МИНИСТЕРСТВО ОБРАЗОВАНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ

УЧРЕЖДЕНИЕ ОБРАЗОВАНИЯ
«БРЕСТСКИЙ ГОСУДАРСТВЕННЫЙ ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ»

Кафедра иностранных языков по техническим специальностям

English Reader in Building

Методические рекомендации по изучающему чтению
текстов на английском языке

для студентов I курса специальности

«Технология и организация строительного производства»

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Методические рекомендации предназначены для организации и проведения аудиторной и самостоятельной работы студентов строительного факультета.

Основной целью рекомендаий является обеспечение активного владения выпускниками неязыкового вуза иностранным языком как средством формирования и формулирования мыслей в социально-обусловленных и профессионально-ориентированных сферах общения.

Содержание рекомендаций раскрыто в 10 уроках. В структуре каждого урока содержится: аутентичный текст по специальности строительной проблематики, предтекстовые (1), послетекстовые (5) задания и тексты для дополнительного чтения (10).

Данные рекомендации одобрены на заседании кафедры иностранных языков по техническим специальностям и рекомендовано к изданию.

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Unit 1

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Commitment, demand, to perceive, objective, constraint, relevant, real estate, completion, ultimate, authority, to acquire, to conceive, feasibility, to assess, to define, blueprint, to estimate, procurement, to designate, demolition, conversion, sequential, iteration, to seek, proper, regardless.

Task II: Read the text.

The acquisition of a constructed facility usually represents a major capital investment, whether its owner happens to be an individual, a private corporation or a public agency. Since the commitment of resources for such an investment is motivated by market demands or perceived needs, the facility is expected to satisfy certain objectives within the constraints specified by the owner and relevant regulations. With the exception of the speculative housing market, where the residential units may be sold as built by the real estate developer, most constructed facilities are custom made in consultation with the owners. A real estate developer may be regarded as the sponsor of building projects, as much as a government agency may be the sponsor of a public project and turns it over to another government unit upon its completion. From the viewpoint of project management, the terms "owner" and "sponsor" are synonymous because both have the ultimate authority to make all important decisions. Since an owner is essentially acquiring a facility on a promise in some form of agreement, it will be wise for any owner to have a clear understanding of the acquisition process in order to maintain firm control of the quality, timeliness and cost of the completed facility. Essentially, a project is conceived to meet market demands or needs in a timely fashion. Various possibilities may be considered in the conceptual planning stage, and the technological and economic feasibility of each alternative will be assessed and compared in order to select the best possible project. The financing schemes for the proposed alternatives must also be examined, and the project will be programmed with respect to the timing for its completion and for available cash flows. After the scope of the project is clearly defined, detailed engineering design will provide the blueprint for construction, and the definitive cost estimate will serve as the baseline for cost control. In the procurement and construction stage, the delivery of materials and the erection of the project on site must be carefully planned and controlled. After the construction is completed, there is usually a brief period of start-up or shake-down of the constructed facility when it is first occupied. Finally, the management of the facility is turned over to the owner for full occupancy until the facility lives out its useful life and is designated for demolition or conversion.

Task III: Choose the sentences true to the text.

1. The commitment of resources for such an investment is motivated by market demands.
2. Only a few constructed facilities are custom made in consultation with the owners.
3. A government agency may be the sponsor of a public project.
4. It will be wise for any owner to have a clear understanding of the acquisition process.
5. Various possibilities can't be considered in the conceptual planning stage.
6. The project will be programmed with respect to the timing for its completion.

Task IV: Choose the most suitable word or expression.

1. The facility ... to satisfy certain objectives.

a) are known b) expects c) is expected

2. A real estate developer may be regarded as ... of building projects.

a) consumes b) the sponsor c) objectives

3. The technological and economic feasibility of each alternative will be ...

a) success b) assessed c) to assess

4. The financing ... for the proposed alternatives must also be examined.

a) schemes b) delivery c) fashion

5. Detailed engineering design will ... the blueprint for construction.

a) perceive b) providing c) provide

6. Definitive cost ... will serve as the baseline for cost control.

a) estimate b) estimated c) ultimate

Task V: Complete the sentences according to the text.

1. Most constructed facilities ...
2. The terms "owner" and "sponsor" ...
3. An owner is essentially acquiring ...
4. There is usually a brief period ...
5. An owner may have in-house ...
6. Most owners choose to handle ...

Task VI: Answer the following questions. Use the information from the text.

1. What is the commitment of resources motivated by?
2. Where does a government agency turn a public project?
3. Why are the terms "owner" and "sponsor" synonymous?
4. Why is it wise for any owner to have a clear understanding of the acquisition process?
5. How is the best possible project selected?
6. What do most owners choose?

Task VII: Discuss the following points of the text with your groupmate.

1. The facility is expected to satisfy certain objectives.
2. Most constructed facilities are custom made.
3. It is wise for any owner to have a clear understanding of the acquisition process.
4. A project is conceived to meet market demands.
5. Detailed engineering design will provide the blueprint for construction.
6. There is usually a brief period of start-up or shake-down of the constructed facility.

Unit 2

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Pertinent, to be aware, diverse, advantage, to provide, beneficial, to execute, to hire, to affect, tax law, fiscal, to cause, substantial, competitive, reward, to encompass, warehouse, to be familiar with, to engage, sophistication, to proceed, to confront, to involve, to forecast, profoundly, to replace, to shift, saturation, to decline.

Task II: Read the text.

Major Types of Construction

Since most owners are generally interested in acquiring only a specific type of constructed facility, they should be aware of the common industrial practices for the type of construction pertinent to them. Likewise, the construction industry is a conglomeration of quite diverse segments and products. Some owners may procure a constructed facility only once in a long while and tend to look for short term advantages. However, many owners require periodic acquisition of new facilities and/or rehabilitation of existing facilities. It is to their advantage to keep the construction industry healthy and productive. Collectively, the owners have more power to influence the construction industry than they realize because, by their individual actions, they can provide incentives or disincentives for innovation, efficiency and quality in construction. It is to the interest of all parties that the owners take an active interest in the construction and exercise beneficial influence on the performance of the industry.

In planning for various types of construction, the methods of procuring professional services, awarding construction contracts, and financing the constructed facility can be quite different. For the purpose of discussion, the broad spectrum of constructed facilities may be classified into four major categories, each with its own characteristics.

Residential Housing Construction

Residential housing construction includes single-family houses, multi-family dwellings, and high-rise apartments. During the development and construction of such projects, the developers or sponsors who are familiar with the construction industry usually serve as surrogate owners and take charge, making necessary contractual agreements for design and construction, and arranging the financing and sale of the completed structures. Residential housing designs are usually performed by architects and engineers, and the construction executed by builders who hire subcontractors for the structural, mechanical, electrical and other specialty work. An exception to this pattern is for single-family houses which may be designed by the builders as well.

The residential housing market is heavily affected by general economic conditions, tax laws, and the monetary and fiscal policies of the government. Often, a slight increase in total demand will cause a substantial investment in construction, since many housing projects can be started at different locations by different individuals and developers at the same time. Because of the relative ease of entry, at least at the lower end of the market, many new builders are attracted to the residential housing construction. Hence, this market is highly competitive, with potentially high risks as well as high rewards.

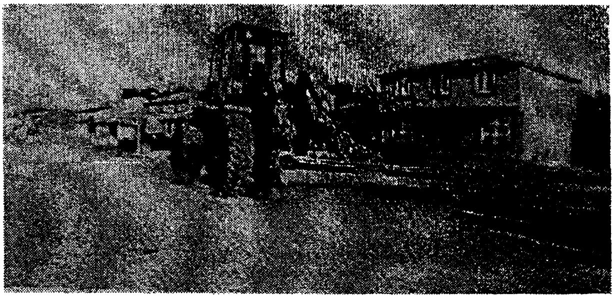


Figure 1-2: Residential Housing Construction (courtesy of Caterpillar, Inc.)

Institutional and Commercial Building Construction

Institutional and commercial building construction encompasses a great variety of project types and sizes, such as schools and universities, medical clinics and hospitals, recreational facilities and sports stadiums, retail chain stores and large shopping centers, warehouses and light manufacturing plants, and skyscrapers for offices and hotels. The owners of such buildings may or may not be familiar with construction industry practices, but they usually are able to select competent professional consultants and arrange the financing of the constructed facilities themselves. Specialty architects and engineers are often engaged for designing a specific type of building, while the builders or general contractors undertaking such projects may also be specialized in only that type of building. Because of the higher costs and greater sophistication of institutional and commercial buildings in comparison with residential housing, this market segment is shared by fewer competitors. Since the construction of some of these buildings is a long process which once started will take some time to proceed until completion, the demand is less sensitive to general economic conditions than that for speculative housing. Consequently, the owners may confront an *oligopoly* of general contractors who compete in the same market. In an oligopoly situation, only a limited number of competitors exist, and a firm's price for services may be based in part on its competitive strategies in the local market.

Task III: Choose the sentences true to the text.

1. It is to the owners' advantage to keep the construction industry healthy and productive.
2. Collectively, the owners have little power to influence the construction industry.
3. The owners can't provide incentives for innovation, efficiency and quality in construction.
4. The methods of procuring professional services, awarding construction contracts, financing the constructed facility are the same.
5. The developers or sponsors usually serve as surrogate owners and take charge, making necessary contractual agreements.
6. Many new builders are attracted to the residential housing construction.

Task IV: Choose the most suitable word or expression.

1. The construction industry is a conglomeration of quite ... segments and products.

a) difficult b) diverse c) similar

2. Many owners ... periodic acquisition of new facilities.

a) reject b) will provide c) require

3. The residential housing market is heavily ... by general economic conditions.
a) affected b) increase c) caused
4. This market is highly competitive, with potentially high risks as well as high ...
a) rewards b) costs c) competitors
5. Specialty architects and engineers are often ... for designing a specific type of building.
a) undertaking b) engaged c) shared
6. A firm's price for services may be based in part on its ... strategies in the local market.
a) competitive b) complexity c) considerable

Task V: Complete the sentences according to the text.

1. Owners should be aware of ...
2. The broad spectrum of constructed facilities ...
3. Residential housing designs are usually ...
4. A slight increase in total demand ...
5. Specialty architects and engineers are often ...
6. This market segment is ...

Task VI: Answer the following question. Use the information from the text.

1. What should owners be aware of?
2. What does the construction industry include?
3. Why do the owners take an active interest in the construction?
4. Whom are residential housing designs performed by?
5. Why are many new builders attracted to the residential housing construction?
6. What does institutional and commercial building construction encompass?

Task VII: Discuss the following points of the text with your groupmate.

1. Many owners require periodic acquisition of new facilities.
2. The methods of procuring professional services can be quite different.
3. The developers or sponsors make necessary contractual agreements for design and construction.
4. The residential housing market is affected by general economic conditions.
5. The owners select competent professional consultants.
6. The owners may confront an oligopoly of general contractors.

Unit 3

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Degree, to seek, to deal with, previous, to evaluate, provision, option, preliminary, to insure, to occur, fee, threat, litigation, lack, prominent, disclaimer, representative, contention, expense, to solicit, to submit, to stipulate, merit, to undermine.

