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INSTITUTE OF SCIENCE AND TECHNOLOGY
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SCHOOL OF BUILDING & ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

UNIT – I –Construction Operations Management– SARA5301

Construction Operations Management– SARA5301

SYLLABUS

UNIT 1 OPERATIONS PLANNING 9 Hrs

Introduction to OM, facilities and capacity planning plant lay-out design SLP, ALDEP, CORELAP, learning curves and location analysis; Production shop - types, assembly line, and theory of constraints; Material requirement planning (MRP) - master production schedule (MPS), bill of material (BOM), and planning process; Aggregate planning - medium term capacity management, manipulation of demand and supply, chase and level strategies; Business Economics.

UNIT 2 OPERATIONS SCHEDULING 12 Hrs

Operations scheduling - job order scheduling, heuristics for decision rules, Decision Analysis & Modelling ,Moore's, Johnson's procedure, Economic Common Cycle Scheduling (ECC scheduling).

UNIT 3 INVENTORY MANAGEMENT 9 Hrs

Introduction to inventory management - ABC analysis, Economic Order Quantity (EOQ) Models and it's variants, inventory control under uncertainty; Logistics Management, Supply Chain Management, Warehouse Management, Value Engineering Concepts,

UNIT 4 PRODUCTIVITY 9 Hrs

Productivity and work-study - time study, Just in Time (JIT), Kanban System, method study, wage incentive plans, work sampling; Break even analysis; Forecasting.

UNIT 5 CONSTRUCTIVE ASSIGNMENTS 6 Hrs

ABC analysis for a small project and logistics planning with application of relevant concepts.

Max. 45 Hours

Course objectives

- To acquire vital competencies in production, operations & distribution management, leading to an improvement in job skills.
- Apply concepts of operations management such as Warehouse Planning, Operations & Supply Chain Strategies, and New Product Development.
- Learn to create a balance between operations and supply expertise and general business knowledge by disseminating new techniques in the area of operations management.

Course Outcomes

1. CO1 Interpret the planning of operations as per demand and supply.
2. CO2 Predict the flow of materials and effectively take decisions for streamlining operations.
3. CO3 Skillfully plan and control the process of transformed resources as they move through supply networks, and operations.
4. CO4 Demonstrate the application of the strategic concepts from the perspective of an organization or business unit level.
5. CO5 Assess productivity with different methods and analysis.
6. CO6 Analyze and evaluate business operations using basic quantitative analysis techniques.

COURSE SUMMARY

UNIT 1 OPERATIONS PLANNING

1. Plant lay-out
2. Design SLP
3. ALDEP
4. CORELAP
5. Learning curves
6. Location analysis
7. Production shop
8. MRP
9. MPS
10. BOM
11. Planning process
12. Capacity Planning
13. Aggregate planning
14. Chase and level strategies
15. Business Economics

UNIT 2 OPERATIONS SCHEDULING

1. Operations scheduling
2. Heuristics for decision rules
3. Decision Analysis & Modeling
4. Moore's & Johnson's procedure,
5. Economic Common Cycle Scheduling (ECC scheduling).

UNIT 3 INVENTORY MANAGEMENT

1. Supply Chain Management,
2. Inventory management
3. Economic Order Quantity (EOQ) Models and it's variants,
4. Inventory control under uncertainty;
5. Logistics Management,
6. Warehouse Management,
7. Value Engineering Concepts

UNIT 4 PRODUCTIVITY

1. Productivity
2. VSM
3. Just in Time (JIT)
4. Kanban System,
5. Wage incentive plans
6. Work sampling;
7. Break even analysis
8. Forecasting.

UNIT 1 OPERATIONS PLANNING

MODULE 1 INTRODUCTION TO COM

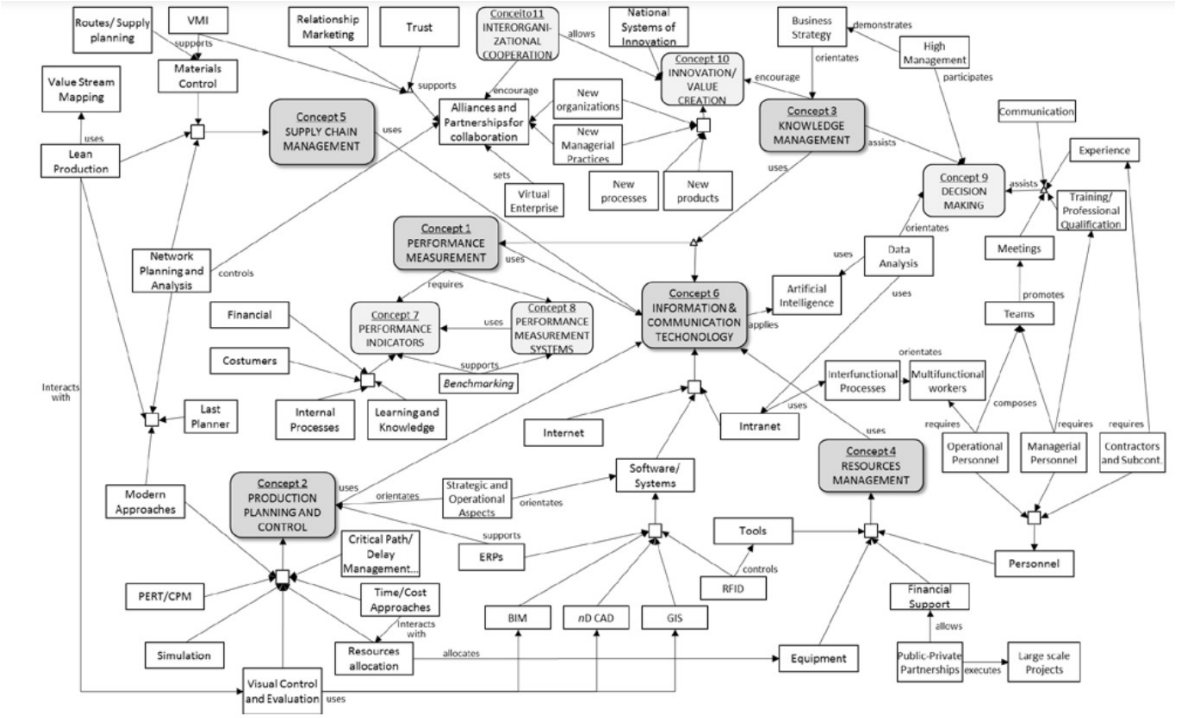
1. JOB PROFILE

Examples of Job profile posted in websites and required in the industry.

WHAT IT TAKES TO BE AN OPERATION MANAGER?

- Work hand-in-hand with the project team to create a mutual understanding of the project strategy based on the requirement of the job
- Conduct in-depth reviews and analysis of all project or contract documents so as to be familiar with every detail and/or requirements
- Work with safety units in a bid to plan and manage safety programs for each project and make sure that all aspects of safety are reached
- Help project managers and engineers in the arrangement and analysis of projects and scheduling of reports on projects
- Oversee projects as they are being carried out to make sure that the work is done according to outlined specifications, and that they also conform with project timetable
- Convey project needs from the project manager to the management of the firm. For example, in a case whereby extra funds are needed for the completion of a project, the project manager communicates the situation to the management of the company usually through the construction operations manager
- Assist in the maintenance, development, and enhancement of the company's relationship with contractors in a bid to produce strategic partnership
- Train and mentor employees in areas of project management and estimating.

2. UNDERSTANDING THE PROCESS



3. THE CONTEXT OF COM

- Construction is an activity of great importance for a country's economy, acting in the execution of residential and commercial buildings, infrastructure works and the diverse services related.
- Currently there are high investments in infrastructure works, especially in developing countries, the Large Scale Construction Project
- Although it is a very traditional economic activity, it is known that construction is still seen as a low efficient sector
- The conflict between predetermined schedule and unpredictable reality results in significant wastes in the system.
- The enhancement of a works size and the uniqueness of each big project enhance the complexity for the management of operational aspects in construction
- The construction systems can be classified as Make to Order (MTO), for the execution of pre-established projects ,or Engineered to Order (ETO), for the execution of a work, including its conception

- Large Scale Construction Projects are generally ETO systems.
- This way, the operational management of the construction processes is a fundamental aspect for the efficiency enhancement desired by the sector.
- But, this knowledge area still does not have an integrated framework for concepts and practices.
- There is a great number of initiatives, tools and models found in the literature to support some aspects of the management processes in an independent way
- Concepts Model representing the State of the Art of Operations Management for Construction.
- It consists of the main background to reach the result desired.
- Research Framework for Operations Management in Large Scale Construction Projects.
- This framework can be considered an innovative approach for these fields – the Operations Management discipline in ETO systems and the Construction Sector.
- The innovative approach comes from the background of collaborative networks and Virtual Enterprises, refining, grouping and reorganizing. Operations Management focuses on the execution of a production system.
- As Vollmann et al. (2006, p. 83) delimitates, it represents "the mission that the production should realize to achieve the firms strategic goals".
- This way, Operations Management contemplates a series of decision areas.
- Some authors, as Pillkington and Meredith (2009), made some bibliometric analysis of the publications from this knowledge area, from 1980 to 2006, identifying the main subjects as:
    - Manufacturing Strategy
    - Quality and its Metrics
    - Statistical Methods
    - Process Design
    - Services
    - Qualitative Methods
    - Supply Chains
    - Product/Service Innovation
    - RBV (Resources Based View)
    - Measures/Balanced Scorecard, and
    - Inventory Control

4. DECISION AREAS

- In a similar study, Taylor and Taylor (2009) found as the main topics for the Operations Management discussions, between 2004 and 2009:

1. Supply Chain Management,
2. Operations Strategy,
3. Performance Management,
4. Service Operations,
5. Lean Methods,
6. Resources Planning Systems,
7. Quality Management and
8. Product Development/Design

- Choudhari, Adil e Ananthakumar (2010) purposes in its research framework, six broad decision areas for production systems, that includes many of the subjects mentioned above:

1. Production Planning and Control
2. Organizational structure and control
3. Human Resource
4. Facilities
5. Sourcing and
6. Process Technology

- The majority of the classifications presented are generalizations and they cope mostly with traditional systems of manufacturing and services.
- Other studies discuss

1. inter-firm relationships
2. the integration with lean competences
3. marketing

SELECTED DECISION AREAS

The areas are:

1. Production Planning and Control

2. Resources Management – personnel, equipments and tools
3. Knowledge Management – innovation and competences
4. Supply Chain Management (SCM) – relations in the chain, materials sourcing and inventory control
5. Performance Measurement
6. Information and Communication Technology (ICT)

1. Production Planning and Control

- Techniques used to plan the operational activities in the construction sector

The most frequent practices were:

- simulation, delay analysis,
- critical path method (CPM) and
- resources levelling.
- All of these techniques are very well known, specially the CPM that has evolved through the time, with computational applications based on its principles

2.Resources Management

- Transformation agents (personnel, financial support, materials and equipment).
- The discussions made about these four aspects are:

1. to organize,
2. train, make teams and manage people;
3. the use of public-private partnerships to provide financial support (big projects);
4. the best way to select and manage materials and equipment

3.Knowledge Management

- Processes of Decisions making - especially considering the business strategy
- The main discussions are about

1. the managerial function,
2. the identification of the most valuable knowledge of the enterprise and
3. the use of meetings as a way to exchange experience

3.Supply Chain Management

- Materials control,
- logistics and its fields,
- marketing,
- inventory,
- application of lean principles (to the improvement of the production flow) and
- partnering relations between participants of the chain

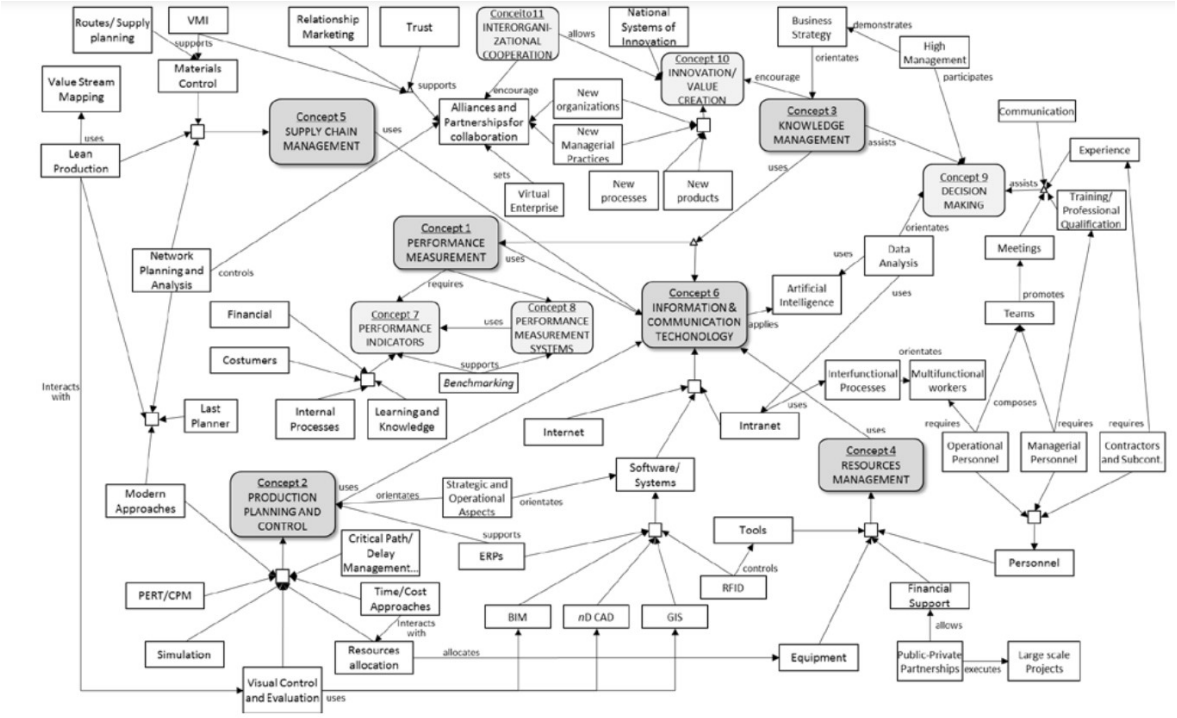
5.Performance Measurement

- Performance Indicators and Systems focused on the operational level, on the performance of a single enterprise, or on a single phase of the Construction Life Cycle

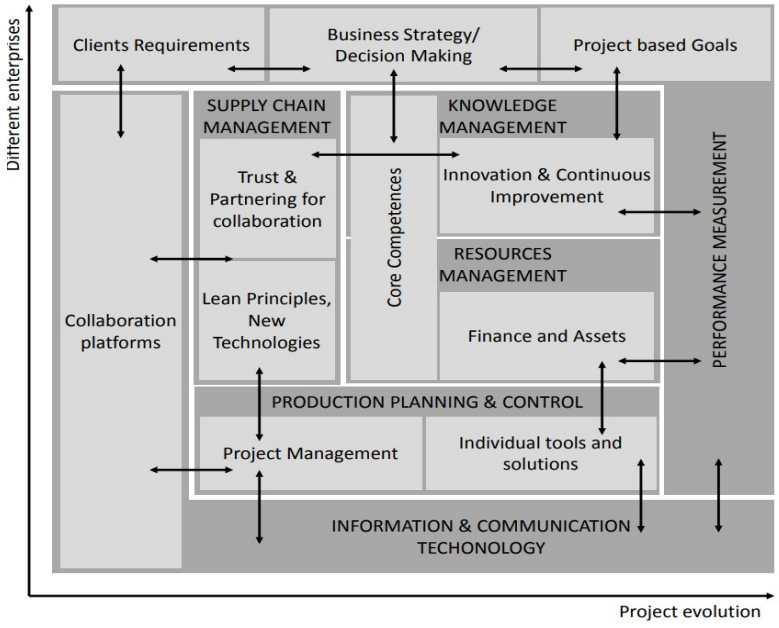
6. Information and Communication Technology

- What Is Enterprise Resource Planning (ERP)?
- Enterprise resource planning (ERP) is a process used by companies to manage and integrate the important parts of their businesses.
- Many ERP software applications are important to companies because they help them implement resource planning by integrating all of the processes needed to run their companies with a single system.
- An ERP software system can also integrate planning, purchasing inventory, sales, marketing, finance, human resources, and more.
- ERP software can integrate all of the processes needed to run a company.
- ERP solutions have evolved over the years, and many are now typically web-based applications that users can access remotely.
- Some benefits of ERP include the free flow of communication between business areas, a single source of information, and accurate, real-time data reporting.
- An ERP system can be ineffective if a company doesn't implement it carefully.

5. Concepts Model for Operations Management



1.Collaborative Network

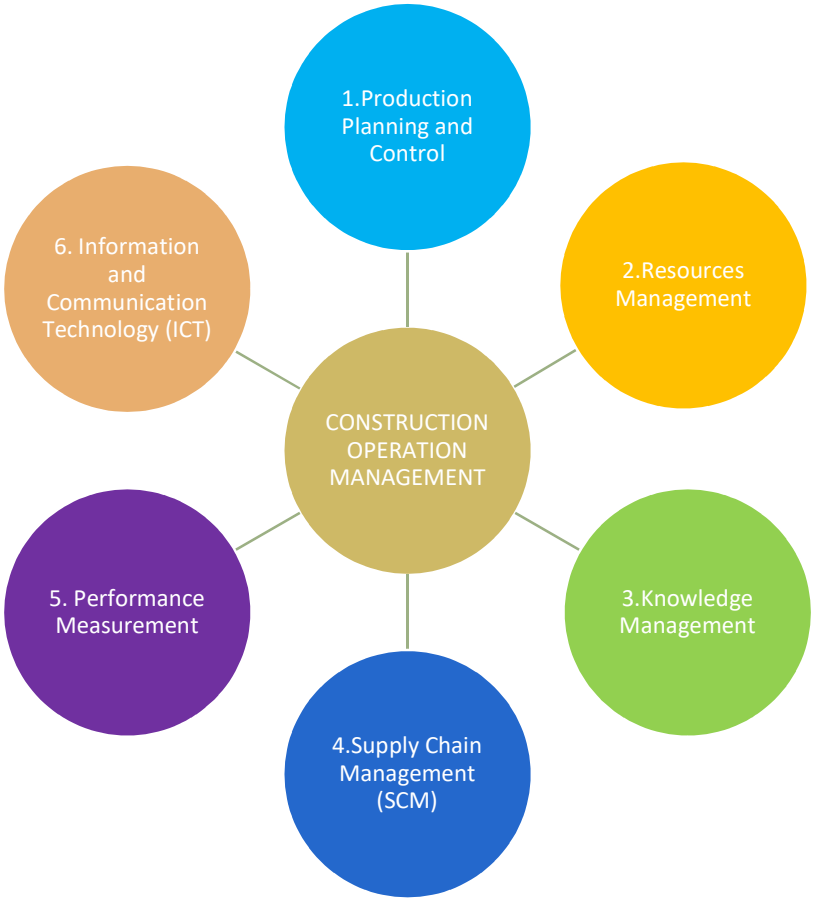


: Research Framework for Operations Management in Large Scale Construction Projects

