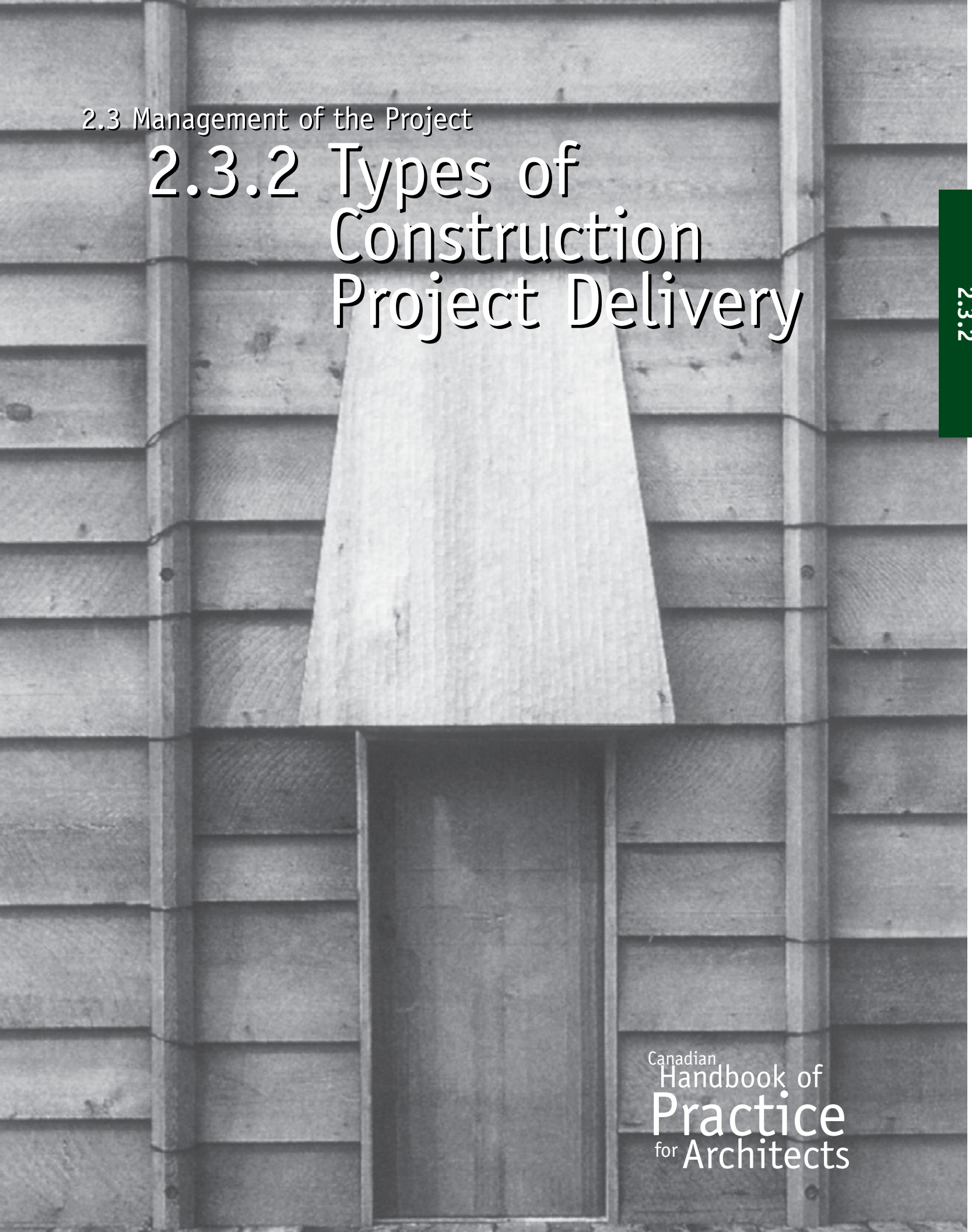

2.3.2 Types of Construction Project Delivery

Canadian Handbook of Practice for Architects

2.3.2

Introduction

Types of Construction Project Delivery
- Stipulated Price Contract (Design-Bid-Build)
- Construction Management
- Design-Build
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- Pre-qualification of Contractors
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Types of Construction Project Delivery

Introduction

The design and construction industry is changing at a rapid pace. Options for project delivery have multiplied and more than one option is available for each project, depending on the client's needs and the project team's ability to deliver. *Project delivery* methods in the construction industry have evolved in response to:

- increased owner requirements;
- more urgent time frames;
- increased demands for quality and safety;
- the need to reduce adversarial relationships in construction;
- economic pressures.

Project delivery is a general term describing the comprehensive process used to successfully complete the design and construction of buildings and other facilities. The term is used to include all the procedures, actions, sequences of events, obligations, interrelations, contractual relations, and various forms of agreement.

There is no "best" delivery system; each is appropriate in particular circumstances.

Types of Construction Project Delivery

This section provides:

- a brief description of common delivery methods;
- a basis for comparing them;
- a general evaluation of their advantages and disadvantages.

Stipulated Price Contract (Design-Bid-Build)

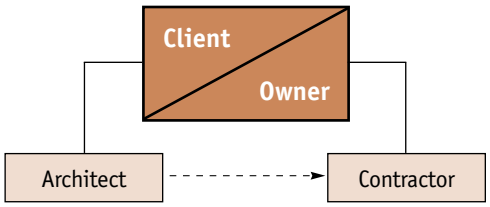
Most building projects follow this traditional method of project delivery (sometimes referred to as "Design-Bid-Build") in which:

- the owner engages an architect to prepare the design, drawings, and specifications;
- the owner hires a contractor by competitive bidding to build the facility under a construction contract (usually CCDC 2, *Stipulated Price Contract*);
- the architect administers the contract, and reviews and certifies the construction.

This *design-bid-build* form of project delivery is characterized by:

- its three distinct phases;
- its two independent contracts between: the architect and the client/owner; the contractor and the client/owner;
- the linear sequencing of the process.

Illustration 1: Design-Bid-Build



Key to the Diagram
——— contract between two parties
- - - - - monitor/review/administer

Advantages
- widespread use and familiarity;
- clear roles assigned to each party;
- generally a transparent process
- thorough resolution of the program requirements and design prior to construction;
- Direct professional relationship between the client / building users and the architect;
- has a known price before construction begins.

Disadvantages
- separation of design and construction restricts useful communication;
- clients sometimes perceive "extras" to be more prevalent and costly in this form of

The following table provides a brief Executive Summary of the some common Types of Construction Project Delivery:

Method of Construction Project Delivery	Standard Form of Contract	Description
Design-Bid-Build	RAIC Document Six: Canadian Standard Form of Contract for Architectural Services *followed by* CCDC 2 Stipulated Price Contract (CCDC 3 or CCDC 4 may also be used)	Owner engages the architect to provide design services and prepare construction documents which are issued for competitive bids. General contractors submit bids for the project and the construction contract is awarded to the lowest bidder. The architect administers the construction contract.
Construction Management	CCDC 5a - Construction Management Contract for Services CCDC 5b - Construction Management Contract for Services and Work	Owner engages the architect to provide design services and prepare construction documents. The Construction Manager works for the Owner as a consultant providing services that normally include design input on constructability, cost estimating, scheduling, bidding, coordination of contract negotiations and award, timing and purchase of critical materials, cost control and coordination of construction activities
Design-Build	CCDC 14 Design-Build Stipulated Price Contract CCDC 15 Design-Builder / Consultant Contract (subcontract)	A method of project delivery in which the Owner contracts directly with a single entity that is responsible for both design and construction services for a construction project
Public Private Partnership (P3)	No standard form of contract	A form of partnership between the public and private sectors where a combination of financing, design, construction, operation and maintenance of public projects relies on alternate sources of financing and revenue to cover all or part of the capital costs (including debt servicing, principal payment and return on equity), as well as operating and maintenance costs of for the project.
Single Purpose Entity for Integrated Project Delivery	Not yet available in Canada, as of January 2009 In the US, AIA Document C195	This new form of project delivery, championed by the AIA, creates a new single purpose entity or limited liability company which includes members such as the owner, architect, construction manager and other key project participants in the design and construction the project. The entity enters into contracts with non-members for design, trade contractors and suppliers for services, labour and materials. The entity enters into a separate agreement with the Owner to obtain project funding.

project delivery than others (although every form of project delivery carries a construction contingency);
- the contractor is unknown when the construction documents are prepared.
- contracts, particularly for public sector projects, are awarded to the low bidder who may not be well-qualified to do the work. Prequalification of contractors on public sector bids is not common.

