

**ADDIS COLLEGE
CONSTRUCTION MANAGEMENT MASTER'S PROGRAM**

Advanced Construction Quality, Cost and Time Management (COTM 6202)

5. Construction Contract and Project Time and Cost Issues

Organized by: Belachew Asteray (Ph.D.)

Feb 2020

5. Construction Contract and Project Time and Cost Issues...

- In general, a Contract is
 - an **agreement** or ***willful promise*** between two parties
 - legally **enforceable at law** for both parties
 - obligations to be distinct from those required by law.
- “**Enforceable at law**” means that if the agreement reached between the two parties breached (deviations occur from the promises) by one of the parties, the aggrieved party may bring **a legal action against the other** to demand the enforcement of its rights with the support of law.
- However, not all agreements or promises **are contracts**. Some may **lack enforceability at law**.

5. Construction Contract and Project Time and Cost Issues...

- The general ***Law of Contract*** is governed under the Civil Code from Article 1675-Article 2026.
- A contract is
 - an agreement whereby **two or more persons** as between themselves **create, vary or extinguish obligations** of a proprietary nature (Article 1675 of the Civil Code).
- The definition contains the following elements:
 - the contract is **an agreement**;
 - The agreement is to be made **between two or more** persons;
 - the agreement is **binding between such** two or more persons;
 - The agreement is to **create, vary & extinguish obligations**;
 - The agreement is to create **obligations**;
 - That the nature of obligations is **proprietary**.

5. Construction Contract and Project Time and Cost Issues...

- According to Article 1678 (**Elements of Contract**) of the Civil Code:
- No valid contract shall exist unless
 - a. The parties are **capable of contracting** and give their **consent** sustainable at law.
 - b. The **object of the contract** is sufficiently defined and is possible and lawful.
 - c. The contract is made in the **form** prescribed by law.
- The following are the fundamental elements of contract:
 - **Capacity** of the contracting parties;
 - **Consent** of the contracting parties;
 - **Object** of the contract; and
 - **Form of contract**, if any;

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• Components of Construction Contract Document...

- **Project Description:** a blurb or extract of what the project is about
- **Contract Price:**
 - the type of contract price been awarded and
 - the total amount of money being contracted.
- **Payment Basis:**
 - **How** the money is going to be paid to the service provider.
 - Either on a monthly basis or whatever payment method is preferred, it should also specify what percentage of money should be retained on every application for payment.
 - It will also define when the payment is due, the penalty for late payments, interest being accrued and other applicable situations related to the payment and invoicing terms.
- **Construction Schedule or Calendar:**
 - The total of days or how the project schedule will be divided.
 - It should describe either calendar days or business days and can be presented either through a CPM, Gantt Chart, or just a bar chart.
- **Contract Document List:**
 - A list of all contract documents that form part of the contract agreement.

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• Components of Construction Contract Document...

• **Construction Scope:**

- Description of all activities including some descriptions of things that will form part of the project. The scope normally can be measured or quantifiable.

• **Construction Conditions & Responsibilities:**

- The section of conditions and responsibilities is the one that sets responsibilities for the owner and the contractor, and the extents of who is responsible for providing documents and information.
- It contains specific terms for liens, penalties, withholding, arbitration rules and specific instructions on how to process claims and proceed with disputes.

• **Contract Laws:**

- Governing laws, liens requirements, claims procedures, arbitration procedures, insurance, substantial completion requirements, final completion, and liquidated damages.
- It can also provide procedures on how to terminate or suspend the work and the agreement with the contractor.

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- **Components of Construction Contract Document...**

- **Conditions of Contract**

- **Construction Contract:** Conditions of contract are terms which rule the relationships between the owner and the contractor, define each party's rights and obligations, specify method of payment and determine actions required when existing any disputes between the owner and the contractor.

- **General Conditions of Contract:** They are **standard terms** that suit the majority of projects, they include:

- Definition of the project
- Contract components
- Rights and responsibilities for the owner and the contractor
- Project schedule
- Payment method
- Warranty and delay penalty

5. Construction Contract and Project Time and Cost Issues...

- **Components of Construction Contract Document...**

- **Special Conditions of Contract**

- They are the modifications required to suit the uniqueness of the project, make the contract flexible for the nature of the project and achieve project objectives.
- This is usually an extension of the contract and an addendum to the general conditions.
- It should specify certain conditions and clauses that pertain to each particular project or job.
- Pay special attention to specific instructions and requirements on how to perform the work.

- **Signed Technical Proposals/documents**—Approaches and Methodology,

- **Signed Financial Proposals-**

5. Construction Contract and Project Time and Cost Issues...

- **Factors which affect the selection of construction contract are:**

1. **Project objectives:**

- The type of contract should meet with project objectives.

2. **Project constraints:**

- There is no any construction project without constraints.
- Thus, project constraints should be considered while selecting type of construction contracts.

