the case of major alterations or expansions, the operations phase can also involve recycling through the first five phases of a project mentioned above, whether the work is done in-house or by contract.

Preconstruction Site Investigation, Planning, Scheduling, Estimating, and Design

Planning aims at a workable program that will achieve project goals and serve as a standard against which actual progress can be measured. The importance of fact finding at this stage of professional construction management cannot be overemphasized. The manager must first understand the designer's objectives and operating methods, but, above all, he must thoroughly investigate, and become expert on, the local job-site conditions and area construction practices important to developing proposed contract packages, fair-cost estimates and realistic schedules.

After the professional construction manager has obtained a thorough knowledge of job-site conditions that will affect performance of the work, preparation of the work plan for the project can begin. An early work plan for overall project execution is important in creating a team effort among the designer, owner, and professional construction manager, and it forms the basis for planning that will continue throughout the project as additional information becomes available. Approaches to initial planning will vary with project objectives, but the component parts of a project work plan will generally include the following items or their equivalents:

Preliminary estimate

Summary schedules

Work packages

Construction planning

Each of these will be discussed in the following sections.

Construction Site Conditions

Successful contractors and subcontractors native to the area are fully cognizant of factors affecting performance of construction work at the job site; those who are not soon fail. The professional construction manager must also become knowledgeable of these factors if he is to offer his services to the owner and the designer. Programs and bid packages that have worked well in one section of the country will not necessarily work as well in another.

Representatives of the professional construction manager must visit the site of the work. Their investigation is similar to that of a contractor planning to bid a project or a portion of a project, and likewise must be conducted by experienced construction professionals who can translate information obtained into the best way to minimize construction costs which will later be evaluated by the bidders. The professional construction manager who does not develop his program in this manner is not fulfilling his obligation to the owner, nor is he enhancing his own position.

The items to investigate on the site are many and varied. A knowledgeable general contractor or specialty contractor will have developed his own method of appraising site conditions. The selection of items for investigation and the conclusions drawn are the result of many years of experience in managing and estimating construction work. Individuals may approach the investigation from different directions, but the overall conclusions must be similar.

General Planning

By visiting the site, the professional construction manager can see access roads, railroads, and other factors firsthand. He can then choose areas for locating temporary facilities, develop a preliminary plan for contractor storage areas, and later allow for existing electrical, water, or other service utilities in developing or evaluating bid packages and in reviewing owner-furnished items. He can observe interferences with existing facilities and develop a plan for site security. The investigator should also be alert for conditions on the site that may necessitate changes from preliminary design information that he may have. Again, the professional construction manager will approach his investigation of general conditions exactly as would a general contractor planning to bid the work.

On one professional construction management project, the manager visited the site a second time after preliminary earthwork drawings were received. These drawings had been prepared by a local architect on the basis of a contour survey prepared as a part of the property acquisition several years before. It immediately became obvious that someone had dumped a significant amount of loose fill on the site, completely changing the site conditions from those shown on the previous survey. All this material had to be removed so that unsuitable top soil could be stripped. Through a resurvey and modification of the plans and specifications prior to bidding, a lump-sum bid for the actual conditions was awarded. In comparing unit prices for additional work as actually bid by the low bidder, it was clear that the owner received a substantial saving over performance of the added work by the unit prices originally contemplated.

Site visits are generally the only way that items of the type described here can be taken into account in the overall program. As the project evolves, the professional construction manager must continue to be fully informed of new developments peculiar to the site, and he must be able to communicate his on-site knowledge to the designer, the owner, and his own personnel.

Area Construction Practice

Equally important to the job-site investigations, or even more important, is the investigation of the normal method of doing business in the project locale. Even if the manager is familiar with the area, he should systematically review the local conditions and practices. If he is operating in a new area, the investigation is of paramount importance. Some of the significant items that must be investigated in order to develop a suitable program are outlined in the following subsections.

Local Work Practices and Jurisdiction

Each area is unique in the local practices and jurisdictions which have evolved over the years. The professional construction manager handling a phased construction program is constantly faced both with fitting his construction packages to the design schedule and with tailoring them to the optimum size that will attract qualified contractors. In order to achieve this objective while making bid packages attractive to potential bidders, he must know the prevailing practices in the area.

The general and specialty contractors operating in the area are fully familiar with these types of area practices. The professional construction manager must become equally well informed to be able to define the work packages in the most expedient and economical manner.

Key Local Prices

Local prices for standard items can be readily obtained, and they are of significant value in comparing alternative methods as well as in making the fair-cost estimates. Such local prices can include readi-mix concrete, sand and gravel, lumber, reinforcing steel, concrete blocks, precast concrete, pipe and fittings, cement, and other items.

In certain areas, precast concrete plants have developed standard sections that are very economical when compared with other methods. In other areas, no precast plant is readily available.

Local Contractors

The professional construction manager must develop a representative list of qualified, interested contractors for each proposed bid package. The list should be large enough to ensure competition, yet small enough to create significant interest in all bidders. By far the best procedure is to invite only fully qualified bidders to submit proposals, so that the award can be made to the lowest responsive bidder.

Preliminary lists of prospective bidders should generally be developed prior to financial screening. A knowledgeable professional construction manager, even if initially unfamiliar with the project area, will have developed local contacts who can give valuable information. Union representatives, contractor associations, local architects and engineers, and many others can give valuable assistance in prescreening available contractors.

Other Key Local Contacts

In most areas, the local chamber of commerce can furnish economic data, discuss weather and climate conditions, confirm local business licenses, assist with tax information, and offer considerable other assistance.

The local building department is in many areas a key factor to a successful, early start for a phased construction program. Some areas require all plans and specifications to be approved before construction can begin. Others require special licenses for the professional construction manager's field construction manager who is in direct charge of the job-site work. All areas have special permits and fees required at various stages in the program, such as sewer and water connections. In some areas, these contracts are best handled by the designer, especially if he represents a local firm; but in others, the designer needs input from the professional construction manager.

Local utilities should be contacted so that an early determination of the method of supplying construction power, water, and other required temporary utilities can be made.

A large amount of local business information is often available. In any relatively unfamiliar area, the ingenuity of the professional construction manager is challenged by the need quickly to gain an understanding that will serve as a base for the planning phase.

Establishment of Project Field Office

The information developed in the early site visits is by nature preliminary. It is important to build upon this base continuously throughout the planning, design, and procurement phases so that new or revised information may be incorporated into the program.

Ideally, the field office should be established in advance of the award of the first contract so that potential bidders can be shown the work site and so that a local contact with other potential bidders, agencies, and others is maintained. The field construction manager will be the key representative in all dealings with local people; the earlier he assumes this position, the better for all concerned.

Preliminary Estimate

When the overall scope and conceptual design have evolved to the point where the manager has a reasonable idea of the requirements of the owner and the implementation program of the designer, preparation of a preliminary estimate can proceed.

The preliminary estimate initially serves to check the design against the owner's original budget or appropriation estimate.

The preliminary estimate is also necessary for preparing a realistic overall project schedule that forecast occupancy dates and specifies completion schedules for individual construction contracts. The preliminary estimate forms the basis for cost control during design and procurement and is extremely useful in determining the proper size of individual contract packages that will stimulate maximum competition and intrest among selected bidders.

Summary Schedules

Three separate but distinct summary schedules are important for effective control on most multiple-facility projects. These include a design and procurement schedule, a construction schedule summarized by individual contracts, and a construction schedule summarized by individual facilities.

Design and Procurement Schedules

For best results, a schedule for each proposed bid package must be prepared showning the detailed design and specification period, package review and approval period, bidding period, and evaluation and award period. This schedule must be developed early and must be used by the designer, owner, and manager in performing their assigned tasks. The schedule will form the control standard for monitoring actual performance during the planning and design and the procurement phases, since the construction schedule is wholly dependent upon award contracts by the required dates.

In general, most designers will prepare an overall design schedule. The manager must take the proposed bid packages and, with the designer, develop a control design schedule by bid package. Depending upon construction schedule requirements, adjustments can be made with the designer to schedule an orderly design completion that fits the needs of the critical path.

A period for owner and manager review of the preliminary bid packages is a necessity if the designer is preparing bidding documents under the manager's general instruction regarding scope. If the manager prepares the bid packages from plans and specifications furnished by the designer, a review period by owner and designer is equally important. This review period is generally the last chance to avoid errors, take advantage of recent knowledge, and avoid later plan changes which will result in additional costs if made after contract award.

Reasonable bid periods should be scheduled by the manager, taking into account his knowledge of the present bidding volume in the area. If sufficient time is planned from the beginning, schedules can be more easily met, and more competitive bids will normally be received.

The professional construction manager has a unique opportunity to solicit alternate quotations, either by specifying clear choices in the contract document or by encouraging the ingenuity of the bidders. Evaluation of alternates, whether requested or volunteered, takes time; a reasonable period for evaluation and award of each bid package should therefore be included in the schedule.

Summary Construction Schedules

When a preliminary estimate and a design schedule by contract package have been finalized, a Critical Path Method (CPM) precedence diagram (or arrow diagram) can be prepared setting forth the logic of the contemplated program in sufficient detail to determine the critical path and to develop key contract milestones. This diagram will enable adjustments to be made to the design and procurement schedule so that critical items are taken into account by the designer, owner, and manager.

After the planning is complete and the CPM logic is developed and reviewed, working summary bar-chart schedules can be prepared showing early- and late-start dates, early and late completion dates, the anticipated duration of each contract package, and also the interrelationships between the separte packages. Monitoring of actual performance when compared to early and late-start scheduled performance will show status of schedule at all times, and is an integral part of the project control system.

On a multiple-feature project, a similar bar chart can be prepared, fully consistent with early- and late-start schedules, showing relationships of the separate facilities, and with provision for monitoring actual performance by facility in a similar manner.

Work Packages

After the professional construction manager has become thoroughly familiar with the project locale, after the preliminary design schedule is developed, and after the preliminary estimate is complete, he can define proper work packages and develop a reasonably detailed scope. Two of many important factors that should influence this process are construction economy and design constraints.

Construction Economy

Bid package development is one of the most significant contributions of the professional construction manager. The scope of packages should be designed to be of a size that will prove most economical by stimulating competition, that will minimize overall costs by avoiding unnecessary tiers of contractors and subcontractors, and yet that will take advantage of the coordination skills of the various general and trade contractors in the area.

Design Constraints

The packages must be scoped to fit a reasonable design schedule when earliest completion is important. Design constraints will modify the content of bid packages in balance with overall objectives. A successful phased construction program is wholly dependent upon the care and skill that go into defining work packages in order to balance economic considerations with completion requirements to achieve maximum overall benefit to the owner.

Construction Planning

Basic construction planning during or before the detail design phase will include an organization chart, project staffing schedule, temporary facility requirements of the construction manager, selection of the particular individuals to be assigned, and delineation of their responsibilities. A complete cost estimate to serve as the manager's budget can be readily prepared if initial planning is sound.

Temporary Facilities

An important phase of construction planning is the analyzing of temporary utility and general conditions requirements for the project; this analysis is similar to a general contractor's appraisal. Temporary utilities can be furnished by the owner, be built into individual contract packages, or be obtained from others based upon local practice and job-site conditions. Utility bills can be paid for by the owner, or individual contractors can be billed or required to furnish their own utilities. Again, the best solution depends upon the professional construction manager's knowledge of the area.

Much of the construction planning can be best accomplished from the job site. Sending in the field construction manager at an early date and depending upon him to develop construction planning details under job-site conditions is usually most productive.

Successful general contractors have developed the knowledge and skills necessary to plan temporary facility requirements and perform general conditions items in a manner most economical for the project. A qualified professional construction manager must have similar knowledge and skills.

Procedure Outline

Each project is unique. The manager must be able to assess the conditions and problems as they develop and to react without delay to further the interests of the project.

However, with three parties involved in the management of the project, it is important that each understand the responsibilities and duties of the others.

Cash-Flow Requirements

An estimate of cash-flow requirements for the project can be readily prepared from the preliminary estimate and from the summary schedule. Some owners require more accurate cash-flow projections than others. A simple cash-flow projection based upon prior planning can be prepared as a part of the control package. If warranted, actual requirements can be tabulated monthly and compared with earlier forecast requirements.

CHAPTER 3
A PERFORMANCE VIEWPOINT

Every contractor wants to improve jobsite performance. But how? What elements of performance require his attention? And what does he mean by performance? Suppose a large corporate owner and a general contractor agree to develop a program to ensure high performance on a showcase project. The owner develops special training films, organized by the professional construction manager. Lectures introduce new hires to the job. The contractor schedules weekly foremen meetings to discuss job progress and sets up awards dinners to involve foremen in job-improvement efforts. Extra attention to lunch areas, toilet facilities, and employee parking all demonstrate management's sincere interest in the welfare of the craftsmen. Surveys of work delays help identify problems. Weekly subcontractor meetings seek solutions to problems and elicit suggestions for avoiding future problems.

At the end of the project, both the owner and the contractor agree that the job went well, that performance was high, and that labor worked productively. To support their conclusions, they point to the fact that the job was completed on time and within budget, that the work quality was high, and that only a few minor labor problems surfaced during the work.

But is this all we have? Doesn't one get the feeling that something more is required before making a judgment regarding the performance of the job? We would also like to have measurements of performance improvement and to know how much was spent to achieve it. In other words, was the benefit worth the expense? We want to base judgments of jobsite performance not only on what was accomplished but also on how it was done and at what cost. But how do we distinguish the accomplishments at the jobsite from the methods used to achieve them? And how do both accomplishments and methods relate to performance?

Work and Motivation

Before proceeding, think for a moment about two commonly misapplied measurements of performance - work and motivation. Many contractors accept the false idea that performance means the same thing as hard work. They work hard and they demand that their employees work hard. Their supervisory and managerial people put in long hours, catch up on paperwork in the evenings and over weekends, and sacrifice friends and family for the sake of "working hard." According to this work ethic, any people who do not get to work early and look busy all day long must not be interested in keeping their jobs. Promotions often depends on how much time people give to the job, not on what they are able to accomplish. And those who do not work hard enough, whether in the office or in the field, often may find that they must soon seek employment elsewhere.

Construction companies that foster such attitudes believe that hard work is the only way to stay alive in a competitive business. Union and nonunion construction labor generally accept the same misleading principles - that working hard and looking busy measure an individual's worth on the job. This evaluation is just not true, because it looks only at work methods while ignoring accomplishments.

A second mistaken belief comes from thinking that motivation underlies the work ethic. Unless people are "motivated," they will not perform well. And, in the absence of other measurements of performance, motivation is frequently taken as a measurement in itself. Some contractors substitute judgments concerning individual motivation for measurements of performance. In their view, poor motivation (as evidenced by an unwillingness to "work hard" and a "bad attitude") means poor performance, regardless of actual accomplishment. Unfortunately, many competent people lose jobs or miss promotions because they "aren't motivated."

The problem here is not the supervisor or contractor who demands hard work and motivation as proof of good performance. Rather, it is the lack of an alternative point of view that offers actual measurements of performance and a methodology for using these measurements to improve performance.

Competent Performance

Construction methods are an essential element of jobsite performance. But methods are not the same thing as performance. Pitctures of a completed job, for example, can tell us a great deal about its cost, size, and materials yet reveal little or nothing about the performance of the work force that built it. A 50-ft concrete bridge span could have been erected with staging and centering support, or it could have been precast and lifted into place; the completed bridge (accomplishment) and the construction technique (method) that put it in place represent two different aspects of the contractor's performance. We must learn to distinguish between them in order to develop useful measurement of jobsite performance.

Look at accomplishment

Imagine a specific construction task and the work methods employed to complete it - framing a wall, for example. We see a carpenter measure, mark, and cut a 2x4, then raise and nail it into place. The method seems straightforward. Now we attempt to measure it. A stop-watch tells us how long it takes to measure and cut the board. To measure the energy used, we weigh the board and compute how far it was lifted into place. Then we count the number of hammer swings needed to secure it. We even interview the carpenter to discover how he felt about the job while doing it: were the sawhorses the right height, did the saw cut well, and was the hammer too light or too heavy? But no matter how many measurements we collect of the methods, we cannot tell whether the accomplishment is valuable. We do not know if the wall is in the right place or of the right size. Is it plumb? Is it solid? Is it being built too early, too late, or right on schedule? In other words, is the accomplishment something we value and are willing to pay for?

To answer questions concerning the performance of the job, we must look at the whole job - both the carpenter's methods and what he accomplished with them. The carpenter might have completed the framing by using a 14-oz or a 20-oz hammer, by using a handsaw or a power saw, and by listening to a radio or working in silence, with none of these alternative methods greatly affecting his performance. Performance includes both the carpenter's methods and what the carpenter accomplished with them.

Clearly, a contractor can change the carpenter's framing methods by insisting that a plumb bob be used instead of a level, by forbidding radios on the jobsite, or by adding a second carpenter. But common sense tells us that we should not change the work methods just because we can do so - that we should make a change only if it will result in producing a more valuable performance. Every contractor seeks to improve performance. Valuable performance comes from using methods that lead to valuable accomplishments.