Construction Management

Construction management is a broad term covering a variety of project delivery scenarios in which a construction manager (CM) is added to the building team at an early stage to oversee such elements as schedule, cost, construction method, or building technology. A construction manager may be:

- an architect;
- a contractor;
- an engineer or developer;
- an individual or team with specialized training in construction management.

Because this method adds a consultant and the associated fee, it is more commonly used on large, complex projects than those that are relatively small and simple. However, occasionally an architect acts as the construction manager on small projects such as house additions and renovations. Construction management is not a licensed activity in most provinces.

CMs can serve in different capacities with varying degrees of authority and responsibility (advisor, agent or constructor). Depending upon how the project is organized, a CM can:

- act as an **advisor** during a particular phase of the design, documentation or construction process;
- **manage** the construction of the project, with the owner contracting directly with each trade contractor. In this case, the CM may, or may not, be permitted to assume responsibility for construction activities typically outlined in General Conditions of the specifications (for example, temporary facilities, site layout, clean-up).

Savings in project costs are usually achieved only by the use of a delivery system that returns savings on sub-contractor bids directly to the owner with an "open book" accounting system and full transparency of all bids.

The fee paid to the construction manager is relative to the services to be performed. Refer to *CCDC 5a, Construction Management Contract for Services* and *CCDC 5b, Construction Management Contract for Services and Work* and their guides.

Typical responsibilities of a CM include:

- assisting in preliminary planning relative to the design requirements for the project;
- advising on schedules, budgets, and costs of various alternative methods, on material selection and availability, and on detailing during the design phase;
- advising on and arranging for all services and all trade contractors and suppliers to carry out the various phases of the work;
- planning, scheduling, coordinating, and supervising the activities of all trade contractors;
- providing technical and clerical services in the administration of the project.

Advantages
- direct contractual relationship with the owner;
- construction advice during the design process;
- the opportunity to call bids sequentially, thus saving time by permitting a start on construction before all documentation has been completed ("fast track");
- careful monitoring of costs and schedule (different checks and balances apply during design and construction because the architect, trade contractors, and CM are independent entities).

Disadvantages
- construction usually commences before the total costs are known;
- added costs and time in selection of an additional consultant;
- more complex relationships therefore traditional roles may be confused,
- the professional relationship between architect and owner and architect and contractor now includes a third party, sometimes complicating direct communication;

- potential for less control over final cost in an unstable construction market;
- Change Orders and delay claims are possible from prime or trade contractors who bid too low;
- there may be conflicts of interest if there is no independent cost consultant and the CM will be undertaking some of the construction work;
- the owner, as the "constructor," may not want to accept responsibility for construction safety;
- multiple construction contracts increase administrative costs for the Owner and the potential for coordination problems.

Design-Build

In Design-Build, the owner contracts with one firm to provide both design and construction. In fact, there are two variations on Design-Build: in some cases the Owner will initially engage an "advocate" architect (sometimes called a "bridging" consultant or Owner's Advisor) to prepare the Owner's Statement of Requirements and provide advice, and then engage a Design-Builder. In other instances, only a Design-Builder is hired.

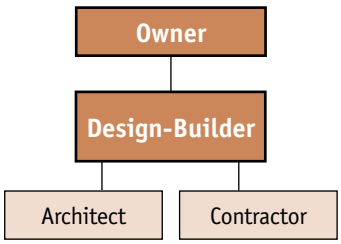
A Design-Build project usually has two phases:

- *Phase 1:* The Design-Builder, possibly in competition with other Design-Builders, provides architectural design services and, throughout the design process, monitors costs to ensure the building remains within the owner's budget. Based on the design developed in the first phase, the Design-Builder usually proposes a stipulated maximum price, which includes a fee for managing the construction.

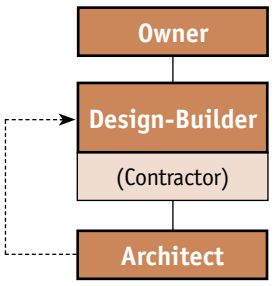
Illustration 2: A Comparison of Design-Bid-Build vs. Design-Build

Design-Bid-Build	Design-Build
Two contracts with the owner (more if engineers hired directly by the owner).	One contract with the owner (one point of primary responsibility).
Architect has contract with the owner.	Architect has contract with the Design-Builder (or is the Design-Builder).
Architect is usually engaged, and design and drawings complete, before the contractor is known.	Contractor is engaged before the design is complete.
Design and construction process is usually linear.	Design and construction process is more suitable for "fast track."
Familiar relationships: insurable, bondable, and acceptable under professional regulations.	Emerging relationships: terms of reference need to be checked for insurability, bondability, and acceptability under professional regulations.

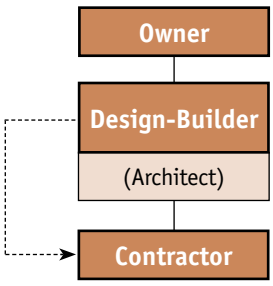
Design-Build (generic)



Design-Build (contractor-led)



Design-Build (architect-led)



Key to the Diagram

—— contract between two parties

- - - - - monitor/review/administer

- *Phase 2:* The parties enter into a stipulated price contract for the completion of the building. It is also possible to have a cost plus fee agreement in the Design-Build method of project delivery. The builder works to save costs during construction. Any savings accrue to the owner, who pays only the actual cost of construction, plus the Design-Builder's fee.

Refer to CCDC 14, *Design-Build Stipulated Price Contract*.

The following chart is a simplified comparison of Design-Bid-Build vs. Design-Build.

Advantages

- functional program (statement of owner's requirements) and owner's decisions are committed early;
- cost benefit analysis is addressed early in the design process;
- immediate feedback is received from the contractor on design options;
- streamlined process can increase efficiency;
- team approach is reinforced.

Disadvantages

- the responsibility for design approvals shifts from the owner to the Design-Builder;
- decisions by the Design-Builder are based more on initial cost rather than on design or long-term value;
- the cost is determined before the design is complete;
- additional fees when two architects are involved - an advocate architect engaged by the owner and a second architect engaged by the Design-Builder;
- architect's role as leader of the design team is reduced;
- high risk to the architect for preparing the proposal, which may or may not be successful;
- potential for tension between the "regulated" professional (architect) and the "unregulated" building contractor;
- potential for a lack of communication between the architect and the owner or building users;
- potential conflicts of interest in preparing Change Orders and certification because the architect's client and builder are one and the same.

Refer also to the *Design-Build Practice Manual* published by the Canadian Design-Build Institute.

Public Private Partnership

Public Private Partnerships or P3s (called "Alternate Financing and Procurement" or AFP in Ontario) is a relatively recent method of project delivery for public projects. It is generally used for infrastructure (civil engineering works) and larger scale public buildings, however, some governments are "bundling" several small buildings of the same type into one contract. P3s occur when the private sector works with governments or other public agencies to bring private sector capital and/or expertise to provide and deliver public services. The scale of a P3 project usually is significant and may include financing, design, construction, and very often facilities management and operations.