3. **Project delivery method:**

- Project delivery method **determines the relationships between parties getting involved in the project** and how they interact with each other from project initiation to project closure.

5. Construction Contract and Project Time and Cost Issues...

- **Construction Contract**

- **Project Time Issues**

- **Contract time**

- **Delay**

- **Acceleration**

- **Time extension**

- **Optimization of contract time**

- **Project Cost Issues**

- **Contract price**

- **Scope Change**

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Advanced Construction Quality, Cost and Time Management (COTM 6202)

6. Project Quality-Cost-Time Tradeoff Analysis

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6. Project Quality-cost-time Tradeoff Analysis...

- **Quality, Cost, and Time** become an Iron Triangle *for measuring project success.*
- Many researchers have investigated about Quality-Cost-Time in a Project Network *under uncertainty*, particularly it focuses on
 - **single parameter** (Quality/Cost/Time only) or
 - **combination between parameters** (trade off or relation between parameters).
- Knowing the probability to meet these three targets is important, especially *during the project planning.*
- Management can gain information insights about the confidence level to meet the target and potential risk in the future.

6. Project Quality-cost-time Tradeoff Analysis...

- **Time, cost, and quality** of an activity are interrelated and have impacts on each other since the reduction or increase of one factor would be at the expense of the other.
- Usually, utilizing resources that are *more expensive to complete an activity* **increases its direct cost** and reduces its duration.
- On the other hand, the activity duration usually increases and its direct cost decreases when **less expensive resources** are used.
- **Quality** has a **strong impact on both time and cost** of construction activities.

6. Project Quality-cost-time Tradeoff Analysis...

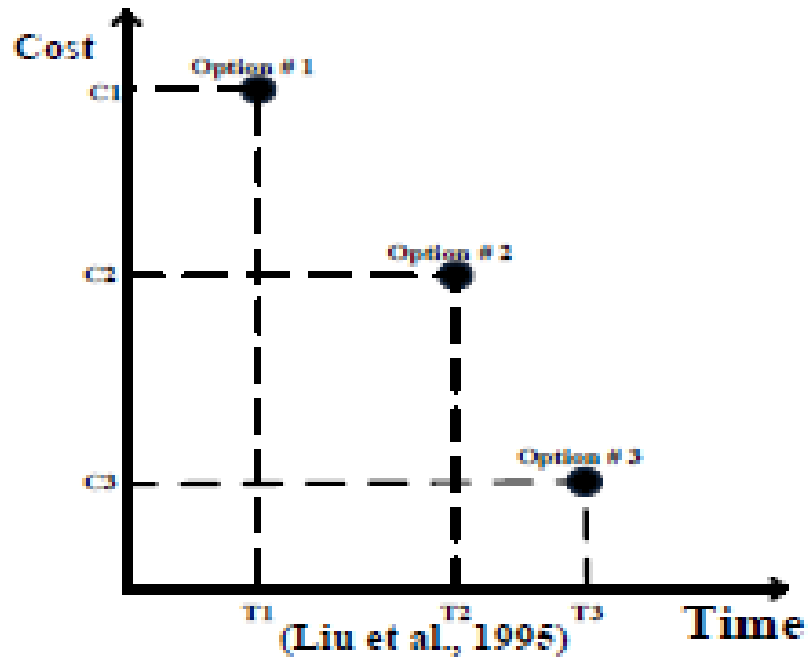
- For instance, *improving quality may increase the cost and duration of projects*; however, poor quality management will significantly increase the cost and time of projects because of
 - the *additional time and money* required for repairs, rework, or removal of low quality defects, which are much higher than using *strict quality control procedures*.
- *Activities' durations increase* when using *quality control procedures* such as tests or inspection procedures
- but low quality control does not reduce durations since the *time needed to solve a problem or repair a defect* may be much longer than the time spent in quality control procedures.