- The framework establishes that collaboration for construction networks should be achieved by a very integrated approach encompassing, among other related questions, the interplay of materials processes (construction site), information processes (contractor's ICT platform) and monitoring and controlling processes

CONSTRUCTION OPERATION MANAGEMENT & the 6 areas

Operations management (OM) is the **administration** of **business** practices to create the highest level of efficiency possible within an organization. It is concerned with converting materials and labor into goods and services as efficiently as possible to maximize the profit of an organization



MODULE 2 - INTRODUCTION TO OPERATIONS MANAGEMENT

1. INTRODUCTION TO OPERATIONS MANAGEMENT

1. Operations and Productivity

2. Operations Strategy in a Global Environment

3. Project Management

4. Forecasting

10 OM STRATEGY DECISIONS

- Design of Goods and Services
- Managing Quality
- Process Strategy
- Location Strategies
- Layout Strategies
- Human Resources
- Supply-Chain Management
- Inventory Management
- Scheduling
- Maintenance

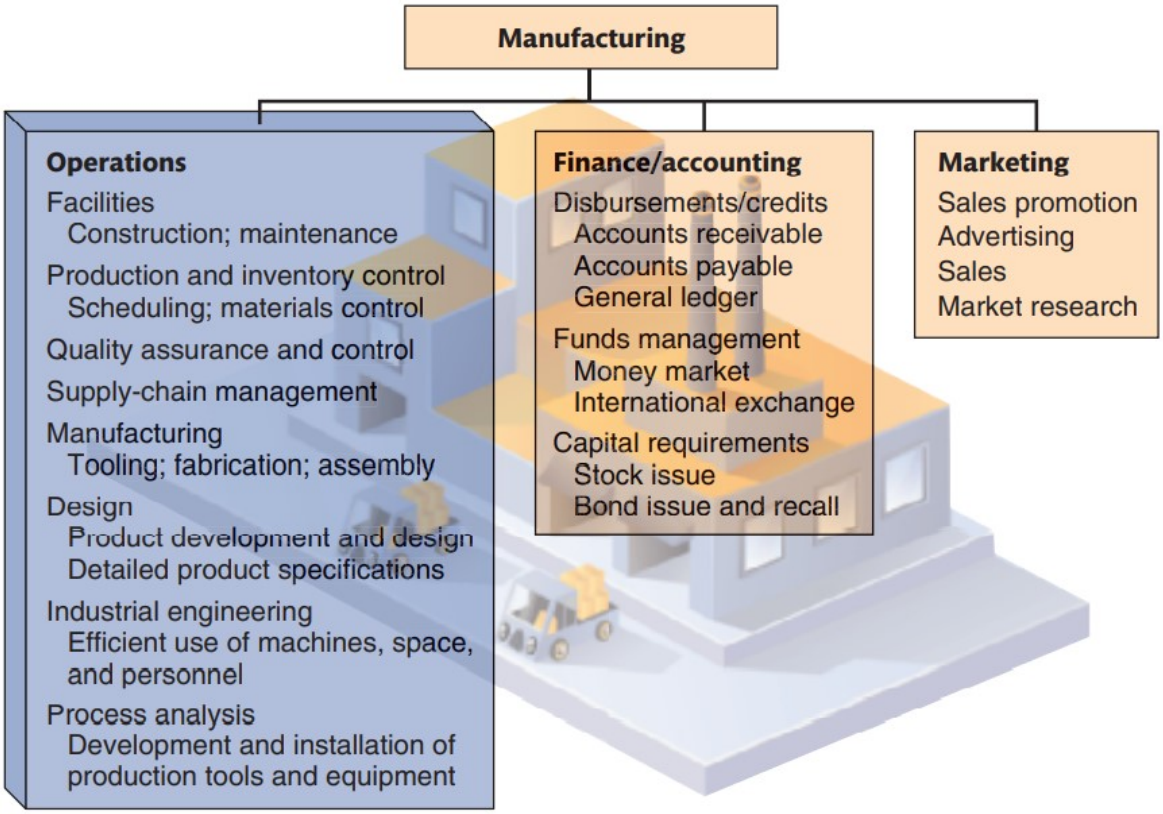
- **WHAT IS OPERATIONS MANAGEMENT?**

- ◆ Organizing to Produce Goods and Services
- ◆ The Supply Chain
- ◆ Why Study OM?
- ◆ What Operations Managers Do
- ◆ The Heritage of Operations Management
- ◆ Operations for Goods and Services
- ◆ The Productivity Challenge
- ◆ Current Challenges in Operations Management
- ◆ Ethics, Social Responsibility, and Sustainability

◆ What is Operations Management?

- Operations management (OM) is a discipline that applies to restaurants like Hard Rock Cafe as well as to factories like Ford and Whirlpool.
- The techniques of OM apply throughout the world to virtually all productive and service enterprises.
- It doesn't matter if the application is in an office, a hospital, a restaurant, a department store, or a factory—the production of goods and services requires operations management.
- And the efficient production of goods and services requires effective applications of the concepts, tools, and techniques of OM
- To create goods and services, all organizations perform three functions
- These functions are the necessary ingredients not only for production but also for an organization's survival.
- They are:

1. Marketing , which generates the demand, or at least takes the order for a product or service (nothing happens until there is a sale).
2. Production/operations , which creates, produces, and delivers the product.
3. Finance/accounting , which tracks how well the organization is doing, pays the bills, and collects the money.



The Supply Chain

- Through the three functions—marketing, operations, and finance—value for the customer is created.
- However, firms seldom create this value by themselves.
- Instead, they rely on a variety of suppliers who provide everything from raw materials to accounting services.
- These suppliers, when taken together, can be thought of as a supply chain.
- A supply chain is a global network of organizations and activities that supply a firm with goods and services.

Productivity Measurement

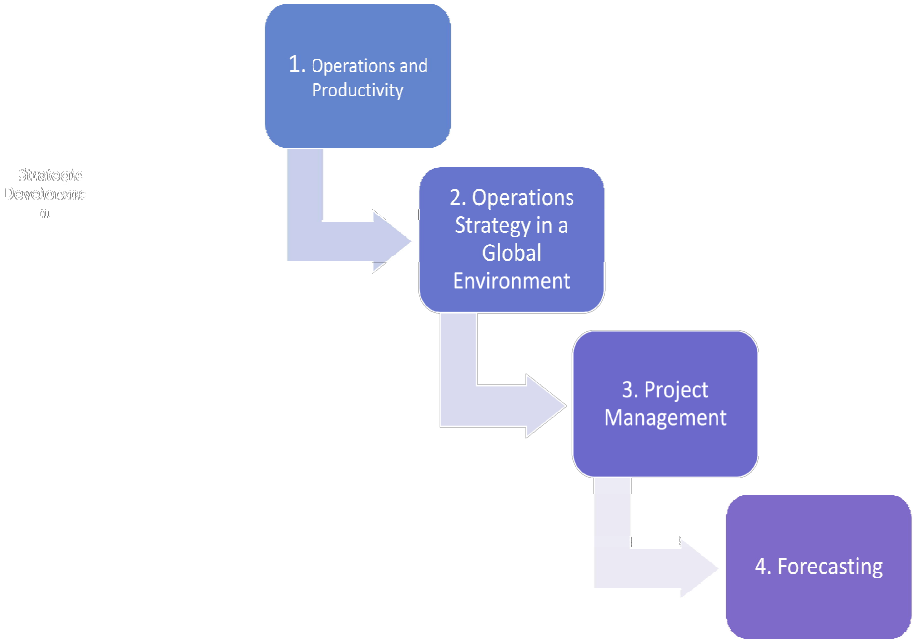
Computing single-factor and multifactor gains in productivity

1. Collins Title Insurance Ltd. wants to evaluate its labor and multifactor productivity with a new computerized title-search system.
2. The company has a staff of four, each working 8 hours per day (for a payroll cost of $640/day) and overhead expenses of $400 per day.

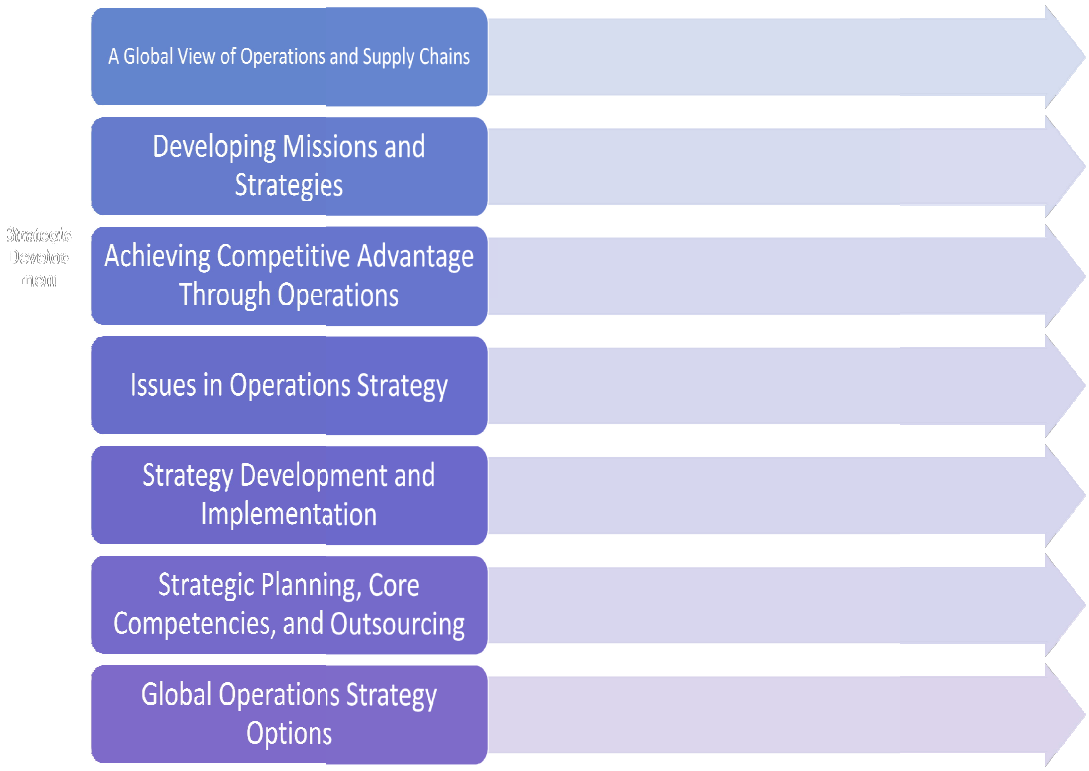
3. Collins processes and closes on 8 titles each day. The new computerized title-search system will allow the processing of 14 titles per day.