Worthy performance

But not all valuable performances may be worth the cost of obtaining them. Spending endless hours measuring and remeasuring the exact location and size of rough-in framing for interior walls may produce perfectly aligned studs, but this may make little visible difference to the finished job. In such a case, although we may admire the accomplishment, we would not be willing to pay for it. Or adding additional carpenters to the job may speed the completion, but would it be worth the cost if the job then had to wait two weeks for an electrician? What we want, therefor, is not just a valuable performance, but a worthy performance. Worthy performance occurs when the value of the accomplishment exceeds the cost of the method.

Expressed as a ratio, we can define worth as value divided by cost:

$$\text{Worth} = \frac{\text{value}}{\text{cost}} \quad (8)$$

In managing construction work, we look to maximize the worth of a job. In framing the interior of a house, for example, we want to erect the walls according to the plans and specifications while using the least amount of the carpenter's time. Getting all the walls in right creates value. Doing it in the minimum time cuts costs. Therefore, the overall worth of the job increases as the value goes up and the costs go down. Competent construciton managers and craftsmen achieve valuable results without excessive costs.

In other words, competent individuals create worth by creating valuable accomplishments while minimizing costly methods. Thus, for a construction site, we can use the worth ratio to define performance, in this case as a ratio of accomplishment to methods:

$$\text{Performance} = \frac{\text{methods}}{\text{accomplishments}} \quad (9)$$

Which is equivalent to

$$\text{Productivity} = \frac{\text{output}}{\text{input}}$$

Here the accomplishment is what we value, and it is the methods that cost us mony. Performance thus describes how well we accomplished the job with the methods we used. Furthermore, competent performance - valuable accomplishments created with the least costly methods. In sum, we can express the combined relationship as:

$$\text{Performance (worth)} = \frac{\text{accomplishment (value)}}{\text{methods (cost)}}$$

This performance ratio tells us that we can raise our individual and company competence by increasing the value of our accomplishments while reducing the amount of time, energy, and money we expend on methods. The performance ratio shown that our competence depends on how much we are able to accomplish, not on how much we put into the effort.

A contractor who can consistently build the same-quality homes for less than his competitors is more competent because of accomplishing more, not because of spending more on the methods. However, to build a better house for less money, the contractor may have invested large sums in equipment, training, prefabricated materials, and scheduling. The effect of this investment is to increase the value of the accomplishment by producing more homes. Contractors improve their performance by investing time, energy, and money in reducing the cost of the methods required to accomplish a given construciton task, not by spending more money on methods unrelated to accomplishment. The contractor and owner at the first of this chapter who sought to improve jobsite performance by investing in a wide variety of methods (films, lectures, awards, and surveys) did so without knowing whether or not these methods contributed to the accomplishments they desired. The performance ratio, by leading us to measurements of accomplishment, can help us pinpoint exactly those work methods which have the largest potential payback for improvement. To understand how to do this, let us first turn our attention to distinguishing between accomplishments and methods.

Accomplishments and Methods

foundations dug is an accomplishment; the number of manhours on the backhoe represents the methods. Measurements of accomplishments are not the same thing as measurements of methods. And neither type of measurement, by itself, tells us much about the worth of the performance in question. We do not know if the foundations are the correct depth, and we do not know if a bulldozer could have done the job more cheaply.

Two views of measurement

To help illustrate the distinction between measurements of accomplishments and measurements of methods, let us attempt to measure the performance of two imaginary plumbers, Mr. Tighwrench and Mr. Leaks. Both arrive at the jobsite with their tools, ready to go to work, but we need only one. So we propose to test three plumber skills - plan reading, pipe layout, and soldering - in order to determine which plumber is the more competent. Each plumber will take two sets of tests, one written and one practical. One set of tests will be administered in the trailer by the project engineer, and the other set will be administered outside on the job by the plumber foreman. Table 3.1 shows Mr. T's and Mr. L's scores on the two tests. After both plumbers have completed the tests, the engineer and the plumber foreman compare their results. The engineer has a hard time deciding which plumber is the more competent both scored very well on the written test. The plumber foreman, however, has no problem of all and immediately chooses Mr. Tightwrench. But why do the different measurements give such different results? Why

TABLE 3.1 Comparison of Two Types of Performance Measurements

Skill	Engineer's test	Score T	Score L	Foreman's test	Score T	Score L
1.Plan reading	Correctly identifies plan symbols.	100%	98%	Work items correctly located from blueprints.	100%	20%
2.Pipe layout	Follows right steps in pipe layout.	100%	98%	Percentage of pipe cut to correct length.	100%	0%
3.Soldering	Knows right solder type and torch temperature.	80%	85%	Percentage of joints that do not leak.	100%	0%

does the engineer's test miss discovering Mr. Leaks' incompetence?

Look more closely at the measurements chosen by the foreman; they all measure accomplishments. They all measure something of value to the job. Conversely, each of the engineer's tests measures how much each plumber knows about the methods used to accomplish plumbing tasks. The scores on the engineer's test show that both plumbers know a great deal about how to accomplish a task, but the scores on the foreman's test show that only Mr. Tinghtwrench applies these methods with competence to achieve valuable results.

Observing the worker's methods

But does this mean that Mr. Leaks is totally incompetent? If we were to peer over Mr. Leaks' shoulder while he was working at the tasks set out for him by the plumber foreman, we might discover something very remarkable. As we watch Mr. Leaks read the blueprints to attempt to locate various work areas in the building, we notice that because the split-level floors are identified only by elevations, he has erred in assuming that the ground floor is the lobby level when, in fact, the two are one-half flight apart.

Further, we would see that in the second task Mr. Leaks followed all the right steps in laying out the dimensions for the pipe to be cut but failed only in the last step, forgetting to add an extra 1/2 in at each end for the overlap point. Had Mr. Leaks made this small correction to his measurements, all his pipe cuts could have been correct. His pipe layout methods are very nearly the same as Mr. Tightwrench's, but he lacks one critical skill - remembering to allow for the overlap.

Finally, observing Mr. Leaks' performance in soldering pipe joints, we see that he does every step right except that he repeatedly fails to buff out the inside of the elbow joints, thus leaving a tarnished surface to which the solder cannot fully adhere.

Accomplishments count

Our analysis of Mr. Leaks' shortcomings leads us to the conclusion that he knows a great deal about plumbing (the engineer's scores of plumbing methods) but can do hardly anything of value (the foreman's scores of plumbing accomplishment). Further, when we look closely at Mr. Leaks' methods as he goes about performing the foreman's tasks, we see that his methods do not differ greatly from Mr. Tightwrench's. In fact, with only small changes to Mr. Leaks' methods, his performance might have been as competent as Mr. Tightwrench's.

From this example, we come to an interesting conclusion: People may be very much alike in their methods while, at the same time, differing greatly in what they are able to accomplish.

Measure Accomplishments First

As we have seen, contractors value the accomplishments of the people who work for them, provided these accomplishments produce something of worth. If carpenters are able to frame an entire house in a week, we do not care if they play a radio while they work or whether they use a folding rule or a tape measure. We care only for what they accomplish, not how they do it. Accomplishments alone have value; methods are the cost we pay to get something accomplished.

Improving performance

Now if small changes in methods can produce significant changes in accomplishment, then we ought to be willing to invest small amounts of money to change work methods so as greatly to increase the resulting accomplishment. If we can substitute a level for a plumb bob and thereby cut an hour off the time a carpenter takes to frame each interior wall, it will be well worth the cost of the level to save the time. Through such small investments, we can significantly raise the worth of our performance. For although the accomplishment remains the same (the interior walls), the cost of building the walls goes down (the price of a level less the savings in hourly wages). The worth of our performance goes up whenever we can push the ratio of accomplishment (value) to methods (cost) higher, either by raising value or reducing cost.

$$\text{Performance (worth)} = \frac{\text{accomplishment (value)}}{\text{methods (cost)}}$$

The relationship between accomplishment and methods tells us that we should not attempt to measure methods until we have first measured accomplishment. It serves no purpose to observe and judge the steps a plumber takes in making a pipe joint unless we first know that the plumber's joints leak. We have no reason to evaluate a person's ability to read blueprints until we see that the person has difficulty in using blueprints. Or, to state it another way, we should have some reason to believe that a greater potential value exists before we look to the cost of capturing it.

We want to change work methods only if this will produce a more valuable accomplishment. But we cannot readily judge which methods to change simply by observing them, for we cannot expect to observe in detail all the work methods of everyone on a jobsite. Therefore, we start by measuring the accomplishment we value. Only when our measurements show a deficiency in the accomplishment do we need to examine the methods that caused the deficiency.

The need to measure

To improve the worth of their endeavors, contractors first need measurements of what it is they accomplish. Only after they can pinpoint the deficiencies in their accomplishments can they reasonably expect to discover what methods they need to change in order to overcome these deficiencies. To do this, contractors need to learn to collect quantifiable measurements of their accomplishments.

Quantifiable measurements of construction accomplishment can lead to improved jobsite performance, while studies of methods alone will rarely help to improve a job.(10) For example, suppose we were to visit a job at a remote site that was experiencing difficulties keeping its equipment running. Upon looking into the problem, we might discover that replacement parts are not kept in stock, that maintenance personnel lacked training on some items of equipment, and that the absence of a heated repair shed hampered people working on the equipment outside in the cold.

From this information, we could devise a better method for ordering extra spare parts and stocking them, we could develop courses to teach mechanics additional skills, and we could erect a heated temporary repair shed. And for each proposed change, we could calculate the cost.

Keeping the equipment running is the accomplishment we value and are willing to pay for; we go through the numbers to determine the least costly way to achieve our goal. In order to measure the worth of alternative methods, we must first translate both the accomplishment and the intended changes in work methods into economic terms. If the value of keeping equipment running exceeds the cost, then the investment in changing the method is worth it.

But until we know that we have an equipment problem, we have no need to examine the parts-ordering process, the skill of the mechanics, or the air temperature. In other words, measurements of the methods, by themselves, offer little promise of discovering worthwhile means to improve performance. Decisions concerning how much money to spend to install a computer (and to train someone) to keep track of spare parts, how much to budget for training mechanics, and how much to pay for renting and erecting a temporary shelter cannot be made without reference to the expected increase in the value of what we want to accomplish. Knowing the magnitude of the equipment problem we face (or anticipating the size of the problem before it arises) gives us both a reason for investigating methods and a means to judge the relative worth of the changes required.

Performance, Profits, and Productivity

Most of us readily acknowledge that a difference does exist between what people do and how they do it. In construction, accomplishment is the finished work-in-place; methods are the way the work was done. Yet in daily practice this distinction between accomplishments and methods blurs. Contractors tend to focus most of their attention on the methods, without giving a great deal of thought to overall performance. Yet when one stops to think about it, most construction companies employ pretty much the same construction methods. However, companies differ considerably in what they accomplish. Some are highly profitable; others fail. Just like Mr. Tightwrench and Mr. Leaks, companies may be very much alike in their methods while, at the same time, differing greatly in what they are able to accomplish. It follows, therefore, that small investments made to improve methods may have a surprisingly large impact upon performance. And as construction performance rises, so, too, should construction profits. However, although performance and profits are related, they are not at all the same thing.

Profits do not measure performance

Profit is the difference between what a contractor receives for a job and what it costs to do the job. Profit measures how much money a contractor makes. Clearly, a contractor can make money on a job without performing well. Circumstances can lead a client to accept a bid and sign a contract for far more than a job is worth. With an overpriced job, even an incompetent contractor can make a profit. Some contractors make their profits by cutting corners and doing less than they should to satisfy their clients; although such contractors do not stay in business long, a seemingly endless number of incompetent contractors stand ready to enter the business to take the places of those who fail. Every contractor needs to earn a profit to stay in business but only the competent contractors - those whose performance consistently produces worth - earn profits regularly and, in the process, build the long-term goodwill necessary to remain successful against their competitors.

Because profits measure only the difference between the price of a job and the cost of a job, profits do not provide a good measurement of performance. We often assume that because a construction firm has been in business for many years and has earned profits over that time, the firm is competent in its performance. However, while the two may be related, it is a mistake to only associate profits with performance. Profits may come from many sources - such as timely materials purchases overpriced jobs, or clever accounting methods - that have little bearing on the performance of the on-site construction process. Conversely, high performance may not lead to profitability. Many competent contractors lose money and go out of business for reasons not associated with their ability to perform well. For example, lack of financing, strikes, inattention to cash-flow problems, dishonest employees, and an inability to bid and market construction services are all reasons for profit losses. Profitability and performance measure two different aspects of the construction business.

Productivity measures only one performance dimension

And what about productivity? Doesn't productivity equate to high performance and profitability? Like performance, productivity is defined as a ratio that relates measurements of output to measurements of input. The ratio is often given as:

$$\text{Productivity} = \frac{\text{output}}{\text{input}}$$

In many ways the productivity ratio appears to be the same thing as the performance ratio - with output corresponding to accomplishment and value, and input to methods and cost. Labor productivity, the relationship between manhours and work accomplished, offers an important and very useful measurement of jobsite performance. But, because it measures only a single output (work accomplished) relative to a single input (labor manhours), labor productivity does not equal performance. For example, a contractor may be able to construct a house with a minimum of manhours because he carefully plans the job ahead of time, uses skilled workers, and provides the right equipment and materials when they are needed. His labor productivity is high. Yet he may pay excessive rental charges to keep all the equipment on site all of the time, and he may pay too much for higher-grade materials that exceed the specifications. Overall, his performance suffers. Good productivity can lead to high performance, but it is not the only contribution (or, necessarily, the most important contribution) to jobsite performance.

It is time now to turn our attention to measurements of performance so that we can see how to locate those construction methods which will cost the least to improve and which will contribute the most to increasing the worth of the completed job.

CHAPTER 4
MEASUREMENTS OF PERFORMANCE

The performance viewpoint distinguishes between accomplishments and the work methods employed to achieve these accomplishments. Measurements of accomplishment can point to deficiencies in work methods. By correcting such deficiencies, management improves construction performance.

We seek better measurements of construction performance in order to improve it. Useful measurements, because they provide management with valuable feedback concerning jobsite performance, lead to reducing the cost of construction relative to the value of work-in-place. Three considerations determine which measurements to collect:

We must meet management's need for information in order to support actions that will improve performance.

We must collect the most relevant measurements, taking care not to overlook important dimensions of performance measurements.

Whatever measurement system we develop must prove practical in daily use. (11)

The Performance Ability Ratio (PAR) (12)

We have defined performance as a ratio of accomplishment to methods. The worth of performance was given as the value of the accomplishment divided by the cost of the methods. However, it is not enough merely to assess the value of a particular piece of work-in-place, to calculate the cost of getting it there, and thereby to evaluate the worth of the performance. Knowing that a four-person iron-worker crew has placed 4 tons of rebar in four hours tells us something about the worth of the crew's performance but does not tell us how well they are doing. To provide us with a means for judging their relative worth, our measurements of performance must compare actual performance against a yardstick of desired performance. We need to know whether or not 4 tons-in-place for 16 manhours of work is reasonable, relative to some accepted standard of performance. In other words, how many manhours should it normally take to place 4 tons of rebar? (or, conversely, how many tons should a crew of four normally be able to place in four hours?)

Setting worthy standards

Construction standards, which set forth the amount of manhours normally required for a given task, form the basis for construciton estimating. Estimators carefully figure the amount of work required for a construction task and then multiply the number of units of work by the number of manhours needed to accomplish a single unit of the work in order to get a figure for the total manhours required to complete the task. The standards used in estimating vary widely and, even within a single job, may vary according to the estimator's perception of expected job conditions.

Yet estimates normally come from data that tell us only the average of how much time is needed to complete a single unit of work. The average is clearly not the best we can do. If we truly seek to improve jobsite performance, we must never be satisfied with average performance. Only exemplary performance provides us with a worthwhile yardstick by which to measure our relative performance. Exemplar performance is the historically best instance of the performance. Exemplar performance, therefore, is the most worthy instance of performing a particular construction task or job -that instance in which the value of the accomplishment most exceeds the cost of the methods.