6. Project Quality-cost-time Tradeoff Analysis...

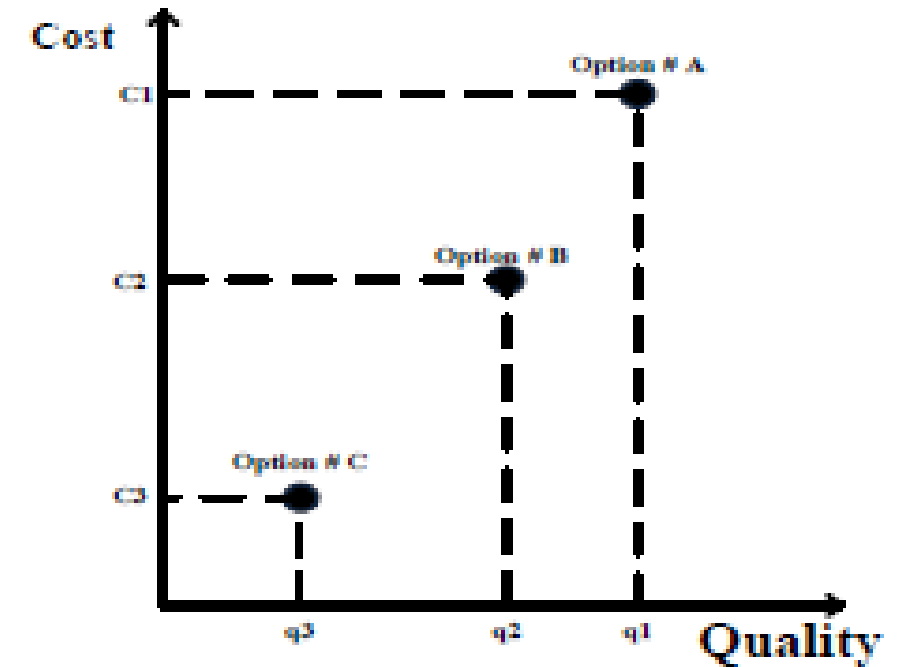
- Duration, cost, and quality of an activity *are affected by*
 - the utilized construction method,
 - crew formation,
 - materials, equipment and subcontractors,which *create many options to complete the work* of such an activity.

6. Project Quality-cost-time Tradeoff Analysis...

Fig Time-cost and quality-cost relationships for the activity level



- For the **time-cost relationship** in the Figure,
- executing the activity using **option 1** results in *a reduced duration and a higher cost*;
- however, executing it utilizing **option 3** results in *a longer duration and a less cost*.



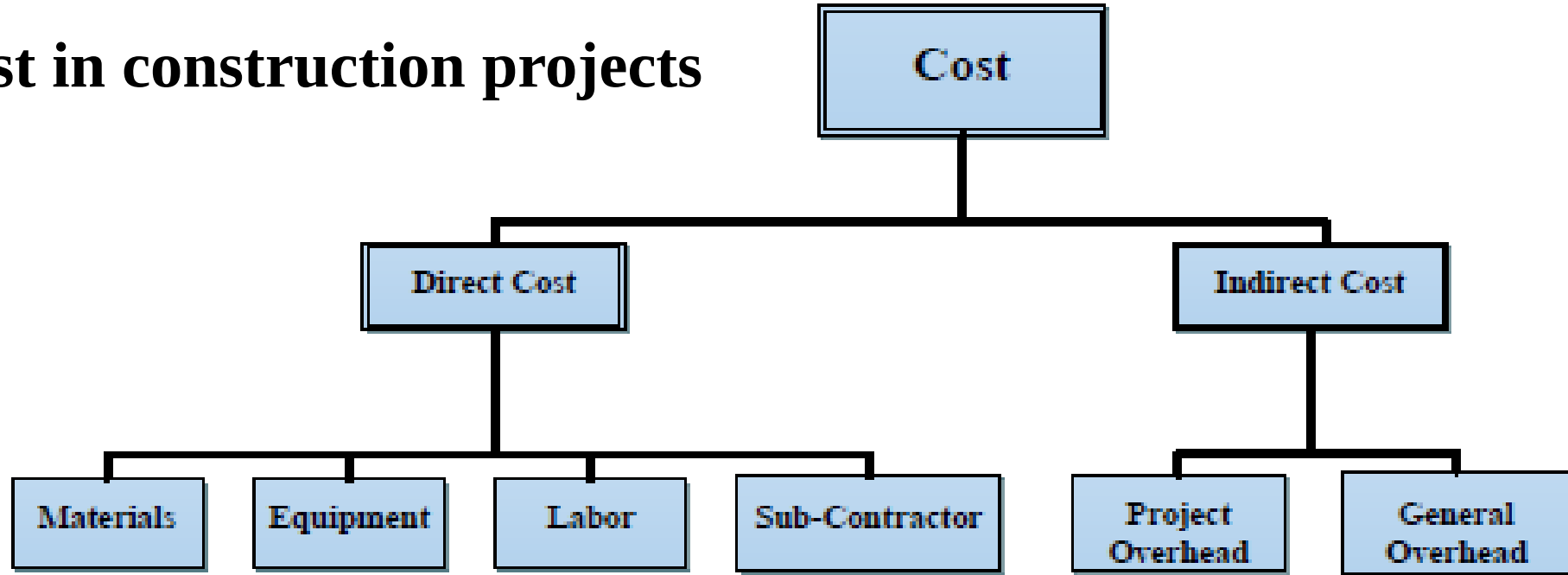
- For the quality-cost relationship,
- executing the activity using **option A** results in *improved quality and a higher cost*;
- however, executing it utilizing **option C** results in *poor quality and a less cost*.

6. Project Quality-cost-time Tradeoff Analysis...

- On the other hand, the *time-quality relationship cannot be represented by a general relationship*.
- For instance, *applying poor quality control procedures* to an activity may reduce its duration;
- however, *utilizing an advanced construction method* may also
 - *reduce the activity's duration* and
 - increase its quality performance as well.