4. Although the staff, their work hours, and pay are the same, the overhead expenses are now $800 per day.

MODULE 3 OPERATIONS STRATEGY IN A GLOBAL ENVIRONMENT



Operations Strategy in a Global Environment



Domestic business operations decide to change to some form of international operations for six main reasons:

1. Improve supply chain
2. Reduce costs and exchange rate risks
3. Improve operations
4. Understand markets
5. Improve products
6. Attract and retain global talent

An effective operations management effort must have a mission so it knows where it is going and a strategy so it knows how to get there.

- Mission —The purpose or rationale for an organization's existence.
- Strategy —How an organization expects to achieve its missions and goals.

The three strategic approaches to competitive advantage are:

1. Differentiation
2. Cost leadership
3. Response

4. ISSUES IN OPERATIONS STRATEGY

- Resources view —A view in which managers evaluate the resources at their disposal and manage or alter them to achieve competitive advantage.
- Value-chain analysis —A way to identify the elements in the product/service chain that uniquely add value.
- Five forces model —A way to analyze the five forces in the competitive environment
- Forces in Porter's five forces model are

(1) immediate rivals,
(2) potential entrants,
(3) customers,
(4) suppliers, and
(5) substitute products

STRATEGY DEVELOPMENT AND IMPLEMENTATION

- SWOT analysis —A method of determining internal strengths and weaknesses and external opportunities and threats.
- Key success factors (KSFs) —Activities or factors that are key to achieving competitive advantage.
- Core competencies —A set of unique skills, talents, and activities that a firm does particularly well.
- A core competence may be a combination of KSFs.
- Activity map —A graphical link of competitive advantage, KSFs, and supporting activities.

MODULE 4 FORECASTING

1. Forecasting

◆ What Is Forecasting?
◆ The Strategic Importance of Forecasting
◆ Seven Steps in the Forecasting System
◆ Forecasting Approaches
◆ Time-Series Forecasting
◆ Associative Forecasting Methods: Regression and Correlation Analysis
◆ Monitoring and Controlling Forecasts
◆ Forecasting in the Service Sector

Forecasting Time Horizons

A forecast is usually classified by the future time horizon that it covers. Time horizons fall into three categories:

1. Short-range forecast: This forecast has a time span of up to 1 year but is generally less than 3 months. It is used for planning purchasing, job scheduling, workforce levels, job assignments, and production levels.
2. Medium-range forecast: A medium-range, or intermediate, forecast generally spans from 3 months to 3 years. It is useful in sales planning, production planning and budgeting, cash budgeting, and analysis of various operating plans.
3. Long-range forecast: Generally 3 years or more in time span, long-range forecasts are used in planning for new products, capital expenditures, facility location or expansion, and research and development.

Quantitative forecasts

1. **Jury of executive opinion** —Takes the opinion of a small group of high-level managers and results in a group estimate of demand.
2. **Delphi method** —Uses an interactive group process that allows experts to make forecasts.
3. **Sales force composite** —Based on salespersons' estimates of expected sales.
4. **Market survey** —Solicits input from customers or potential customers regarding future purchasing plans.
5. **Time series** —Uses a series of past data points to make a forecast.

MODULE 5 USING REGRESSION ANALYSIS FOR FORECASTING

FORECASTING

- Unlike time-series forecasting, associative forecasting models usually consider several variables that are related to the quantity being predicted. Once these related variables have been found,
- a statistical model is built and used to forecast the item of interest. This approach is more powerful than the time-series methods that use only the historical values for the forecast variable.
- Many factors can be considered in an associative analysis. For example, the sales of Dell

- PCs may be related to Dell's advertising budget, the company's prices, competitors' prices and promotional strategies, and even the nation's economy and unemployment rates. In this case, PC sales would be called the dependent variable, and the other variables would be called independent variables. The manager's job is to develop the best statistical relationship between PC sales and the independent variables. The most common quantitative associative forecasting model is linear-regression analysis.

MODULE 6 DESIGNING OPERATIONS

DESIGNING OPERATIONS

- Goods and Services Selection
- Generating New Products
- Product Development
- Issues for Product Design
- Product Development Continuum
- Defining a Product
- Documents for Production
- Service Design
- Application of Decision Trees to Product Design
- Transition to Production

Goods and Services Selection

- Although the term products may often refer to tangible goods, it also refers to offerings by service organizations.
- The objective of the product decision is to develop and implement a product strategy that meets the demands of the marketplace with a competitive advantage.
- Product Decision —The selection, definition, and design of products.
- The four phases of the product life cycle are introduction, growth, maturity, and decline.
- Product-by-value analysis —A list of products, in descending order of their individual dollar contribution to the firm, as well as the total annual dollar contribution of the product

Product Strategy Options Support Competitive Advantage

- A world of options exists in the selection, definition, and design of products.

- Product selection is choosing the good or service to provide customers or clients. For instance, hospitals specialize in various types of patients and medical procedures.

- A hospital's management may decide to operate a general-purpose hospital or a maternity hospital or, as in the case of the Canadian hospital Shouldice, to specialize in hernias.

- Hospitals select their products when they decide what kind of hospital to be.

- Numerous other options exist for hospitals, just as they exist for Taco Bell and Toyota.

- Service organizations like ABC Hospital differentiate themselves through their product. ABC differentiates itself by offering a distinctly unique and high-quality product.

- Its world-renowned specialization in hernia-repair service is so effective it allows patients to return to normal living in 8 days as opposed to the average 2 weeks—and with very few complications.

Product Life Cycles

- Products are born. They live and they die. They are cast aside by a changing society.

- It may be helpful to think of a product's life as divided into four phases. Those phases are introduction, growth, maturity, and decline.

- Product life cycles may be a matter of a few days (a concert t-shirt), months (seasonal fashions), years (Madden NFL football video game), or decades (Boeing 737). Regardless of the length of the cycle, the task for the operations manager is the same: to design a system that helps introduce new products successfully. If the operations function cannot perform effectively at this stage, the firm may be saddled with losers—products that cannot be produced efficiently and perhaps not at all.

PRODUCT DEVELOPMENT

- Product Development System
- Quality Function Deployment (QFD)
- Organizing for Product Development
- Manufacturability and Value Engineering

MODULE 7 PROCESS & LAYOUT & LOCATION STRATEGIES

PROCESS & LAYOUT & LOCATION STRATEGIES

1. Competitiveness

• degree to which a nation can produce goods and services that meet the test of international markets

2. Productivity

• ratio of output to input

3. Output

• sales made, products produced, customers served, meals delivered, or calls answered

4. Input

• labor hours, investment in equipment, material usage, or square footage

Facility Layout

• Translate the broader decisions about a firm's strategy such as competitive priorities, process, and capacity into actual physical arrangements of people, equipment, and space.
• When???
    • New Facility
    • General Re-layout (retrofit)
        • Expansion due to new product(s)/ sales growth in existing products
        • Re-organization of work areas
        • Addition of automation technology
        • Product discontinuation

AGGREGATE PLANNING OBJECTIVES

- Minimize Costs/Maximize Profits
- Maximize Customer Service
- Minimize Inventory Investment
- Minimize Changes in Production Rates
- Minimize Changes in Workforce Levels
- Maximize Utilization of Plant and Equipment

Capacity Options — change capacity:

• Changing inventory levels

• Varying work force size by hiring or layoffs (firing)

• Varying production capacity through overtime or idle time• Subcontracting or •Using part-time workers

MODULE 8 - MRP MPS & BOM & CORELAP

What Is Material Requirements Planning (MRP)?

- Material requirements planning (MRP) is a computer-based inventory management system designed to improve productivity for businesses.
- Material requirements planning (MRP) is the earliest computer-based inventory management system.
- MRP works backward from a production plan for finished goods to develop inventory requirements for components and raw materials.
- Advantages of the MRP process include the assurance that materials and components will be available when needed, minimized inventory levels, reduced customer lead times, optimized inventory management, and improved overall customer satisfaction.

- Disadvantages to the MRP process include a heavy reliance on input data accuracy ,the high cost to implement, and a lack of flexibility when it comes to the production schedule.

BOM

- A critical input for material requirements planning is a BOM an extensive list of raw materials, components, and assemblies required to construct, manufacture or repair a product or service.

- BOM specifies the relationship between the end product (independent demand) and the components (dependent demand). Independent demand originates outside the plant or production system, and dependent demand refers to components.

- Companies need to manage the types and quantities of materials they purchase strategically; plan which products to manufacture and in what quantities; and ensure that they are able to meet current and future customer demand—all at the lowest possible cost.