Task II: Read the text.

Selection of Professional Services

When an owner decides to seek professional services for the design and construction of a facility, he is confronted with a broad variety of choices. The type of services selected depends to a large degree on the type of construction and the experience of the owner in dealing with various professionals in the previous projects undertaken by the firm. Generally, several common types of professional services may be engaged either separately or in some combination by the owners.

Financial Planning Consultants

At the early stage of strategic planning for a capital project, an owner often seeks the services of financial planning consultants such as certified public accounting (CPA) firms to evaluate the economic and financial feasibility of the constructed facility, particularly with respect to various provisions of federal state and local tax laws which may affect the investment decision. Investment banks may also be consulted on various options for financing the facility in order to analyze their long-term effects on the financial health of the owner organization.

Architectural and Engineering Firms

Traditionally, the owner engages an architectural and engineering (A/E) firm or consortium as technical consultant in developing a preliminary design. After the engineering design and financing arrangements for the project are completed, the owner will enter into a construction contract with a general contractor either through competitive bidding or negotiation. The general contractor will act as a constructor and/or a coordinator of a large number of subcontractors who perform various specialties for the completion of the project. The A/E firm completes the design and may also provide on site quality inspection during construction. Thus, the A/E firm acts as the prime professional on behalf of the owner and supervises the construction to insure satisfactory results. This practice is most common in building construction.

In the past two decades, this traditional approach has become less popular for a number of reasons, particularly for large scale projects. The A/E firms, which are engaged by the owner as the prime professionals for design and inspection, have become more isolated from the construction process. This has occurred because of pressures to reduce fees to A/E firms, the threat of litigation regarding construction defects, and lack of knowledge of new construction techniques on the part of architect and engineering professionals. Instead of preparing a construction plan along with the design, many A/E firms are no longer responsible for the details of construction nor do they provide periodic field inspection in many cases. As a matter of fact, such firms will place a prominent disclaimer of responsibilities on any shop drawings they may check, and they will often regard their representatives in the field as observers instead of inspectors. Thus, the A/E firm and the general contractor on a project often become antagonists who are looking after their own competing interests. As a result, even the constructability of some engineering designs may become an issue of contention. To carry this protective attitude to the extreme, the specifications prepared by an A/E firm for the general contractor often protects the interest of the A/E firm at the expense of the interests of the owner and the contractor.

In order to reduce the cost of construction, some owners introduce value engineering, which seeks to reduce the cost of construction by soliciting a second design that might cost less than the original design produced by the A/E firm. In practice, the second design is submitted by the contractor after receiving a construction contract at a stipulated sum, and the saving in cost resulting from the redesign is shared by the contractor and the owner. The contractor is able to absorb the cost of redesign from the profit in construction or to reduce the construction cost as a result of the re-design. If the owner had been willing to pay a higher fee to the A/E firm or to better direct the design process, the A/E firm might have produced an improved design which would cost less in the first place. Regardless of the merit of value engineering, this practice has undermined the role of the A/E firm as the prime professional acting on behalf of the owner to supervise the contractor.

Task III: Choose the sentences true to the text.

1. The type of services selected doesn't depend on the type of construction.
2. The owner often seeks the services of financial planning consultants.
3. Investment banks may also be consulted on various options for financing the facility.
4. The owner will enter into a construction contract with a general contractor only through negotiation.
5. The A/E firm completes the design and may also provide on site quality inspection.
6. This traditional approach has become very popular for a number of reasons.

Task IV: Choose the most suitable word or expression.

1. The owner is ... with a broad variety of choices.
a) depended b) confronted c) experiencing
2. Several common types of professional services may be...
a) engaged b) separate c) undertaken
3. Investment banks may also be consulted on various...
a) facility b) negotiations c) options
4. The A/E firm ... the design and may also provide on site quality inspection.
a) completes b) insured c) had completed
5. This traditional ... has become less popular.
a) scale b) approach c) pressure
6. Many A/E firms are no longer ... for the details of construction.
a) preparing b) provided c) responsible

Task V: Complete the sentences according to the text.

1. A large number of subcontractors perform various ...
2. The A/E firm supervises the construction ...
3. The A/E firms have become ...
4. They will often regard their representatives ...
5. The second design is submitted by the contractor ...
6. The contractor is able to reduce ...

Task VI: Answer the following questions. Use the information from the text.

1. When is the owner confronted with a broad variety of choices?
2. What does the type of services depend on?
3. Why does the owner often seek the services of financial planning consultants?
4. When will the owner enter into a construction contract?
5. What may the A/E firm provide?
6. What do some owners introduce value engineering for?

Task VII: Discuss the following points of the text with your groupmate.

1. The owner is confronted with a broad variety of choices.
2. The owner often seeks the services of financial planning consultants.
3. The owner engages an architectural and engineering firm.
4. The A/E firms have become more isolated from the construction process.
5. The A/E firm and the general contractor on a project often become antagonists.
6. Some owners introduce value engineering.

Unit 4

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

To avoid, to scrutinize, to sacrifice, to reduce, turnkey, breed, inception, to retain, to appreciate, stake, to deserve, to bear, mutual, to assign, a participant, maintenance, exception, to obtain, forecast, inventory, aid, lease, tenant .

Task II: Read the text.

Design/Construct Firms

A common trend in industrial construction, particularly for large projects, is to engage the services of a design/construct firm. By integrating design and construction management in a single organization, many of the conflicts between designers and constructors might be avoided. In particular, designs will be closely scrutinized for their constructability. However, an owner engaging a design/construct firm must insure that the quality of the constructed facility is not sacrificed by the desire to reduce the time or the cost for completing the project. Also, it is difficult to make use of competitive bidding in this type of design/construct process. As a result, owners must be relatively sophisticated in negotiating realistic and cost-effective construction contracts.

One of the most obvious advantages of the integrated design/construct process is the use of *phased construction* for a large project. In this process, the project is divided up into several phases, each of which can be designed and constructed in a staggered manner. After the completion of the design of the first phase, construction can begin without waiting for the completion of the design of the second phase, etc. If proper coordination is exercised, the total project duration can be greatly reduced. Another advantage is to exploit the possibility of using the *turnkey* approach whereby an owner can delegate all responsibility to the design/construct firm which will deliver to the owner a completed facility that meets the performance specifications at the specified price.

Professional Construction Managers

In recent years, a new breed of construction managers (CM) offers professional services from the inception to the completion of a construction project. These construction managers mostly come from the ranks of A/E firms or general contractors who may or may not retain dual roles in the service of the owners. In any case, the owner can rely on the service of a single prime professional to manage the entire process of a construction project. However, like the

A/E firms of several decades ago, the construction managers are -appreciated by some owners but not by others. Before long, some owners find that the construction managers too may try to protect their own interest instead of that of the owners when the stakes are high.

It should be obvious to all involved in the construction process that the party which is required to take higher risk demands larger rewards. If an owner wants to engage an A/E firm on the basis of low fees instead of established qualifications, it often gets what it deserves; or if the owner wants the general contractor to bear the cost of uncertainties in construction such as foundation conditions, the contract price will be higher even if competitive bidding is used in reaching a contractual agreement. Without mutual respect and trust, an owner cannot expect that construction managers can produce better results than other professionals. Hence, an owner must understand its own responsibility and the risk it wishes to assign to itself and to other participants in the process.

Operation and Maintenance Managers

Although many owners keep a permanent staff for the operation and maintenance of constructed facilities, others may prefer to contract such tasks to professional managers. Understandably, it is common to find in-house staff for operation and maintenance in specialized industrial plants and infrastructure facilities, and to use of outside managers under contracts for the operation and maintenance of rental properties such as apartments and office buildings. However, there are exceptions to these common practices. For example, maintenance of public roadways can be contracted to private firms. In any case, managers can provide a spectrum of operation and maintenance services for a specified time period in accordance to the terms of contractual agreements. Thus, the owners can be spared the provision of in-house expertise to operate and maintain the facilities.

Facilities Management

As a logical extension for obtaining the best services throughout the project life cycle of a constructed facility some owners and developers are receptive to adding strategic planning at the beginning and facility maintenance as a follow-up to reduce space-related costs in their real estate holdings. Consequently, some architectural/engineering firms and construction management firms with computer-based expertise, together with interior design firms, are offering such front-end and follow-up services in addition to the more traditional services in design and construction.

Facilities management is the discipline of planning, designing, constructing and managing space -- in every type of structure from office buildings to process plants. It involves developing corporate facilities policy, long-range forecasts, real estate inventories, project (through design, construction and renovation), building operation and maintenance plans and furniture and equipment inventories.

A common denominator of all firms entering into these new services is that they all have strong computer capabilities and heavy computer investments. In addition to the use of computers for aiding design and monitoring construction, the service includes the compilation of a computer record of building plans that can be turned over at the end of construction to the facilities management group of the owner. A computer data base of facilities information makes it possible for planners in the owner's organization to obtain overview information for long range space forecasts, while the line managers can use as-built information such as lease/tenant records, utility costs, etc. for day-to-day operations.

Task III: Choose the sentences true to the text.

1. Designs won't be scrutinized for their constructability.
2. It is easy to make use of competitive bidding in this type of design/construct process.
3. The drawback of the integrated design/construct process is the use of phased construction for a large project.
4. The total project duration can be reduced.
5. The owner can rely on the service of a single prime professional.
6. Maintenance of public roadways can be contracted to private firms.

Task IV: Choose the most suitable word or expression.

1. Many of the conflicts between designers and constructors might ...
a) was engaged b) be avoided c) scrutinize
2. A design/construct firm must ... that the quality of the constructed facility is not sacrificed.
a) be engaged b) be reduced c) insure
3. Another ... is to exploit the possibility of using the turnkey approach.
a) advantage b) obvious c) is divided
4. The construction managers are ... by some owners but not by others.
a) relied b) appreciated c) completion
5. The party which is required to take higher risks ... larger rewards.
a) demands b) will establish c) involved
6. The contract price will be higher even if ... bidding is used.
a) competitive b) deserved c) dual

Task V: Complete the sentences according to the text.

1. A common trend in industrial construction is ...
2. It is difficult to make use ...
3. Each of the phases can be ...
4. An owner cannot expect that ...
5. Managers can provide a spectrum ...
6. The line managers can use ...

Task VI: Answer the following questions. Use the information from the text.

1. How can conflicts between designers and constructors be avoided?
2. What is the advantage of the integrated design/construct process?
3. How is the project divided in the phased construction?
4. In what case can the total project duration be reduced?
5. Where do construction managers come from?
6. When will the contract price be higher?

Task VII: Discuss the following points of the text with your groupmate.

1. Many of the conflicts between designers and constructors might be avoided.
2. The use of phased construction for a large project.
3. Construction managers offer services from the inception to the completion of a construction project.
4. An owner must understand his own responsibility.
5. Managers can provide a spectrum of operation and maintenance services.
6. Facilities management is the discipline of planning, designing, constructing and managing space.