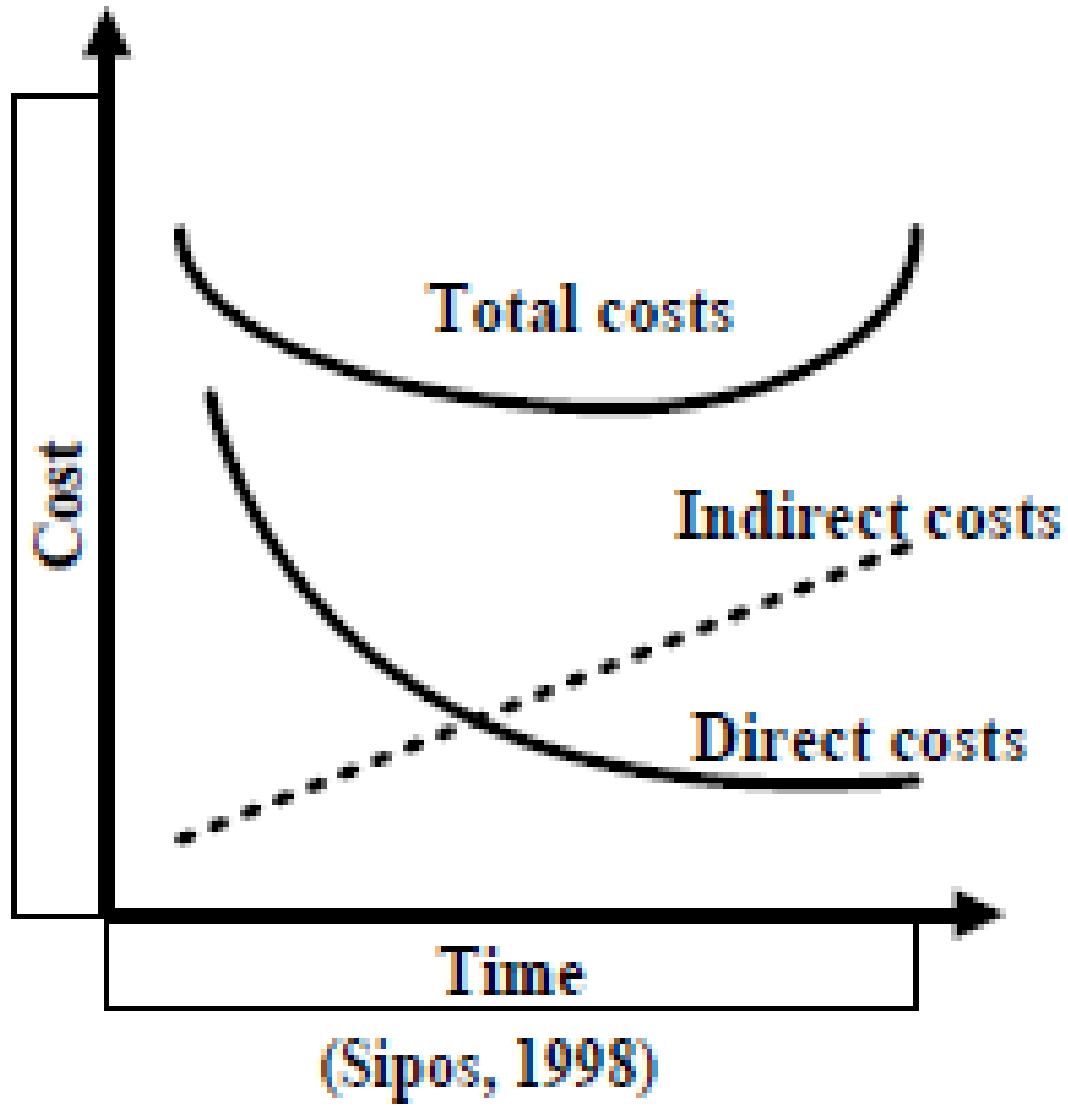
6. Project Quality-cost-time Tradeoff Analysis...