Exemplar and current performance

For example, suppose current records for a construction job show that ironworker performance for a four-person crew spending four hours placing similar rebar averages 3.2 tons placed for every 16 manhours (MH) worked (Normally we would write 3.2 tons per 16 MH as 0.2 ton/MH, an expression equivalent to 3.2/16.) Suppose, further, that on good days the crew places as much as 4.8 tons in 16 MH(0.3 ton/MH). Now the 4.8 tons (or 0.3 ton/MH) would represent the exemplar, the best the crew is able to achieve. The measurement of their relative job performance would then be given as the ratio of their exemplar to their average (or current) performance. This ratio is the performance ability ratio (PAR) and is given as:

$$\text{Performance ability ratio (PAR)} = \frac{\text{current performance (Pc)}}{\text{exemplar performance (Px)}}$$

A PAR equal to 1.0 would mean that current work equals the best. A PAR greater than 1.0 indicates a potential for performance improvement. The larger the PAR, the greater the room for improvement. In the example above, if the average of 3.2 tons reflected current work, then the PAR for placing rebar would be given as:

$$\text{PAR} = \frac{4.8 \text{ (tons per 16 MH)}}{3.2 \text{ (tons per 16 MH)}} = 1.5$$

A note on numerical conventions

Expressing the ratio in the more conventional terms of units per single manhour provides the same answer:

$$\text{PAR} = \frac{0.3 \text{ ton/MH}}{0.2 \text{ ton/MH}} = 1.5$$

Many contractors, however, prefer to measure work rates in terms of manhours per unit-in-place, or, in this case, manhours per ton of in-place rebar. Inverting the calculations above gives us 16 MH per 3.2 tons (16/3.2), or 5.0 MH/ton for the average. The exemplar would be 16 MH per 4.8 tons (16/4.8), or 3.33 MH/ton. If we use this MH/unit convention, then we must also invert the PAR calculation, giving us:

$$\text{PAR} = \frac{\text{current performance (Pc)}}{\text{exemplar performance (Px)}}$$

Refiguring the PAR now gives us the same number:

$$\text{PAR} = \frac{5.0 \text{ MH/ton (average)}}{3.33 \text{ MH/ton (exemplar)}} = 1.5$$

The PAR is always calculated so that the smaller number is divided into the larger number to give a result greater than 1.

Choosing the exemplar

The PAR can be used in many ways. By comparing current performance to the exemplar, it serves as a measurement of the relative worth of jobsite performance. But whose exemplar should be used? This job's, the company's best, the industry's best? And what measurement of current performance should be used? Today's, last week's, this task's, all tasks', all jobs'? The answer is simple: Any of them. Depending on our purpose in measuring performance, our choice of exemplar and current performance will vary. The PAR is a dynamic measurement. It will change over time because the current performance will change and because, if we are competently managing performance, the exemplar will improve. If we chose the company's best historical performance as our exemplar and measure current performance against it, then sooner or later we ought to be able to improve on the exemplar, thereby setting a new setandard for future PAR measurements.

In most instances, construction companies will want to set the exemplar as their own historical best, principally because they can measure their own bests and seldom know their competitors' bests. However, different jobs may be so unlike in their characteristics and conditions that it would make no sense to compare them. An exemplar for piping from a job in Alaska may not apply to a job in Texas. And an exemplar for piping installed at ground level may not apply to piping on the same job installed 40 ft in the air. To avoid mixing apples and oranges, we may need to determine every task's own exemplar in order to make useful judgments concerning measurements of relative worth. Yet, as we shall see, as long as the measurements are consistent, a great deal of comparison among different tasks will be possible.

Besides offering a relative standard for comparing performance among tasks and jobs, the exemplar also provides a dynamic standard. It will change over time as performance improves. Every day offers the opportunity to do better than the day before.

The size of the PAR

No company can maintain a PAR of 1.0; current average performance is bound to be lower than exemplar performance. Variation is inevitable. Yet the closer to 1.0 the PAR, the more competent the company. A high PAR, on the other hand, indicates incompetence, which is to say that large variations between the exemplar and current performance reveal unique opportunities for management improvement.

On construction jobs, PARs can vary widely for different types of work. In general, the more repetitive and uncomplicated the task, the lower the PAR, and vice versa. Over time on a single job, as people become more skilled at the task, the PAR ought to decrease. PARs for similar tasks on jobs with several crews working under similar conditions will also vary. Table 4.1 shows the range for some respresentative PAR measurements.

According to Table 4.1, the industry's worst PARs occur in nuclear construction, where it is not uncommon to find PARs greater than 5. While some of the high variation in nuclear- construction performance can be attributed to the exacting nature of the work and the difficult conditions under which much of it is performed, the greatest cause of these large PARs is directly due to inadequate measurement and feedback. Good measurement and feedback would have allowed managers to focus their attention on improving the work methods that offered the greatest payback in terms of increased productivity and higher-quality construction.

Dimensions of Performance Measurements

Knowing the importance of performance measurements does not tell us what to measure or how to measure it. A simple table of the six possible measurements, however, provides an easy-to-use guide for describing and measuring any aspect of construction accomplishment.

TABLE 4.1 Representative PAR Measurements (13)

Task	Range of measured PAR
Installing H-pile lagging	1.1 to 1.4
Rebuilding conveyor belt	1.2 to 1.4
Pulling wire and connections	1.2 to 1.6
Installing 1/2 - to 2 - in pipe	1.3 to 2.8
Installing 4 - in pipe	1.3 to 3.3
Installing 5 - to - 8 - in pipe	1.3 to 3.0
Placing soldier beams	1.8 to 2.6
Installing nuclear pipe hangers	1.7 to 10.0
Nuclear welding (all pipe)	3.2 to 19.2

The need for measurements

We have seen the potential value of computing the PAR but have not yet seen how to measure the accomplishments and methods that are needed to compute it. What are the dimensions of construction performance? Most constractors can readily tell a good job from a poor one. But how? What qualities set one job apart as superior from the rest? How does an owner know whether or not a constractor performs well?

The two most common measurements of construction performance ask if a job was completed on time and within budget. These measurements compare actual contractor performance with expected performance. On-time completion means that the job finished as it was scheduled. Within budget means no cost overruns. Time and budget measurements frequently come too late to guide daily management decision making; they are better-suited as gross measurements of a completed job. On-site management needs more refined measurements for job control, measurements that provide timely feedback concerning current performance.

Six measurement dimensions

Three categories of measurements, encompassing six dimensions, are sufficient to describe every aspect of construction performance:

Quality

1. Accuracy
2. Workmanship

Quantity

3. Productivity
4. Schedule

Resources

5. Manpower
6. Materials, tools, and equipment

Any single construction accomplishment will require one or more of the six dimensions in order to be measured accurately. The six dimensions identify the full range of variation in accomplishments. The amount of variation depends upon the work methods chosen. For example, accuracy and productivity would be used to describe an electrician's accomplishment of pulling wire through conduits and making connections, but the amount of materials consumed and equipment used would hardly differ among craftsmen performing the same task. To judge whether or not a dimension applies to a specific construction task, ask the questions listed in Table 4.2. If the answers to any of them are yes, then that dimension may be needed in order to measure the accomplishment accurately.

Measuring accomplishments

Table 4.3 shows how the dimensions of performance measurements apply to a sample of construction accomplishments. While all the dimensions are used in Table 4.3, remember that a dimension of performance applies only when an accomplishment can vary significantly along that dimension. For example, a masonry crew laying up a brick panel can hardly vary the materials or tools. Their crew size and skills may affect the work only marginally. Yet productivity and schedule, the two primary dimensions of most construction tasks, will certainly apply. Accuracy, too, will be a critical measurement of masonry performance. And if the masonry panel forms an extremely visible part of a main entrance area, a measurement of workmanship may also apply. Table 4.3 also includes a column for units of measurements to indicate what measurements might be collected.

Productivity and manpower

The examples in Table 4.3 repeat some of the same measurements, dimensions, and units. For example, both "Productive work?" and "Reasonable labor cost?" appear for all but one of the accomplishments. Because hourly labor performs most construction tasks, productivity (installed units per manhour or, conversely, manhours per installed unit) measures a key dimension of performance. However, because the skill of the labor force may vary considerably and because the hourly wage rate may also vary according to craft skills, measuring the labor cost of the completed work provides another dimension for comparing performance. A very productive job, performed with highly skilled (and highly paid) labor, may indeed turn out to be less costly than the same job performed by less-skilled (and lower-paid) labor who require twice as long to complete the work.

TABLE 4.2 Questions for Measuring Performance Requirements (14)

Quality Questions
1. Accuracy measures how closely the job conforms to plans, specificaitons, code requirements, and accepted industry standards for workmanship. will any variation from the plans and specificaitons affect the worth of the finished task? Will errors result in rework? Do minor errors make a difference?
2. Workmanship measures significant differences in the worth of the finished job created by master-craftsmanship skills (assuming, of course, that all work meets standards for accuracy). Is it a showcase job that will be critically judged? Is it a novel design that requires special care in assembly?
Quantity Questions
3. Productivity measures differences in the rate at which the work is accomplished over time. will any variation in productivity rates (number of units installed per manhour) significantly affect job costs? Will higher (or lower) productivity rates affect manpower and schedule?
4. Schedule measures how closely the job adheres to an optimum construciton schedule. Will any variation from the schedule affect the job? Will an early or late completion of tasks affect other aspects of the job?
Resource Questions
5. Manpower measures differences in labor costs not reflected in the measurements of productivity in question 3. Will any variation in the skills of the labor force make a difference to the job? Will any variation in the type of craftsmen or craftsman classifications affect job costs? Is there a minimum or maximum number of people that should be on the job at any one time? Will crew size affect job costs? Will inattention to jobsite safety raise job costs?
6. Materials, tools, and equipment collects measurements of construction resources other than manpower. Can variations in job costs be attributed to differences in materials, tools, and equipment use? Will significant variations in the amount and type of equipment and tools used affect the job? Will material waste, loss, or theft create significant job costs?

TABLE 4.3 Examples of Performance Measurements (15)

Accomplishment	Measurement	Dimension	Unit
Form work for concrete wall	Correct placement?	Accuracy	Inches
	Complete when ready to pour?	Schedule	Hours
	Solidly braced?	Accuracy	Yes/No
	Productive work?	Productivity	Sq ft/MH
	Reasonable labor cost?	Manpower	Dollars
	Little wasted materials?	Materials	Dollars
Rough-stone stairway	Steps level and solid?	Accuracy	Yes/No
	aesthetic appearance OK?	Workmanship	Yes/No
	Productive work?	Productivity	Steps/MH
	Reasonable labor cost?	Manpower	Dollars
	Little wasted stone?	Materials	Dollars
	Completed in time?	Schedule	Days
Lavatory fixtures	Fixtures work properly?	Accuracy	Yes/No
	Installation neat and proper?	Accuracy	Yes/No
	Productive work?	Productivity	Units/MH
	Reasonable labor cost?	Manapower	Dollars
	Completed on time?	Schedule	Days
Steel frame	All connections correct?	Accuracy	Yes/No
	Safe work practices?	Manpower	Yes/No
	Productive work?	Productivity	Tons/MH
	Reasonable labor cost?	Manpower	Dollars
	Completed on time?	Schedule	Days
	Reasonable equipment cost?	Equipment	Dollars

TABLE 4.3 Examples of Performance Measurements (Contd)

Accomplishment	Measurement	Dimension	Unit
Hung ceiling	Ceiling level?	Accuracy	Inches
	Supports well anchored?	Accuracy	Yes/No
	Edges neat and proper?	Accuracy	Yes/No
	Productive work?	Productivity	Sq ft/MH
	Reasonable labor cost?	Manpower	Dollars
	Little wasted materials?	Materials	Dollars
	Completed on time?	Schedule	Days
Foundation excavation	Reasonable equipment cost?	Equipment	Dollars
	Reasonable labor cost?	Manpower	Dollars
	Safe work practices?	Manpower	Yes/No
	Completed on time?	Schedule	Days
	Size of hole correct?	Accuracy	Feet
Telephone system	Do all phones work?	Accuracy	Yes/No
	Productive work?	Productivity	Lines/MH
	Reasonable labor cost?	Manpower	Dollars
	Completed on time?	Schedule	Days

Schedule

The mesurement question "Completed on time?" appeared for every accomplishment in Table 4.3. Normally, schedule is a critical dimension of construciton performance. Depending on the task at hand, the units of measurement may range from hours to days, weeks, or even months.

Measure only variation

Although Table 4.3 includes examples of all six dimensions of performance measurements, not every job need be measured along every dimension. We measure only when a variation along a dimension is likely to cause a significant variation in the accomplishment. In the case of the foundation excavation in Table 4.3, for example, labor productivity was not included as a measurement since the excavation equipment is likely to be a far larger factor in determining job performance. Labor cost, however, is measured. If the excavation included installation of lagging between H-piles, then the productivity of labor in placing the lagging (a labor-intensive task) would be measured. And safety, while a central concern of every job, requires special attention on jobs with dangers of injury from falls (the leading cause of injuries in construction).

Developing Measurements and Units

While most contractors readily understand most of the dimensions and units of measurement given above, they may find it difficult to apply the concepts to a real job. Let us spend a moment, therefore, going step by step through a typical construction job and collecting performance measurements.

Suppose we wish to measure the weekly performance of an electrical crew installing metal conduit and boxes, running wire, and making connections in a commercial building project. What measurements apply here? To develop the appropriate measurements for the job, it is best to go down the list of all measurements to ensure that none is overlooked. We begin with Table 4.4, developing a checklist of appropriate measurements.

Now, looking over the list of questions to be answered in Table 4.4, we see that we have identified eitht measurements that will be critical to the weekly performance of the job.

TABLE 4.4 Checklist of Performance Requirements and Measurements(16)

Quality Questions	Measurement and unit
1. Accuracy	
(a) Will variation from standards of accuracy significantly lower the worth of the finished job?	
Yes; if wiring does not serve needs, rework will be required.	Labor (MH) and materials ($)
Yes; if wiring is not safe, rework will be required.	Labor (MH) and materials ($)
(b) Will errors or variation result in rework?	
Yes, if work fails to meet plans, specs, or code requirements.	Labor (MH) and materials ($)
(c) Do minor errors make a difference?	
No, only in appearance.	
2. Workmanship	
(a) Is it a showcase job that will be critically judged?	
No, conduit will be covered.	
(b) Will master-craftsmanhip or exemplar skill create significant differences in finished work?	
No.	
(c) Is it a novel design that requires special care in assembly?	
No.	
Quantity Questions	
3. Productivity	
(a) Will variation in productivity rates (number of units installed per manhour) affect job costs?	
Yes, higer productivity will require fewer MH.	Productivity (units/MH)
(b) Will higher (or lower) productivity rates affect manpower and schedule?	

TABLE 4.4 Checklist of Performance Requirements and Measurements (Contd)

Yes, higher productivity will require fewer people and speed the job.	Labor (MH) and schedule (days)
Yes, lower productivity will require more people or more overtime to meet the same schedule or else result in schedule delays.	Labor (MH) and overtime (MH) and schedule (days)
4. Schedule	
(a) Will variation from the schedule affect the job?	
Yes. it may crate additional plannning and control problems.	Foremen (MH)
(b) Will early or late completion of tasks affect other aspects of the job?	
Yes, late work will hold up other trades and cause out-of-sequence work, leading to overtime, overstaffing, or delays.	Overtime (MH) and labor(MH) and schedule (days)
Resource Questions	
5. Manpower	
(a) Will variation in the skills of the labor force make a difference to the job?	
Yes, higher-skilled craftsman and foremen may cost more per hour.	Foremen ($/MH) and labor ($/MH)
Skilled people may make fewer rework errors.	Labor (MH)
Skilled people may require less direct supervision.	Foremen (MH)
(b) Will variation in the type of craftsmen affect job costs?	
Yes, hourly rates for trades and trade classifications may vary.	Labor ($/MH)

TABLE 4.4 Checklist of Performance Requirements and Measurements(Contd)

(c) Will the number of people on the job at any one time affect the job cost?	
Yes, understaffing may slow the work pace and cause delays (while overstaffing may lead to productivity loss).	Schedule (days)
(d) Will crew size affect job costs?	
Yes, for the same number of craftsmen, smaller crews may require more foremen for supervision.	Foremen (MH)
(e) Does the job pose special risks of injuries from falls or equipment that demand extra safety protection?	
Yes, floor openings and scaffolds must meet Occupational Safety and Health Administration (OSHA) standards, and electricians must follow safe practices.	Labor (MH) and foremen (MH)
6. Materials, tools, and equipment	
(a) Will significant variations in the amount and type of equipment and tools used affect the job?	
No. Electricians use standard tools and equipment in good condition.	
(b) Will material waste, loss, or theft create significant job costs?	
Yes.	Materials ($)

They are:

Job measurement	Unit	Comment
Labor	MH	The number of paid manhours
Overtime	MH	Paid manhours at overtime rates
Foremen	MH	Paid manhours at foreman rates
Schedule	Days	Days ahead or behind schedule
Labor wage rate	$/MH	Labor cost per manhour
Foreman wage rate	$/MH	Foreman cost per manhour
Productivity rates	Units/MH	Amount installed per labor manhour
Materials	$	Dollar cost of waste and loss

Using Measurements of Productivity

All the measurements, except productivity, appear relatively straight-forward and easy to get. Job records show wage rates and hours worked by labor and foremen, both straight time and overtime. Materials costs for the job, in excess of the cost for the estimated amounts, can be attributed to waste or theft, if any, or to an error in the quantity estimate. And we clearly know whether we finished the job on time. But what about productivity? How do we measure that?