Critics of the process argue that the cost of P3 projects exceeds the cost of the same projects delivered under more traditional forms of project delivery because of the costs for financing and the hidden costs of "risk transfer" to the private sector. Governments and public agencies argue that these projects would not have been possible under traditional government processes using public funds. Furthermore, they argue that these projects can be delivered more quickly through P3s in response to the growing "infrastructure deficit".

This form of project delivery is used as a procurement method for larger infrastructure projects in government sectors in parts of Europe and Australia. For example, PFI or Private Finance Initiative is the standard method of project delivery in England.

Advantages

- uses the efficiencies and expertise of the private sector for public sector projects;
- allows projects to be financed in ways which may not be possible through public methods (such debentures, taxation, etc.) and may not be accounted for as a capital expenditure;
- life cycle costs can be reduced because with private sector operating the facility these costs become critical;

- single point responsibility;
- architects may develop long term relationships with ongoing consortia (project entities);
- reduced time and construction schedule to deliver projects compared with traditional public sector methods;
- design often becomes the "differentiating" quality in a proposal.

Disadvantages

- transfers or allocates certain financial risks to the private sector;
- "best value" is not always achieved as initial capital costs sometimes become overly important;
- potential for a lack of communication between the architect and the owner or building users;
- building users have less control over the process and its outcomes;
- sometimes more difficult to obtain professional liability insurance;
- difficult for small architectural practices to compete in this market.

Others

Other management and project delivery include:

- project management
- just-in-time;
- turnkey development;
- lease-back;
- cost plus

Project Management

The main difference between PROJECT MANAGEMENT and CONSTRUCTION MANAGEMENT is that the Project Manager has a contract with a client and in turn employs the architectural and engineering consultants to form his group, whereas under the Construction Management aspect the owner engages the architectural and engineering consultants, and at the same time or shortly afterwards, engages the services of a Construction Manager.
(Canadian Construction Association, *A Guide to Construction Management Contracts*)

In this delivery method, the Project Manager (PM) is usually hired by an owner during the pre-design phase to **manage the entire project** and engage all the disciplines required, including the architect and the consulting engineers. The typical project management project may have the same three phases (Design-Bid-Build) as traditional project delivery, or it may use sequential tendering to achieve earlier completion.

Advantages

- a well-informed owner is better able to make decisions on cost-versus-quality issues;
- the quality of the design may improve when the architect can draw on the PM's experience.

Disadvantages

- this arrangement is NOT permitted by the regulations of *most* provincial associations of architects. For example, in Ontario, unless the Project Manager is a "Design-Builder," this is contrary to OAA Regulation 42(55) as well as the Code of Ethics of OAQ and the *Architects Act* of British Columbia;
- unless the architect can maintain a direct link with the owner, the owner's ability to control construction quality is reduced because efficiencies or cost reductions implemented by the PM that affect quality may not be discussed directly with the owner.

Just-in-Time

This approach combines aspects of fast tracking, partnering, systems architecture, and strong incentives for repeat work. Large projects are broken into small work packages. Small teams of architects and contractors program, plan, demolish, and construct these areas on an hourly basis driven primarily by schedule, where time is the most critical factor.

Turnkey Development

Turnkey is generally described as a project delivery method that includes various real estate functions as well as design and construction. These functions may include site acquisition, entitlements, construction and/or long-term financing or other functions. This method may be carried out under Design-Build or developer proposal methods.

Unit Rates

Use of this method is limited primarily to heavy civil engineering work — such as roads, and site

preparation — where the contractor is paid for measured quantities at quoted unit rates. The method could be appropriate for the cost of repetitive units or identical buildings. The architect should ensure that unit rates are applied only to the design and documentation phases. The bidding and contract negotiations phase, as well as the contract administration phase, require full services.

Lease-back

Under this method, the project is financed, constructed, and owned by the builder, and the building is "leased-back" to the owner.

Cost Plus

In the cost plus method, the contractor is compensated for the actual costs of the work, plus a fee. The fee is based on:

- an agreed-upon fixed sum; or
- a percentage of the cost of the work.

Often called "time and materials," this method is appropriate for small, complicated projects in which time is a factor or total costs are initially difficult to determine. A variation of cost plus is "cost plus to a maximum upset price" or guaranteed upset price. The cost plus method normally uses CCDC 3, *Cost Plus Contract*, but is now frequently replaced by the construction management delivery method, which includes many of the advantages and few of the disadvantages.

Advantages

- costs are based on actual quantities and mark-ups with no "unknown factor";
- suitable when time frame is more important than construction costs (saves time because a formal tender call is not required);
- flexible in response to unknowns at the start of construction;
- suitable where extraordinary quality is required;
- construction may begin before design is complete.

Disadvantages

- no incentive to avoid cost overruns;
- often not permitted on publicly funded projects;
- total cost is unknown until project completion.

Contractors

Each type of project delivery has variations, which can be organized to suit the requirements of the project and the involvement of the contractor. Selecting the contractor best suited to the particular type of project delivery is an important decision.

Pre-qualification of Contractors

The purpose of pre-qualification is to ensure that the selected contractor is capable of delivering quality and value specific to the project requirements. The client, through pre-determined criteria, eliminates candidates who cannot demonstrate that they have the necessary financial capacity, technical expertise, managerial ability, and relevant experience for the project at hand. Pre-qualification is rarely used for public projects, where the opportunity to be considered as the contractor must be open to all. Refer also to Chapter 2.3.9, *Construction Procurement*.

CCDC 11, *Contractor's Qualification Statement*, is the standard document used for pre-qualification.

Multiple Contracts

There may be a variety of reasons to have multiple contracts for one project, such as:

- two or more general contractors are working on the same site;
- there is a need for sequential tendering for different parts of the project;
- the owner may be undertaking some of the work with his/her own forces, concurrent with a general contractor.

Some provinces have legislation which defines the owner as the constructor when there are multiple contracts. This has the effect of making the owner responsible for safety at the construction site.

Sequential tendering is sometimes required for different parts or phases of a project; in this instance, separate bid packages are issued for these parts, usually in the same sequence as required for construction (such as site work, foundations, structural shell, etc.).

Types of Construction Contracts

Standard Forms of Contract

The construction industry has recognized the advantages of jointly preparing standard forms of contract. Many of the documents are developed and endorsed by the Canadian Construction Documents Committee (CCDC). Refer to Chapter 1.2.1, *The Construction Industry*, for the composition and role of this committee.
The CCDC publishes Standard Contract Forms, including:

- CCDC 2, *Stipulated Price Contract*;
- CCDC 3, *Cost Plus Contract*;
- CCDC 4, *Unit Price Contract*.
- CCDC 14 *Design-Build Stipulated Price Contract*.

The forms, which are available in both English and French, are sub-divided into three parts:

- Agreement between Owner and Contractor;
- Definitions;
- General Conditions.

The use of CCDC Standard Contract Forms is recommended. Because each document is reviewed periodically by the CCDC and revised as required, the architect should obtain and complete the latest edition when preparing construction contracts for the client's use and execution.

Refer to "List: Canadian Construction Documents" at the end of Chapter 1.2.1, *The Construction Industry*.

Stipulated Price Contract
[CCDC 2, *Stipulated Price Contract* and CCDC 20, *A Guide to the Use of CCDC 2*]
This is the most common type of fixed-price contract. The stipulated price is established through bidding — either open bidding or invitation of bids from pre-qualified bidders. The successful contractor is paid a fixed price for the completed construction. The fixed price or time for construction can only be adjusted by Change Orders.