Types of cost in construction projects



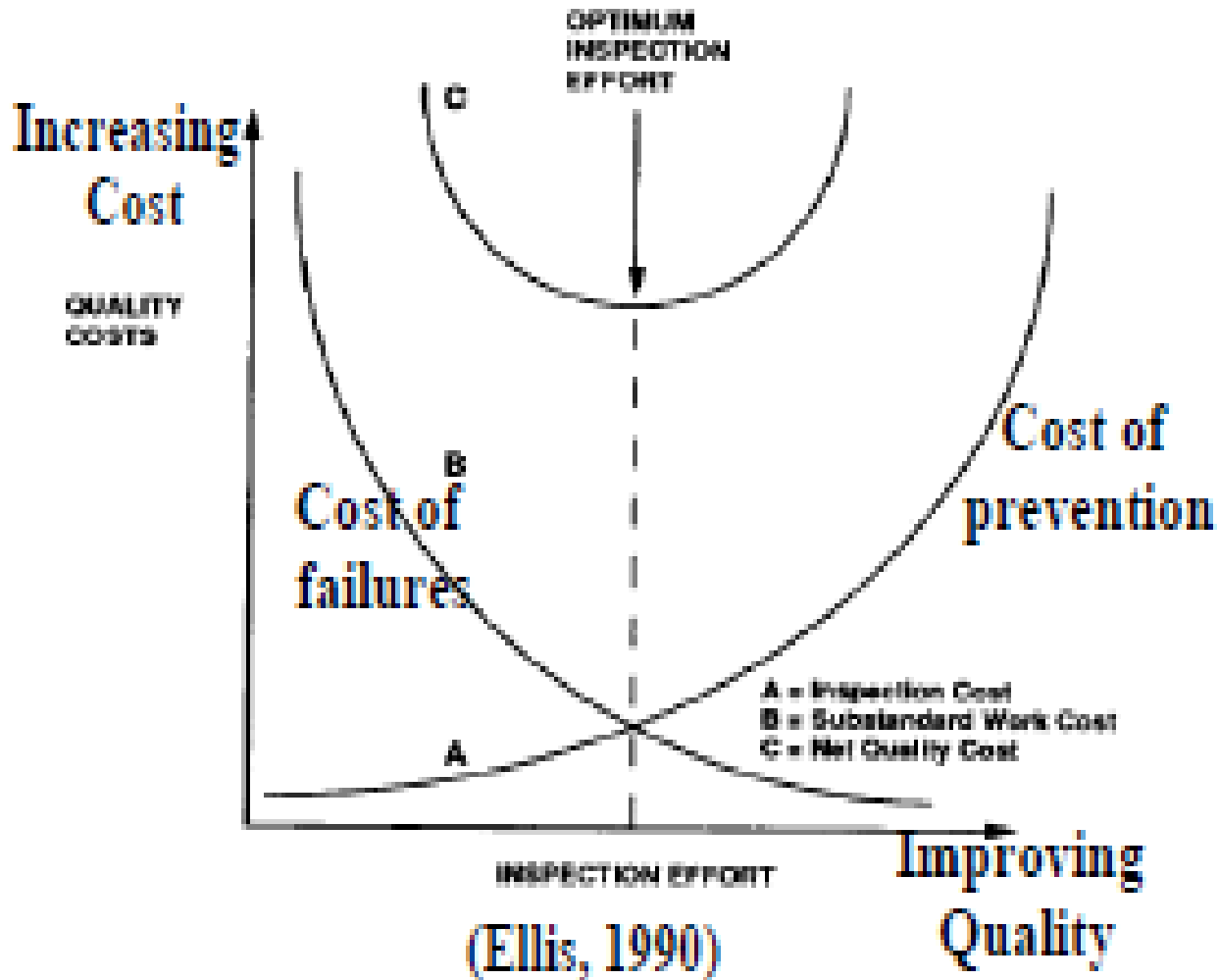
- For the project level, the **total project direct costs**, which include the costs of materials, labor, equipment, and subcontractors, usually **increase when the project is accelerated**.
- The total project **indirect costs**, which are usually proportional to the project duration, **decrease when its total duration is reduced**.

6. Project Quality-cost-time Tradeoff Analysis...



- To obtain *the total project time-cost relationship*, the direct and indirect time cost relationships are combined as shown in the Figure.

6. Project Quality-cost-time Tradeoff Analysis...



- **Costs of prevention or appraisal**, which are the costs of quality control procedures undertaken to ensure that the project meets a desired quality level or **to avoid defects or failures**, increase when the project quality is improved.
- **Costs of failures**, which are the costs associated with rework or repairing defects, decrease when the project quality is improved.
- The **optimum cost of quality** of projects is obtained as shown in the right part.

6. Project Quality-cost-time Tradeoff Analysis...

- *What is time-cost trade-off analysis?*
- Time-cost trade-off analysis (TCT) or Time-cost optimization is considered *one of the most important features of projects' planning and controlling*.
- The *main idea of time-cost trade-off analysis* is
 - *to strike a balance* between
 - the *decreased indirect costs* and *the increased direct costs* of activities *when the project is accelerated*.

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- According to Hegazy (2002) and (2006), **time-cost trade-off analysis may be applied to accelerate construction projects** for one or more of the following reasons:
 1. There is a **predefined deadline date to be met**.
 2. There is a **bonus incentive for early completion**.
 3. There is a **penalty for late completion**.
 4. **Minimizing indirect costs and overhead costs**.
 5. Costs of additional resources for accelerating the construction process are minor.
 6. The owner loses income for every day the project is incomplete, in money producing investment projects such as hotels or factories.
 7. There is a possibility of signing a more profitable **contract**.
 8. Lower risk of inflation, labor shortage, and weather conditions if the project duration is shortened.
 9. **Improve the project cash flow.**

6. Project Quality-cost-time Tradeoff Analysis...

- *Time-cost-quality trade-off Analysis*
- In traditional **time-cost trade-off analysis**, despite its significant impact on the total cost and duration of construction projects, **quality was not considered**.