Grouping similar accomplishments

For item 3.a in Table 4.4, one measurement of the units installed might be the ratio of the linear feet of installed conduit to the number of boxes installed. Now if we find that this ratio does not vary greatly relative to the average of past jobs, then we might safely lump the conduit and boxes together and simply count the feet of conduit installed as a representative measurement of the amount of work accomplished. Similarly, if the amount of wire pulled and the number of terminations made are also proportional to the amount of conduit installed, then we may lump them all together in a single unit of measurement - the number of feet of completed, wired conduit.

Knowing the amount of installed conduit thus gives us a measurement of the amount of work accomplished. And knowing the number of manhours it took to install the conduit, mount the boxes, pull the wire, and complete the terminations gives us a measurement of the cost of the installation method. Dividing the feet of installed conduit by the manhours worked gives us a measurement of average productivity in feet per manhour (or manhours per foot, if one prefers to invert the calculation).

Separating dissimilar accomplishments

However, we must examine the job to be sure that the number of bends, the amount of cutting and connections, and the location of the conduit are also average for work of this kind. If a portion of the work is unusual (say that the conduit must be bolted to the underside of a concrete slab 30 ft above the floor), then this amount of work ought to be counted separately from the rest. Differences in conduit sizes and locations may lead to differences in productivity during installation. In such cases, we need to measure each portion of the work separately.

Let us assume that we have successfully grouped similar accomplishments and have distinguished those which are dissimilar. Table 4.5 shows our results. The two types of conduit include the boxes, wire, and terminations necessary to complete the work. Three different installment conditions distinguish between work at floor level, on ladders, and on scaffolds. The measurements of the amounts placed and the manhours charged allow us to compute our productivity for the job in question.

TABLE 4.5 Productivity of Electrical Conduit Installation

	A	B	C	D
1		Amount	Manhours	Productivity
2	Accomplishment	placed (ft)	charged	(ft/MH)
3				
4	One-half-inch conduit			
5	(a) up to head height	600	42	14.3
6	(b) overhead	800	77	10.5
7	(c) above 12 ft	200	34	5.9
8				
9	One-inch conduit			
10	(a) up to head height	400	32	12.5
11	(b) overhead	700	75	9.3
12	(c) above 12 ft	300	55	5.5
13				
14	Total MH		315	

Table 4.5 shows 315 labor manhours charged among the six possible classifications of work. Presumably, climbing ladders accounts for the relatively low productivity in overhead work, and setting up and climbing scaffolds accounts for the even lower productivity when working above 12ft. such measurements, if collected over many jobs, would give an estimator accurate numbers for estimating future work. The numbers would also give a contractor the means for calculating his or her PAR among jobs.

Measuring crew productivity

At first glance it would seem possible to collect measurements of individual performance (work accomplished and manhours charged) in order to calculate the productivity for every craftsman on the job and therefore to compute a PAR among individuals. In practice, however, individual performance measurements usually prove impractical, if not impossible.

Attempts to measure individual productivity in construction tend to fail for two reasons. First, tracking the number of tasks accomplished by each individual is difficult, particularly when the crew works as a team. It is impossible to charge individual time to specific work items when several crew members may assist in the different subtasks required for final installation. Second, most people resist individual performance measurements because they fear that these may be used to penalize them unfairly. Construction workers, in particular, pride themselves on being able to accomplish a wide variety of demanding tasks; everyone recognizes that some excel at one task, others at another task. Depending on which task is measured, even normally superior performers may not do well.

Fortunately we need not impose an impossible reporting burden on each craftsman or on ourselves. Instead, aggregate measurements of crew performance will serve us quite well. (Table 4.5, for example, records 315 hours worked by nine craftsmen in one week.) In general, therefore, we use measurements of crew performance because these are relatively easy to obtain and tell us a great deal about the adequacy of the work methods used to accomplish the work-in-place.

Measuring contractor performance

Suppose, now, that the numbers in Table 4.6 represent productivity measurements collected over five similar jobs, all running at about the same time and under more or less the same conditions. What do they tell us about the contractor's performance?

To get the PAR for each type of conduit installation, we divide the average performance for all jobs into the exemplar perfomance from the single best job (in this case, Job 5 represents the exemplar every time). For example, the largest PAR of 1.7, given for 1/2-in conduit placed at heights over 12 ft, is calculated from the aveage (6.2 ft per manhour) divided into the exemplar (10.3 ft per manhour). This large PAR tells us that a significant variation exists in the performance of crews installing this work on different jobs. This variation results from differences in management competence. The supervisor for Job 5 has crews installing the conduit nearly 3 times as fast as the supervisor for Job 3. What is it that makes Job 5 so superior?

Let us assume that all five jobs are really comparable - similar amounts of work installed under similar conditions. If we were able to measure the productivity of individual craftsmen on all the jobs carefully, we would certainly discover variations in individual performance as well. But given the large difference between Job 5 and the rest of the jobs, we know it is highly unlikely that the difference results from a single "super craftsman" at Job 5 and a distribution of many incompetents among the other crews. It is far more likely that the supervisor on Job 5 employs superior methods to place the crews (with their tools and materials) up in the air and to keep them working once they are up there. Discovering the secret of Job 5 and transferring this knowledge to the supervisors at the other jobs should lead to higher productivity rates and a lower PAR.

Measurements and Performance

We have seen that we can measure jobsite performance along six different dimensions: accuracy, workmanship, productivity, schedule, manpower, and the materials, tools, and equipment that go into a job. These performance measurements provide us

TABLE 4.6 Comparing Productivity Measurements for Five Current jobs

	A	B	C	D	E	F	G	H
1	Accomplishment	Job1	Job2	Job3	Job4	Job5	Average	PAR
2								
3	Formula							(F/G)
4								
5	One-half inch conduit							
6	(a) up to head height	14.3	12.7	10.3	15.4	19.1	14.4	1.3
7	(b) overhead	10.5	9.8	9.8	13.6	14.9	11.7	1.3
8	(c) above 12 ft	5.9	4.1	3.9	7.0	10.3	6.2	1.7
9								
10	One-inch conduit							
11	(a) up to head height	12.5	10.6	9.5	13.0	14.8	12.1	1.2
12	(b) overhead	9.3	7.4	6.6	9.9	11.2	8.9	1.3
13	(c) above 12 ft	5.5	4.3	2.7	6.0	8.5	5.4	1.6

with a means to uncover opportunities presented in the form of large PARs, the ratio of our exemplar performance to our average. by striving to bring average performance up to exemplar performance, we continually improve our work methods and therefore raise the worth of our performance.

But to what extent are the measurements really important? Do they really justify the effort and time required to collect them? Do measurements tell us something that we could not find out by simpler means? The answers to these questions depend on many things. They depend on the individual contractor and the nature of the work. Small jobs, few in number and consisting of unique installations, might not benefit greatly from formal measurement methods. Yet if the work is repetitive or requires many manhours, measurements may well help pinpoint opportunities for improved performance. Small contractors who know their jobs inside and out rely on their experience and intimate knowledge of the job to find ways to improve. But as contractors grow in size and such close contact with every job becomes impossible, measurements become essential to performance improvement.

CHAPTER 5
THE WORTH OF PERFORMANCE

While many contractors agree that efforts to improve productivity may be worthwhile, few know how to calculate the benefits and costs of such efforts. Performance measurements not only point out areas of high potential gain, they can also provide the information needed to calculate the worth of this gain. And knowing the worth of the potential gain, we can then go about systematically examining alternative methods to capture this gain, weighing the costs of each method against the worth. Let us begin, therefore, by learning how to calculate worth.

Calculating Worth

Perhaps the best way to explain the concept of worth calculations is to jump right into an example to show how it's done. In this example we will assume that we are already measuring our productivity on a weekly basis and thus have the data necessary for the calculations.

A simple example

Table 5.1 gives the data for our example. Here we see numbers representing five separate work items (A through E) being installed by a contractor. Columns B through D show the estimated amount of work to install, the estimated manhours (MH), and the expected unit rate (given in amount per manhour, column B divided by column C). Columns

TABLE 5.1 Summary of Unit-Rate Performance (Amount per Manhours) to Date

	A	B	C	D	E	F	G	H	I
1	Item to	Estimate			Actual to date			Best-week	
2	install	Amount	MH	Unit rate	Amount	MH	Unit rate	Unit rate	PAR
3									
4	Formula			(B/C)			(E/F)		(H/G)
5									
6	Item A	16000	12000	1.33	8000	8000	1.00	1.55	1.6
7	Item B	18000	18000	1.00	5000	4000	1.25	1.40	1.1
8	Item C	15000	30000	0.50	5000	8000	0.63	0.70	1.1
9	Item D	1250	5000	0.25	400	1500	0.27	0.50	1.9
10	Item E	4000	2000	2.00	500	500	1.00	1.30	1.3
11									
12	Total		67000			22000			

E through G show the actual numbers to date; column E shows the amounts (collected by field counts) of installed items, column F shows the manhours charged to each item (collected from weekly time sheets), and column G computes the average unit rate to date by dividing the actual manhours (column F) into the installed amounts (column E). Column H shows the best unit rates so far for any single week - the exemplars. The exemplars come from the weekly counts of work accomplished and manhours charged to each item (not shown). Dividing the weekly amounts by the weekly manhours gives a weekly unit rate for each item. The exemplars were found by going back through all the weekly unit-rate calculations and picking out the single best weekly unit rate for each item. Finally, column I computes the performance ability ratios (PARs) by dividing the exemplar from column H by the average from column G. The PARs range from a low of 1.1 for items B and C to a high of 1.9 for item D.

Given this information, is it worthwhile for the contractor to attempt to improve one or more of the unit rates? if so, which ones? If we were asked to look over the data and make a guess to test our judgment before we get into an analysis of the numbrs, we might be hard put to know where to begin.

Comparing the estimated unit rates to the actual to-date unit rates in Table 5.1, we see that items B and C are doing better than the estimate, that items A and E are behind, and that item D is right about on target. The best-week unit rates in column H show that the exemplars have exceeded the estimate for all items except E. So how does the job stand at this point in time? At the present average rate of production, can the job be completed within the manhour estimate?

Projecting rates

To answer the questions concerning job status, we first extend Table 5.1 to the right to create Table 5.2 Column J repeats the row headings from column A. In column K we subtract the amount to date (column E) form the estimated amount (column B). This difference gives us the amount remaining to be installed. Dividing the amount left to install in column K by the average rate to date (column G in Table 5.1) gives us the manhours needed to complete each of the items (assuming that the average rate of production will be sustained for the remainder of the project). Column L provides the results of this calculation. The sum of the individual item projections in column L-41,088 MH - projects the total manhours required to complete the job if the average unit rate to date prevails for the remainder of the project.

In Table 5.2, the amounts left to install (column K) are the differences between the estimated amounts in column B and the amounts installed to date in column E. Column O, the manhours left in the estimate, represents the differences between the estimated manhours in column C and the actual manhours to date in column F (from Table 5.1). The sum for column O shows 45,000 MH remaining out of the original 67,000 MH estimated for the whole job. Our projection at average unit rates in column L gives 41,088 MH, a projected savings of 3922 MH over the estimate (subtracting column L form column O).

Working at estimated rates

What if the remainder of the work were to be installed at the original estimated unit rates in column D instead of the average unit rates to date in column G? By dividing the estiamted unit rates (column D) into the amount remaining to install (column K), we get the manhours required to finish the job at the estiamted rates. Column M shows this result. If the rest of the job goes exactly according to estimate, a total of 44,150 MH will be required to finish the job - only 850 MH less than the original estimate.

Compare this result to our earlier calculations for completing the job at the average unit rates. If the remainder of the work could be accomplished at the average unit rates to date (given in column G in Table 5.1), then the job could be completed in the manhours shown in column L. Since the average unit rates total only 41,088 MH as compared to 44,150 MH at the estimated unit rates, the difference represents a potential savings of 3062 MH if the job could be completed at the average unit rates rather than at the estimated unit rates.

Working at exemplar rates

But suppose it were possible to complete the job at the best unit rates so far - the exemplars. How many more manhours might be saved? Dividing the amounts left to install (column K) by the best unit rates (column H) gives the numbers shown in column N. Working at the exemplar unit rates for the remainder of the job, we find that it would take only 33,125 MH to complete the job - a savings of 7963 MH over working at the average unit rates, and 11,025 MH better than working at the estimated unit rates. By subtracting the manhours required to commplete the job at the exemplar unit rates (column N) from the

TABLE 5.2 Analysis of Job to Date

	J	K	L	M	N	O	P	Q
1	Item to	Amount left to	MH at ave.	MH at est.	MH at best	MH left	Potent. MH	Potent. MH
2	install	install	rate	rate	rate	est.	savings	worth
3								
4	Formula	(B-E)	(K/G)	(K/D)	(K/H)	(C-F)	(O-N)	(L-N)
5								
6	Item A	8000	8000	6000	5161	4000	-1161	2839
7	Item B	13000	10400	13000	9286	14000	4714	1114
8	Item C	10000	16000	20000	14286	22000	7714	1714
9	Item D	850	3188	3400	1700	3500	1800	1488
10	Item E	3500	3500	1750	2692	1500	-1192	808
11								
12	Total		41088	44150	33125	45000	11875	7962

manhours left in the original estimate if the exemplar unit rates could be achieved for the remainder of the job - a total of 11,875 MH.

Now clearly it will not be possible to realize all the potential savings in column P. The best weekly unit rates may not be sustainable for each item over the remainder of the job. But if we must pick one of the items to concentrate our efforts on, which one should it be? Column P shows items C as having the largest potential savings - 7714 MH. But is this really the place to concentrate our efforts? If we assume that we can actually sustain the average unit rates to date (in column G) for the remainder of the job, then some of the savings in column P are already in the bank. What we really need to do is to compare the difference between working at our average and working at our best. Column Q does this. By subtracting the number of manhours it will take to complete the job working at the best unit rates (column N) from the manhours needed at the average unit rates (in column L), we get the real potential worth of improving each item from aveage to exemplar.

Item A, which showed a potential overrun of 1161 MH in column P, now displays a potential worth of 2839 MH. This worth is the number of manhours we could gain by bringing the unit rate for item A up from average to best. Referring back to Table 5.1, we see that the average rate to date for item A is 1.00 unit per manhour, only three-fourths as high as the estimate, yet the best weekly rate is 1.55 units per manhour, a considerable improvement over the estimate. And since only half of item A has been installed, bringing the unit rate up closer to the exemplar for the remainder of the job would add up to a substantial savings.

Table 5.2 therefore tells us that the job is coming in about 3900 MH below the estimate (based on current average unit rates) but that it could come in nearly 11,900 MH below the estimate if the remainder of the work could be accomplished at the exemplar unit rates. While it is highly unlikely that we can capture all the extra 8000-MH savings, by concentrating on item A we could pick up as much as 2839 MH.

Relating worth to PARs

While the analysis so far has pointed out the potential worth of bringing each item up from average to exemplar, we have not yet looked at the potential cost of doing so. Refer back to column I in Table 5.1. Here we have calculated each of the PARs for the five work items. Item A, our largest potential worth, also has a large PAR of 1.6. A large PAR means a large difference between average and best. And the larger the variation between average and best, the easier it is to improve, to bring the average up closer to the best. A large PAR usually means that one or more exemplar crews are employing superior work methods that can be effectively transferred to the average performers. Note, however, that item D has the largest PAR of 1.9. It also has a fairly high worth of 1488 MH. Here is another good candidate for improvement. Item C, which shows a higher worth than item D, has a PAR of only 1.1, indicating a very narrow gap between exemplar crew performance and average crew performance. It will be very hard to squeeze this gap much closer.

Checking for inaccurate numbers

Although our analysis appears straightforward, we must be careful never to be misled by looking only at the numbers. We must also apply a great deal of common sense and look behind the numbers to see where they have come from and what they really represent. It may be, for example, that the best unit rate recorded for item A does not reflect a sustainable rate. Or, with only half the amount of that item installed so far, the low average unit rate may reflect unusually poor productivity rates during startup, and so the best rate may indeed be closer to the current rate of production. Only a more careful analysis of the job can give the true picture behind the numbers. The numbers only point to areas of potential savings, areas to which management should first turn its attention.

If the worth for item A turns out not to be a true picture, then turn to item D. Actually, it ought to take less effort to improve item D than item A, since the PAR of 1.9 indicates a very large variation in unit rates, with the average unit rate well below the best. Something on the job is holding the average unit rate well below the best that the crews are able to achieve. It should not take much effort to discover the cause of the problem and to eliminate it, thereby raising the productivity for item D. The greater the difference between the average and the best, as measured by the PAR, the greater the potential for improvement and, in general, the easier to capture the improvement.

CHAPTER 6
THE METHODS ENGINEERING MODEL

One critical aspect of creating competent jobsite management is to establish practical performance goals - goals which are clear, which are measurable, and which reflect accomplishments we value. In addition, the goals must be achievable. To reach performance goals we must learn to develop efficient methods.