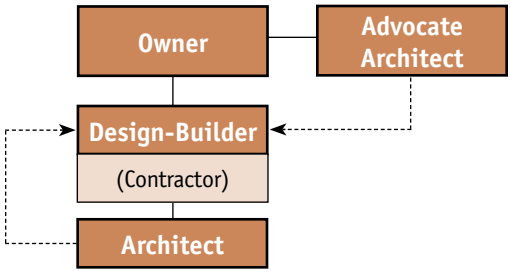
The contractor is required to perform work called for in the contract, regardless of what it actually costs. Thus, the contractor must take great care when pricing such work, taking into account potential cost increases caused by inflation, material shortages, or difficulties in meeting performance requirements.

A stipulated price contract can produce maximum profit for the contractor, who also assumes maximum risk, including the risk of unexpected additional costs such as those that might result from inflation or material shortages. This type of contract should be used when the construction costs are reasonably predictable and when full documentation is available.

Design-Build Stipulated Price Contract
[CCDC 14, *Design-Build Stipulated Price Contract*]
In the Design-Build stipulated price contract, the owner deals with one single business entity, which arranges to provide both design services and construction of the project under one contract package. Prices established before design is completed may cause disagreement over the scope of the work or the details of construction intended for inclusion in the stipulated price.

The prime contract is between the owner and the Design-Builder, where the Design-Builder could be a contractor, an architect, a broker, or a joint venture between a contractor and an architect. The architect should contact the respective provincial association to verify regulations concerning the architect's role as a Design-Builder, and for joint venture restrictions. The Design-Builder's consultants are the only consultants recognized in the contract, although the owner may also appoint an advocate architect or other consultants to represent the owner's interests.

Illustration 3: Bridging



The second contract [CCDC 15, *Design-Builder / Consultant Contract*] is between the project's Design-Builder and the architect.

Cost Plus Contract (percentage or fixed fee)
[CCDC 3, *Cost Plus Contract* and CCDC 43, *A Guide to the Use of CCDC 3*]
In a cost plus contract, the contractor is compensated for the actual costs of the work, plus a fee based upon either an agreed-upon fixed sum or a percentage of the costs. Often called *time and materials*, this method is appropriate for small, complex projects in which total costs are initially difficult to determine.

A cost plus contract is one of the simplest types of cost-reimbursement contracts. It has the following features:

- the owner reimburses the contractor for the allowable costs incurred in the course of construction;
- costs are paid regardless of the progress of the work and no matter how far the task is from completion;
- work may cease when the construction costs equal the funds provided for under the contract.

Guaranteed Maximum Price Contract
[CCDC 3, *Cost Plus Contract* with Guaranteed Maximum Price Option]
In this type of contract, the contractor is compensated for the actual costs, plus a fee with an agreed-upon maximum price. This is sometimes called an *upset price* contract. The contractor bears all costs beyond the pre-determined maximum. If the actual costs are below the maximum, the contractor may share the savings with the owner, depending on the terms of the contract. The guaranteed maximum price can be adjusted only by Change Order.

Unit Price Contract
[CCDC 4, *Unit Price Contract*]
In a unit price contract, the contractor is paid a pre-determined price for each unit or quantity of work or material used in the project's construction. The unit price can be derived through bidding or negotiation. The actual quantities involved are generally verified by independent inspection, for example, by a clerk of the works or a quantity surveyor.

Unit prices form the basis for payment of the contract price. Quantities in the schedule of prices are estimated. The contract price is:

- the final sum of the product of each unit price stated in the schedule of prices;
  multiplied by
- the actual quantity of each item that is incorporated in or made necessary by the work;
  plus
- lump sums and allowances, if any, stated in the schedule of prices.

Currently, CCDC 4, *Unit Price Contract*, has limited use in Canada for building construction. It is used primarily for civil engineering work.

Other Types of Contracts

Other types of construction contracts include:

- government or "in-house" contracts;
- contracts with economic price adjustment;
- incentive-based contracts;
- standing offer contracts;
- purchase order contracts;
- oral contracts.

Government or "In-house" Contracts
Various federal, provincial, and municipal governments have their own forms of contract which include different General Conditions. These documents are printed forms, and normally are not amended.

In some instances, a public body or large corporation will choose to prepare its own forms of contract for construction. The architect required to administer these documents should review these contracts prior to providing a proposal for contract administration services. Refer to Chapter 2.1.9, *Risk Management and Professional Liability*, for the pitfalls in the use of non-standard contracts.

Contracts with Economic Price Adjustment
Some fixed-price contracts contain economic price adjustment clauses that protect the contractor and the client against wide fluctuations in labour or material costs when market conditions are unstable. These clauses may provide for adjustment of the contract price for increases or decreases from an agreed-upon level measured against the following:

- published or established prices of specific items;
- specified costs of labour and material actually experienced during performance;

- specified labour or material cost standards or indices, such as the consumer price indexes.

Incentive-based Contracts
(also known as incentive contracts, cost-plus-incentive-fee contracts, and cost-plus-award-fee contracts)

The contractor and the owner's contracting officer agree on:

- target cost;
- target profit;
- target fee;
- incentive formula for determining the final fee.

The formula provides for an adjustment in the fee, based on any difference between the target cost and the total allowable cost of performing the contract. The award amount paid varies according to the client's evaluation of the contractor's performance in such areas as:

- quality;
- completion time;
- ingenuity;
- cost-effective management.

Standing Offer Contracts
Government or institutional clients may retain one or more consulting firms, or construction companies pre-qualified by proposal call, to provide professional or construction services on an *as and when requested* basis (sometimes referred to as being "on retainer" or "on call"). Occasions arise when consulting or construction services are required to augment existing resources within a professional and technical services branch of government. Such a situation can encompass:

- peak workload relief;
- project review to ensure a higher degree of performance;
- situations where in-house expertise is not available.

Purchase Order Contract
Authorized officials (public or private) may purchase design and construction services not exceeding a stated amount using purchase orders. The use of purchase orders is usually restricted to:

- small transactions;
- one delivery and one payment;
- off-the-shelf items;
- small repairs.

Oral Contracts
Oral contracts should *never* be used. All agreements should be in writing.

Written client-architect agreements are a requirement of the Architectural Institute of British Columbia.

Definitions

Construction Manager: An individual employed to oversee and direct the construction elements of a project, usually the whole of the construction elements, and the parties who are to perform them; a company which contracts with an owner to perform such services for a fee.

Design-Build: Methods of project delivery in which one business entity or alliance (Design-Builder) forges a single contract with the owner, and undertakes to provide both the professional design services (architectural/engineering) and the construction.

Project Manager: The leader of the team of all necessary disciplines (design, construction, supply, etc.). The project manager provides all major essentials for the project. (The term "project manager" may be confused with construction manager; the meaning has become blurred and is currently often used merely for the individual within the conventional hierarchy.)

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Appendix — Project Management

1. Scheduling the Project

Project schedules are planning tools that help project managers and teams organize various defined tasks in order to meet deadlines or dates which may be set out in an agreed-upon schedule or in the contract. In addition, schedules help to monitor tasks until the project is complete. Although a variety of scheduling techniques are available for many types of projects, the project manager must select a method which can be adapted to the scale and complexity of the work.

Milestone Chart

This simple method of scheduling involves setting target dates for each project activity. The name of the person responsible for each activity may also be noted. This method is used for:

- bidding;
- simple projects with a linear implementation;
- summaries of more complex scheduling arrangements.

This chart has limited potential because it can only indicate the end date — not the start date — of activities. Moreover, it does not show relationships between activities.