- MRP helps companies maintain low inventory levels. Making a bad decision in any area of the production cycle will cause the company to lose money. By maintaining appropriate levels of inventory, manufacturers can better align their production with rising and falling demand.

- Master scheduling follows aggregate planning. It expresses the overall plans in terms of specific end items or models that can be assigned priorities. It is useful to plan for the material and capacity requirements.

Master Production Schedule

- **Functions of MPS**
  Master Production Schedule (MPS) gives a formal detail of the production plan and converts this plan into specific material and capacity requirements. The requirements with respect to labor, material and equipment are then assessed

What Is Enterprise Resource Planning?

- Enterprise Resource Planning (ERP) system is an Information Technology (IT) business solution that enables construction companies and their contractors to manage capital projects effectively and efficiently throughout the project lifecycle.

- Many studies have demonstrated the benefits of ERP systems in construction, correspondingly, more studies have reported the importance of investigating the critical success factors (CSFs) of the implementation process.

- Top management involvement and awareness, training and support for users, and implementation team composition are the most significant factors of ERP implantation success.

MODULE 9 - Capacity Planning

Decisions taken with respect to

- Capacity of the operating unit
- Manner in which existing capacity is performing.

Also will impact productivity & overall profitability of the operating system put to use

Issues in process analysis

- Do I have adequate number of resources to meet the demand?
- What is the utilization of my resources?
- If I need to increase the capacity of my system how should I modify the process?
- Should I add some more resources?
- What will be the cost of my operations?
- Process Analysis: Definition & Scope
- ü Process analysis utilizes some analytical mechanism to understand the impact of process design on output, cost or any other performance metric
- ü Alternative process configurations on the chosen performance metric
- When an operation is planning how much capacity it needs, it must also think about how it plans to react to the demand it faces.
- The operation must be aware of the options available to satisfy demand. There are three general strategies that can be used in the medium term:

They are:

1. Level production
2. Chase demand
3. Demand management

- These strategies are not mutually exclusive and most organisations use a mix of these three, however it is likely that one method will dominate the strategy.
- These strategies are not reactionary to small daily swings in demand but look at demand over a longer time frame. Such decisions require planning and investment.
- Level production largely ignores demand fluctuations and works on producing units efficiently and then either storing the finished goods or satisfying demand from stock.

Aggregate planning

- Demand Options — Change demand: •Influencing demand • Backordering during high demand periods • Counter-seasonal product mixing

Level planning strategy

• Produce same amount every month

• Keep work force level constant

• Find alternative work for employees when there is less demand

• Vary non-work force capacity or demand options

• Inventory levels allowed to fluctuate

• Often results in lowest production costs

• Toyota, Nissan employ this strategy

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SCHOOL OF BUILDING & ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

UNIT – II –Construction Operations Management– SARA5301

UNIT II- OPERATIONS SCHEDULING

MODULE 10 OPERATIONS SCHEDULING INTRODUCTION

1. Operations scheduling
2. Heuristics for decision rules
3. Decision Analysis & Modeling
4. Moore's & Johnson's procedure,
5. Economic Common Cycle Scheduling (ECC scheduling).

Operations scheduling

ADVANTAGES OF WORK-STUDY

- Smooth production flow with minimum interruptions
- Reduce the cost of product by eliminating waste and unnecessary operations
- Worker-Management relations
- Reduction in rejections and scrapes
- Help to achieve better work conditions.
- Better workplace layout.
- Improves the existing process or methods
- Helps to establish the standard time for an operation & Train and mentor employees in areas of project management and estimating.

COMMONLY USED RECORDING TECHNIQUES

1. Charts

2. Diagrams

3. Cycle Graph

1. Charts

- Operation Process Chart (outline process chart)
- Flow Process Chart
- Two Handed Process Chart
- SIMO

FLOW PROCESS CHARTS

- Material Type
- Man Type
- Equipment Type

DIAGRAMS

- Flow Diagram
- String Diagram
- Two and Three dimensional Diagram

DEFINITION OF WORK MEASUREMENT/ TIME STUDY

WORK MEASUREMENT is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.

Qualified Worker

- A qualified worker is one who is accepted as having the necessary physical attributes, who possesses the required intelligence and education, and who has acquired the necessary skill and knowledge to carry out the work in hand to satisfactory standard of safety, quantity and quality

Representative Worker

- As one whose skill and performance is the average of a group under consideration and who is not necessarily a qualified worker

DEFINITION OF A RATING

- Rating is the assessment of the worker is rate of working relative to the observer's concept of the rate corresponding to standard pace.

Standard Rating

- The average rate at which qualified workers will naturally work at a job, when using the correct method and when motivated to apply themselves to their work

FACTORS AFFECTING RATE OF WORKING

- Variation in quality of material
- Changes in operating efficiency of tools and equipment
- Changes in methods or conditions of operation
- Variation in mental attention for the performance of work
- Changes in surrounding conditions - light, climate, temperature etc.
- In general, each element of activity must be rated during its performance before the time is recorded, without regard to previous or succeeding elements.
- No consideration should be given to the aspect of fatigue, since the allowance for recovery from fatigue will be assessed separately
- Standard performance is the rate of output which qualified workers will naturally achieve without over-exertion as an average over the working day or shift, provided that they know and adhere to the specified method and provided that they are motivated to apply themselves to their work.
- This performance is denoted as 100 on the standard rating and performance scales

The work content of a job or operation is defined as:

- Basic Time + Relaxation Allowance + any allowance for additional work.
- That part of contingency allowance which represents work

CONTINGENCY: A contingency allowance is a small allowance of time which may be included in a standard time to meet legitimate and expected items of work or delays, the precise measurement of which is uneconomical because of their infrequent or irregular occurrence.

RELAXATION: Relaxation allowance is an addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs.

- The amount of allowance will depend on the nature of the job.

MODULE 11 HEURISTICS FOR DECISION RULES

What Are Heuristics?

A heuristic, or a heuristic technique, is any approach to problem-solving that uses a practical method or various shortcuts in order to produce solutions that may not be optimal but are sufficient given a limited timeframe or deadline. Heuristics methods are intended to be flexible and are used for quick decisions, especially when finding an optimal solution is either impossible or impractical and when working with complex data.

- Heuristics are methods for solving problems in a quick way that delivers a result that is sufficient enough to be useful given time constraints.
- Investors and financial professionals use a heuristic approach to speed up analysis and investment decisions.
- Heuristics can lead to poor decision-making based on a limited data set, but the speed of decisions can sometimes make up for the disadvantages.

Heuristics are simple rules of thumbs for problem solving that follow a logic that is quite different from consequential logic. They have long been regarded, as an inferior technique for decision making that is the source of irrational decision behavior. Recently, decision making researchers have demonstrated that some heuristics are highly efficient and can compete with complex decision models in some application domains.

Modern construction projects are delivered in complex, fast pace environments. Stakeholders are required to participate in dynamic project settings with resource constraints, information constraints, and time constraints. To overcome gaps in knowledge, to deliver decisions quickly, and to overcome human limits in cognitive ability, decision makers typically employ heuristics, or "rules of thumb" to arrive at relatively quick answers. Heuristics are cognitive shortcuts that an individual employs to arrive at quick decisions (Goodwin et al., 2004). These heuristics are used in a variety of ways, ranging from using the process of elimination (elimination heuristic) to applying different cognitive weights to options based on recent experience, reputation, or familiarity (Shah & Oppenheimer, 2008).

Modern construction provides a difficult decision making environment for workers. Construction stakeholders often work in environments with limited time, with limited information, and with limited

knowledge. Decision makers in these environments typically use mental rules of thumb (formerly known as heuristics). These rules of thumb help decisions makers arrive at quick answers and often increase efficiency. They can be used in a variety of ways.

An individual may use the process of elimination to find a solution. Others may base their decision off a company, person, or object 's reputation. Others may only choose an option that is recognizable. Rules of thumb take many forms and are used by all people. Studying rules of thumb can benefit an industry. This has already been proven in many industries, such as insurance (Handel & Kolstad, 2015), medicine (Martin et al., 2012), and economics (Grandori, 2010).

The construction industry has begun to study rules of thumb that impact early stages of the construction process, but it still lacks rules of thumb that impact the process of physical construction. The aim is to assist the construction industry in gaining a fuller view of decision making shortcuts used by its stakeholders. The results of two studies conducted with a Mid-Atlantic Contractor are outlined with seven heuristic used by construction workers.

Heuristics are the brain's natural response to its own bounded rationality and limited processing power.

Heuristics are a brains mental shortcuts that aid decision makers. Heuristics are often built off experience and assist decision makers by increasing decision efficiency. Heuristics take many forms, and are often used in a variety of contexts. For example, when employing the representativeness heuristics, an individual will make a judgement or decision about a whole population based on a sample size. Moreover, when employing the anchoring heuristic, an individual will anchor to a salient, or known value, and make adjustments to that value cognitively.

Heuristics are first and foremost, mental benefits to an individual (Goodwin et al., 2004). Heuristics are partly the reason why experience in a particular industry is so valuable. Experienced individuals in a particular area of study will have typically developed beneficial heuristics in that industry. But, heuristics don't always result in positive outcomes. If over relied on and used unknowingly, especially by less experienced individuals, heuristics can have negative decision making results.