Imagine the "world's greatest" construction crew, a highly trained team of master craftsmen, working together smoothly to build a beautiful model home of highest quality at the lowest possible cost. Is the crew competent? The difference between competence and efficiency becomes clear if we are told that the world's greatest crew built the house on the wrong homesite! Efficient methods may not always lead to competent performance. Efforts to alter methods, while essential to engineering high performance, always follow after an analysis of accomplishment. Efficient methods are not an end in themselves.

Management and Methods Improvement

Suppose a general contractor employs a general foreman to oversee the work of several carpenter crews in the remodeling of a small retail mall bulding. Under the general foreman's guidance and direction, the carpenter crews do very well, at least according to the company's performance measurements. The crews tear out unwanted walls and counters in lightning speed and rapidly frame new walls, windows doors, and counters. Unfortunately for the general contractor, the carpenter crews, in their haste to complete their own work, provide only minimal support for the other trades on the job. When asked to move equipment and materials to make room for scaffolding for the sheetmetal and ceiling subcontractors, the general foreman refuses to let electricans and plumbers into areas where their work may interfere with the carpenters' progress. The subcontractors on the job soon realize that the delays caused by the general foreman are costing them money in overtime and out-of-sequence work. In the future, any bids they submit to the general contractor for work will carry a high markup to cover the extra costs of working with little or no support. Over time, the higher bids will diminish the amount of work the general contractor will be able to get, and the company may go out of business.

In spite of the high marks gained by the general foreman in managing the carpenters' work, he is incompetent. Although he utilizes work methods for his crews that could produce a competent job for the contractor, he fails because he misses an important goal - fostering co-operation and good will among the many subcontractors on the job. If the contractor redefines the general foreman's role to include cooperation with other trades, the foremean may become a very competent performer, generating good will on the job through work methods that incorporate cooperative behavior while only slightly diminishing crew efficiency. In such a case, the contractor can change the general foreman's performance from incompetent to competent not by direct manipulation of his behavior, but by supplying him with information about another measurement of his performance - the relative number of complaints (or praise) from subcontractors on the job.

Here, the conractor can take responsibility for the methods used by the general foreman by finding a way to change them to improve performance. Yet in many construction situations, management places the responsibility for methods change on the work force rather than accepting the responsibility for engineering better performance. How many times has management clained. "The workers don't care," or "They have no motivation," or "They're too dumb to do it right the first time"? Such judgments put the blame on the other side. Seldom, if ever, does mangement turn the judgment around on itself by saying, "We haven't provided the right incentives to get our workers to perform better," or "We haven't trained them very well in how to do the work correctly," or "The feedback we've given our workers has been inadequate." To admit that management may be at fault hurts. That's why many contractors find it easier to blame their labor force for poor performance.

Competent management, however, accepts responsibility for engineering jobsite performance. After all, this is presumably what management gets paid for. To do so, it needs a means to identify and measure jobsite competence along with a means to identify the causes of deficent performance. Management needs a performance engineering model, a model that will guide it in troubleshooting work methods and in arriving at effective strategies for changing methods to raise overall performance.

Elements of Work Methods

What influences jobsite methods? Suppose I wish to start a small masonry contracting business, doing residential work. To succeed and make money, I must engineer competence among my work force. The accomplishment end is easy: I set, objectives for performance and develop measurements of accomplishment. I know the quality of work expected in laying up brick walls, and I know the amount of work a mason can be expected to accomplish in a day. but, how do I ensure that a mason working for me will meet my standards for quality and will work productively?

Behavior and environment

I start by hiring a mason, Mr. Will Martter. Mr. Martter is an ordinary person in most every way except one - he possesses a unique set of masonry skills. He can follow general instructions, as well as detailed plans and specifications, to create brick walls. To accomplish this, he takes many specific actions, such as setting up level lines, mixing mortar, laying bricks, and finishing joints. Mr. Martter has worked for more than 30 years as a mason, and he continues to work in the trade because he likes it; he finds the work both challenging and satisfying. As is the case for other people, Mr. Martter's work skills have become part of his personal characteristics, part of what he brings to the job each day. His inherent skills, combined with those actions he takes on the job which display his skills, are what we generally call his work behavior. A person's work behavior is how we see the person act and what we see the person do on the job. I shall designate this work behavior B.

But Mr. Martter alone, even with all the experience and skill of his masonry work behavior, is not sufficient for me to get the results I need for my business. I also need a work environment. This work environment, which I shall designate E, is just as fundamental an element of the work methods on the jobsite as Mr. Martter's behavior repertory. I must provide Mr. Martter with the information he needs, such as the plans and specifications for a wall and the feedback he needs to direct his performance toward the accomplishments I seek; I must also make sure he has the tools and equipment he needs as well as the necessary materials for the wall; and, of course, I must supply the incentives he desires, in the form of wages, recognition for good work, flexible work hours, and such. If I miss any one of these three elements, Mr. Martter will fail to accomplish any work at all.

Work methods

So I find that the behavior B brought to the job by the mason, plus the opportunities and limitations placed on the work by the site environment E, combine to create on-site work methods M that will produce the finished wall, the accomplishment A that I want. Thus the construction method M employed on the job is a combination of two elements, behavior plus environment:

$$M = B + E$$

Now Chapter 3 developed a relationship between work methods M and accomplishment A that defined performance P. Performance, we saw, is equal to accomplishment divided by methods;

$$P = \frac{A}{M}$$

Combining the two relationships and substituting our new definition of methods (M = B + E), we see that:

$$P = \frac{A}{(B+E)} = \frac{V}{C}$$

That is, performance P is equal to what I am able to accomplish A divided by the work methods, where these methods are a combination of work-force behavior B and the work environment E.

Performance deficiencies

As defined before the worth W of the performance is represented by the ratio of value V to costs C, given as:

$$W = \frac{V}{C}$$

This definition of worth parallels our definition of performance; worth W is the performance P we desire. Accomplishment A provides the value V to the job, and the methods M represent the costs C. So we see that both the behavioral and the environmental aspects of the work methods are included in the job costs. The lower the cost of either, the greater the worth (and the higher the performance) I can produce.

Now, of course, I must pay the costs of the methods I have chosen for constructing brick walls - the costs of hiring a mason possessing a desired behavior repertory and then of providing him or her with an adequate work environment. If the methods are my costs and the brick wall is the accomplishment I value, then the overall worth of the performance depends upon how high a value I am able to create for a minimum cost.

The definitions above tell me that I must pay for both the behavior of my labor force and for their supporting work environment. Further, the relationships tell me that for any given accomplishment, a deficiency in performance can always be traced to a deficiency in behavior or to a deficiency in the work environment, or both. And, because management exerts considerable control over both behavior and environment, performance ultimately reflects management competence. Thus, if I wish to improve my performance as a contractor, I will look to correcting deficiencies either in the behavior of my labor force or in the working environment I provide for them, or both. But in order to discover where faults lie concealed in my methods, I require a systematic means of investigating performance deficiencies.

The Methods Engineering Model

Upon closer examination of the story about Mr. Martter, we find that we have identified all that we need to know about work methods in order to construct a model of the requirements for superior jobsite performance. First, in looking at the work environment E, we see that management must provide three elements essential to establishing the work-accomplishment methods to be used at the jobsite;

Environmental requirements

1. Management is obligated to provide information, normally the plans and specifications, necessary for doing the work plus feedback, (in the form of ongoing direction and approval), necessary to keep the work on track.
2. Management is obligated to provide the resources (in the form of tools, equipment, and materials) necessary for doing the work.
3. Managment is obligated to offer the incentives (primarily in the form of wages) necessary for doing the work.

Second, in looking at Mr. Martter's work behavior, we see that he also possesses three behavioral elements B required for working efficiently at the jobsite:

Behavioral requirements

1. He possesses a body of skills (in the form of his training and experience) necessary for doing the work.
2. He possesses the physical and mental capability (in terms of his health and intelligence) necessary for doing the work.
3. He possesses the motives (in his desire to continue in the masonry craft) necessary for doing the work.

Each of these six elements is an essential requirement for establishing efficient work methods at the jobsite. If any element is totally missing, no work can be accomplished. At the same time, at no jobsite is every element totally present; no job is so perfect that its work methods cannot be improved. Every jobsite is made up of a mix of the six elements, each interacting with the others to produce the resulting work methods.

An example of incompetence

To understand the importance of each of the six elements, suppose we set out to engineer incompetent construction performance by creating the most inefficient work methods. Table 6.1 lists some of the actions we might take.

While these rules for engineering incompetent performance may strike some contractors as ridiculous, many contractors follow one or more of them regularly. It doesn't take much to imagine situations in which these rules are commonly applied at construction projects.

Creating competence

If we reverse the rules in Table 6.1, however, we can arrive at a more sensible model for engineering performance. Any construction job characterized by the rules in Table 6.2 would certainly reveal a high degree of competence in work methods.

In reading down the list, it is clear that performance engineering is not free. It costs money to engineer more efficient work methods. Yet since no construction job employs perfect work methods and since improvements are therefore always possible, the question is not how much it will cost to improve the work methods but whether this improvement will raise the worth of the job. If the cost is lower than the value it produces, the overall worth increases. The key concept here is leverage. We need to use the methods engineering model to find those improvement strategies which offer the greatest leverage for improving jobsite performance.

Glassman Glaziers, Inc.

Gunther Glassman started his glazing company just after the war and quickly prospered. His hero was Ludwig Mies Van DerRohe, the German-born architect who practically invented the all-glass skyscraper. Gunther's daughter, Judy, received all the benefits her father never had, including an expensive college education, a graduate degree in sociology, and a well-heeled lifestyle. But when a sudden stroke killed Gunther shortly after Judy's second marriage fell apart, she decided to make something of herself by taking over the family business. Judy is a very smart lady; she kept all the senior management people and stayed well out of their way while she applied herself to learning everything she could about the glazing business.

Management and motivation

People tell her that the only unknown in the business is the labor force. Management can engineer glass walls and get the materials and equipment to install it. But management cannot get labor to work, certainly not the way they did "in the old days after the war." Nowadays you never know if the workers on the job will make money for you or lose it. They just don't have any motivation. They do sloppy work and can't follow directions. It is a risky business. Profits sure aren't what they used to be.

Judy listens carefully to such statements. But she doubts that they're all really true. In school, her subjects had included the study of behavior in the workplace. Her old college texts emphasized the psychological aspects of behavior, stressing how different every individual is in terms of motivation and behavior. But to Judy's way of thinking, it hadn't made sense then and it still doesn't make sense now. Everyone she sees on her jobs

TABLE 6.1 A Model for Engineering Incompetent Construction Performance

Environmental Elements
1. Information .Give people incomplete plans and poorly written specifications. .Change the plans frequently as the work progresses. .Never plan the work ahead or tell people what they will do next. .Provide little or no guidance as to how to perform well. .Do not tell people what is expected of them. .Don't let people know how well they are performing. .Make misleading statements about how the job is progressing. 2. Resources .Use equipment that is unsuited to the task. .Fail to have tools available when they are needed. .Use inferior materials. .Avoid following safety rules. .Overwork equipment so that it either breaks or is unavailable. .Deliver materials only after they are needed. 3. Incentives .Make sure that poor performers get paid as much as good ones. .See that good performance gets punished in some way. .Don't reward people for good performance. .Fail to tell people when they have done a good job.
Behavioral Elements
4. Skills .Leave the training to chance. .Hire unskilled people and do not train them. .Give new workers experience working next to poor performers. .Put the burden of acquiring skills on the workers. .Provide training that is irrelevant to jobsite conditions. .Permit foremen to skip holding regular safety meetings. 5. Capability .Understaff the crews for physically demanding tasks. .Fail to provide protection from adverse weather. .Provide inadequate toilets and washup facilities. .Select people for tasks they find difficult to perform. .Do not insist on safety protection. 6. Motives .Make sure the job has no future. .Avoid making working conditions more pleasant. .Give empty pep talks to pressure people to work harder. .See that good performers work themselves out of a job quicker.

Table 6.2 The Methods Engineering Model

Environmental Elements
1. Information .Provide clear and correct plans and well-written specifications. .Avoid changes to the plans as the work progresses. .Plan the work well ahead and keep people informed as to plans. .Provide frequent feedback as to how well people perform. .Tell people exactly what is expected of them. .Show people how to perform well. .Keep the work force informed as to progress against schedule. 2. Resources .Use equipment that is well-suited to the task. .Have tools available when they are needed. .Use adequate materials. .Follow all safety rules. .Provide equipment when it is needed. .Make sure materials are available as needed. 3. Incentives .Make wages contingent upon performance. .Provide nonmonetary incentives. .Reward people for good performance. .Tell people when they have done a good job.
Behavioral Elements
4. Skills .Design the training to fit jobsite conditions. .Use only exemplary performers to train new workers on the job. .Remove obstacles to continued training. .Ensure that competent people teach jobsite safety. .Draw on individual experience whenever possible. 5. Capability .Fit the crew staffing to the tasks. .Protect workers from adverse weather. .Select people for tasks they perform best. .Insist that all workers wear safety protection. 6. Motives .Hire individuals who enjoy construciton work. .Make people feel good about working on the job. .Keep good performers on the job. .Offer career opportunities.

behaves pretty much the same, and she can't believe that they all thinks their motives aren't all that different - they all want to make a living working as glaziers. Trying to improve jobsite performance by changing the workers' motives would be silly. So, true to her academic backgroud, Judy decides to do "field research"; she goes out and asks the workers themselves how they feel about their jobs and what they see as deficiencies in their work methods.

Categorizing gripes

For several weeks Judy interviews workers (they couldn't believe she was actually paying them to stand around and talk to her). Once she gets them talking, Judy finds the workers interesting to listen to and willing to tell her a great deal about the work. They seem to take pride in their skills and like their work. However, they all complain about something. Judy's notes turn out to contain every major gripe she has heard on 22 different jobsites, ranging in size from 4 to 47 workers. As she compiles her notes, she groups similar gripes under three problem headings:

1. Knowledge problems

. No one spends time at the beginning of a job showing workers how to install novel glass and frame designs they have never seen before.

. New workers at the site are not shown how to do the work but are left to learn by watching others.

. Management never asks experienced workers for suggestions.

. No one is ever told exactly what is expected of them, so everyone just does what others do.

. Plans and directions are frequently confusing, and time is wasted getting clear answers.

. Work is seldom planned ahead of time, so workers are unsure what to do next when they reach the end of a task.

. Work must sometimes be redone because of inadequate directions as to how it should have been done the first time.

2. Capacity problems

. People often waste time waiting for deliveries of glass, yet glass stored at the site is often damaged or broken.

. The lifting equipment is old and often inadequate; to place heavy panes correctly requires considerable time and effort.

. The safety harnesses are old and worn, and workers often feel scared working at heights.

. The company refuses to purchase expensive, "state-of-the-art" vacuum- powered handgrips for holding glass panes.

. Not enough equipment is assigned to large jobsites working several crews.

3. Motivation problems

. No matter how well workers perform on a job, their pay is locked into a contract wage scale that is the same for everyone.

. While they are working on one job, orkers are never told if they will be needed on another job.

. Project management is quiuck to criticize slack performance and never acknowledges superior performance.

. Workers feel that management "looks down on them."

Looking over her list of problems, Judy feels both a sense of accomplishment and a sense of discouragement. She feels that her list provides a valuable guide to improving productivity, but she doesn't know where to start. All the problems seem formidable. All the solutions seem too time-consuming, too expensive, or too contrary to company traditions. but, she decides, that won't stop her from trying.

The missing pieces

Judy's efforts to locate the causes of her company's problems are commendable. Her list of problems (with its three categories) appears promising. However, the missed two critical steps. First, she failed to define and measure the accomplishments she values. While she assumed that profitability was her overall goal and improved jobsite productivity a subgoal, she needs specific measurements of jobsite performance in order to locate deficient performance. Where are the largest performance ability rations (PARs)? Without measurements of what it is she wants to accomplish on the job, she cannot easily design solutions that will aaddress the largest sources of incompetence. Second, Judy cannot set priorities among alternative problems since she has no way of judging which solution will most likely offer the greatest leverage - that is, which will provide the greatest value relative to its cost. Let us look at a way to resolve this question of priorities.

Priorities in Work-methods Analysis

To set priorities to improve work methods, we first need to locate tasks that promise a large return for a minimum of effort. (To do this, we have learned how to compute PARs and calculate potential worth.) We next need to know exactly what actions to take to improve the work methods and in what order to take these actions. The methods engineering matrix satisfies thihs second need.

A matrix of categories

Turn back to the methods engineering model in Table 6.2. Notice that Judy's three categories of problems include all six of the elements identified in the model, but grouped differently. We can use Judy's three categories to help structure the six elements of the methods engineering model into the matrix shown in Figure 6.1. The methods engineering matrix permits us to pigeonhole any jobsite methods problem into one of six boxes. Each box is identified as either an environmental problem or a behavioral one. Further, each box falls into one of Judy's three categories - knowledge, capacity, or motivation.