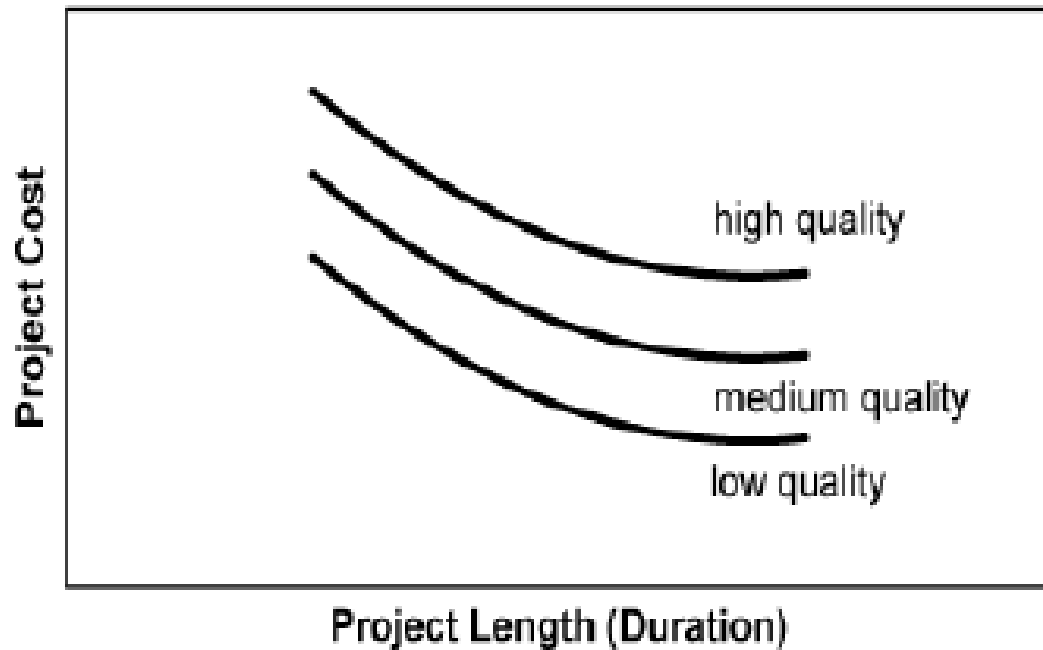


Figure: time-cost trade-off analysis for different quality levels (Pollack-Johnson & Liberatore, 2006)

As shown in the Figure, different **time-cost trade-off analysis** curves for different quality levels illustrate that *the curve of a higher quality level lies above and to the right of that for a lower quality level*.

- Therefore, the *quality performance* of each execution option or construction method should be incorporated into the trade-off analysis.

6. Project Quality-cost-time Tradeoff Analysis...

- *Time-cost-quality trade-off Analysis...*
- In other words, it is required *to convert the traditional two-dimensional Time-cost trade-off analysis into an advanced three dimensional *time-cost-quality trade-off analysis (TCQT)*.*
- The *main purpose* of *time-cost-quality trade-off analysis* is
 - to determine an optimal or near optimal trade-off among the total cost, time and quality of a considered project,
 - which means *to complete the project before a defined deadline*, while its total cost is minimized and its *overall quality is maximized*.

6. Project Quality-cost-time Tradeoff Analysis...

- *Optimization techniques for Time-cost-quality trade-off Analysis problems*
- **Optimization** is the *process of finding the best available values of an objective function* given a defined domain or optimization variables, and subjected to optimization constraints (Ng & Zhang, 2008).
- Optimization *tries to find the best solution of a problem* that has many alternative solutions.
- Most common optimization techniques utilized for *Time-cost-quality trade-off Analysis* problems are categorized as follows:
 1. *Heuristic Methods*
 2. *Mathematical Methods*
 3. *Evolutionary Algorithms*

6. Project Quality-cost-time Tradeoff Analysis...

- **Heuristic Methods**
- Heuristic methods are ***non-computer approaches*** that rely on the ***rule of thumb of decision makers*** to find ***an optimal or near optimal solution***.
- Heuristic methods are divided into:
 1. **Serial heuristic**: “in which ***processes are first prioritized*** and retain their values throughout the scheduling procedure”.
 2. **Parallel heuristic**: “in which ***process priorities are updated each time*** a process is scheduled”.
- Despite the simplicity, the ease of application, and the small computational efforts, there are ***difficulties and disadvantages*** associated with utilizing heuristic methods.
- For instance, they do not guarantee optimality, and they are ***effective only for linear relationships***.