Unit 5

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Diverse, loosely, to lump, welfare, restoration, an impact, value, output, to employ, erection, repair, approximately, to exceed, to decline, expenditure, relative, peculiar, favorable, to avoid, a pitfall, noteworthy, to enhance, to foster, collaboration, to quantify, applicable, aggregation, volume, to concern.

Task II: Read the text.

The Changing Environment of the Construction Industry

The construction industry is a conglomeration of diverse fields and participants that have been loosely lumped together as a sector of the economy. The construction industry plays a central role in national welfare, including the development of residential housing, office buildings and industrial plants, and the restoration of the nation's infrastructure and other public facilities. The importance of the construction industry lies in the function of its products which provide the foundation for industrial production, and its impacts on the national economy cannot be measured by the value of its output or the number of persons employed in its activities alone.

To be more specific, construction refers to all types of activities usually associated with the erection and repair of immobile facilities. Contract construction consists of a large number of firms that perform I construction work for others, and is estimated to be approximately 85% of all construction activities. The remaining 15% of construction is performed by owners of the facilities, and is referred to as *force-account* construction. Although the number of contractors in the United States exceeds a million, over 60% of all contractor construction is performed by the top 400 contractors. It can be seen that construction is a significant factor in the Gross National Product although its importance has been declining in recent years. Not to be ignored is the fact that as the nation's constructed facilities become older, the total expenditure on rehabilitation and maintenance may increase relative to the value of new construction.

Owners who pay close attention to the peculiar characteristics of the construction industry and its changing operating environment will be able to take advantage of the favorable conditions and to avoid the pitfalls. Several factors are particularly noteworthy because of their significant impacts on the quality, cost and time of construction.

New Technologies

In recent years, technological innovation in design, materials and construction methods have resulted in significant changes in construction costs. Computer-aids have improved capabilities for generating quality designs as well as reducing the time required to produce alternative designs. New materials not only have enhanced the quality of construction but also have shortened the time for shop fabrication and field erection. Construction methods have gone through various stages of mechanization and automation, including the latest development of construction robotics.

The most dramatic new technology applied to construction has been the Internet and its private, corporate Intranet versions. The Internet is widely used as a means to foster collaboration among professionals on a project, to communicate for bids and results, and to procure necessary goods and services. Real time video from specific construction sites is widely used to illustrate construction progress to interested parties. The result has been more effective collaboration, communication and procurement.

The effects of many new technologies on construction costs have been mixed because of the high development costs for new technologies. However, it is unmistakable that design professionals and construction contractors who have not adapted to changing technologies have been forced out of the mainstream of design and construction activities. Ultimately, construction quality and cost can be improved .with the adoption of new technologies which are proved to be efficient from both the viewpoints of performance and economy.

Labor Productivity

The term *productivity* is generally defined as a ratio of the production output volume to the input volume of resources. Since both output and input can be quantified in a number of ways, there is no single measure of productivity that is universally applicable, particularly in the construction industry where the products are often unique and there is no standard for specifying the levels for aggregation of data. However, since labor constitutes a large part of the cost of construction, labor productivity in terms of output volume (constant dollar value or functional units) per person-hour is a useful measure. Labor productivity measured in this way does not necessarily indicate the efficiency of labor alone but rather measures the combined effects of labor, equipment and other factors contributing to the output.

While aggregate construction industry productivity is important as a measure of national economy, owners are more concerned about the labor productivity of basic units of work produced by various crafts on site. Thus, an owner can compare the labor performance at different geographic locations, under different working conditions, and for different types and sizes of projects.

Construction costs usually run parallel to material prices and labor wages. Actually, over the years, labor productivity has increased in some traditional types of construction and thus provides a leveling or compensating effect when hourly rates for labor increase faster than other costs in construction. However, labor productivity has been stagnant or even declined in unconventional or large scale projects.

Task III: Choose the sentences true to the text.

1. Construction means all types of activities associated with the erection and repair of immobile facilities.
2. Contract construction consists of a few firms that perform construction work for others.
3. Construction is a minor factor in the Gross National Product.
4. The total expenditure on rehabilitation and maintenance may increase.
5. Owners won't be able to take advantage of the favorable conditions.
6. Technological innovation affected greatly the construction costs.

Task IV: Choose the most suitable word or expression.

1. The ... of the construction industry lies in the function of its products.
a) participants b) welfare c) importance
2. Contract construction is ... to be approximately 85% of all construction activities.
a) providing b) estimated c) employed
3. The importance of construction has been ... in recent years.
a) exceeded b) declining c) expressed
4. Several factors ... the quality, cost and time of construction.
a) influence b) changes c) will cost
5. Computer aids have ... capabilities for generating quality designs.
a) improved b) reducing c) required
6. The Internet is widely used to ... collaboration among professionals.
a) mix b) apply c) foster

Task V: Complete the sentences according to the text.

1. The construction industry plays ...
2. New materials have shortened ...
3. The internet is widely used to procure ...
4. The result has been more effective ...
5. Construction quality and cost ...
6. There is no single measure ...

Task VI: Answer the following questions. Use the information from the text.

1. How much have construction costs changed in recent years?
2. How did new materials influence the quality of construction?
3. What is the Internet used for?
4. Why is it necessary to adopt new technologies?
5. What does the term productivity mean?
6. What are the owners concerned about?

Task VII: Discuss the following points of the text with your groupmate.

1. The construction industry plays a central role in national welfare.
2. Construction refers to all types of activities on erection and repair of immobile facilities.
3. Technological innovations have resulted in significant changes in construction costs.
4. The Internet is widely used in construction industry.
5. Construction quality can be improved with the adoption of new technologies.
6. Labor productivity measures the combined effects of labor, equipment and other factors.

Unit 6

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Visible, environment, to heighten, to drill, offshore, rig, to propose, to mount, entire, failure, vitality, a joint venture, to assume, a debt, lean, a fee, to deepen, reduction, waste, to empower, intent, to spread.

Task II: Read the text.

International Competition

A final trend which deserves note is the increasing level of international competition in the construction industry. Owners are likely to find non-traditional firms bidding for construction work, particularly on large projects. Separate bids from numerous European, North American, and Asian construction firms are not unusual. In the United States, overseas firms are becoming increasingly visible and important. In this environment of heightened competition, good project management and improved productivity are more and more important. A bidding competition for a major new offshore drilling platform illustrates the competitive environment in construction.

The winning bidder arranged overseas fabrication of the rig, kept overhead costs low, and proposed a novel assembly procedure by which construction equipment was mounted on completed sections of the platform in order to speed the completion of the entire structure. The result was lower costs than those estimated and bid by traditional firms.

Of course, U.S. firms including A/E firms, contractors and construction managers are also competing in foreign countries. Their success or failure in the international arena may also affect their capacities and vitality to provide services in the domestic U.S. market.

Contractor Financed Projects

Increasingly, some owners look to contractors or joint ventures as a resource to design, to build and to finance a constructed facility. For example, a utility company may seek a consortium consisting of a design/construct firm and a financial investment firm to assume total liability during construction and thereby eliminate the risks of cost escalation to ratepayers, stockholders and the management. On the other hand, a local sanitation district may seek such a consortium to provide private ownership for a proposed new sewage treatment plant. In the former case, the owner may take over the completed facility and service the debt on construction through long-term financing arrangements; in the latter case, the private owner may operate the completed facility and recover its investment through user fees. The activities of joint ventures among design, construction and investment firms are sometimes referred to as *financial engineering*.

This type of joint venture has become more important in the international construction market where aggressive contractors often win contracts by offering a more attractive financing package rather than superior technology. With a deepening shadow of international debts in recent years, many developing countries are not in a position to undertake any new project without contractor-backed financing. Thus, the contractors or joint ventures in overseas projects are forced into very risky positions if they intend to stay in the competition.

Lean Construction

"Lean manufacturing" had a revolutionary effect on many industries, especially automotive assembly companies. Characteristics of this approach include:

- Improvement in quality and reduction of waste everywhere. Rather than increasing costs, reducing defects and waste proved to improve quality and reduce costs.
- Empowering workers to be responsible for satisfying customer needs. In construction, for example, craftsman should make sure their work satisfied the design intent.
- Continuous improvement of processes involving the entire workforce.

Lean construction is intended to spread these practices within the construction industry. Of course, well managed construction projects already have many aspects of lean construction. For example, just-in-time delivery of materials is commonplace to avoid the waste of large inventory stockpiles. Green building projects attempt to re-use (recycle) all construction wastes. But the systematic attention to continuous improvement and zero accidents and defects is new.

Task III: Choose the sentences true to the text.

1. The level of international competition in the construction industry is increasing.
2. Owners aren't going to find non-traditional firms bidding for construction work.
3. Separate bids from European, North American and Asian construction firms are unusual.
4. The winning bidder proposed a novel assembly procedure.
5. US firms aren't competing in foreign countries.
6. Only the firms' success may affect their capacities.

Task IV: Choose the most suitable word or expression.

1. A bidding competition illustrates the ... environment in construction.
a) increasing b) competitive c) visible
2. Construction ... was mounted on completed sections of the platform.
a) bids b) offshore c) equipment
3. The result was lower costs than those ... and bid by traditional firms.
a) estimated b) including c) to compete
4. A utility company may ... a consortium.
a) provide b) be affected c) seek
5. The private owner may operate the ... facility.
a) escalation b) completed c) entire
6. The contractors or joint ventures in overseas projects are ... into very risky positions.
a) forced b) bidding c) to improve

Task V: Complete the sentences according to the text.

1. The owner may service the debt on construction through ...
2. The activities of joint ventures among design, ...
3. Aggressive contractors often win contracts by ...
4. Many developing countries are not in a position ...
5. Reducing defects and waste proved ...
6. Craftsmen should make sure ...

Task VI: Answer the following questions. Use the information from the text.

1. What are owners likely to find?
2. Where are overseas firms becoming increasingly visible and important?
3. What did the winning bidder propose?
4. Where are US firms competing?
5. What may affect the firms' capacities?
6. What consortium may a utility company seek?

Task VII: Discuss the following points of the text with your groupmate.

1. The international competition in the construction industry is increasing.
2. US firms are competing in foreign countries.
3. A utility company may seek a consortium.
4. Many developing countries are not in a position to undertake any new project.
5. "Lean manufacturing" had a revolutionary effect on many industries.
6. The attention to improvement and zero accidents and defects is new.

Unit 7

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Influential, outcome, to reside, evaluation, familiarity, delay, peculiar, frequency, challenge, to ally, to advance, to tackle, to judge, pervasive, to anticipate, to overcome, to reinforce, to acquire, rote, narrow, to relegate, to assume, regardless, to handle, intricate, ultimate, a hallmark.

Task II: Read the text.

The Role of Project Managers

In the project life cycle, the most influential factors affecting the outcome of the project often reside at the early stages. At this point, decisions should be based on competent economic evaluation with due consideration for adequate financing, the prevalent social and regulatory environment, and technological considerations. Architects and engineers might specialize in planning, in construction field management, or in operation, but as project managers, they must have some familiarity with all such aspects in order to understand properly their role and be able to make competent decisions.