	Knowledge	Capacity	Motivation
Environmental Elements	1. Information	2. Resources	3. Incentives
Behavioral Elements	4. Skills	5. Capability	6. Motives

Figure 6.1 The methods engineering matrix.

A sequence for analysis

In what sequence do we attack the problems identified in the matrix? Let us start with the last one. We have already seen that individual motives in construction cannot vary too greatly, for if people did not want to work at construciton, they would work elsewhere. So it is unlikely that variance in motives causes large jobsite PARs. The same is true of capability. Nearly all workers are physically fit for the job, and all crews working at similar tasks encounter more or less similar physical conditions. And, although individual skills may vary considerably, most crews contain a mix of experienced and less experienced workers. So unless crew assignments consciously separate the most skilled workers from the least skilled, crew skills are also unlikely to be a source of large PARs on the job. We see, therefore, that the behavioral elements of the matrix are unlikely to be the starting place for finding worthwhile improvements to work methods.

In fact, the matrix in Figure 6.1 lays out the elements in the most likely order of discovering the causes of deficient performance. All elements are equally important in engineering efficient work methods. but solutions to correcting deficiencies in the environmental elements promise a greater payoff for less cost and effort. In general, it is usually for easier for management to make changes to the work environment that to change the work behavior of the labor force. Therefore, it pays to follow the sequence in Figure 6.1 in a search for improvement strategies, looking first to the least expensive and least difficult solutions.

Begin with information. Ask if crews have the information they need to do the work properly. Do they know how it should be done? do they know how well it can be performed (the exemplar)? Poor direction and lack of feedback concerning how well they are doing their jobs may well be the single largest source of jobsite incompetence at all levels.

Next, look at resources, the tools, equipment, and materials required to do the job. Do workers have the resources they need in order to perform well? Large measurements of lost time on jobs due to waiting come primarily from management's consistent failure to provide resources when they are needed.

Then examine incentives. How can incentives be improved and made more contingent upon good performance? If wage scales are fixed by contract, what nonmonetary incentives might be offered? And how can one eleiminate negative incentives that discourage good performers and reward poor ones?

Finally, if a large PAR still persists after manipulating the environmental elements, decide whether any training to improve job skills will help. While worker skills are an extremely important aspect of jobsite performance, contractor-run training programs can prove to be very expensive. If training is used, it should be directed specifically to the tasks on the job.

The methods engineering model and the matrix, then, provide a performance troubleshooting sequence. Once we know that a problem exists, the model gives an orderly way to discover cost-effective strategies for improving deficient work methods. Remember, however, that the model does not pretend that one element is more important than another. It merely orders the elements so that solutions with the greatest worth are more likely to be discovered first.

Applying the model

Suppose we now apply the model to Judy's problems. In doing so, we quickly develop a checklist of questions (given in Table 6.3) that lead us directly to priorities for attempting solutions.

In reading down Table 6.3, one thing stands out immediately. While the sequence of questions leads generally toward more expensive solutions, the single question and answer in item 5, "Capability," calls for immediate attention. Safety is not an "expensive" solution. Instead, failure to provide a safe workplace may be one of the most expensive decisions a contractor can make. The search to find and remedy unsafe conditions never stops; worker capability on the job can be drastically reduced by accidents, sometimes serious enought to halt further work. So always pay attention to safety issues first.

Besides the safety issue, we see that the first deficiency on the list turns out to be information. Here the problem turns out to be with the foremen and project supervisors who do not spend enough time planning the jobs. Poor planning results in confused

Table 6.3 The Methods Engineeering Model-Troubleshooting Checklist

Variables	Solutions
Environment	
1. Information	
.Are plans and directions clear? .Are work standards clear? .Is work planned ahead? .Is performance feedback offered?	No. Field supervisors must learn to plan ahead, anticipate problems, give clear directions, and provide feedback.
2. Resources	
.Is equipment adequate? .Are tools adequate? .Are materials available?	No. New equipment and tools must be purchased and methods found to deliver early and protect glass.
3. .Incentives	
.Are nonmonetary rewards used? .Are workers treated with dignity?	No. Good performance must be recognized, acknowledged, and rewarded.
Behavior	
4. Skills	
.Do workers know how to install? .Are new workers trained?	No. Training must begin for novel installations and new hires.
5. Capability	
.Can workers perform well?	No. New safety equipment must be purchased to allay workers'fear.
6. Motives	
.Do workers want to perform well?	Yes.

directions, lack of cordination, and unforeseen problems with plans and installation. Workers also fail to get adequate feedback concerning how well they are doing, particularly on rush jobs where management always seems too busy to pay attention to the work being done. Improving jobsite information is usually the least expensive way to improve performance. Judy needs to review the workload on her foremen and project supervisors and make sure that they alter their priorities. Planning the jobs and providing clear direction and feedback should be their primary responsibility.

New equipment and tools may represent a significant expense for the company. But failing to provide workers with the resources they need to do the job tells them that management doesn't really care about them, only about saving money. If the company cannot afford to reoutfit all the crews at once, then new equipment, as it is purchased over time, might be used to reward those crews whose work is most outstanding. giving vacuum-powered handgrips to the crews that do the best work each month, for example, may provide an excellent incentive for crews to improve. Recognition for a job well done, even if it is only a token reward, fosters a sense of pride in accomplishment and encourages crews to continue to do well in the future.

Setting up a training program for new hires and for crews faced with difficult or novel installations can become another source of recognition for exemplar performers. Judy can use her exemplar performers to teach others how to do the work. Pulling several of the best workers and foremen off a job for half a day or sot to figure out the best way to install glass on an upcoming job solves two problems: It gives recognition to individuals who have demonstrated superior work skills, and it anticipates potential installation problems beforehand, giving management time to develop work methods to avoid the problems.

Once Judy (or any contractor) uses the work-methods engineering model to analyze a job, the solutions become obvious. Repeated application of the methods model to many jobs will soon eliminate the most common problems and, in the process, improve the performance of both work crews and management.

Jobsite Motivation

The methods engineering model distinguishes two aspects of motivation: incentives and motives. Incentives refer to the work environment, the wages, rewards, and recognition offered by management. Motives refer to the personal attitude toward the job that an individual brings to work each morning. Combined, the two define the motivation that drives someone to try to accomplish a construction task. If either incentives or motives are missing, motivation also disappears.

The final question in Table 6.3 assumes that the workers' motives are not a problem, that the people want to work and will do so if the other environmental and behavioral elements are met. Yet, on some jobs, worker motives may indeed be questioned. Workers may no longer want to work on jobs that have "gone sour." Some projects, suffering from incompetent management, experience jobsite conditions that greatly reduce workers' desire to accomplish anything at all.

Motives can change

It ought to be apparent that working conditions at the jobsite can affect individual motives, and hence motivation. an unskilled apprentice who receives no encouragement for his or her efforts, but hears only criticism, will find the job less and less satisfying. Although the pay remains the same, the desire to do the work diminishes. Other inner motives, such as the desire to learn a trade and earn a living, the comradeship of other craftsmen on the job, and the pleasure of working with one's hands, may not be strong enough to compensate for the misery of daily hassle and rebuffs. Motivation fails, and either the apprentice quits the job or the work falls off so mush that he is fired. Because management has failed to provide a positive work environment, the worker suffers. In such a case, the lack of positive feedback (information), and the lack of assistance in learning (skills) affect motives and undermine motivation.

In fact, there is no way to alter one element of the model without having at least some effect on other elements, sometimes a very large effect. Lighter tools (resources) may make it easier for women to use them (capacity). Training (skills) and feedback (information) can provide powerful personal reasons for wanting to do a good job (motives). This interrelationship among job elements and motivation demonstrates how useless the word motivation is when discussing jobsite problems. When a contractor says that the work force is not motivated, it does not tell us anything about why motivation lags. Is it because the contractor does not pay enough (incentives), or because the equipment on the job continually breaks down (resources), or because directions are confusing and make little sense (information)? One thing we do know, however, is that the alleged lack of motivation is very unlikely to stem from the workers' own motives. They probably want to work and like construction work; so why has management failed to tap that feeling and reinforce it? The answer is nearly always to be found in the incompetence of management. A competently run job seldom experiences a "motivation" problem.

Focus on results

So how does one separate motivational elements from knowledge and capacity in designing better work methods? Suppose we find a defciency caused by confusion over unclear shop drawings. After we have an engineer redraw portions of the plans to clarify the installation details, we find that we get exemplary performance. Obviously, part of the reason for the improvement is informational; the better drawings make the work easier. But part of the improvement may also be motivational; by removing a source of frustration, we have made the job more pleasant. How do we tell the difference? In such a situation, we cannot tell the difference. But there is no reason to worry over which effect, information or motivation, caused the performance improvement. we are concerned only with the results.

The methods engineering model cannot tell us if the information on the job is adequate or if the workers' motivation is high. It can only tell us where to look first for obvious flaws. First we look at information. If we find nothing there that we can correct, we go on to look at resources, and so on. The model cannot find every defect in jobsite work methods, it can only help us search for observable defects in an orderly fashion. It prompts us to ask the "obvious" questions (the ones we so often forget to ask) with the sole aim of improving performance.

Every solution will have a crossover effect on the other elements of the model. We need not concern ourselves with quantifying this effect, for we are not behavioral scientists. We are construction contractors, managers, and field supervisors, interested only in raising on-site job performance.

The methods engineering model offers us a way out of the "motivation" and "attitude" trap that so frequently leave contractors helpless in their desire to improve productivity. The model provides a simple method for discovering the real reasons for performance deficiencies.

CHAPTER 7
TROUBLESHOOTING CONSTRUCTION PERFORMANCE

Troubleshooting and the Performance Audit

In order to troubleshoot a project and identify the actions that will lead to improvement, we need a simple quide to follow. Successful troubleshooting of jobsite performance follows six steps, called a performance audit. (17)

The performance audit

1. Identify accomplishments. Make sure the items of work describe measureable accomplishments, not merely jobsite activities. We want to identify and measure work-in-place. Vague task categories such as "wiring" and "framing" describe activities, not measureable accomplishments.
2. Identify requirements. Here we apply the questions for the performance measurement requirements of quality, quantity, and resources from Table 4.2. Asking and answering the questions identifies the key measurements and units to use for each of the accomplishments identified in step 1.
3. Define exemplary performance. Having identified the accomplishments and requirements, the next step is to define what constitutes exemplary performance for each of the accomplishments and measurements. How do we distinguish exemplars? For

measurements of productivity, we look for higher amounts installed per manhour. But what about measurements of work quality and jobsite safety?

4. Measure exemplary and average performance. Collecting the numbers for each of the accomplishment measurements may require considerable time and effort. The numbers, however, provide the basis for locating significant variations in performance.

5. Compute the PARs and worth. Analysis of the measurements leads to finding the greatest opportunities for imporvement and the biggest potential paybacks.

6. Apply the methods engineering model. Only after we have completed each of the five steps above are we ready to apply the model as a guide for developing strategies to improve performance. In applying the model, pose these questions:

INFORMATION: Do people know what accomplishments are expected of them and what the standards are? Do people get regular feedback as to how well their perform relative to the exemplar? Do they get information on where their deficiencies are so that they may improve? Is the feedback complete, accurate, intelligible, and timely?

RESOURCES: Are the drawings, tools, equipment, and materials suited to the job? Are they available when needed? Can people reach exemplary performance with the resources available to them?

INCENTIVES: Are the incentives sufficient to encourage exemplary performance? Are they contingent upon good performance? Are there competing negative incentives that inhibit good performance? Are all the available incentives used?

SKILLS: Do people have the necessary knowledge and training to perform well? Could they reach exemplary performance if their lives depended on it?

CAPACITY: Do people have the physical capacity to perform well? Do weather, hazards, health, and personal conditions make it impossible to achieve exemplary performance?

MOTIVES: Is the work so unrewarding and punishing that no one will want to perform well even if provided with excellent incentives?

Answers to these questions help us devise strategies to improve work methods. To see how the troubleshooting sequence might be applied in the field, let us follow an example in detail.

Busten Poure Company, Inc.

The Busten Poure Company specializes in paving replacement. Each winter it submits bids to the county for sidewalk and street-repair work. The bids are unit-price bids; Busten Poure bids so many dollars per square yard for various types of work. This spring, the county hired Mike Nickles, a student in construciton mangement at a local university, as a summer intern. Mike will work as a project engineer, inspecting the work of four of the Busten Poure crews on three of the county street-replacement jobs in residential neighborhoods. In addition, to get course credit for his internship, Mike must write a detailed report on some aspect of his experience. Mike chooses to investigate the productivity of Busten Poure's paving crews.

Applying the performance audit

1. Mike begins by identifying accomplishments. He lists six:

. Locate and mark paving areas for replacement.

. Break and remove existing paving.

. Prepare and grade subsurface for new slab.

. Prepare formwork.

. Place and finish new slab.

. Clean up.

In reviewing the list of accomplishments with the full-time project engineer for the county, Mike finds that the first acccomplishment, locating and marking the paving areas to be replaced, has already been done by the county. Engineers identified, and marked with spray paint, all substandard squares to be replaced. (A square is the area between expansion joints in the concrete streets, normally measuring 13 ft by 20 ft, one-half the width of a 26-ft-wide residential street.)

Breaking and removing the existing 6-in concrete road surface requires a paving breaker, a loader, and one or more dump trucks for hauling away the pieces. After the old slab has been removed, along with any "spongy" soil beneath, crews add gravel aggregate to fill holes and to provide a firm foundation for the new concrete. Because each new slab needs to meet county requirements for minimum thickness, crews take care in raking out the gravel to maintain the correct depth for the finished slab. A 1-ton roller then compacts the gravel.

Crews then place the formwork for the new slab, making sure to maintain the correct slopes for proper drainage. After these preparations, Mike, in his role as a county engineer, must inspect the work and approve the next step, placing the concrete. Placing and finishing the slabs then proceeds quickly. Finally, crews clean up the area befor leaving it, backfilling and resodding along the curbs as well. (As crews normally work ion three or four locations on several streets at the same time, Mike can see that just keeping track of the work will be a big job.)

2. Next, Mike must identify the requirements of the job. For this, he turns to the performance measurement requirement question (refer to Table 4.2). For each accomplishment, Mike asks as many quality, quantity and resource questions as he can think of followed by the measurements (and units) he will use. He comes up with the following list:

Requirement	Measurement (and unit)
ACCURACY. It seems unlikely that crews	Depth (inches)
would break out the wrong slab.	Gravel fill (OK,Not OK)

However, the depth of each new slab must be at least 6 in. Subsurface fill must be firm. Also, slabs must slope properly to drain. The concrete mix must meet strength specifications and must be finished properly.	Slope (OK, Not OK) Mix (OK, Not OK) Finish (OK, Not OK)
WORKMANSHIP. Mike finds no requirements here.	None
PRODUCTIVITY. Because some of the slabs vary in size, Mike decides to use square yards divided by manhours (SY/MH)as his primary productivity measurement. Since nearly all the slabs are 6 in deep, the area measurement can be easily converted to cubic yards (CY) in order to measure the amount of material removed and hauled and the amount of concrete placed per manhour. Formwork placement can be measured in linear feet per manhour (LF/MH).	Break (SY/MH) Remove (SY/MH) Haul (SY/MH) Prepare (SY/MH) Formwork (LF/MH) Place (SY/MH) Finish (SY/MH)
SCHEDULE. Mike is unsure how schedule affects the contractor. Her contract requires her to replace several hundred thousand square yards of pavement before November 1. No other interim-schedule deadlines affect the work. However, since the contractor intends to work only the	"Progress ratio" (percentage of work done divided by percentage of working days used)

four crews on the three contracts Mike will oversee, Mike assumes that tracking the progress against the time remaining will be important to avoid either putting on more crews or working overtime near the end of the project.	
MANPOWER. The number of people in each crews and their craft skills affect jobsite performance. Differences in wage scales for crafts affect costs. Also, the amount of overtime, if any, affects the hourly wage scale.	Crew size (#/crew) Skills (craft) Wages ($/MH) Overtime (MH)
MATERIALS, TOOLS, AND EQUIPMENT. Until Mike knows better, he decides to keep track of all the materials, tolls, and equipment at each site.	Concrete (CY/slab) Gravel (CY/slab) Tools (type) Equipment (type) Equipment (condition) Equipment (hours used)

3. Mike talks to the other county engineers to identify exemplary performance. This turns out to be relatively easy for some of the measurements. Exemplary performers always meet the depth requirement exactly and never fail to get approval on the other measurements of accuracy. Exemplary performers must have good productivity rates (although Mike has no idea what good means in numerical terms) for the firms to make money. And exemplary performers always finish before the schedule deadline.

But no one knows what exemplary performance means in terms of cres size or mix of craft skills. Every crew seems to vary. And they use different tools and equipment some of the time. Exemplary performers, however, could be expected to waste a minimum of concrete and gravel.