6. Project Quality-cost-time Tradeoff Analysis...

- **Mathematical Methods**
- Mathematical methods demonstrated *computational efficiency, accuracy, and robustness* compared to heuristic methods.
- They *convert optimization problems into mathematical models* containing objective functions, decision variables, solution domains, and constraints.
- Mathematical methods include *linear programming, integer programming, and dynamic programming*.
- **Linear Programming**
 - Linear programming (LP) is a *special case of mathematical optimization appropriate for problems whose requirements are represented by linear relationships*.
 - It assumes that the optimum solution can be obtained at any point.
- **Integer Programming**
 - Integer programming (IP) is an optimization technique in which *some or all of the variables must be an integer*.
 - It is *appropriate for problems with both linear and discrete relationships*.
 - It *requires excessive computational efforts*, particularly for problems containing a large number of variables or a large searching space.

6. Project Quality-cost-time Tradeoff Analysis...

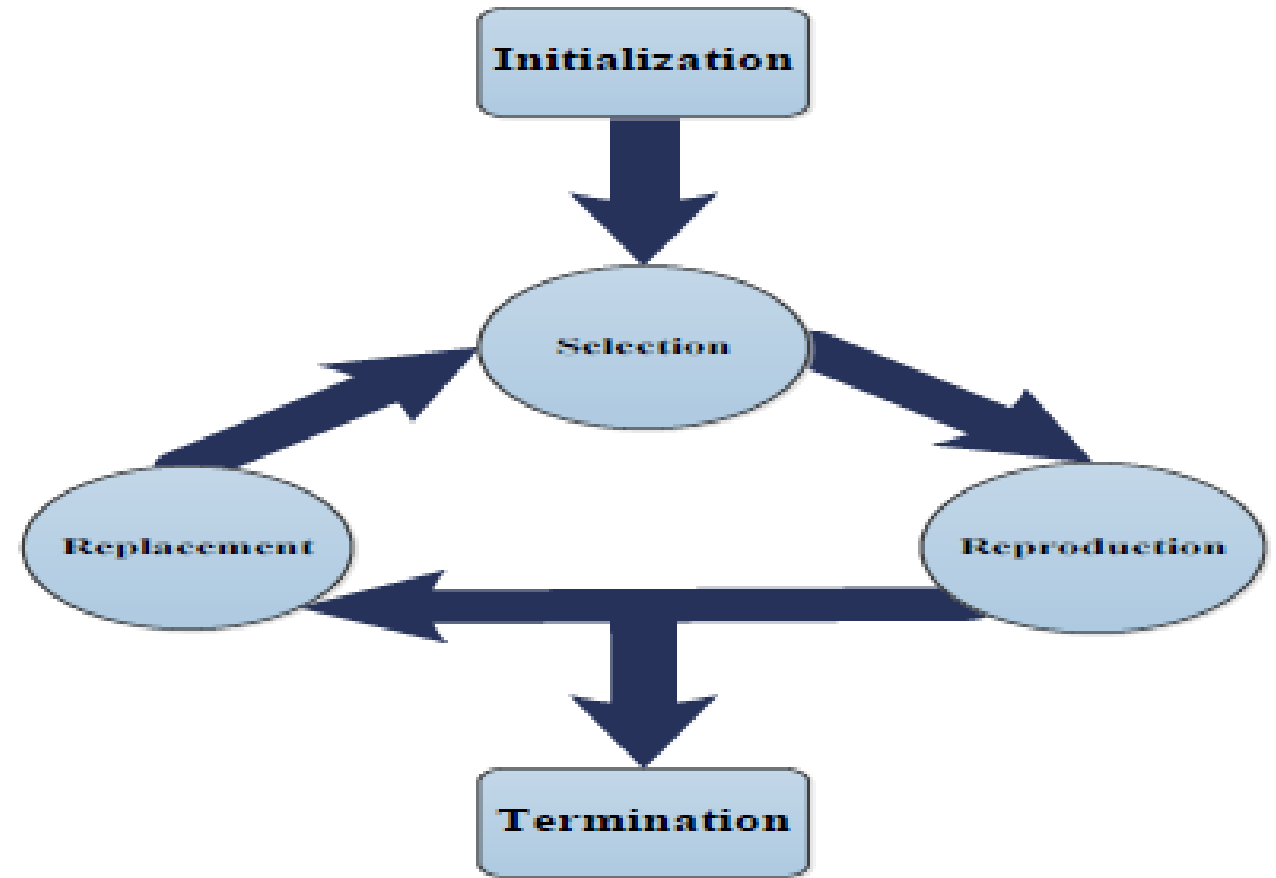
- Mathematical Methods...
- Dynamic Programming
 - Dynamic programming (DP) is a technique *for optimizing complex problems by breaking them down into simpler sub-problems*.
 - It starts with a small part of the problem to find its optimal solution; such a solution is then utilized to find an optimal solution for a larger part of the problem until the whole issue is solved (Ezeldin & Soliman, 2009).
 - Dynamic programming is *appropriate for networks that can be divided into series or parallel sub-networks*.
 - **Disadvantages:** Despite its efficiency, *complexity of formulation and lack of a general algorithm* are limitations of the dynamic programming technique.
- Generally, mathematical programming techniques *cannot obtain optimal solutions for large-scale projects*.
- They do *not guarantee an optimum solution* and may be trapped in a local optimal solution.
- Furthermore, the process of *formulating constraints and objective functions* is prone to errors.
- They also cannot handle more than one objective.