Since the 1970's, many large-scale projects have run into serious problems of management, such as cost overruns and long schedule delays. Actually, the management of *megaprojects* or *superprojects* is not a practice peculiar to our time. Witness the construction of transcontinental railroads in the Civil War era and the construction of the Panama Canal at the turn of this century. Although the megaprojects of this generation may appear in greater frequency and present a new set of challenge, the problems are organizational rather than technical.

It is customary to think of engineering as a part of a trilogy, pure science, applied science and engineering. It needs emphasize that this trilogy is only one of a triad of trilogies into which engineering fits. This first is pure science, applied science and engineering; the second is economic theory, finance and engineering; and the third is social relations, industrial relations and engineering. Many engineering problems are as closely allied to social problems as they are to pure science.

As engineers advance professionally, they often spend as much or more time on planning, management and other economic or social problems as on the traditional engineering design and analysis problems which form the core of most educational programs. It is upon the ability of engineers to tackle all such problems that their performance will ultimately be judged.

The greatest stumbling block to effective management in construction is the inertia and historic divisions among planners, designers and constructors. While technical competence in design and innovation remains the foundation of engineering practice, the social, economic and organizational factors that are pervasive in influencing the success and failure of construction projects must also be dealt with effectively by design and construction organizations. Of course, engineers are not expected to know every detail of management techniques, but they must be knowledgeable enough to anticipate the problems of management so that they can work harmoniously with professionals in related fields to overcome the inertia and historic divisions.

Paradoxically, engineers who are creative in engineering design are often innovative in planning and management since both types of activities involve problem solving. In fact, they can reinforce each other if both are included in the education process, provided that creativity and innovation instead of routine practice are emphasized. A project manager who is well educated in the *fundamental principles* of engineering design and management can usefully apply such principles once he or she has acquired basic understanding of a new *application area.* A project manager who has been trained by rote learning for a specific type of project may merely gain one year of experience repeated twenty times even if he or she has been in the field for twenty years. A broadly educated project manager can reasonably hope to become a leader in the profession; a narrowly trained project manager is often relegated to the role of his or her first job level permanently.

The owners have much at stake in selecting a competent project manager and in providing her or him with the authority to assume responsibility at various stages of the project regardless of the types of contractual agreements for implementing the project. Of course, the project manager must also possess the leadership quality and the ability to handle effectively intricate interpersonal relationships within an organization. The ultimate test of the education and experience of a project manager for construction lies in her or his ability to apply fundamental principles to solving problems in the new and unfamiliar situations which have become the hallmarks of the changing environment in the construction industry.

Task III: Choose the sentences true to the text.

1. Decisions should be based on competent economic evaluation.
2. Many large-scale projects have overcome serious problems of management.
3. Many engineering problems aren't allied to social problems.
4. Engineers are not expected to know every detail of management techniques.
5. A narrowly educated project manager can hope to become a leader in the profession.
6. The project manager must possess the leadership quality.

Task IV: Choose the most suitable word or expression.

1. Project managers should make competent ...

a) outcome b) to evaluate c) decisions

2. Many large-scale projects have... into cost overruns.
a) schedule b) run c) decisions
3. The greatest ... block to effective management in construction is the inertia.
a) applied b) ultimate c) stumbling
4. Engineers must ... the problems of management.
a) anticipate b) remain c) be tackled
5. Both engineering design and management ... problem solving.
a) will overcome b) involve c) are applied
6. The project manager must also ... the leadership quality.
a) ultimate b) be handled c) possess

Task V: Complete the sentences according to the text.

1. The management of megaprojects or superprojects ...
2. This first is pure ...
3. The social, economic and organizational factors must also ...
4. Engineers should work harmoniously with professionals ...
5. Engineers are often innovative ...
6. A broadly educated project manger ...

Task VI: Answer the following questions. Use the information from the text.

1. Where do the most influencial factors reside in the project life cycle?
2. What problems do megaprojects cause?
3. What are engineering problems allied to?
4. What do engineers spend much time on?
5. How much should engineers know about management?
6. How do owners select a competent project manager?

Task VII: Discuss the following points of the text with your groupmate.

1. Architects and engineers should make competent decisions.
2. Many large projects have run into serious problems of management.
3. Engineering is a part of a trilogy.
4. Technical competence in design and innovation remains the foundation of engineering practice.
5. Engineers are often innovative in planning and management.
6. The owners have much at stake in selecting a competent project manager.

Unit 8

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Expense, to purchase, avoidable, to tie, excess, inventory, to deteriorate, storage, to steal, flow, tight, sufficient, to obtain, a request, bulk consistency, realm, to merge, to subtract, to alert, an invoice, to overlap, bulk, to haul, concrete, a pipe, a valve, to process, to stockpile, a beam, to weld, to attach, precise, dimension.

<u>Task II:</u> Read the text.

Materials Management

Materials management is an important element in project planning and control. Materials represent a major expense in construction, so minimizing *procurement or purchase* costs presents important opportunities for reducing costs. Poor materials management can also result in large and avoidable costs during construction. First if materials are purchased early, capital may be tied up and interest charges incurred on the excess *inventory* of materials. Even worse, materials may deteriorate during storage or be stolen unless special care is taken. For example, electrical equipment often must be stored in waterproof locations. Second, delays and extra expenses may be incurred if materials required for particular activities are not available. Accordingly, insuring a timely flow of material is an important concern of project managers.

Materials management is not just a concern during the monitoring stage in which construction is taking place. Decisions about material procurement may also be required during the initial planning and scheduling stages. For example, activities can be inserted in the project schedule to represent purchasing of major items such as elevators for buildings. The availability of materials may greatly influence the schedule in projects with *a fast track* or very tight time schedule: sufficient time for obtaining the necessary materials must be allowed. In some case, more expensive suppliers or shippers may be employed to save time.

Materials management is also a problem at the organization level if central purchasing and inventory control is used for standard items. In this case, the various projects undertaken by the organization would present requests to the central purchasing group. In turn, this group would maintain inventories of standard items to reduce the delay in providing material or to obtain lower costs due to bulk purchasing. This organizational materials management problem is analogous to inventory control in any organization facing continuing demand for particular items.

Materials ordering problems lend themselves particularly well to computer based systems to insure the consistency and completeness of the purchasing process. In the manufacturing realm, the use of automated *materials requirements planning* systems is common. In these systems, the master production schedule, inventory records and product component lists are merged to determine what items must be ordered, when they should be ordered, and how much of each item should be ordered in each time period. The heart of these calculations is simple arithmetic: the projected demand for each material item in each period is subtracted from the available inventory. When the inventory becomes too low, a new order is recommended. For items that are nonstandard or not kept in inventory, the calculation is even simpler since no inventory must be considered. With a materials requirement system, much of the detailed record keeping is automated and project managers are alerted to purchasing requirements.

Material Procurement and Delivery

The main sources of information for feedback and control of material procurement are requisitions, bids and quotations, purchase orders and subcontracts, shipping and receiving documents, and invoices. For projects involving the large scale use of critical resources, the owner may initiate the procurement procedure even before the selection of a constructor in order to avoid shortages and delays. Under ordinary circumstances, the constructor will handle the procurement to shop for materials with the best price/performance characteristics specified by the designer. Some overlapping and rehandling in the procurement process is unavoidable, but it should be minimized to insure timely delivery of the materials in good condition.

The materials for delivery to and from a construction site may be broadly classified as : (1) bulk materials, (2) standard off-the-shelf materials, and (3) fabricated members or units. The process of delivery, including transportation, field storage and installation will be different for these classes of materials. The equipment needed to handle and haul these classes of materials will also be different.

Bulk materials refer to materials in their natural or semi-processed state, such as earthwork to be excavated, wet concrete mix, etc. which are usually encountered in large quantities in construction. Some bulk materials such as earthwork or gravels may be measured in bank volume. Obviously, the quantities of materials for delivery may be substantially different when expressed in different measures of volume, depending on the characteristics of such materials.

Standard piping and valves are typical examples of standard off-the-shelf materials which are used extensively in the chemical processing industry. Since standard off-the-shelf materials can easily be stockpiled, the delivery process is relatively simple.

Fabricated members such as steel beams and columns for buildings are pre-processed in a shop to simplify the field erection procedures. Welded or bolted connections are attached partially to the members which are cut to precise dimensions for adequate fit Similarly, steel tanks and pressure vessels are often partly or fully fabricated before shipping to the field. In general, if the work can be done in the shop where working conditions can better be controlled, it is advisable to do so, provided that the fabricated members or units can be shipped to the construction site in a satisfactory manner at a reasonable cost.

Task III: Choose the sentences true to the text.

1. Poor materials management can lead to large costs.
2. If materials are purchased late, capital may be tied up.
3. Insuring a timely flow of materials doesn't concern project managers.
4. Decisions about material procurement aren't required during the initial planning.
5. Cheaper suppliers or shippers may be employed to save time.
6. The use of automated materials requirements planning systems is common.

Task IV: Choose the most suitable word or expression.

1. Materials represent a major ... in construction.
a) procurement b) expense c) reducing
2. Materials may ... during storage.
a) deteriorate b) steal c) be excessed
3. Insuring a timely flow of material is an important ... of project managers.
a) requirement b) inventory c) concern
1. Decisions about material procurement may also be ...
a) required b) scheduled c) inserting
2. More expensive suppliers or shippers may be ... to save time.
a) obtaining b) employed c) influenced
3. The materials for delivery to and from a ... site may be broadly classified.
a) shipping b) involved c) construction

Task V: Complete the sentences according to the text.

1. Poor materials management ...
2. Electrical equipment often must be ...
3. Decisions about material procurement ...
4. The various projects would present ...
5. The use of automated ...
6. Bulk materials refer to ...

Task VI: Answer the following questions. Use the information from the text.

1. What presents important opportunities for reducing costs?
2. What may interest charges be incurred on?
3. How much may the availability of materials influence the schedule in projects?
4. When is the calculation quite simple?
5. In what case may the owner initiate the procurement procedure?
6. When is the delivery process relatively simple?

Task VII: Discuss the following points of the text with your groupmate.

1. Materials management is an important element in project planning and control.
2. Decisions about material procurement may also be required.
3. The use of automated materials requirements planning systems is common.
4. The owner may initiate the procurement procedure.
5. Bulk materials refer to materials in their natural or semi-processed state.
6. Fabricated members are pre-processed in a shop.

Unit 9

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Description, to identify, implementation, to envision, precedence, execution, anticipation, inherent, to proceed, simultaneous, desirable, a viewpoint, sequence, overall, an impact, to assume, to devise, elaborate, accordingly, to resolve, to foresee, consequent.

Task II: Read the text.

The Design and Construction Process

Design and Construction as an Integrated System

In the planning of facilities, it is important to recognize the close relationship between design and construction. These processes can best be viewed as an integrated system. Broadly speaking, design is a process of creating the description of a new facility, usually represented by detailed plans and specifications; construction planning is a process of identifying activities and resources required to make the design a physical reality. Hence, construction is the implementation of a design envisioned by architects and engineers. In both design and construction, numerous operational tasks must be performed with a variety of precedence and other relationships among the different tasks.