4. Ready with his performance measurements, Mike sets out to collect the numbers he needs to measure exemplar performance and to measure average performance. Over the next six weeks on the job, Mike gathers the numbers shown in Table 7.1.

The numbers in Table 7.1 show that Mike's measurements of accuracy turn out to be relatively unimportant, since they show no variation. Most of the measurements of productivity show substantial variations; Mike could not collect manhours for the formwork since it is normally done while preparing and grading. He combines placing and finishing since both of these tasks are done at the same time, usually by the same people. The schedule ratio, figured by calculating the percentage of work completed and dividing it by the percentage of workdays used out of the total workdays in the contract, shows the job staying slightly ahead of schedule. Manpower measurements prove more difficult, since the number of people working varies from week to week among the crews, as does the craft makeup of the crews. Mike collects numbers for the average crew size and makekup but knows that more detailed numbers are needed. He wants to calculate producivity rates for different crew sizes and makeups in order to sudy the effect of crew size and makeup on productivity.

Lastly, in the category of materials, tools, and equipment (MTE), the measurements of materials show little wasted concrete (more or less is used in the curbs in order to empty the trucks) but substantial variation in gravel used. Tool use does not vary among the crews, but the number of hours they use their equipment does vary. Again, Mike decides that he needs to measure equipment usage for each crew in order to examine its effect on productivity.

5. Mike combines what he believes to be the important measurements from Table7.1 in Table 7.2 to compute the PARs and calculate the worth of improved

TABLE 7.1 Busten Poure's Performance Measurements

	A	B	C	D
1	Work measurement	Unit	Average	Exemplar
2				
3	Accuracy			
4	Slab depth	Inches	6 in	6 in
5	Gravel fill	OK, Not OK	OK	OK
6	Slope	OK, Not OK	OK	OK
7	Concrete mix	OK, Not OK	OK	OK
8	Finish	OK, Not OK	OK	OK
9				
10	Productivity			
11	Break	SY/MH	170	220
12	Remove	SY/MH	60	75
13	Haul	SY/MH	18	30
14	Prepare	SY/MH	19	25
15	Formwork	LY/MH	NA	NA
16	Place and finish	CY/MH	11	15
17				
18	Schedule			1
19	Progress ratio	%	1.06	1.08
20				
21	Manpower			
22	Av crew size	#/crew	10	NA

TABLE 7.1 Busten Poure's Performance Measurements (Contd)

	A	B	C	D
23	Foreman	#/crew	1	NA
24	Finishers	#/crew	3	NA
25	Drivers	#/crew	2	NA
26	Laborers	#/crew	4	NA
27	Overtime	MH/week	12	2
28				
29	MTE			
30	Concrete	CY/slab	5	4.9
31	Gravel	CY/slab	4.1	2.3
32	Tools	Type	NA	NA
33	Pavement breaker	Hours used	3	NA
34	Loader	Hours used	3	NA
35	Backhoe	Hours used	1	NA
36	Drump trucks	Hours used	20	NA

performance for each item. He obtains the PARs by dividing the average into the exemplar, except in the cases of overtime and gravel where, because of the units chosen for measurements, the exemplar is the lower number. In those two cases he must divide the lower number into the higher to get the PAR.

To compute worth, he estimates that about 200,000 SY of concrete remain to be replaced and that the job will run another 30 weeks. For rows 4 through 10, worth is calculated as the difference between completing the remaining 200,000 SY at the average and at the Exemplar. In row 4, for example, it will take 1176 MH to break 200,000 SY working at 170 MH/SY but only 909 MH at the exemplar of 220 MH/SY. The difference is only 267 MH. The worth of overtime, in row 13, is calculated by figuring 30 weeks times

4 days per week (no overtime on Fridays) to get the days remaining. At 12 MH per day, overtime will amount to 1440 MH; at only 2 MH per day it will run only 240 MH, a difference of 1200 MH. The worth of gravel in row 16 comes from dividing the remaining 200,000 SY by 29, the number of square yards in a typical 13-ft by 20-ft square, and then multiplying by the number of cubic yards of gravel per square (the 4.1-CY average and the

TABLE 7.2 Busten Poure's Performance, PARs, and Worth

	A	B	C	D	E	F	G
1	Work measurement	Unit	Average	Exemplar	PAR	Worth	Unit
2							
3	Productivity						
4	Break	SY/MH	170	220	1.3	267	MH
5	Remove	SY/MH	60	75	1.3	667	MH
6	Haul	SY/MH	18	30	1.7	4444	MH
7	Prepare	SY/MH	19	25	1.3	2526	MH
8	Place and finish	SY/MH	11	15	1.4	4848	MH
9							
10	Avg Productivity	SY/MH	3.2	3.9	1.2	11218	MH
11							
12	Manpower						
13	Overtime	MH/wk	12	2	6.0	1200	MH
14							
15	MTE						
16	Gravel	CY/slab	4.1	2.3	1.8	12414	CY

2.3-CY exemplar). The difference between the two is very high, 12,414 CY.

Among the productivity items, the PAR and worth for hauling the broken slabs away stand out. So, too, do the PAR and worth for placing and finishing.

In row 10, column C, Mike computes an average overall productivity for both crews by dividing the total amount of concrete placed by the total number of manhours expended. He also goes back over his data to find the best performance by each crew in any one day. He averages the best from each of the four crews to get an "average exemplar" and enters this number in row 10, column D. From this he computes an overall job PAR of 1.2.

Overtime hours per crew per week offer a large PAR and enough potential manhour savings to make it worth looking into. He is also startled by the potential savings in gravel - over 12,000 CY. In watching the work during the day, he had not noticed such a large difference in gravel use.

6. Now Mike is ready to apply the methods engineering model to try to find the causes of the large PARs. He decides to start with the gravel since it seems less likely to be controversial. He asks the foremen at each of the three jobsites questions about how they decide how much gravel to use. They all tell him that they normally excavate about 6 in of the soil beneath the removed slab and replace it with compacted gravel. When he asks why, he is told that once, just as one crew started a pour, a county engineer walked across the foundation gravel and told them the foundation was too spongy and that he could not allow them to place concrete over it. So they had to stop the pour, excavate all the wet concrete along with the mud and gravel underneath, and replace it with compacted gravel. It was such a pain that, from now on, they almost always take out an extra 6 in to be on the safe side. Mike is aghast. For not only does it cost more for the gravel and the time spent moving and raking it, but at 8 yd of gravel per dump truck, Mike figures it will take an extra 1500 trips just to haul gravel to the jobsites! At an aveage of six trips per truck per day, it comes to 250 extra truck-days. With only 150 workdays remaining in the contract (30 weeks times

5 days per week), this means that the jobs will need two more trucks - with drivers - to haul in all the extra gravel. All this just to "be on the safe side."

Applying the methods engineering model

Organizing what he is told about the gravel use into the format of the methods engineering model, Mike writes:

Questions	Findings
1. Information	
Do foremen know how much it costs to overexcavate the depth of the hole beneath the slabs?	No
Do foremen get feedback on how deep the hole is?	Yes, they see it.
2. Resources	
Do foremen have the tools and equipment needed to excavate to the correct depth?	Yes.
3. Incentives	
Are foremen judged on how much gravel they use?	No.
Does the balance of incentives favor overexcation?	Yes, foremen want to avoid underexcavation.
4. Skills	
Do foremen know how to control the depth of the excavation to avoid overexcavation?	Yes.

5. Capacity	
Are foremen able to control the operator running the excavation equipment?	Yes, normally they run the equipment themselves.
6. Motives	
Would foremen want to control excavation and gravel use if they knew how much it cost the job?	Yes.

Even though his formal write-up looks a little silly to him, it gives Mike confidence that he has not missed anything. It appears to him that foremen only need informaiton concerning how much the overexcavation costs to get them to alter their work methods. (Along with a reminder, perhaps, from the contractor, telling them that she will start judging the foremen's performance on how well they can control costs and that it is better to risk reexcavation once in a while than to continue to waste gravel. Or better yet, test the gravel for sponginess before starting a pour.) At a conservative estimate of $15 per hour for each of the two extra drivers and another $50 per day per truck plus $20 per yard for gravel. Mike figures a potential savings of about $75,000. The cost to the contractor to get this savings? No more than five minutes with each foremean to explain the situation.

(Mike learns later that the contractor is not nearly so dumb. Overexcavation is the exception, not the rule. However, no real controls are used to minimize overexcavation, and Mike guesses it still costs the contractor tens of thousands of dollars each year.)

A second model application

Although Mike feels that he has made a dramatic discovery in improving work methods, his real aim is to study productivity, not material and equipment costs. So he constructs another formal methods engineering model, this time to troubleshooot crew productivity.

Questions	Findings
1. Information	
Do crews know what is expected of them?	Yes. Crews pour 300 SY/day.
Do foremen plan crew work ahead of time?	Yes. But work is very repetitive.
Do crews know how to perform as well as the exemplar?	Yes. Every crew has had exemplary days.
Do crews know how well they are performing relative to the exemplar?	Yes. They compare themselves to their past performances.
2. Resources	
Do crews have the equipment they need to perform well?	Yes.
Do crews have materials when they need then?	Yes. Waits for gravel and concrete are short.
Is equipment operated in a safe manner?	Yes.
3. Incentives	
Are wages contingent upon how well the crews perform?	No. Wages are set by contract.
Do crews receive nonmonetary rewards or recognition for exemplary performance?	No.
Do negative incentives operate	Yes. If crews seem to be

against exemplary performance?	finishing early, the foreman orders more concrete.
4. Skills	
Do crew members have the training and/or experience necessary for exemplary performance?	Yes.
5. Capacity	
Is the crew size optimum for best performance?	No. Crew sizes vary.
Does the mix of crafts promote exemplary productivity?	No. Craft mix varies.
Is weather protection necessary for exemplary productivity?	No.
Does traffic interfere with crew performance?	No.
6. Motives	
Do crews want to perform as well as the exemplar?	Yes. Crews take pride in doing well.

Crew methods

Mike's second model doesn't give the easy answers of his first. Here he must consider the relationship between the overall productivity of the crews (in terms of total square yards of output divided by total manhours of input) and the productivity of each phase of the work (such as breaking, hauling, grading, and finishing). Maximizing the productivity of any one of the subaccomplishments (breaking, for example) might lower the productivity of a related task (removing, for example). Therefore, Mike's analysis of work methods must take into account how each subaccomplishment relates to getting the whole job done.

To study overall crew performance, Mike makes charts of what each worker on the job does during a typical day. Table 7.3 shows one of Mike's charts analyzing the activities of the two 9-person crews, A and B. (Crew C, with 20 persons on Mike's third jobsite, is nearly a composite of A and B.) Crew B has only two finishers and four laborers. Both crews work from 7:00 a.m. until 3:30 p.m., placing 300 SY of concrete paving. They normally form and grade in the afternoon, ready to place and finish the next morning when the air is cooler. (Also, by the time the crew leaves the job in the afternoon, the fresh concrete placed in the morning has usually set up enough to discourage neighborhood kids from writing in it.)

Crew Differences

Mike then computes the productivity for each of the operations using an average of 300 SY per day per crew. He notes that the three finishers in Crew A do not usually work the full day. Two of them lose about an hour at the end of the day, while the third loses about a half hour. Sometimes they stretch out the task of forming for the next day's pour, but more often than not they just work steadily to get it done, then knock off and sit in the shade watching the others complete their tasks. On both crews, the foreman operates the pavement breaker and the loader intermittently throughout the day. However he frequently must interrupt one task to give directions to drivers who are hauling away the broken pavement and returning with gravel. Or he jumps down from the pavement breaker to run the loader to fill a dump truck when it arrives, then resumes breaking. Mike notes that in both crews, the foreman-operator stays very busy, even helping out on the pours whenever an extra hand is needed.

TABLE 7.3 Daily Activities for Two Paving Crews

A	B	C	D	E	F	G	H	I	J
1	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00
2 Crew A									
3 Foreman	Break and		remove			Break and remove			
4 Finisher 1	Forms		Pour			Form			
5 Finisher 2	Forms		Pour			Form			
6 Finisher 3	Forms		Pour			Form			
7 Driver 1	Haul					Haul			
8 Driver 2	Haul					Haul			
9 Laborer 1	Grade		Pour		Grade	Grade			Clean up
10 Laborer 2	Grade		Pour		Grade	Grade			
11 Laborer 3	Tractor		Pour		Tractor	Grade			
12									
13 Crew B									
14 Foreman	Break and		remove		Break and		remove		
15 Finisher 1	Pour				Form				
16 Finisher 2	Pour				Form				
17 Driver 1	Haul				Haul				
18 Driver 2	Haul				Haul				
19 Laborer 1	Pour				Grade				Clean up
20 Laborer 2	Pour				Grade				
21 Laborer 3	Pour				Grade				
22 Laborer 4	Tractor				Tractor				

The extra laborer in Crew B spends most of the day bringing gravel from stockpiles on the street to the holes and doing rough grading with the tractor. Crew B uses the tractor far more than Crew A, but much of the time the Crew B tractor operator sits waiting for other crew members to complete some other task. With only two finishers in Crew B, both must work steadily throughout the day in order to complete their assigned jobs.

Observations

Over the next six weeks, in collecting further measurements of crew productivity and in probing further the causes of variation, Mike makes the following observations:

. Crews work faster when concrete trucks are backed up, waiting to unload.

. When the foreman is busy elsewhere, workers waste much more time.

. Workers who are fast but do not care about quality have lower productivity than slower workers who make fewer mistakes and therefore have less rework to do.

. Crews always pace themselves to commplete the pour (regardless of when they start) just before lunch. (By limiting themselves to 300 SY in the morning, there is no chance that they will have to do more in the afternoon, although they can do the 300 SY in less than two hours when they push it.)

. Crews lose time when drivers do not bring gravel when it is needed.

. As long as most of the crew members are working, no one wastes time, but if several people must stop to wait for something, then others will slow down or stop too.

. Drivers waste about a quarter of their day serving as taxis for the foremen, who must check on crew activities spread out over several streets. Drivers also lose time searching up and down streets for the foreman and the loader in order to pick up a fresh load of rubble.

The ideal crew

With this information and his measurements, Mike tries to design an "ideal crew" that he believes could always achieve exemplary productivity rates. After many false starts, he finally settles on a 15-person crew pouring 600 SY per day (3000 SY for the week) plus a 4-person crew working Saturday to backfill and sod. Table 7.4 shows each task, the number of people assigned to it, and the hours per day each will work. Overtime hours (column D) count the Saturday work at time and a half. The total manhours for the week (column F) divided into the total amount placed for the week (column G) gives the expected average productivity rates in column H. Comparing column H with his measured exemplars in column I, Mike sees that the expected rates represent achievable goals.

Mike predicts that his ideal crew would regularly achieve a productivity rate of 4.6 SY/MH S, 18 percent better than the measured exemplar. This improvement is possible because Mike has redesigned the work methods to take maximum advantage of the individually recorded exemplars and to avoid the lost time normally experienced by crew members. Table 7.5 lays out the typical workday for the crew members.

Task assignments

In developing his ideal crew, Mike gives the following reasons for the number of people and their task assignments:

- Supervision and breaking would be the foreman's sole responsibilities. Since skupervising a nine-person crew took up several hours of the foreman's time and, even then, the foreman was not always available when needed, Mike feels that the foreman needs more time for supervisory activities but could still operate the pavement breaker at least three hours each day. According to Mike's field measurements, the foreman could easily break up 600 SY of pavement in less than three hours, even

TABLE 7.4 The Ideal Crew's Exemplar Productivity Rates

A	B	C	D	E	F	G	H	I
1 Task	Prsns	Hours/ day	OT?	Days/ Week	Total MH	Amount	Av unit rate	Exemplar
2								
3 Break	1	3	1	5	15	3000	200	200
4 Remove	1	8	1	5	40	3000	75	75
5 Haul	3	8	1	5	120	3000	25	30
6 Place & finish	6	7	1	5	210	3000	14	15
7 Formwork	6	1	1	5	30	3000	100	NA
8 Formwork	1	8	1	5	40	3000	75	NA
9 Grading	3	8	1	5	120	3000	25	25
10 Cleanup	4	8	1.5	1	48	3000	63	NA
11 Supervision	1	5	1	5	25	NA	NA	NA
12								
13 Total					648	3000		
14 Average productivity (amount/MH)					4.6			
15 Crew size						15		

with interruptions.

. Removing the broken pieces would require a full-time operator on the loader who could remove 75 SY per hour, or 600SY per day. Operating the loader all day would also eleminate the time lost by drivers returning empty and searching for the foreman in order for him to reload their trucks.

. Hauling 300 SY per day required two drivers, but they did not work all of the time, often waiting an hour for the loader to fill them. Therefore three drivers, with the full-time loader operator, should be able to haul 600 SY each day.