Diagram A: Milestones in the Bid Process

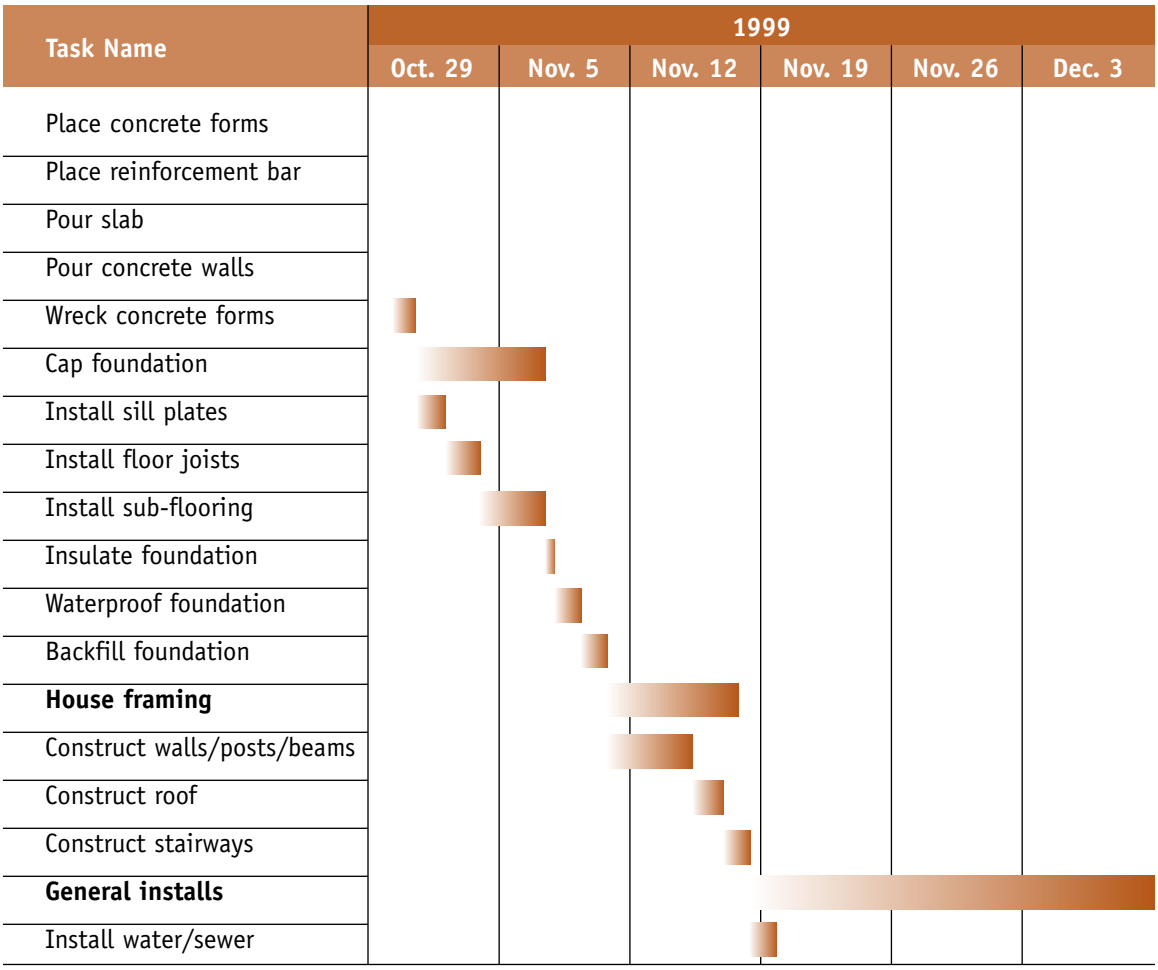
Task	Milestone Date
Issue text to newspapers	February 1, 2009
Distribute documents to bid depositories	February 4, 2009
Publish advertisements for bidders	February 5, 6, and 8, 2009
Issue final addenda	March 4, 2009
Bid closing	**March 11, 2009**
Analyze bids	March 12, 2009
Report to building committee	March 15, 2009
Notice of award of contract	March 17, 2009
Prepare and distribute CCDC 2 and contract documents	March 26, 2009
Start-up meeting	**April 19, 2009**

Gantt Diagram

Unlike a milestone chart, a Gantt diagram (a type of bar chart) lists all the required activities together with a horizontal line for each activity to indicate the beginning and end of each task in accordance with a time period shown at the top of the chart.

The bar chart is very common because it is easy to use, visually clear, and satisfies the requirements for most projects. On the other hand, it does not provide any information on the relative importance of tasks or their interrelationships.

Diagram B: Partial Gantt Chart or Bar Chart



Program Evaluation and Review Technique (PERT)

The Program Evaluation and Review Technique (PERT) is another method for monitoring the progress and periodically adjusting the schedule. PERT involves:

- defining the various tasks and milestones;
- linking these tasks in sequence;
- assigning a time estimate for the completion of each task.

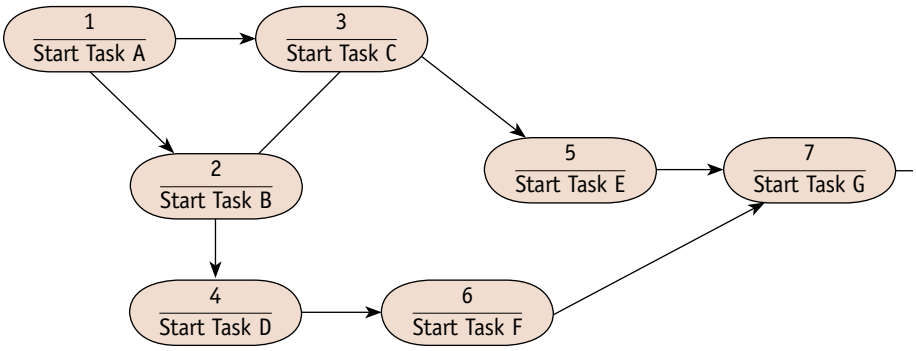
PERT is usually a graphical representation of the *dependency* network for an entire project. Dependencies are timing relationships between tasks which determine the *sequence of activities* or work flow in a project. Tasks are usually represented as boxes, and dependencies are represented as lines connecting the boxes.

PERT has one basic weakness: the fundamental assumptions of the length of time for completing each task are merely estimates and are not precise. Occasionally, formulae are used to increase the probable accuracy of the time estimate. For example, a better estimate of mean time can be achieved using the following formula:

$$T = \frac{a + 4m + b}{6}$$

T = mean time
a = most optimistic time, i.e., the shortest time for completion (best case scenario)
b = most pessimistic time, i.e., the longest time for completion (worst case scenario)
m = most likely time, i.e., the time that the work would most likely be completed based on its execution several times under randomly varying conditions

Diagram C: The PERT Network



T_e = earliest estimated completion time
T_1 = latest estimated completion time
S = slack time

Task A **Cure concrete**
T_e = 0 days
T_1 = 0 days
S = 0 days

Task B **Construct concrete block foundation wall**
T_e = 2 days
T_1 = 2 days
S = 0 days

Task C **Strip formwork**
T_e = 1 day
T_1 = 1 day
S = 0 days

Task D **Install anchors and sill plates**
T_e = 9 days
T_1 = 9 days
S = 0 days

Task E **Install filter fabric, gravel, and drainage tile**
T_e = 2 days
T_1 = 11 days
S = 9 days

Task F **Frame ground floor**
T_e = 11 days
T_1 = 11 days
S = 0 days

Task G **Backfill**
T_e = 13 days
T_1 = 13 days
S = 0 days

Critical Path Method (CPM)
This scheduling method uses arrows or lines to graphically demonstrate the relationships between:

- which activity must be undertaken first;
- which activity cannot be started until another has been completed;
- which activities can be carried out concurrently.

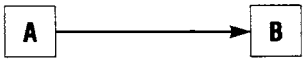
The chart helps to determine *the critical path* and identifies the stages which, if they are delayed, will slow down the entire project. It also identifies which activities can be delayed and for how long without having an impact on the duration of the project. Such delay capacity is called "float."

This type of project scheduling is frequently used for construction projects because many activities are underway at once, each dependent on the other.