Several characteristics are unique to the planning of constructed facilities and should be kept in mind even at the very early stage of the project life cycle. These include the following:

- Nearly every facility is custom designed and constructed, and often requires a long time to complete.
- Both the design and construction of a facility must satisfy the conditions peculiar to a specific site.
- Because each project is site specific, its execution is influenced by natural, social and other locational conditions such as weather, labor supply, local building codes, etc.
- Since the service life of a facility is long, the anticipation of future requirements is inherently difficult.
- Because of technological complexity and market demands, changes of design plans during construction are not uncommon.

In an integrated system, the planning for both design and construction can proceed almost simultaneously, examining various alternatives which are desirable from both viewpoints and thus eliminating the necessity of extensive revisions under the guise of value engineering. Furthermore, the review of designs with regard to their constructability can be carried out as the project progresses from planning to design. For example, if the sequence of assembly of a structure and the critical loadings on the partially assembled structure during construction are carefully considered as a part of the overall structural design, the impacts of the design on construction false work and on assembly details can be anticipated. However, if the design professionals are expected to assume such responsibilities, they must be rewarded for sharing the risks as well as for undertaking these additional tasks. Similarly, when construction contractors are expected to take over the responsibilities of engineers, such as devising a very elaborate scheme to erect an unconventional structure, they too must be rewarded accordingly. As long as the owner does not assume the responsibility for resolving this risk-reward dilemma, the concept of a truly integrated system for design and construction cannot be realized.

It is interesting to note that European owners are generally more open to new technologies and to share risks with designers and contractors. In particular, they are more willing to accept responsibilities for the unforeseen subsurface conditions in geotechnical engineering. Consequently, the designers and contractors are also more willing to introduce new techniques in order to reduce the time and cost of construction. In European practice, owners typically present contractors with a conceptual design, and contractors prepare detailed designs, which are checked by the owner's engineers. Those detailed designs may be alternate designs, and specialty contractors may also prepare detailed alternate designs.

Task III: Choose the sentences true to the text.

1. Design is a process of creating the description of a new facility.
2. Construction is a process of designing.
3. Several characteristics are common to the planning of constructed facilities.
4. Only the construction of a facility must satisfy the conditions peculiar to a specific site.
5. The planning for design and construction proceed almost at the same time.
6. European owners are more open to new technologies.

Task IV: Choose the most suitable word or expression.

1. In both design and construction, ... operational tasks must be performed.
a) identifying b) envisioned c) numerous
2. The anticipation of future ... is inherently difficult.
a) conditions b) facility c) requirement
3. The design professionals must be ... for sharing the risks.
a) undertook b) rewarded c) considering
4. European owners are more willing ... responsibilities.
a) to accept b) subsurface c) elaborate
5. The designers and contractors are more willing ... new techniques.
a) to share b) impacts c) to introduce
6. Specialty contractors may also ... detailed alternate designs.
a) own b) prepare c) reducing

Task V: Complete the sentences according to the text.

1. These processes can ...
2. Construction planning is a process ...
3. Several characteristics should ...
4. Changes of design plans ...
5. The impacts of the design ...
6. Owners typically present ...

Task VI: Answer the following questions use the information from the text.

1. Why is there a close relationship between design and construction?
2. What does construction mean?
3. What tasks must be performed in design and construction?
4. How can design and construction proceed?
5. What is the attitude of European owners to new technologies?
6. What may specialty contractors prepare?

Task VII: Discuss the following points of the text with your groupmate.

1. It is important to recognize the close relationship between design and construction.
2. Construction planning is a process of identifying activities.
3. Several characteristics are unique to the planning of constructed facilities.
4. The planning for design and construction can proceed almost simultaneously.
5. The design professionals must be rewarded for sharing the risks.
6. European owners are more open to new technologies.

Unit 10

Task I: Read the following words from the text and find their Russian equivalents in the dictionary.

Contribution, to embody, appreciation, complexity, preliminary, tentative, screening, viability, to pursue, ambiguity, judicious, appropriate, hostile, environment, severe, to restrict, incentive, expenditure, to sequence, extent, to accomplish, to treat.

Task II: Read the text.

Innovation and Technological Feasibility

The planning for a construction project begins with the generation of concepts for a facility which will meet market demands and owner needs. Innovative concepts in design are highly valued not for their own sake but for their contributions to reducing costs and to the improvement of aesthetics, comfort or convenience as embodied in a well-designed facility. However, the constructor as well as the design professionals must have an appreciation and full understanding of the technological complexities often associated with innovative designs in order to provide a safe and sound facility. Since these concepts are often preliminary or tentative, screening studies are carried out to determine the overall technological viability and economic attractiveness without pursuing these concepts in great detail. Because of the ambiguity of the objectives and the uncertainty of external events, screening studies call for uninhibited innovation in creating new concepts and judicious judgment in selecting the appropriate ones for further consideration.

Innovative design concepts must be tested for technological feasibility. Three levels of technology are of special concern: technological requirements for operation or production, design resources and construction technology. The first refers to the new technologies that may be introduced in a facility which is used for a certain type of production such as chemical processing or nuclear power generation. The second refers to the design capabilities that are available to the designers, such as new computational methods or new materials. The third refers to new technologies which can be adopted to construct the facility, such as new equipment or new construction methods.

A new facility may involve complex new technology for operation in hostile environments such as severe climate or restricted accessibility. Large projects with unprecedented demands for resources such as labor supply, material and infrastructure may also call for careful technological feasibility studies.

An example of innovative design for operation and production is the use of entropy concepts for the design of integrated chemical processes. Simple calculations can be used to indicate the minimum energy requirements and the least number of heat exchange units to achieve desired objectives. The result is a new incentive and criterion for designers to achieve more effective designs. Numerous applications of the new methodology has shown its efficacy in reducing both energy costs and construction expenditures. This is a case in which innovative design is not a matter of trading-off operating and capital costs, but better designs can simultaneously achieve improvements in both objectives.

The choice of construction technology and method involves both *strategic* and *tactical* decisions about appropriate technologies and the best sequencing of operations. For example, the extent to which prefabricated facility components will be used represents a *strategic* construction decision. In turn, prefabrication of components might be accomplished off-site in existing manufacturing facilities or a temporary, on-site fabrication plant might be used. Another example of a strategic decision is whether to install mechanical equipment in place early in the construction process or at an intermediate stage. Strategic decisions of this sort should be integrated with the process of facility design in many cases. At the tactical level, detailed decisions about how to accomplish particular tasks are required, and such decisions can often be made in the field.

Construction planning should be a major concern in the development of facility designs, in the preparation of cost estimates, and in forming bids by contractors. Unfortunately, planning for the construction of a facility is often treated as an after thought by design professionals. This contrasts with manufacturing practices in which the *assembly* of devices is a major concern in design. Design to insure ease of assembly or construction should be a major concern of engineers and architects.

Task III: Choose the sentences true to the text.

1. Innovative concepts in design aren't valued.
2. The design professionals must have some understanding of the technological complexities.
3. There are three levels of technology that are of special concern.
4. Large projects may demand careful technological feasibility studies.
5. Simple calculations aren't enough to indicate the minimum energy requirements.
6. Detailed decisions about how to accomplish particular tasks are required.

Task IV: Choose the most suitable word or expression.

1. Screening studies are carried out ... the overall technological viability .
a) to determine b) to provide c) reducing
2. Innovative design concepts must be tested for technological ...
a) demands b) feasibility c) appreciating
3. Numerous ... of the new methodology have shown its efficacy.
a) applications b) capability c) hostile
4. Prefabrication of components might ... off-site.
a) achieve b) appropriate c) be accomplished
5. Strategic ... should be integrated with the process of facility design.
a) incentive b) exchanging c) decisions
6. Design to insure ease of ... or construction should be a major concern.
a) devices b) assembly c) existing

Task V: Complete the sentences according to the text.

1. Innovative concepts in design ...
2. Screening studies are carried out ...
3. Three levels of technology ...
4. The second level refers to ...
5. Large projects may also ...
6. Innovative design is not a matter ...

Task VI: Answer the following questions. Use the information from the text.

1. What does the planning for a construction project begin with?
2. How much are innovative concepts valued?
3. Why must the constructor have full understanding of the technological complexities?
4. What are the most important levels of technology?
5. What does the third level refer to?
6. What may a new facility involve?

Task VII: Discuss the following points of the text with your groupmate.

1. The planning for a construction project begins with the generation of concepts.
2. Screening studies are carried out to determine the overall technological viability.
3. Innovative design concepts must be tested for technological feasibility.
4. A new facility may involve complex new technology.
5. The choice of construction technology and method involves both strategic and tactical decisions.
6. Construction planning should be a major concern in the development of facility designs.

Supplementary Reading

Text I

Innovation and Economic Feasibility

Innovation is often regarded as the engine which can introduce construction economies and advance labor productivity. This is obviously true for certain types of innovations in industrial production technologies, design capabilities, and construction equipment and methods. However, there are also limitations due to the economic infeasibility of such innovations, particularly in the segments of construction industry which are more fragmented and permit ease of entry.

Market demand and firm size play an important role in this regard. If a builder is to construct a larger number of similar units of buildings, the cost per unit may be reduced. This relationship between the market demand and the total cost of production may be illustrated schematically as in Figure 3-2. An initial threshold or fixed cost F is incurred to allow any production. Beyond this threshold cost, total cost increases faster than the units of output but at a decreasing rate. At each point on this total cost curve, the average cost is represented by the slope of a line from the origin to the point on the curve. At a point H, the average cost per unit is at a minimum. Beyond H to the right, the total cost again increases faster than the units of output and at an increasing rate. When the rate of change of the average cost slope is decreasing or constant as between 0 and H on the curve, the range between 0 and H is said to be *increasing return to scale;* when the rate of change of the average cost slope is increasing as beyond H to the right, the region is said to be *decreasing return to scale*. Thus, if fewer than h units are constructed, the unit price will be higher than that of exactly h units. On the other hand, the unit price will increase again if more than h units are constructed.

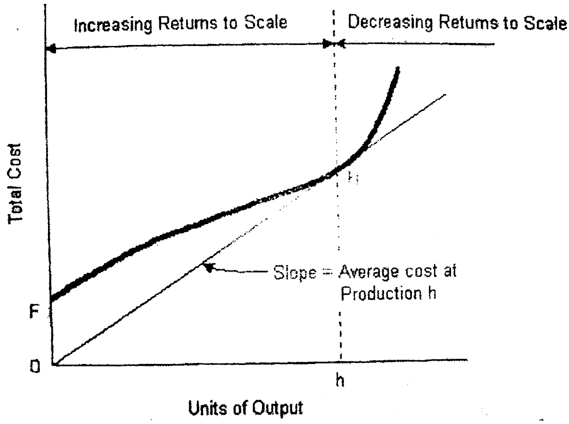


Figure 3-2: Market Demand and Total Cost Relationship

Nowhere is the effect of market demand and total cost more evident than in residential housing. The housing segment in the last few decades accepted many innovative technical improvements in building materials which were promoted by material suppliers. Since material suppliers provide products to a large number of homebuilders and others, they are in a better position to exploit production economies of scale and to support new product development. However, homebuilders themselves have not been as successful in making the most fundamental form of innovation which encompasses changes in the technological process of homebuilding by shifting the mixture of labor and material inputs, such as substituting large scale off-site prefabrication for on-site assembly.