6. Project Quality-cost-time Tradeoff Analysis...

- Evolutionary Algorithms
- Evolutionary algorithms (EA) are *stochastic search methods* that *mimic the metaphor of natural biological evolution* and *the social behavior of the species*.
- These algorithms were developed in order to find optimum or near optimum solutions for large-scale problems with a *large search space*.
- The most *commonly used Evolutionary algorithms techniques* are
 - Genetic Algorithms (GA).
 - Memetic Algorithms (MA),
 - Particle Swarm Optimization (PSO),
 - Ant-Colony Optimization (ACO), and
 - Shuffled Frog Leaping Algorithms (SFL).
- Amongst the above various Evolutionary algorithms techniques, *Genetic Algorithm has been extensively utilized for optimization problems* in general and construction management problems in particular.

6. Project Quality-cost-time Tradeoff Analysis...

- **Genetic Algorithm**
- It was first proposed by John Holland based on *principles inspired by natural genetics*.
- It is a **computerized search method** that was developed based on the principle of “*the survival of the fittest*” and the natural process of evolution through reproduction.



The main phases and operators of GA

6. Project Quality-cost-time Tradeoff Analysis...

- Advantages and disadvantages of GA

Genetic Algorithms	
Advantages	Disadvantages
Effective for searching optimal solutions under uncertainties	Excessive computational efforts
Appropriate for problems with multiple objectives	Sophisticated computerized processes are needed
Widely used for engineering and construction management optimization problems	Excessive processing time for large-scale problems
Capable of searching multiple areas simultaneously within a single run	Tendency to converge towards a local optima in some problems
Acceptable balance between exploration and exploitation during the search process	Stop criterion is not clear in every problem

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- **Multi Objectives Optimization Approaches**
- Multi objectives optimization (MOO) deals with problems that have more than one objective function which are to be *maximized or minimized*.
- Three MOO approaches, which are commonly used for engineering and construction optimization problems, are
 - Goal Programming
 - Pareto Optimum

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- Goal Programming
- It is considered an **extension of the LP method**, which seeks to simultaneously handle multiple conflicting objectives.
- Schematic procedures of GP are as follows:
 1. An **objective function** for each objective is formulated
 2. A **specific numeric target** for each objective is set.
 3. A **weight for each objective** is identified *to describe its relative importance with respect to other objectives*.
 4. A **combined objective function is formulated** to find a solution that minimizes the weighted sum of deviations of these objective functions from their respective numeric target.

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- The objective function is formulated as follow:

$$\text{Min } \sum_{k=1}^n W_1 d_1 + W_2 d_2 + \dots \dots W_n d_n$$

- Where
 - W1 to Wn are **weights corresponding to objective goals** and
 - d1 to dn are **deviations from target goals for each objective.**
- **Advantages and Disadvantages of Goal Programming**

Advantages	Disadvantages
Simplicity, flexibility, and ease of use	Assumptions of weights of objectives are not subjective
Suitable for single and multi-objectives optimization	Difficulty of determining a target value for each objective in some problems
Capability of handling large numbers of variables, constraints and objectives	Tendency for obtaining inefficient solutions (alternative better optimum solutions may be available)

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- Pareto Optimum
- Using the concept of dominance, it is commonly used *to solve MOO problems, where it is not possible to have a single solution that simultaneously optimizes all objectives.*
- According to the Pareto optimum, a solution (I) dominates another solution (II) if
 - solution (I) is no worse than solution (II) in all objectives, and
 - *solution (I) is better than solution (II) in one objective* at least.
- A Pareto front or Pareto set could be defined as *a set of solutions that are not dominated by any member of the entire feasible search space.*
- Therefore, solutions are chosen as optimal *if no objective can be improved without deteriorating the performance of at least one other objective.*
- For MOO problems, a Pareto front is established to provide a set of non-dominated solutions, instead of an individual optimum one, for the final selection by decision makers.

- **Semester Projects: Urban Infrastructures**
 - **Software for Project work**
- **MS Project**
 - **Earned Value Analysis**
 - **Performance Index**
- **Primavera**
- **MatLab**
 - **Optimization using Evolutionary Algorithms**

- Thanks!

- Questions????