Interview Results

Heuristic	%	# Elements	# Contexts
Affect	86	71	11
Reputation	66	51	7
Risk Reduction	71	45	15
Anchoring	60	44	14
Temporal Preference	54	31	5

List of A-Priori Heuristics

Heuristic	Definition
Affect	Risk and benefit judgments are inversely related (Zajonc, 1980).
Anchoring	"Anchoring" to a salient and known value, basing judgment off this value (Tversky & Kahneman, 1974).
Availability	Individuals perceive the likelihood or risk of an event based on how easily one can recall an example of that event (availability) rather than its actual probability (Tversky and Kahneman, 1973).
Default Building	Using traditional, default building characteristics (Beamish & Biggart, 2012).
Recognition	Cognitively weighing "recognizable" options heavier in choice selection. (Goldstein & Gigerenzer, 2002).
Representativeness	Judging a whole group by a sample size (Kahneman & Tversky, 1972)."
Risk Reduction	Allowing fear of risk to impact decision making (Hansen & Singleton, 1983; Mitchell & Greatorex, 1993).
Sunk-Cost	Allowing Sunk Costs to affect a decision. (Arkes & Blumer, 1985)
Myopia	Evaluating options based on immediate gain rather than long term potential gains (Shiv et al, 2005).
Elimination	Using the process of elimination to make a decision (Tversky, 1972).
Reputation	Placing a high cognitive weight on reputation in decision making (Metzger, Flanagin et al., 2010).
Function	Targeted profits become dominant factors for cost-cutting decision making (Beamish & Biggart, 2012).
Flexibility	Producing "flexible" buildings that can meet the needs of many individuals (Beamish & Biggart, 2012).
Familiarity	Individuals assume circumstances underlying past behavior still apply for a present situation (Metcalfe, Schwartz et al., 1993).

Affect heuristic

A project executive for the contractor described the decision making process that occurs for some subcontractors who win a job due to an error in an estimate. He stated, “[If a general contractor or subcontractor makes] a mistake in their estimate and they found out after they've already given the price and they decide to take it anyway, [then they will justify it by thinking] they can get it done quicker and they'll save money because it can't rain as much as it did last year.” In this example, the same underlying factor influences heuristic use. The decision maker is faced with an abundance of variables, particularly influencers of future events in a project, that often leads to problem simplification through the affect heuristic. In this context, in the infrequent instance that subcontractors mistakenly underbid a job, they often employed the affect heuristic. Even in face of their error, they maintained an overly confident view of the potential benefits of the job and discounted risks. Second to construction duration, another apparent usage of the affect heuristic occurred in the contractor’s initial building estimates, appearing in 11 elements. This particular company handled many construction projects using a construction management at risk delivery method, and therefore often performed initial, non-contractual, building estimates for owners before published drawings were available. Initial estimates were performed with either no design documents, or partial design documents - a case of very limited information. As one project manager described when discussing the company’s accuracy of initial building estimates: “typically we end up being low. Hopefully your close, a lot of times you're not.” The lack of knowledge about the building in early design phases was often filled by employing the affect. heuristic and assuming more optimistic

terms for a project in estimating, frequently resulting in initial project estimates that were lower than actual costs.

Owner's often based their expectations of project delivery on their own past projects, or comparable project's in the area. If a similar project had been completed four years ago, they wanted the same price. If a contractor had constructed a project for them five years ago, they wanted it delivered in the same amount of time. Inflation, escalation, and current market prices dictate project costs, and often didn't align with owner expectations.

Reputation Heuristic

The top three contexts of the reputation heuristic included the following relationships 1) the subcontractor's reputation with the contractor, 2) the contractor's reputation with the owner, 3) the contractor's reputation with the subcontractor.

Risk Reduction Heuristic

There was strong evidence of employees applying the risk reduction heuristic, attempting to minimize and avoid risk by all 21 means possible, to their decision making. The top three most mentioned contexts of the risk reduction heuristic occurred when 1) stakeholder's preferred to do nothing in a decision, 2) contractor's decided to bond a sub to mitigate risk, and 3) contractors used the contingency fund to cover uncertainty in scope.

Project delivery requires input from stakeholders for a variety of deliverables including interior buildout design, material selections, and color/finish selections. With the time constraints associated with project deadlines and material delivery, and the information overload that an individual may face when presented with multiple options, stakeholders sometimes decided to refrain from a decision. By refraining from deciding, stakeholders defaulted to the least risky choice: no choice. The most common use of the risk reduction heuristic occurred in stakeholder's decision to do nothing when faced with a problem or choice, shown in five different elements. To reduce the risk of making a poor decision, some stakeholders often would delay that decision making process for an extended period of time, hoping to avoid the consequences of a bad decision. One superintendent discussed the affect this often had on a project's schedule. He said, "some of the biggest holdups that we've had in the past have been the owner and the lack of decision, the ability to make a quick and decisive decision." Another project executive, discussed a possible solution to this decision making dilemma. He said, "I'll assign one person that is the representative of the owner that has the authority, the ability, and the experience to make a proper decision. That's the root cause of all. Probably in my experience, 75 percent of the problems. People can't make a decision."

Temporal Preference

When coding the transcripts, one of the codes documented was stakeholders' tendency to choose an option with the quickest results, even in spite of a cost increase. When this code emerged, the research team did a thorough literature search for a heuristic that explained this phenomenon. Since there was no pre-defined term that described this decision making shortcut, the research team coined this heuristic as "temporal preference."

There was strong evidence in many interviews that project stakeholders placed a high cognitive value on time when making decisions, often defaulting to decision options that provided quicker outcomes. The top three contexts of temporal preference occurred when 1) stakeholders decided on material types 2) owners made project related decisions and 3) contractors made decisions related to means and methods.

Stakeholders often placed a high value on time when selecting material types, , often discussing their willingness to pay higher premiums for materials that provided higher productivity or products that allowed for the overall construction process to move quicker. One superintendent summarized the thoughts of many other employees, in discussing his justification for paying a higher premium for moisture retardant drywall on interior walls, he stated "So we paid for the material to help with the schedule to help increase when we can start other trades." A mason foreman discussed the same thought process that subcontractors have when selecting materials, in describing how he selects a brick type, he stated "There are only two suppliers that represent the 15 different manufacturers, so they'll come up and they'll bring me a couple boards … the ones I know that we'll get good production on, I'll submit them to the architect have them look at it, [and will pay more for the brick that has a higher production rate even if it is costlier]."

Employees also weighed time heavily in their decision making process, particularly when making decisions in respect to schedule. The contractor noted helping subcontractor's by sometimes paying overtime fees for their employees. In the words of one superintendent, he stated "Let's say you lost three weeks because you had to go rework something that's three weeks gone. So you've got to go back and say okay, I'm going to start making this up on longer hours on Saturdays or more manpower, we've got to take that, that three weeks and we got to make that so it gets back to zero." Likewise, a project executive described the thought process of project planning when describing his process for managing a job. "[I ask myself], how can I get the most trades involved at the earliest point in time where they can provide continuous employment for their crew until their part of the job is finished."

Decision analysis is an approach, and the associated techniques, that help a decision maker choose wisely under conditions of uncertainty. Application is based upon:

- Having a choice between alternatives;
- Having importantly different possible outcomes between at least two alternatives, as a result of uncertainty for example; and
- Evaluating each alternative by weighting the possible outcomes with their probabilities of occurrence.

MODULE 12 DECISION ANALYSIS & MODELING

DECISION ANALYSIS IN PROJECTS

1. **Expected Value—The Cornerstone.** Representing a probability distribution as an unbiased, single value.
2. **Optimal Decision Policy.** Appraising value or cost: a consistent approach suited to all decision types.
3. **Decision Trees.** Graphical decision model and expected value calculation.
4. **Value of Information.** Evaluating an alternative to acquire additional information.
5. **Monte Carlo Simulation.** An alternative, popular technique for calculating expected values and outcome probability distributions.
6. **Other Probabilistic Techniques.** Other established and new probability techniques suited to simple situations.
7. **Modeling Techniques -**Project and cash flow projections: approaches, tools and techniques.
8. **Stochastic Project Modeling.** Decisions and other dynamic behavior in models; sensitivity analysis.
9. **Judgments and Biases.** Encoding expert judgments about risks and uncertainties.
10. **Utility and Multi-Criteria Decisions.** Decisions involving objectives other than maximizing monetary value.
11. **Implementing and Using Decision Analysis.** Overcoming barriers to accepting and using decision analysis in projects; management implications.

PREDICTIONS FROM MODELS

It can be said that predicting the future is one of the most important analytic problems in business. Nearly every decision presupposes some sort of prediction. A prediction is a scenario that reflects a set of assumptions, typically that tomorrow is going to be like today. A forecast is a prediction that incorporates specific assumptions about the future that includes someone's opinion about how the future may be different. The differences may be in structure or in values of parameters. For example, the introduction of microcomputers changed the structure of information processing for PM. A change in volume of information used in PM would be a change in parameter value. In the context of this discussion of decision analysis, the forecast is the expected value outcome.

Predicting Approaches

There are three general approaches to predicting the future:

1. Guessing or using intuition;
2. Extrapolating the past, such as by linear regression; and
3. Modeling the system, and using the model to generate a forecast.

The first approach provides predictions that are of questionable credibility. Intuition is believable only if the pre-dicter has recognized experience and a record of reasonably accurate judgments. Seldom are the assumptions clearly stated.

Extrapolation requires suitable historical data and is based on the ceteris paribus (all other things being the same) assumption. Note that this implies that tomorrow will be like yesterday.

Modeling involves designing and building a representation of the system. The model is an abstraction of the real world based upon someone's best understanding. Modeling is particularly valuable in situations that involve new or unique and complex situations.

Most often, a prediction is based upon a set of initial assumptions. Examples include activity costs and completion times. Single-value assumptions result in a single-value outcome calculated through the prediction model. Such models are called deterministic because every value is singly determined.

Deterministic Cash Flow Model

In this article, the perspective will be decision making in a business enterprise, although decision analysis applies to all types of entities.