There are several major barriers to innovation in the technological process of homebuilding, including demand instability, industrial fragmentation, and building codes. Since market demand for new homes follows demographic trends and other socio-economic conditions, the variation in home building has been anything but regular. The profitability of the homebuilding industry has closely matched aggregate output levels. Since entry and exit from the industry are relatively easy, it is not uncommon during periods of slack demand to find builders leaving the market or suspending their operations until better times. The inconsistent levels of retained earnings over a period of years, even among the more established builders, are likely to discourage support for research and development efforts which are required to nurture innovation. Furthermore, because the homebuilding industry is fragmented with a vast majority of homebuilders active only in local regions, the typical homebuilder finds it excessively expensive to experiment with new designs. The potential costs of a failure or even a moderately successful innovation would outweigh the expected benefits of all but the most successful innovations. Variation in local building codes has also caused inefficiencies although repeated attempts have been made to standardize building codes.

Text II

Design Methodology

While the conceptual design process may be formal or informal, it can be characterized by a series of actions: formulation, analysis, search, decision, specification, and modification. However, at the early stage in the development of a new project, these actions are highly interactive as illustrated in Figure 3-4. Many iterations of redesign are expected to refine the functional requirements, design concepts and financial constraints, even though the analytic tools applied to the solution of the problem at this stage may be very crude.

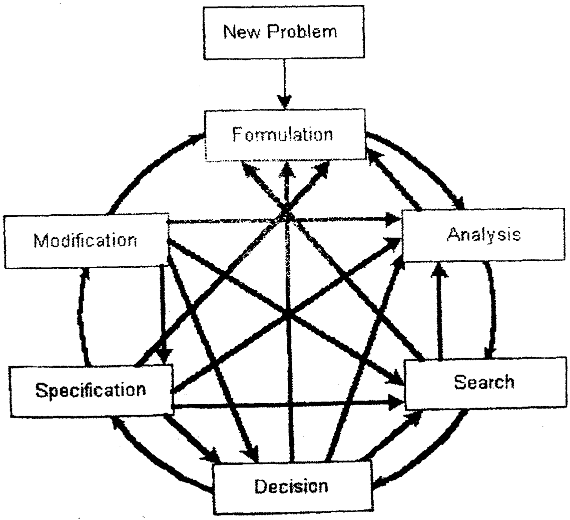
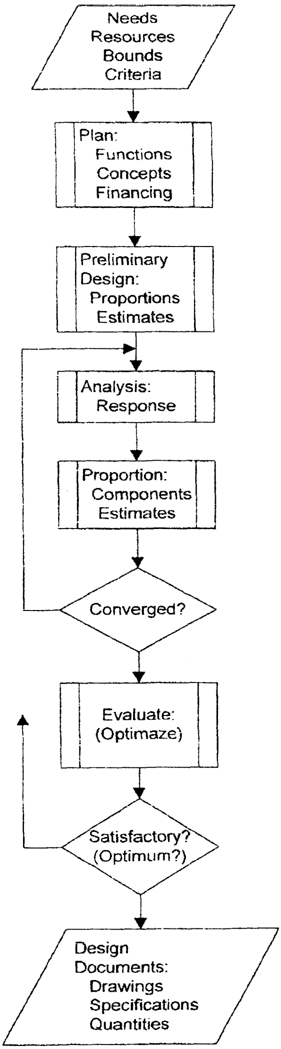


Figure 3-4: Conceptual Design Process

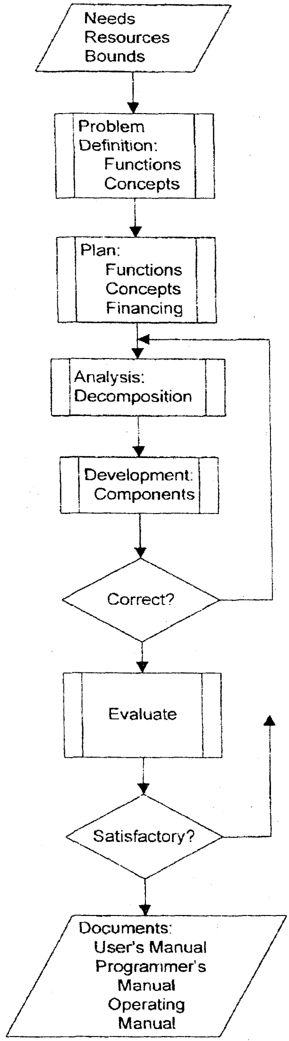
The series of actions taken in the conceptual design process may be described as follows:

- Formulation refers to the definition or description of a design problem in broad terms through the synthesis of ideas describing alternative facilities.
- Analysis refines the problem definition or description by separating important from peripheral information and by pulling together the essential detail. Interpretation and prediction are usually required as part of the analysis.
- Search involves gathering a set of potential solutions for performing the specified functions and satisfying the user requirements.
- Decision means that each of the potential solutions is evaluated and compared to the alternatives until the best solution is obtained.
- Specification is to describe the chosen solution in a form which contains enough detail for implementation.
- Modification refers to the change in the solution or re-design if the solution is found to be wanting or if new information is discovered in the process of design.

As the project moves from conceptual planning to detailed design, the design process becomes more formal. In general, the actions of formulation, analysis, search, decision, specification and modification still hold, but they represent specific steps with less random interactions in detailed design. The design methodology thus formalized can be applied to a variety of design problems. For example, the analogy of the schematic diagrams of the structural design process and of the computer program development process is shown in Figure 3-5.



Schematic diamgram of structural design process.



Schematic diamgram of computer program development process.

Figure 3-5: An Analogy Between Structural Design and Computer Program Development Process

The basic approach to design relies on decomposition and integration. Since design problems are large and complex, they have to be decomposed to yield subproblems that are small enough to solve. There are numerous alternative ways to decompose design problems, such as decomposition by functions of the facility, by spatial locations of its parts, or by links of various functions or parts. Solutions to subproblems must be integrated into an overall solution. The integration often creates conceptual conflicts which must be identified and corrected. A hierarchical structure with an appropriate number of levels may be used for the decomposition of a design problem to subproblems. For example, in the structural design of a multistory building, the building may be decomposed into floors, and each floor may in turn be decomposed into separate areas. Thus, a hierarchy representing the levels of building, floor and area is formed.

Different design styles may be used. The adoption of a particular style often depends on factors such as time pressure or available design tools, as well as the nature of the design problem. Examples of different styles are:

• **Top-down design.** Begin with a behavior description of the facility and work towards descriptions of its components and their interconnections.

• **Bottom-up design.** Begin with a set of components, and see if they can be arranged to meet the behavior description of the facility.

The design of a new facility often begins with the search of the files for a design that comes as close as possible to the one needed. The design process is guided by accumulated experience and intuition in the form of heuristic rules to find acceptable solutions. As more experience is gained for this particular type of facility, it often becomes evident that parts of the design problem are amenable to rigorous definition and algorithmic solution. Even formal optimization methods may be applied to some parts of the problem.

Text III

Physical Structures

The structural design of complex engineering systems generally involves both synthesis and analysis. Synthesis is an inductive process while analysis is a deductive process. The activities in synthesis are often described as an art rather than a science, and are regarded more akin to creativity than to knowledge. The conception of a new structural system is by and large a matter of subjective decision since there is no established procedure for generating innovative and highly successful alternatives. The initial selection of a workable system from numerous possible alternatives relies heavily on the judicious judgment of the designer. Once a structural system is selected, it must be subjected to vigorous analysis to insure that it can sustain the demands in its environment. In addition, compatibility of the structural system with mechanical equipment and piping must be assured.

For traditional types of structures such as office buildings, there are standard systems derived from the past experience of many designers. However, in many situations, special systems must be developed to meet the specified requirements. The choice of materials for a structure depends not only on the suitability of materials and their influence on the form of the structure. For example, in the design of an airplane hangar, a steel skeleton frame may be selected because a similar frame in reinforced concrete will limit the span of the structure owing to its unfavorable ratio or resistance to weight. However, if a thin-shelled roof is adopted, reinforced concrete may prove to be more suitable than steel. Thus, the interplay of the structural forms and materials affects the selection of a structural system, which in turn may influence the method of construction including the use of false work.

Example 3-8: ***Steel frame supporting a turbo-blower***

The design of a structural frame supporting a turbo-blower supplying pressurized air to a blast furnace in a steel mill can be used to illustrate the structural design process. As shown in Figure 3-8, the turbo-blower consists of a turbine and a blower linked to an air inlet stack. Since the vibration of the turbo-blower is a major concern to its operation, a preliminary investigation calls for a supporting frame which is separated from the structural frame of the building. An analysis of the vibration characteristics of the turbo-blower indicates that the lowest mode of vibration consists of independent vibration of the turbine shaft and the blower shaft, with higher modes for the coupled turbo-blower system when both shafts vibrate either in-phase or out-of-phase. Consequently, a steel frame with separate units for the blower side and the turbine side is selected. The columns of the steel frame are mounted on pile foundation and all joints of the steel frame are welded to reduce the vibration levels.

Since the structural steel frame also supports a condenser, an air inlet and exhaust, and a steam inlet and exhaust in addition to the turbo-blower, a static analysis is made to size its members to support all applied loads. Then, a dynamic analysis is conducted to determine the vibration characteristics of the system incorporating the structural steel frame and the turbo-blower. When the limiting conditions for static loads and natural frequencies of vibration are met, the design is accepted as satisfactory.

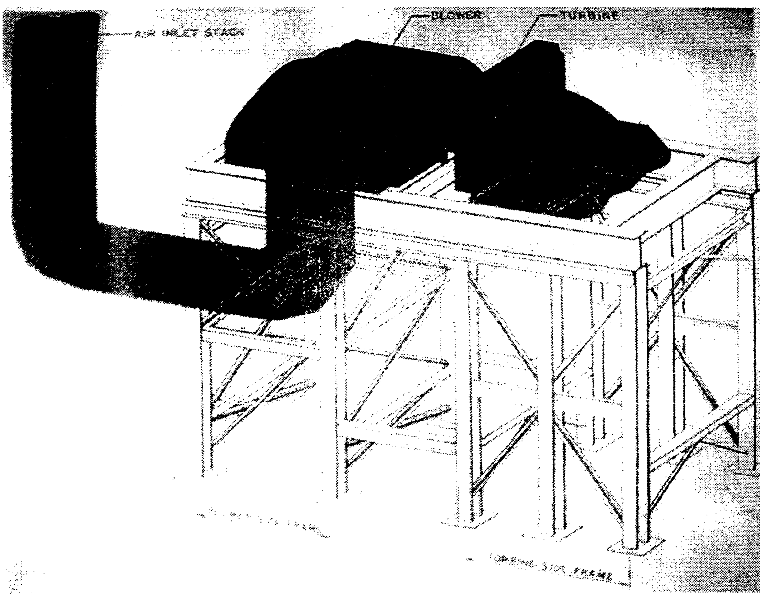


Figure 3-8: Steel Frame Supporting a Turbo-Blower

Example 3-9: ***Multiple hierarchy descriptions of projects***

In the previous section, a hierarchy of functional spaces was suggested for describing a facility. This description is appropriate for functional design of spaces and processes within a building, but may be inadequate as a view of the facility's structural systems. A hierarchy suitable for this purpose might divide elements into *structural functions* such as slabs, walls, frames, footings, piles or mats. Lower levels of the hierarchy would describe individual design elements. For example, frames would be made up of column, beam and diagonal groups which, in turn, are composed of individual structural elements. These individual structural elements comprise the limits on functional spaces such as rooms in a different hierarchical perspective. Designers typically will initiate a view appropriate for their own concerns, and these different hierarchical views must be synthesized to insure consistency and adequacy of the overall design.