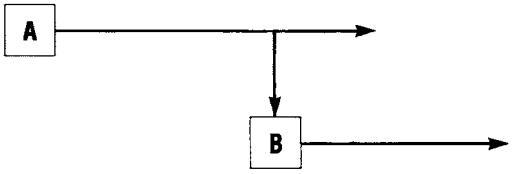
2. Preparing a Critical Path Method (CPM) Schedule

The following section is reprinted with permission from PSMJ Resources, Inc.

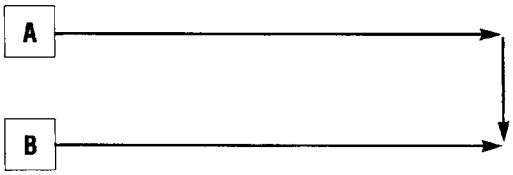
Step 1. Identify Task Interrelationships. The first step in preparing a CPM schedule is to identify systematically all task interrelationships. One way of doing this is to use a task interface diagram, also known as a precedence diagram. This diagram describes each of the three distinctive types of interrelationships graphically as follows:



Task A must be completed before task B can begin.



Task A must be partially completed before task B can begin.



Task A must be completed before task B can be completed.

An example of the first case would be:

Task A = determine heat loads
Task B = select air conditioning unit

Obviously the air conditioning unit cannot be selected until the heat loads are known.

An example of the second case would be:

Task A = prepare structural calculations
Task B = prepare structural drawings
Although structural calculations are necessary for the structural drawings, it is not necessary that the

calculations for *all* the structures be completed before the drawings of *some* of the structures can begin. Thus, task B cannot be started until a certain amount of progress has been made on task A.

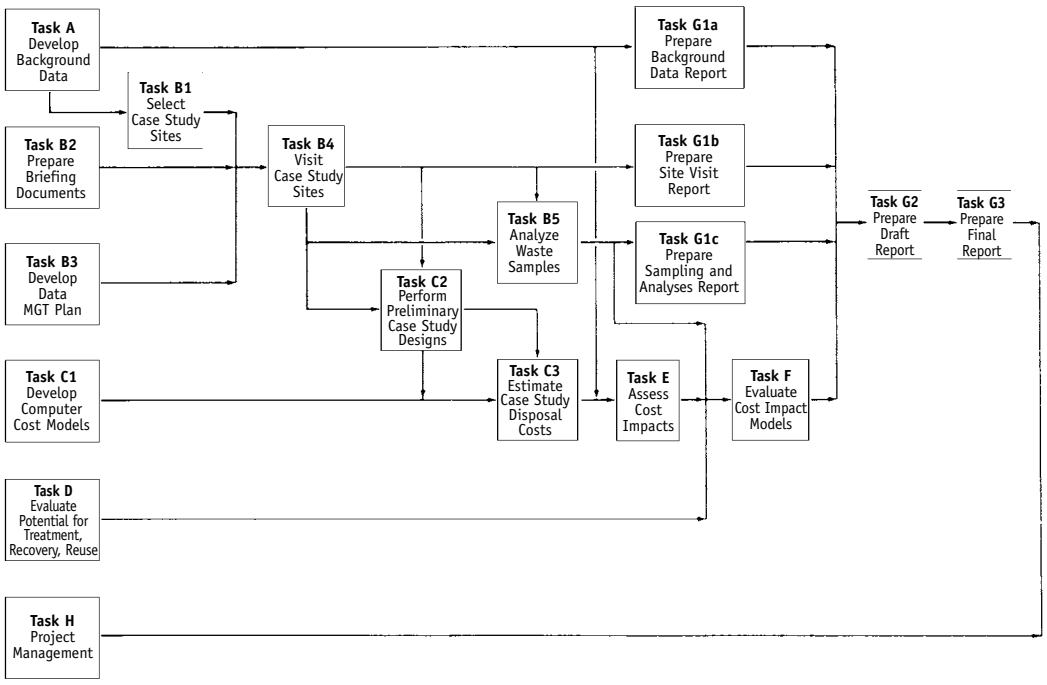
An example of the third case would be:

Task A = prepare piping drawings
Task B = prepare piping specifications

The specifications for common elements (including pipe supports, installation, and testing) can begin as soon as the project is reasonably well defined. However, the specifications cannot be completed until all the drawings are completed, so that all piping materials, valve types and so forth can be selected, identified, and tabulated.

Illustration A-1 shows how these interrelationships can be represented for a complete task outline. Study this diagram to see which of the three types of interrelationships exist between each pair of tasks. Note also that in this example, there is more than one type of interrelationship between two tasks. For example, interrelationship types 2 and 3 exist between tasks C2 and C3. In other words, task C3 (cost estimates) cannot begin until task C2 (preliminary design) is partially completed, and task C3 cannot be completed until task C2 has been completed. This double interface is quite common.

Illustration A-1: Task Interface Diagram



Step 2. Establish Optimum Task Durations. The next step is to establish the optimum duration for each activity on the task outline. This is the length of time (in calendar days) required for the activity to be completed in the most efficient manner possible assuming that all prerequisite tasks have been completed. A typical tabulation of task durations is presented in Illustration A-2 (using the same sample project as in the preceding illustration).

Note that task H, project management, is scheduled to extend 60 days beyond completion of all other tasks. This is typical of most projects performed by design firms. Even if all contractual responsibilities are completed by the contract due date, activities tend to continue beyond that date, such as printing of additional copies of drawings, answering questions from contractors or equipment vendors, organizing project files, or appearing at City Council meetings. Even if all contractual obligations have been met, these residual activities are part of the project management task and should be scheduled as such.

Step 3. Prepare Project Schedule. Having completed the basic task interface diagram and established optimum task durations, you may use these results to prepare a project schedule. Do this either in bar chart format or CPM format, in which the schedule is drawn as a network. The network schedule is best explained by using the same examples of simple two-task projects.

Let us say that the first sample project contains the following tasks and durations:

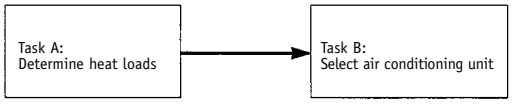
Task A = determine heat loads (five days' duration)
Task B = select air conditioning unit (four days' duration; cannot start until task A is completed)

Illustration A-2: Task Duration

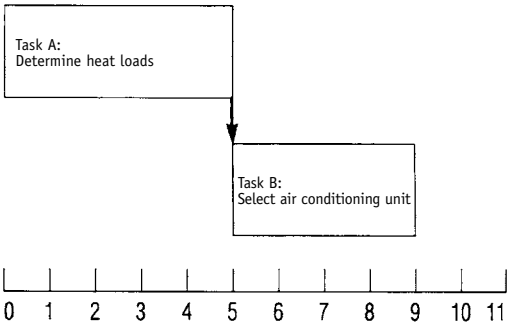
Activity Description	Calendar Days
A. Develop background data	180
B1. Select case study sites	30
B2. Prepare briefing documents	30
B3. Develop data management plan	90
B4. Visit case study sites	180
B5. Analyze waste samples	105
C1. Develop computer cost models	90
C2. Perform preliminary case study site designs	135
C3. Estimate case study disposal costs	30
D. Evaluate treatment, recovery, reuse	90
E. Assess cost impacts	60
F. Evaluate cost impact models	30
G1a. Prepare background data report	60
G1b. Prepare site visit report	60
G1c. Prepare sampling and analysis report	60
G2. Prepare draft report	60
G3. Prepare final report	60
H. Project management	*

* Task H should be completed 60 days after completion of all other activities.