In business, value derives from cash flow. The present value (PV) calculation transforms an incremental cash flow prediction into incremental corporate value. This is the basis for most modem financial analysis. There are many arguable details, such as inflation, tax, and cost of capital assumptions. However, the general process is straightforward.

"Optimal Decision Policy," describe how to value outcomes . Project managers are traditionally concerned with performance, schedule, and cost. While these dimensions are important, it is impossible to make consistent decisions without a way to determine composite value. A single

value measure is needed. The author recommends that non-monetary dimensions be converted into cash flow or money equivalents. This is the simplest approach to deal with multiple objectives.[1] Thus, project performance and schedule are translated into cash flow impact and combined with costs. This single value measure approach is illustrated in Figure 1. In this illustration, the shaded blocks indicate commonly generated outcomes that inherently lead to multi-criteria decision making. Information generated in the development model and feasibility model can be used to generate net cash flow and ultimately the present value (PV) or expected monetary value (EMV). The project model's main purpose, then, is to forecast net cash flow.

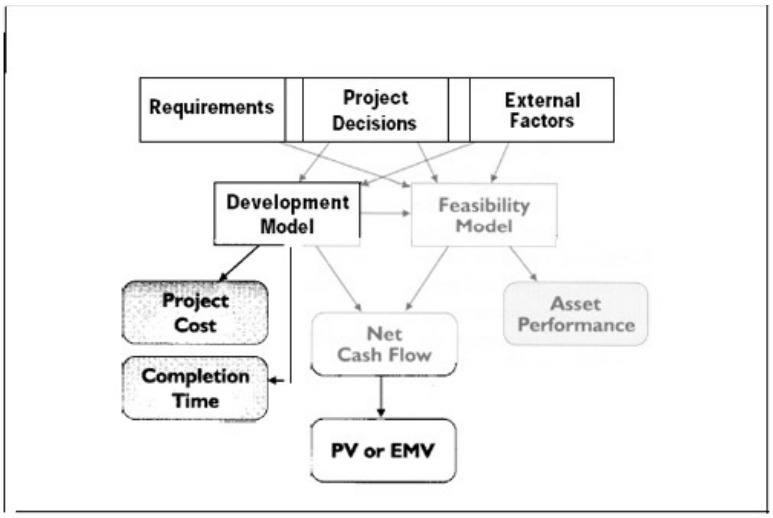
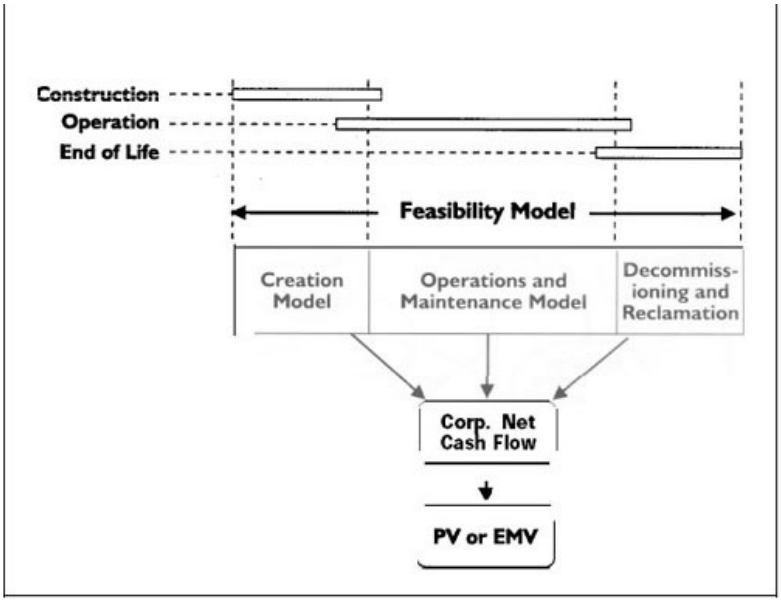


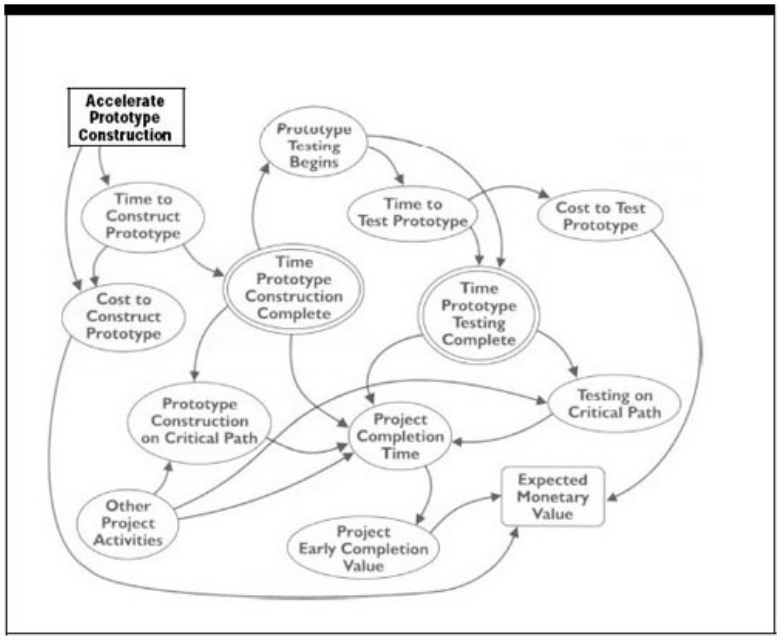
Figure 2. Life-Cycle Scope



Problem and Model Scope

A good project model contains sufficient operating and financial detail as to reasonably represent the impacts of the relevant alternatives in the business decision. Thus, the appropriate model detail depends upon the decision at hand. Sometimes analysis of outputs from the model will indicate that the decision is obvious. In other situations, the differences in outcomes may be marginal. When this is the case, additional analysis effort is warranted, perhaps incorporating additional detail in the model.

Figure 3. Influence Diagram



THE MODELING PROCESS

Initially, someone identifies a problem: a choice about allocating resources. Often, a decision arises because something happens or because a new idea or information surfaces. Increasingly, and importantly, people are recognizing the value of proactively creating new alternatives. Professionals should continually ask, "What can we do to improve the value of this project?"

Often, a project team is involved or assigned to the problem. The team should first define the problem. This definition includes a situation description. The scope of the problem-solving process is important, and this is often dictated by the need that the model measure incremental corporate value.

The following sections describe modeling approaches, system diagrams, other techniques and software tools.

Modeling Approaches

Understanding the project and its elements is essential to developing a valid model. The model should reflect the way the project behaves under different conditions.

A logical framework for developing the model must be chosen. Since there is an inherent flow relationship of the factors in the model, it usually works well to adopt one or more of the following as a theme for the modeling process:

- The sequence of activities
- The flow of units
- The flow of labor hours and material quantities
- The flow of cash
- The flows of income and expenses (accounting book basis)

The idea of conservation of mass, money, etc., is widely applicable, so it is wise to build in checks and balances to ensure that all units of resources are accounted for.

The model is usually built with mathematical formulas and variables. Here are two examples:

Net Cash Flow = (Cash Operating Costs (opcost)) - (Income Tax) - (Capital Expenditures)

Date Prototype Testing Begins = Maximum (Prototype Construction Finish, Testing Facility Construction Finish)

System Diagrams

The first step in any modeling effort is to identify the objectives of the analyses to be performed. For example, in one modeling effort the objective was to develop the basis for selecting the melt process for a casting plant. Three alternatives were available: cupola, induction furnace, and arc furnace. It was not necessary to replicate the exact operating conditions, which would not likely have been optimal. However, it was possible to compare the optimal operating conditions for the three alternatives as derived from linear programming models. In another modeling effort, it was not necessary to replicate actual operating conditions, but to represent these conditions sufficiently that the players (of a business game) felt that it behaved consistent with reality.

Before beginning to actually construct a model, it is helpful to conceptualize the model's organization or structure. A diagram of the problem is a good early investment. This can be developed with little time and effort, before laboring with the details of formulas and values. A conceptual error found at an early stage is much easier and less costly to correct. A system flow diagram can depict the essential features.

In project management, the starting point is often the project plan represented as a work breakdown structure (WBS). This provides a list of the project's activities. The project plan is represented by listing predecessor activities or drawing a project net. work diagram (PND), often referred to as a CPM diagram. Costs and performance details flesh out the inputs to the model.

A similar approach, focusing more on the variables, is an influence diagram. Figure 3 shows an example. This representation shows decision variables (rectangles), chance events (ovals), and the EMV decision variable (rounded rectangle). Variables derived solely from a deterministic calculation are shown as double-ovals. The arrows on the arcs show the direction of influences or causality.

In Figure 3, a decision is being made whether to accelerate an activity, Constructing Prototype, in a large project. This is part of a much larger program or project. Prototype Testing follows, although there may be some delay. Prototype Testing's start date affects its costs and the project's

overall time to complete. Whether an activity is on the critical path determines whether delaying the activity directly delays the project's overall completion time.

Business Modeling Tools

While a computer is not needed for business modeling, it can be very helpful. Computer assistance is preferred for all but the simplest decision problems. Computers allow a much greater scope of considerations to be modelled explicitly.

There is a well-established industry in project software. Much of the commercial software is limited to certain aspects of project management, e.g., controlling cost, resources or completion time. Construction costs are often detailed, but this is one component of corporate net cash flow. Other tools are being developed, or are available but not used extensively, that permit more sophisticated modeling of project network diagrams. These rely on PNDs that permit other logical relationships between activities that are not available in typically available commercial programs for project planning, scheduling and control.