. Pouring and finishing 300 SY consistently took six people 3.5 hours (including cleanup). Therefore, the six ought to be able to do 600 SY in seven hours, leaving each an hour at the end of the day to help complete the formwork for the following day. In the event that all six were not needed for formwork, the four laborers could be reassigned to grading or some other end-of-the-day task (such as repositioning traffic barrels).

. Forming 300 SY usually took about one man-day: less if one person worked on it straight through, and more if the job was split up with interruptions for other tasks. One person working full-time on forming should be able to set the majority of the forms for 600SY in a day, relying on help from others at the end of the day to complete the job. This task might rotate among the three finishers.

. Grading, plus backfilling, sodding, and street sweeping, normally kept three workers (including one with a tractor) busy for half a day (about 15 MH). Extending their task for the full day should complete the grading for 600 SY if they do not spend too much time on the backfilling and sodding tasks. Because of interruptions and the press of other work, crews seldom finished all the necessary backfilling and sodding by the end of each day. Often several people would stay overtime to complete it. Instead, Mike proposes to bring in a crew of four (a foreman who would double as a tractor operator, plus two laborers and a truck driver) on Saturdays to do all the backfilling and sodding for the past week's work. By postponing the backfilling and sodding during the week, the laborers and the tractor would be able to perform the grading and their other tasks more efficiently. In addition, the drivers would not be interrupted with sod requests during the week. Devoting Saturdays to this work would also permit the crew to do a better job and to deal immediately with any complaints from homeowners. Mike figures that the 32 hours of overtime for the extra day, although more than the 10 overtime hours per week that the crews now experience, would more than pay for itself by making the other operations during the week more efficient.

TABLE 7.5 The Ideal Crew's Task Assignments

A	B	C	D	E	F	G	H	I	J
1	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00
2 Ideal Crew									
3 Foreman	Supervision Break					Supervision			
4 Operator	Remove					Remove			
5 Finisher 1	Pour					Pour			Form
6 Finisher 2	Pour					Pour			Form
7 Finisher 3	Form					Form			
8 Driver 1	Haul					Haul			
9 Driver 2	Haul					Haul			
10 Driver 3	Haul					Haul			
11 Laborer 1	Pour					Pour			Form
12 Laborer 2	Pour					Pour			Form
13 Laborer 3	Pour					Pour			Form
14 Laborer 4	Pour					Pour			Form
15 Laborer 5	Grade					Grade			
16 Laborer 6	Grade					Grade			
17 Laborer 7	Grade					Grade			

Productivity gains

Mike also considers that the labor agreement may require a second foreman for a 15-person crew, but at $1 per hour more in wages (making the operator a foreman), it is a relatively small cost for the anticipated gains. If Mike's ideal crew could really achieve an average weekly productivity of 4.6 SY/MH, it would be a 44 percent jump over their present average of 3.2 SY/MH. With 200,000 SY of concrete left to complete, it would take 62,000 MH at 3.2 SQ/MH and only 43,500 MH at 4.6 SY/MH, a savings of 18,500 MH. At an average wage rate of $15 per hour, the potential savings could reach $277,000. No small change.

Altered Incentives

Mike's analysis of crew size and makeup holds considerable promise for Busten Poure, Inc. In order to achieve the potential productivity gains, however, the crews may need additional environmental support in the form of altered incentives. Currently, the crews limit their production to 300 SY per day by pacing themselves. Placing concrete in the cooler mornings allows more rest time in the hotter afternoons. The proposed change in crews would extend concrete placement into the hottest part of the day, something crew members might be expected to resist. After all, what's in it for them? It seems that the change would only make their jobs harder without any offsetting gains. To achieve the expected high productivity, therefore, we must also look to altering the balance of incentives on the job so that crew members would prefer to place 600 SY per day rather than only 300.

Since, by contract, neither the work hours nor the pay scales can be changed, Busten Poure must look to on-the-job incentives. Two potential incentives come to mind. First, Mike noted that regardless of the time a pour started, concrete placement always finished before lunch. Crews took anywhere from 2 to 4.5 hours in the morning to place 300 SY. Their incentive for working faster in the morning was to avoid working in the heat of the afternoon. Suppose that Busten Poure's policy allowed the crew to quit working as soon as they met the 600-SY quota. In other words, as long as the crew could average 600 SY per day, no more would be asked of them. They would be free to relax in the shade for the rest of the day once the work was completed. With such an incentive to get the work done, it would not be surprising to find crews placing the entire 600 SY some mornings before lunchtime. In practice, however, there would be many additional tasks to complete in order to ready the site for the next day's pour - formwork, grading, and sweeping up loose gravel would continue throughout the afternoon, but perhaps at a much more relaxed pace. Such an "early quit" policy might not work, but at least it might be tried.

The second incentive lies in the scheduled Saturday overtime work. Many people like to work overtime because of the increased wage scale. Therefore, overtime work might be assigned to those people who both want it and who work well during the week. Overtime could be treated as an additional incentive, provided crew members desired the overtime work.

The larger picture

The performance engineering viewpoint adopted by Mike led him far beyond the traditional management analysis of jobsite performance. Mike discovered that in order to get the improved productivity he wanted, he would need to offer something in return. This balancing of costs and benefits frequently occurs when one attempts to engineer bettter performance. But even if Mike is unable to create his ideal crew, he has gained a very real sense of control over the job; he knows exactly the accomplishments and the methods that define jobsite performance.

A balance of consequences

While each job may require its own unique set of incentives, contractors must not overlook the importance of altered incentives in developing productive work methods for their crews. Increased productivity generally means doing the same job in fewer manhours. This saves the contractor money but costs the work force, in that they lose the work represented by the manhour savings. When the opportunity for increased productivity presents itself, contractors need to think in terms of how to share the potential savings with the labor force in order to be sure of getting the productivity increase. In other words, before changing work methods, ask, "What's in it for me?" from labor's point of view and then look for that new combination of incentives that will offset any new disincentives. Mike asks his ideal crew to produce more, but he also permits early quits and offers Saturday overtime. Is it enough? Will the work force gain enough to offset the pressures of higher productivity expectations? We do not know until we try it. But it is always this balance of consequences resulting from both positive and negative incentives that affects the workers' willingness to perform well - their motivation.

Job control

The performance audit provides a very powerful tool for job control. Contractors who institute a system of performance measurement, including calculations of worth, backed by the regular application of the methods engineering model, find that they gain increasing control over jobsite performance. Job control translates directly into higher profitability for the contractor and better construction for the owner. Job control also benefits the work force, for it places the onus of responsibility for performance where it belongs - directly on management. In the longer term, as management competence rises and construction becomes an attractive investment alternative, labor will benefit from both the increased work and the increased wages that result from continuing productivity gains.

CHAPTER 8
CONCLUSION

CLOSING STATEMENT

Getting management to change the way it thinks and acts is the single greatest way to improve construction productivity. As contractors often observe, "when work is slow, you can't afford to make changes, and when work is booming, you don't have to". Everyone recognizes that changes can lead to improved performance. But, for the above reason, few are willing to act decisively to make changes.

This paper has marked out means to improve performance through changes in management methods. It presents a self assessment model of how to measure and manage construction productivity and jobsite performance. It is a general model which requires some adaptation. While its effectiveness is enhanced by the degree of tangible information that can be collected, it nevertheless will provide benefits for its user by focusing on the areas of concern relevant for jobsite productivity. Maximazing such productivity is a fundamental component of good project management.

APPENDIX 1
THE ELECTRONIC SPREADSHHEET

The Electonic Spreadsheet

Since measurement and reporting involve the collection, organization, and analysis of numbers, the use of computers can substantially improve our measurement capabilities. More and more contractors are coming to rely on computers to assist them. Computer programs now on the market (and many more to come) help with nearly every phase of construction - from planning and bidding to job management and cost accounting.

One multipurpose program, the electronic spreadsheet (18), offers an invaluable tool to implement the procedures suggested before. Most of the examples used throughout this paper illustrate the use and power of the electronic spreadsheet, which is essentially a very large, empty ledger sheet. Table 8.1 shows a portion of one.

Thousands of cells

Normally, spreadsheet columns are referenced by letters, and rows are referenced by numbers. The sheet in Table A.1 shows only 8 columns and 10 rows; it is, however, only the upper left-hand corner of a sheet that may exend more than 200 columns to the right and more than 1000 rows down. Some programs handle much larger sheets, containing over a million cells. (Each gridded box on the sheet is referred to as a "cell.") The user types words or numbers directly into the cells, much as one would fill out a ledger sheet.

However, instead of entering only words and numbers into the cells, we may

TABLE A.1 The Electronic Spreadsheet (with no Data Yet Typed into its Cells)

	A	B	C	D	E	F
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

also enter formulas that reference other cells on the spreadsheet. Thus, for example, instead of calculating the sum of a column of numbers, we can write a simple formula to add the column for us and display the answer at the bottom. Using formulas to calculate relationships between numbers on an electronic spreadsheet gives the spreadsheet its tremendous power. Once the formulas are in place, any changes we make to the original numbers cause the program to recalculate all the numbers automatically. This means that we can examine many "what if" possibilities, letting the power of the computer refigure all the numbers for us. Or, should we discover a mistake in the numbers we have entered, we need merely retype the correct number - and instantly the entire sheet is updated. The upper left-hand portion of a simple spreadsheet is shown in Table A.2

After setting up the headings for Table A.2, the estimated amounts in column B and the estimated manhours in column F were entered. At the end of the week, when counts of work placed and manhours charged to the job are turned in, the numbers in columns C

TABLE A.2 Example of an Electronic Spreadsheet

	A	B	C	D	E	F	G
1 The R. T. James Construction Company, Inc.							
2 Project 88-23: The Main Street Firehouse							
3 Weekly Project Status Report for week ending: 11 Mar 88							
4							
5	Work	Amount	Amount	Percent	Percent	MH	MH
6	code	estimated	placed	complete	manhours	estimate	charged
7							
8	Formula			(C/B)	(G/F)		
9							
10	10220	1256	566	45%	45%	115	52
11	10230	223	223	100%	115%	54	62
12	10450	354	250	71%	66%	233	154
13	10480	3310	1544	47%	52%	510	266
14	11230	2000	500	25%	21%	400	82
15	11260	32	16	50%	22%	96	21
16	11270	780	360	46%	42%	288	120
17							
18 Total MH					45%	1696	757

and G are updated. In columns D and E, formulas for the percent complete and percent manhours expended automatically figure the percentages for comparision. (For clarity, all the spreadsheets in this book include a row near the top showing the formulas used in the calculations, where appropriate.) In this simple example, we see that we can quickly compare the percentage of work done to date against the percentage of manhours expended for each work done to date against the percentage of manhours expended for

TABLE A.3 The Underlying Spreadsheet Formulas in a Part of Table A.2

	C	D	E	F	G
5	Amount	Percent	Percent	Manhour	
6	placed	complete	manhours	estimate	
7					
8		(C/B)	(G/F)		
9					
10	566	=C10/B10	=G10/F10	115	
11	223	=C11/B11	=G11/F11	54	
12	250	=C12/B12	=G12/F12	233	
13	1544	=C13/B13	=G13/F13	510	
14	500	=C14/B14	=G14/F14	400	
15	16	=C15/B15	=G15/F15	96	
16	360	=C16/B16	=G16/F16	288	
17					
18			=G18/F18	=SUM(F10:F16)	

each work-code item to assess how well the job is going relative to the estimate.

Using formulas in cells

Table A.3 reprints an expanded portion of the same spreadsheet but shows the underlying formulas used to compute the percentages in columns D and E. Note how the formulas reference other cells to obtain the values needed to perform calculations. The formula in cell D10, for example, computes the percent complete for the first work-code item (10220 in cell A10 in Table A.2) by setting the value of the cell equal to the number given in cell C10 (the amount placed to date) divided by the number given in cell B10 (the total estimated amount). Using an electronic spreadsheet greatly simplifies the task of organizing jobsite numbers and calculating important relationships between the numbers.

FOOTNOTES

(1) "A national strategy for improving productivity inbuilding construction". Building Futures Form, Washington D.C., 1979, p. 13.

(2) "Project Management for Executives", Harold Kerzner, p.3.

(3) "Construction Management A Professional Approach", Thomas C. Kavanagh, Frank Muller and James J. O'Brien, P.2.

(4) "Professional Construction Management", Journal of the Construction Division, ASCE, vol. 102, p. 425.

(5) "Professional Constaruction Management", Donald S. Barrie and Boyd C. Paulson, Jr., p. 19-20.

(6) "Directions in Managing Construction", Donald S. Barrie, p. 17.

(7) "Successful Construction Cost Control", Hira N. Ahuja, p. 39.

(8) "Techniques of Value Analysis and Engineering", L.D. Miles, p. 97.

(9) Obid, p. 98.

(10) "Alternative Construction Quality Assurance Program", Journal of the Construction Division, ASCE, vol. 105, Weston T. Hester, p. 187.

(11) "Construction Industry", Parker W. Henry, p. 90.

(12) Obid p. 92.

(13) Obid p. 97.

(14) "Construction Productivity", Alfeld L. E., p. 34.

(15) Obid p. 35.

(16) Obid p. 38.

(17) "A productivity study of housebuilding", Pigott P. T., p. 63.

(18) "The Contractor and the Computer", James Carota, p. 103.

SELECTED BIBLIOGRAPHY

Ahuja Hira N., "Project Management: Techniques in Planning and Controlling Construction Projects", John Wiley Sons, Toronto, 1984.

Ahuja Hira N., "Successful Construction Cost Control", John Wiley and Sons, New York, 1980.

Alfeld Edward Louis, "Construction Productivity", McGraw-Hill, New York, 1988.

Allard Robert K., "Productivity Measurments: a symposium for the seventies", Institute of Personnel Management, London, 1971.

Baron Robert A., "Behavior in Organizations: Understanding and Managing the Human Side of Work", Allyn and Bacon, Inc., Boston, 1986.

Banrie Donald S., "Directions in Managing Construction", John Wiley and Sons, New York, 1981.

Barrie Donald S. and Panlson Boyd C. Jr., "Professional Construction Management", Journal of the Construction Division, ASCE, vol. 102. No. CO3, September 1976.

Barrie Donald S. and Paulson Boyd C., Jr., "Professional Construction Management", McGraw-Hill, New York, 1984.

Blandy Richard, "Structured Chaos: the process of productivity advance", Oxford University Press, melbourne, New York, 1985.

Brichta A.M., "From Project to Production", Pergamon Press, Oxford, 1970.

Building Futures Form, "A national strategy for improving productivity in building and construction", Washington, D.C. 1979, National Academy of Science.

Calvert R.E., "Introduction to Building Management", Butterworths, London, 1986.

Carota James, "The Contractor and the Computer", Hayden Book Company, Rochelle Park, New Jersey, 1978.

Drewin F.J., "Construction Productivity", Elsevier, New York, 1982.

Halphin Daniel W., "Construction Industry-Planning", John Wiley and Sons, New York, 1976.

Henery Parker W., "Construction Industry", John Wiley and Sons In., New York, 1970.

Hester Weston T., "Alternative Construction Quality Assurance Programs", Journal of the Construction Division, ASCE, vol. 105, no. CO3, September 1979.

International City Management Association, "Guide to productivity improvement projects", U.S. Government Print, Washington D.C., 1976.

Kavanagh Thomas C., Muller Frank and O'Brien James J., "Construction Management: A Professional Approach", McGraw-Hill, New York, 1978.

Kerzner Harold, "Project Management for Executives", Van Nostrand Reinhold Inc., New York, 1982.

McNulty Alfred P., "Management of Small Construction Projects", McGraw-Hill, New York, 1982.

Miles L.D., "Techniques of Value Analysis and Engineering", 2nd ed., McGraw-Hill, New York, 1961.

New York State Financial Control Board, "The New York City Productivity Program Review", The State Financial Control, New York, N.Y., 1983.

Oppenheimer Samuel P., "Construction Industry", McGraw-Hill, New York, 1971.

Pigott Pierce T., "A productivity study of housebuilding", Dublin, Foras Inc., 1972.

Purciello John A., "Manpower and Productivity in the Construction Industry", John Wiley and Sons, Newark, New Jersey, 1972.

Randolph Alan W. and Posner Barry Z., "What Every Manager Needs to Know About Project Management", Sloan Management Review, Summer 1988, Pgs. 65-72.

Schermerhon John R. Jr., "Management for Productivity", John Wiley and Sons, New York, 1984.

Schlesinger Leonard A., Eccles Robert G. and Gabarro John J, "Managing Behavior in Organizations", McGraw-Hill, New York, 1983.

Sterling Anthony, "Production Management", American Management Association, 1983.

Testa Carlo, "Construction Industry", Van Nostrand Reinhold, New York, 1972.

Turner G.J. and Elliott K.R.J., "Project Planning and Control in the Construction Industry", Cassell, London, 1964.

Verdes Palos, "The Design of Systems for Planning and Control", Maps Co., California, 1970.