The task interface diagram for this project will be:



This interface diagram can be converted to the network schedule shown below based on the defined task durations:

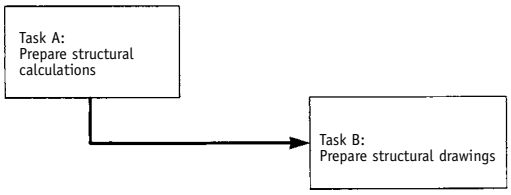


The vertical arrow in the network schedule serves the same purpose as the horizontal arrow in the interface diagram: to show that task B cannot begin until task A is completed. The arrow for the network schedule must be vertical to show that no time should elapse between completion of task A and start of task B. These vertical arrows are known as "dummy activities."

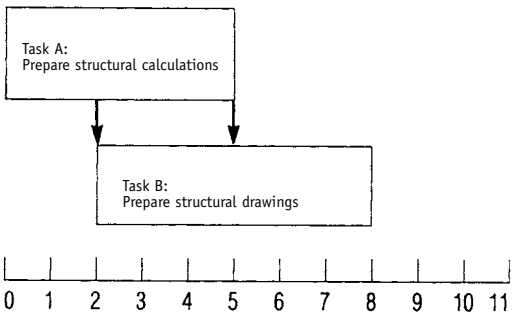
The second example contains the following tasks and durations:

Task A = prepare structural calculations (five days' duration)
Task B = prepare structural drawings (six days' duration; can begin after two days' work on task A)

The task interface diagram:



This diagram can be developed into the following network schedule:

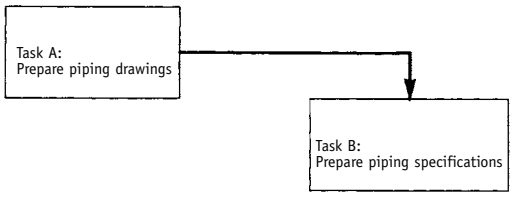


Note that the above schedule presumes that sufficient progress can be made by working on task A for two days in order to permit task B to be started. Again, the vertical arrow in the network schedule identifies the interrelationship between tasks A and B.

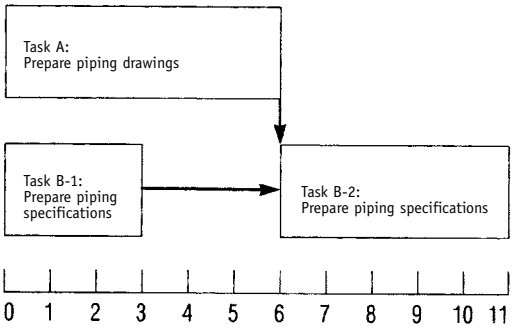
The third example defines the tasks and their durations as follows:

Task A = prepare piping drawings (six days' duration)
Task B = prepare piping specifications (eight days' duration; can start concurrently with task A, but three days' work remains after task A is completed)

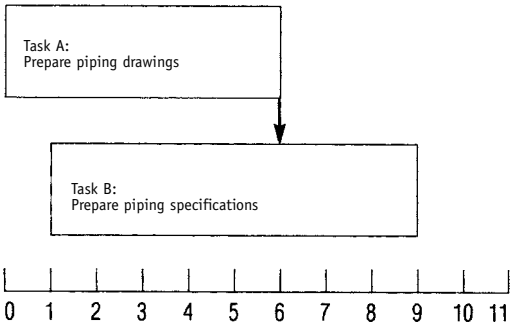
The task interface diagram:



From this interrelationship and durations of tasks, the following network diagram may be drawn:



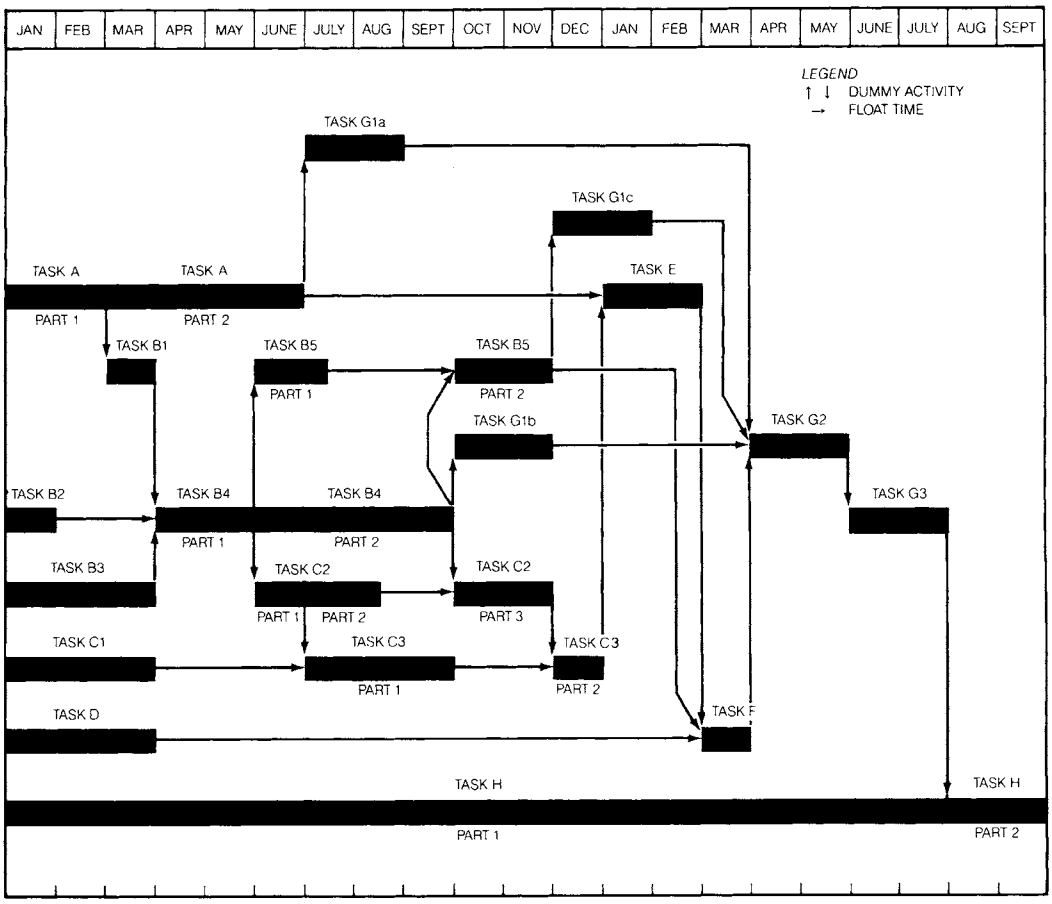
Note that task B can proceed up to a certain point, at which time you will need input from task A. If you had found that only three days of productive work could be done on task B prior to completion of task A, the schedule for the project above would have been:



Although the optimum duration of task B had been established as eight days, eleven days will actually be required to complete this activity. The additional three days are spent waiting for task A to be completed before the second part of task B can be started. This delay is shown by the horizontal arrow connecting parts one and two of task B. These horizontal arrows are referred to as float time.

The methods shown in the above examples may be used to develop a network schedule such as the one shown in Illustration A-3.

Illustration A-3: Time-Based Task Interface Diagram



Step 4. Determine Critical Paths. The last step in the CPM procedure is to determine which tasks are critical — that is, which tasks will affect the project completion date if any delay occurs. The critical tasks for each of the four two-task project examples are shown in Illustration A-4. For projects with fewer than 100 tasks, the critical tasks may be determined by graphic inspection, with results such as those in Illustration A-5.