Text IV

Industrialized Construction and Pre-fabrication

Another approach to construction innovation is to apply the principles and organizational solutions adopted for manufacturing. Industrialized construction and pre-fabrication would involve transferring a significant portion of construction operations from the construction site to more or less remote sites where individual components of buildings and structures are produced. Elements of facilities could be prefabricated off the erection site and assembled by cranes and other lifting machinery.

There are a wide variety and degrees of introducing greater industrialization to the construction process. Many components of constructed facilities have always been manufactured, such as air conditioning units. Lumber, piping and other individual components are manufactured to standard sizes. Even temporary items such as forms for concrete can be assembled off-site and transported for use. Reinforcing bars for concrete can also be pre-cut and shaped to the desired configuration in a manufacturing plant or in an automated plant located proximate to a construction site.

A major problem in extending the use of pre-fabricated units is the lack of standardization for systems and building regulations. While designers have long adopted standard sizes for individual components in designs, the adoption of standardized sub-assemblies is rarer. Without standardization, the achievement of a large market and scale economies of production in manufacturing may be impossible. An innovative and more thorough industrialization of the entire building process may be a primary source of construction cost savings in the future.

Example 3-12: ***Planning of pre-fabrication***

When might pre-fabricated components be used in preference to components assembled on a construction site? A straightforward answer is to use pre-fabricated components whenever their cost, including transportation, is less than the cost of assembly on site. As an example, forms for concrete panels might be transported to a construction site with reinforcing bars already built in, necessary coatings applied to the forms, and even special features such as electrical conduit already installed in the form. In some cases, it might be less expensive to pre-fabricate and transport the entire concrete panel to a manufacturing site. In contrast, traditional construction practice would be to assemble all the different features of the panel on-site. The relevant costs of these alternatives could be assessed during construction planning to determine the lowest cost alternative.

In addition to the consideration of direct costs, a construction planner should also consider some other aspects of this technology choice. First, the planner must insure that prefabricated components will satisfy the *relevant building codes* and *regulations*. Second, the *relative quality* of traditional versus pre-fabricated components as experienced in the final facility should be considered. Finally, the *availability of components* at the required time during the construction process should also be considered.

Example 3-13: ***Impacts of building codes***

Building codes originated as a part of the building regulatory process for the safety and general welfare of the public. The source of all authority to enact building codes is based on the police power of the state which may be delegated by the state legislature to local government units. Consequently, about 8,000 localities having their own building codes, either by following a national model code or developing a local code. The lack of uniformity of building codes may be attributed to a variety of reasons:

• Neighboring municipalities may adopt different national models as the basis for local regulation.

• Periodic revisions of national codes may not be adopted by local authorities before the lapse of several years.

• Municipalities may explicitly decline to adopt specific provisions of national model codes or may use their own variants of key provisions.

• Local authorities may differ in interpretation of the same language in national model codes.

The lack of uniformity in building codes has serious impact on design and construction as well as the regulatory process for buildings. Among the significant factors are:

• Delay in the diffusion of new building innovations which may take a long time to find their ways to be incorporated in building codes.

• Discouragement to new production organizations, such as industrialized construction and prefabrication.

• Duplication of administrative cost of public agencies and compliance cost incurred by private firms.

<u>**Text V**</u>

Computer-Aided Engineering

In the past twenty years, the computer has become an essential tool in engineering, design, and accounting. The innovative designs of complicated facilities cited in the previous sections would be impossible without the aid of computer based analysis tools. By using general purpose analysis programs to test alternative designs of complex structures such as petrochemical plants, engineers are able to greatly improve initial designs. General purpose accounting systems are also available and adopted in organizations to perform routine bookkeeping and financial accounting chores. These applications exploit the capability for computers to perform numerical calculations in a preprogrammed fashion rapidly, inexpensively and accurately.

Despite these advances, the computer is often used as only an incidental tool in the design, construction and project management processes. However, new capabilities, systems and application programs are rapidly being adopted. These are motivated in part by the remarkable improvement in computer hardware capability, the introduction of the Internet, and an extraordinary decline in cost. New concepts in computer design and in software are also contributing. For example, the introduction of *personal* computers using microcircuitry has encouraged the adoption of interactive programs because of the low cost and considerable capability of the computer hardware. Personal computers available for a thousand dollars in 1995 have essentially the same capability as expensive mainframe computer systems of fifteen years earlier.

Computer graphics provide another pertinent example of a potentially revolutionary mechanism for design and communication. Graphical representations of both the physical and work activities on projects have been essential tools in the construction industry for decades. However, manual drafting of blueprints, plans and other diagrams is laborious and expensive. Stand alone, computer aided drafting equipment has proved to be less expensive and fully capable of producing the requiring drawings. More significantly, the geometric information required for producing desired drawings might also be used as a database for computer aided design and computer integrated construction. Components of facilities can be represented as three dimensional computers based *solid models* for this purpose.

Geometric information forms only one component of integrated design databases in which the computer can assure consistency, completeness and compliance with relevant specifications and constraints. Several approaches to integrated computer aided engineering environments of this type have already been attempted.

Computers are also being applied more and more extensively to non-analytical and non-numerical tasks. For example, computer based specification writing assistants are used to rapidly assemble sets of standard specifications or to insert special clauses in the documentation of facility designs. As another example, computerized transfer of information provides a means to avoid laborious and error-prone transcription of project information. While most of the traditional applications and research in computer aids have emphasized numerical calculations, the use of computers will rapidly shift towards the more prevalent and difficult problems of planning, communication, design and management.

Knowledge based systems represent a prominent example of new software approaches applicable to project management. These systems originally emerged from research in artificial intelligence in which human cognitive processes were modeled. In limited problem domains such as equipment configuration or process control, knowledge based systems have been demonstrated to approach or surpass the performance of human experts. The programs are marked by a separation between the reasoning or "inference" engine program and the representation of domain specific knowledge. As a result, system developers need not specify complete problem solving strategies (or algorithms) for particular problems. This characteristic of knowledge based systems makes them particularly useful in the ill-structured domains of design and project management.

Computer program assistants will soon become ubiquitous in virtually all project management organizations. The challenge for managers is to use the new tools in an effective fashion. Computer intensive work environments should be structured to aid and to amplify the capabilities of managers rather than to divert attention from real problems such as worker motivation.

Text VI

Relevance of Construction Schedules

In addition to assigning dates to project activities, project scheduling is intended to match the resources of equipment, materials and labor with project work tasks over time. Good scheduling can eliminate problems due to production bottlenecks, facilitate the timely procurement of necessary materials, and otherwise insure the completion of a project as soon as possible. In contrast, poor scheduling can result in considerable waste as laborers and equipment wait for the availability of needed resources or the completion of preceding tasks.

Attitudes toward the formal scheduling of projects are often extreme. Many owners require detailed construction schedules to be submitted by contractors as a means of monitoring the work progress. The actual work performed is commonly compared to the schedule to determine if construction is proceeding satisfactorily. After the completion of construction, similar comparisons between the planned schedule and the actual accomplishments may be performed to allocate the liability for project delays due to changes requested by the owner, worker strikes or other unforeseen circumstances.

In contrast to these instances of reliance upon formal schedules, many field supervisors disdain and dislike formal scheduling procedures. In particular, the *critical path method* of scheduling is commonly required by owners and has been taught in universities for over two decades, but is often regarded in the field as irrelevant to actual operations and a time consuming distraction. Progressive construction firms use formal scheduling procedures whenever the complexity of work tasks is high and the coordination of different workers is required.

Formal scheduling procedures have become much more common with the advent of personal computers on construction sites and easy-to-use software programs. Sharing schedule information via the Internet has also provided a greater incentive to use formal scheduling methods. Construction supervisors often carry schedule and budget information around with wearable or handheld computers. As a result, the continued development of easy to use computer programs and improved methods of presenting schedules have overcome the practical problems associated with formal scheduling mechanisms. But problems with the use of scheduling techniques will continue until managers understand their proper use and limitations.

A basic distinction exists between *resource oriented* and *time oriented* scheduling techniques. For resource oriented scheduling, the focus is on using and scheduling particular resources in an effective fashion. For example, the project manager's main concern on a high-rise building site might be to insure that cranes are used effectively for moving materials; without effective scheduling in this case, delivery trucks might queue on the ground and workers wait for deliveries on upper floors. For time oriented scheduling, the emphasis is on determining the completion time of the project. Hybrid techniques for resource leveling or resource constrained scheduling in the presence of precedence relationships also exist. Most scheduling software is time-oriented, although virtually all of the programs have the capability to introduce resource constaints.

Text VII

Labor Productivity

Productivity in construction is often broadly defined as output per labor hour. Since labor constitutes a large part of the construction cost and the quantity of labor hours in performing a task in construction is more susceptible to the influence of management than are materials or capital, this productivity measure is often referred to as *labor productivity.* However, it is important to note that labor productivity is a measure of the overall effectiveness of an operating system in utilizing labor, equipment and capital to convert labor efforts into useful output, and is not a measure of the capabilities of labor alone. For example, by investing in a piece of new equipment to perform certain tasks in construction, output may be increased for the same number of labor hours, thus resulting in higher labor productivity.

Construction output may be expressed in terms of functional units or constant dollars. In the former case, labor productivity is associated with units of product per labor hour, such as cubic yards of concrete placed per hour or miles of highway paved per hour. In the latter case, labor productivity is identified with value of construction in constant dollars per labor hour.

Productivity at the Job Site

Contractors and owners are often concerned with the labor activity at job sites. For this purpose, it is convenient to express labor productivity as functional units per labor hour for each type of construction task. However, even for such specific purposes, different levels of measure may be used. For example, cubic yards of concrete placed per hour is a lower level of measure than miles of highway paved per hour. Lower-level measures are more useful for monitoring individual activities, while higher-level measures may be more convenient for developing industry-wide standards of performance.

While each contractor or owner is free to use its own system to measure labor productivity at a site, it is a good practice to set up a system which can be used to track productivity trends over time and in varied locations. Considerable efforts are required to collect information regionally or nationally over a number of years to produce such results. The productivity indices compiled from statistical data should include parameters such as the performance of major crafts, effects of project size, type and location, and other major project influences.