Illustration A-4: Critical Tasks for Sample Projects

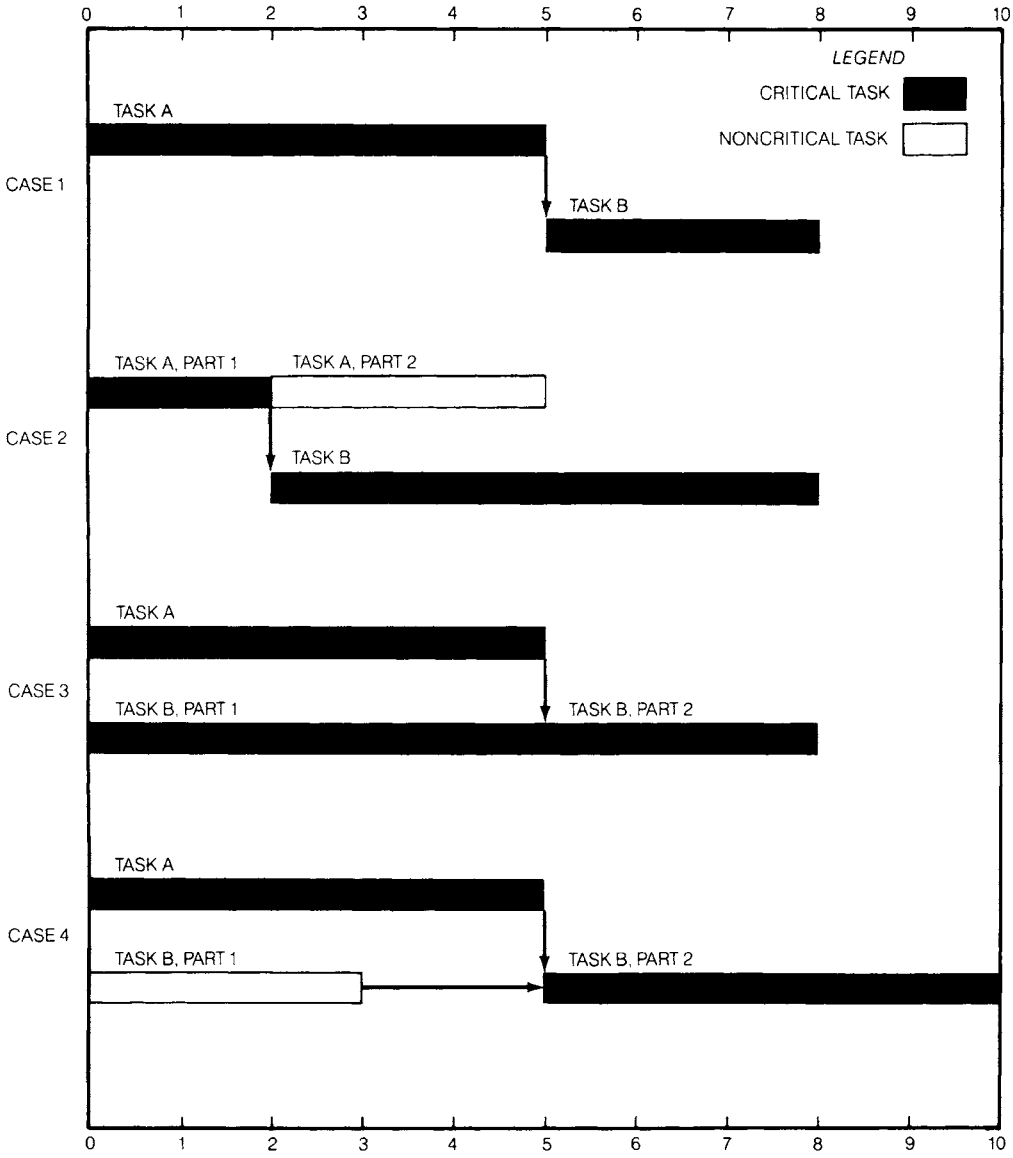


Illustration A-5: Critical Path Diagram

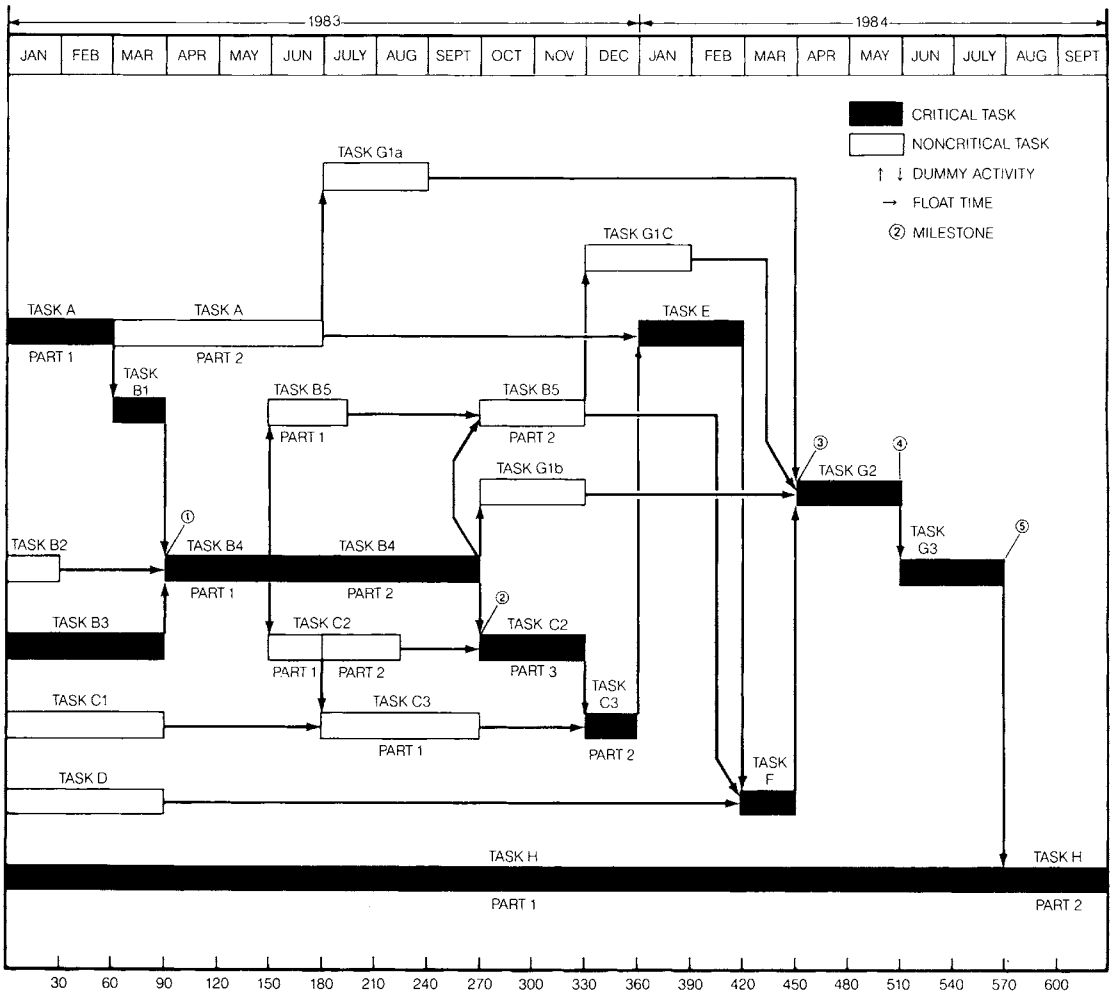


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Chart: Standard Forms of Construction Contract and their Application

Type Of Construction Project Delivery	Contract Form
"Design-Bid-Build"	**CCDC 2** *Stipulated Price Contract*
"Time and Materials"	**CCDC 3** *Cost Plus Contract (percentage or fixed fee)*
"Maximum Upset Price"	**CCDC 3** *Cost Plus Contract (guaranteed maximum price)*
Unit Rates	**CCDC 4** *Unit Price Contract*
Construction Management	**CCDC 5a** *Construct Management Contract — For Services* **CCDC 5b** *Construction Management Contract — For Services and Work*
Design-Build	**CCDC 14** *Design-Build Stipulated Price Contract*
Project Management	n/a

Note: This is a very simplified representation of various types of construction project delivery as well as different pricing mechanisms and contract forms.