In order to develop industry-wide standards of performance, there must be a general agreement on the measures to be useful for compiling data. Then, the job site productivity data collected by various contractors and owners can be correlated and analyzed to develop certain measures for each of the major segments of the construction industry. Thus, a contractor or owner can compare its performance with that of the industry average.

Productivity in the Construction Industry

Because of the diversity of the construction industry, a single index for the entire industry is neither meaningful nor reliable. Productivity indices may be developed for major segments of the construction industry nationwide if reliable statistical data can be obtained for separate industrial segments. For this general type of productivity measure, it *is* more convenient to express labor productivity as constant dollars per labor hours since dollar values are more easily aggregated from a large amount of data collected from different sources. The use of constant dollars allows meaningful approximations of the changes in construction output from one year to another when price deflators are applied to current dollars to obtain the corresponding values in constant dollars. However, since most construction price deflators are obtained from a combination of price indices for material and labor inputs, they reflect only the change of price levels and do not capture any savings arising from improved labor productivity. Such deflators tend to overstate increases in construction costs over a long period of time, and consequently understate the physical volume or value of construction work in years subsequent to the base year for the indices.

Factors Affecting Job-Site Productivity

Job-site productivity is influenced by many factors which can be characterized either as labor characteristics, project work conditions or as non-productive activities. The labor characteristics include:

- age and experience of workforce
- leadership and motivation of workforce

The project work conditions include among other factors:

- Job size and complexity.
- Job site accessibility.
- Labor availability.
- Equipment utilization.
- Contractual agreements.
- Local climate.
- Local cultural characteristics, particularly in foreign operations.

The non-productive activities associated with a project may or may not be paid by the owner, but they nevertheless take up potential labor resources which can otherwise be directed to the project. The non-productive activities include among other factors:

- Indirect labor required to maintain the progress of the project
- Rework for correcting unsatisfactory work
- Temporary work stoppage due to inclement weather or material shortage
- Time off for union activities
- Absentee time, including late start and early quits
- Non-working holidays
- Strikes

Each category of factors affects the productive labor available to a project as well as the on-site labor efficiency.

Text VIII

Resource Oriented Scheduling

Resource constrained scheduling should be applied whenever there are limited resources available for a project and the competition for these resources among the project activities is keen. In effect, delays are liable to occur in such cases as activities must wait until common resources become available. To the extent that resources are limited and demand for the resource is high, this waiting may be considerable. In turn, the congestion associated with these waits represents increased costs, poor productivity and, in the end, project delays. Schedules made without consideration for such bottlenecks can be completely unrealistic.

Resource constrained scheduling is of particular importance in managing multiple projects with fixed resources of staff or equipment. For example, a design office has an identifiable staff which must be assigned to particular projects and design activities. When the workload is heavy, the designers may fall behind on completing their assignments. Government agencies are particularly prone to the problems of fixed staffing levels, although some flexibility in accomplishing tasks is possible through the mechanism of contracting work to outside firms. Construction activities are less susceptible to this type of problem since it is easier and less costly to hire additional personnel for the relatively short duration of a construction project. Overtime or double shift work also provide some flexibility.

Resource oriented scheduling also is appropriate in cases in which unique resources are to be used. For example, scheduling excavation operations when one only excavator is available is simply a process of assigning work tasks or job segments on a day by day basis while insuring that appropriate precedence relationships are maintained. Even with more than one resource, this manual assignment process may be quite adequate. However, a planner should be careful to insure that necessary precedences are maintained.

Resource constrained scheduling represents a considerable challenge and source of frustration to researchers in mathematics and operations research. While algorithms for optimal solution of the resource constrained problem exist, they are generally too computationally expensive to be practical for all but small networks. The difficulty of the resource constrained project scheduling problem arises from the combinatorial explosion of different resource assignments which can be made and the fact that the decision variables are integer values representing all-or-nothing assignments of a particular resource to a particular activity. In contrast, simple critical path scheduling deals with continuous time variables. Construction projects typically involve many activities, so optimal solution techniques for resource allocation are not practical.

One possible simplification of the resource oriented scheduling problem is to ignore precedence relationships. In some applications, it may be impossible or unnecessary to consider precedence constraints among activities. In these cases, the focus of scheduling is usually on efficient utilization of project resources. To insure minimum cost and delay, a project manager attempts to minimize the amount of time that resources are unused and to minimize the waiting time for scarce resources. This resource oriented scheduling is often formalized as a problem of "job shop" scheduling in which numerous tasks are to be scheduled for completion and a variety of discrete resources need to perform operations to complete the tasks. Reflecting the original orientation towards manufacturing applications, tasks are usually referred to as "jobs" and resources to be scheduled are designated "machines." In the provision of constructed facilities, an analogy would be an architectural/engineering design office in which numerous design related tasks are to be accomplished by individual professionals in different departments. The scheduling problem is to insure efficient use of the individual professionals (i.e. the resources) and to complete specific tasks in a timely manner.

The simplest form of resource oriented scheduling is a reservation system for particular resources. Since the resource assignment is known in advance, other users of the resource can schedule their activities more effectively. The result is less waiting or "queuing" for a resource. It is also possible to inaugurate a preference system within the reservation process so that high-priority activities can be accommodated directly.

In the more general case of multiple resources and specialized tasks, practical resource constrained scheduling procedures rely on heuristic procedures to develop good but not necessarily optimal schedules. While this is the occasion for considerable anguish among researchers, the heuristic methods will typically give fairly good results. Manual methods in which a human scheduler revises a critical path schedule in light of resource constraints can also work relatively well. Given that much of the data and the network representation used in forming a project schedule are uncertain, the results of applying heuristic procedures may be quite adequate in practice.

Text IX

Use of Advanced Scheduling Techniques

Construction project scheduling is a topic that has received extensive research over a number of decades. The previous chapter described the fundamental scheduling techniques widely used and supported by numerous commercial scheduling systems. A variety of special techniques have also been developed to address specific circumstances or problems. With the availability of more powerful computers and software, the use of advanced scheduling techniques is becoming easier and of greater relevance to practice. In this chapter, we survey some of the techniques that can be employed in this regard. These techniques address some important practical problems, such as:

- scheduling in the face of uncertain estimates on activity durations,
- integrated planning of scheduling and resource allocation,
- scheduling in unstructured or poorly formulated circumstances.

Scheduling with Uncertain Durations.

Unfortunately, activity durations are estimates of the actual time required. During the preliminary planning stages for a project, the uncertainty in activity durations is particularly large since the scope and obstacles to the project are still undefined. Activities that are outside of the control of the owner are likely to be more uncertain. For example, the time required to gain regulatory approval for projects may vary tremendously. Other external events such as adverse weather, trench collapses, or labor strikes make duration estimates particularly uncertain.

Two simple approaches to dealing with the uncertainty in activity durations warrant some discussion before introducing more formal scheduling procedures to deal with uncertainty. First, the uncertainty in activity durations may simply be ignored and scheduling done using the expected or most likely time duration for each activity. Since only one duration estimate needs to be made for each activity, this approach reduces the required work in setting up the original schedule. Formal methods of introducing uncertainty into the scheduling process require more work and assumptions. While this simple approach might be defended, it has two drawbacks. First, the use of expected activity durations typically results in overly optimistic schedules for completion; a numerical example of this optimism appears below. Second, the use of single activity durations often produces a rigid, inflexible mindset on the part of schedulers. As field managers appreciate, activity durations vary considerably and can be influenced by good leadership and close attention. As a result, field managers may lose confidence in the realism of a schedule based upon fixed activity durations. Clearly, the use of fixed activity durations in setting up a schedule makes a continual process of monitoring and updating the schedule in light of actual experience imperative. Otherwise, the project schedule is rapidly outdated.

A second simple approach to incorporation uncertainty also deserves mention. Many managers recognize that the use of expected durations may result in overly optimistic schedules, so they include a contingency allowance in their estimate of activity durations. For example, an activity with an expected duration of two days might be scheduled for a period of 2.2 days, including a ten percent contingency. Systematic application of this contingency would result in a ten percent increase in the expected time to complete the project. While the use of this *heuristic* contingency factor can result in more accurate schedules, it is likely that formal scheduling methods that incorporate uncertainty more formally are useful as a means of obtaining greater accuracy or in understanding the effects of activity delays.

The most common formal approach to incorporate uncertainty in the scheduling process is to apply the critical path scheduling process and then analyze the results from a probabilistic perspective. As noted earlier, the duration of the critical path represents the minimum time required to complete the project. Using expected activity durations and critical path scheduling, a critical path of activities can be identified. This critical path is then used to analyze the duration of the project incorporating the uncertainty of the activity durations along the critical path. The expected project duration is equal to the sum of the expected durations of the activities along the critical path. Assuming that activity durations are independent random variables, the variance or variation in the duration of this critical path is calculated as the sum of the variances along the critical path.

Text X

Centralized Database Management Systems

Whichever conceptual model or database management system is adopted, the use of a central database management system has a number of advantages and some costs compared to the commonly employed special purpose datafiles. A datafile consists of a set of records arranged and defined for a single application system. Relational information between items in a record or between records is not explicitly described or available to other application systems. For example, a file of project activity durations and scheduled times might be assembled and manipulated by a project scheduling system. This datafile would not necessarily be available to the accounting system or to corporate planners.

For the purpose of project management, the issue of improved availability is particularly important. Most application programs create and *own* particular datafiles in the sense that information is difficult to obtain directly for other applications. Common problems in attempting to transfer data between such special purpose files are missing data items, unusable formats, and unknown formats.

As an example, suppose that the Purchasing Department keeps records of equipment rental costs on each project underway. This data is arranged so that payment of invoices can be handled expeditiously and project accounts are properly debited. The records are arranged by individual suppliers for this purpose. These records might not be particularly useful for the purpose of preparing cost estimates since:

- Some suppliers might not exist in the historical record.
- Finding the lowest cost supplier for particular pieces of equipment would be exceedingly tedious since every record would have to be read to find the desired piece of equipment and the cost.
- No direct way of abstracting the equipment codes and prices might exist.

An alternative arrangement might be to separately record equipment rental costs in the Purchasing Department Records, the Cost Estimating Division, and the Company warehouse. While these multiple databases might each be designed for the individual use, they represent considerable redundancy and could easily result in inconsistencies as prices change over time. With a central DBM, desired views for each of these three users could be developed from a single database of equipment costs.

Life is never so simple. Installing and maintaining databases is a costly and time consuming endeavor. A single database is particularly vulnerable to equipment failure. Moreover a central database system may be so expensive and cumbersome that it becomes ineffective. But lack of good information and manual information management can also be expensive.

One might also contrast the operation of a formal, computerized database with that of a manual filing system. For the equipment supplier example cited above, an experienced purchasing clerk might be able to immediately find the lowest cost supplier of a particular piece of equipment. Making this identification might well occur in spite of the formal organization of the records by supplier organization. The experienced clerk will have his (or her) own subjective, conceptual model of the available information. This subjective model can be remarkably powerful. Unfortunately, the mass of information required, the continuing introduction of new employees, and the need for consistency on large projects make such manual systems less effective and reliable.

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