Often a custom model is needed, tailored to the situation at hand. Available tools include:

- Computer spreadsheets
- Formula-based modeling tools, such as Lotus Improv
- Procedural programming languages, such as Microsoft Visual Basic
- Graphical modeling tools, such as High Performance Systems' ithink
- Simulation languages some of which now permit visual display of the results of dynamic interactions
- A variety of other tools to aid in defining and refining logical relationships between variables, i.e., flows

Decision Making in Construction Management: AHP and Expert Choice Approach

The term and content of construction project management are outlined. The main problems of construction management are identified and possibilities to solve them are discussed. The model for decision making in construction management by using multi-criteria methods was created and applied to real case study. AHP method and “Expert Choice” computer program are employed for calculations.

1. INTRODUCTION

Construction management and technology are the two key factors influencing the development of the construction industry. Over the past 40 years, although several new and advanced technologies have been applied to construction projects, the efficiency of the industry has remained quite low [1]. Prior researchers suggests that digital technologies enable rapid, flexible forms of project organizing [2]. The construction project management process begins with identification of the user requirement, project constraints, resource needs, and establishment of realistic objectives to meet the strategic goals. It is an iterative process as new information becomes available through efforts by various professionals involved in the project. Today, mobile hardware, cloud computing and integrated software are becoming used for storage and retrieval, automated search, and prototyping and simulation functions. The objectives of project

management are to execute a project so that deliverables can meet scope requirements on budget and schedule, and at acceptable risk, quality, safety, and security levels.

2. PROBLEMS OF CONSTRUCTION MANAGEMENT

One of the most important tasks in construction is selection of the right contractor. Choosing the proper contractor from numerous applicants that are available today in market is a complicated problem for clients. In dealing with the long-term assets, it is crucial to select a proper contractor, which could ensure the quality of the constructed building. The achievement of this aim largely depends on the efficiency of the performance of the contractor that is selected [4]. Contractor selection studies have dated back to as early as 1960s. Few of the more referred papers of that era due to their classical contribution are those by Busch, Dickson, Hakansson and Wootz, and Dempsey. These studies established the importance of quality of products and delivery are important factors for supplier selection [5-7]. All construction processes are risky. Contractual risk management forms only one part of the companies' legal risk management and, in this way, it is part of companies' comprehensive general risk management. The goals of contractual risk management do not restrict the management of legal risks in contracting. Contractual risk management also covers other risks in business by using methods of contractual planning and management [8-9]. More problems in construction management are identified in developing countries. Mohamed [10] defined most important construction management system problems: All issues of construction management must be solved as soon as they are identified. Senaratne and Sexton [11] highlights that in the information age, organization theories have addressed problem-solving as an information processing activity. However, in this era, with the realization of knowledge-based views of the organization, shared problem-solving is increasingly recognized as a knowledge creation trigger. During shared problem-solving, stakeholders bring different types of knowledge into the problem situation and it is captured, created and shared by the team members. In construction projects, shared problem-solving often takes place through pragmatic problemsolving on site, in particular, through managing project changes.

3. MODEL FOR MULTI-CRITERIA DECISION MAKING IN CONSTRUCTION MANAGEMENT

3.1. Multi-criteria methods and construction management

MCDM refers to making decisions in the presence of multiple, usually conflicting, criteria. Each different criterion may have different units of measurement, quality characteristic, and relative weight. It is possible that some criteria can be measured numerically and other criteria can only be described subjectively. Foundations of modern MCDM were developed in 1950s and 1960s. There are dozens methods available for solving MCDM problems. The MCDM methods are able to provide solutions for a wide range of management problems. Development of MCDM researches accelerated during the 80s and early 90s, and seems to have continued its rapid growth. Köksalan et al. [12] and Kahraman et al. [13] provided a brief history of the development of MCDM methods. Zavadskas and Turskis [14] and Zavadskas et al. [15] presented detailed studies about MCDM methods application in different fields of economics and management. Saaty [16] published a detailed study on the AHP applications. Recently, development of hybrid and modular methods is becoming increasingly important. They are based

on previously developed well-known methods and their modification, by applying fuzzy and grey number theory. Relatively recently are developed MCDM methods, such as Complex Proportional Assessment (Copras) [17-18], Additive Ratio Assessment (Aras) [19-20], Multi-Objective Optimization On The Basis Of Ratio Analysis (Moora), Moora Plus Full Multiplicative Form (Multimoora) [21-22], Step-Wise Weight Assessment Ratio Analysis (Swara) [23], Weighted Aggregated Sum Product Assessment (Waspas) [24], Kemeny Median Indicator Ranks Accordance (Kemira) [25] Are Developed And Applied To Solve Real Life Problems. It Is Important To Mention That Multi Criteria Decision Making Methods Have Different Issues When Used In Different Context.

An owner who selects a contractor using the low-bid method should be aware of several possible consequences. First, the competitive bidding process assumes that all firms (including general contractors, subcontractors, and material suppliers) bid the work as cheaply as the designer's specifications and drawings can reasonably be interpreted. Second, a common misconception among laymen is that professional drawings and specifications automatically guarantee that each contractor must or will provide the identical results as every other bidder, and that those eventual results will be according to the owner's expectations. Finally, it should be mentioned that without a contractor's input during design, the eventual low-bid amount remains unknown until the design is completed and bid. So the owner and architect must uneasily wait until the design phase and bidding phases are completed before they know whether their project was designed on budget, under budget, or, as is too often the case, over budget.

3.2. Model creation for multi-criteria decision making

When making decision based on multi criteria method, certain steps should be made. The model for multi-criteria decision making is developed. Firstly, alternatives of the solution should be defined. For example, when choosing contractor in construction process- all possible contractors for the project should be identified. Secondly, criteria of those alternatives should be set. It means that factors that are important and have influence on choice of contractor should be identified. Thirdly, system of criteria evaluation should be established. Each criteria is evaluated differently, so the system should be defined. For example, experience of contractor could be evaluated as outstanding, very good, average, below average or unsatisfactory whereas profitability could be defined as high, average or low and etc. Fourthly, criteria weights should be defined. In this step important and less important criteria should be identified. The more important the criteria is, the bigger weight it should have. Then each criteria of each alternative should be evaluated. Finally, counting with the help of computer software should be made and the best alternative chosen.

4. CASE STUDY: DECISION MAKING IN TURKISH CONSTRUCTION PROJECT MANAGEMENT

4.1. Description of project and problem under consideration

Seven storey 3 star hotel is being built in the southern part of Turkey, near Mediterranean Sea in the region of Antalya. Stakeholders of the hotel decided to build a swimming pool. The main measurements of the pool are as follows: Length - 25 metres; Max depth - 2.2 metres; Width - 10 metres; Shape - Oval. The construction project is in its last stage of building. However, some works should still be done. Project manager needs to select contractor for building swimming

pool in the area of the hotel. So the main goal is to choose the right contractor for building the swimming pool. The main objectives of contractor choice are as follows: to achieve good quality; to achieve good design; to select optimal financial options.

4.2. Formation of alternatives

In this case as an example contractor's selection will be analysed according to multi criteria method. Choice of contractors is one of the most important decisions of construction manager, because it influences the success of all project greatly. Contractor will be chosen for building swimming pool in the area of hotel. Totally 5 contractors will be analysed for building swimming pool in hotel area. Contractor is chosen according to counting of multi criteria method, where subjective and objective factors of contractors are evaluated. All contractor are Turkish companies set in the biggest cities of country - Ankara, Istanbul and Izmir.

4.3. Set of criteria system and estimation of values of criteria

Choice of contractor for construction project works depends on many different factors. Some factors are more important like technical experience or safety record, others less important like safety record. So when choosing contractor it is important to evaluate: 1) technical experience, 2) performance records, 3) financial stability, 4) management and employees qualification, 5) capacity, 6) safety record, and 7) operation and equipment.

These are main criteria when choosing contractor. Also sub-criteria should be taken into account. For example, when evaluating capacity, number of projects on which contractor is currently working should be evaluated as well as capacity to add this exact project. Based on the literature overview, and questioning of experts and stakeholders the criteria set was determined. So there are two levels in this model criteria and sub criteria.

TE - Technical Experience - indicates how much experience contractor has in doing technical, civil, electrical, mechanical works and landscaping. The number of projects is considered. The evaluation of technical experience can be outstanding (if contractor completed more than 20 projects), very good (if contractor completed 15-20 projects), average (if contractor completed 10-15 projects), below average (if contractor completed 5-10 projects) and unsatisfactory (if contractor completed less than 5 projects).

PE - Performance Record - indicates whether contractor completes projects on time, evaluates quality and cost control systems as well as quality of already finished projects. Sub criteria of performance record, for example, quality of finished products can be evaluated as outstanding, very good, average, below average and unsatisfactory. This sub criteria is evaluated qualitatively not quantitatively so it is not based on any numbers.

FS - concerns Financial Stability of the contractor. It evaluates contractor‘s profitability, availability of credit as well as dept volume. It can be high, average or low.

ME - Management and employees qualification - evaluates number of contractor‘s projects that experienced failure, experience of manager and labour force.

CA – Capacity - evaluates number of projects contractor works on at the moment, capacity to add this project and status of current projects. SR - safety record - concerns strength of safety program, number of accidents in the last 5 years, availability of safety training for new employees.

OE - operation equipment - evaluates capabilities of technical field personnel and suitable equipment resources. Its sub criteria, for example capabilities of technical field personal, is evaluated qualitatively according to competences of employees.

4.4. Calculation according to the model

Expert Choice“ software which is based on AHP method was used to determine criteria weights. Factors of level one from the model – criteria - were as an input of the matrix, which was counted with the help of computer software. First of all criteria weights of the main criteria were determined. If CR is less than 0.1, then it is assumed that expert is consistent in his evaluations. In the similar way weights of sub-criteria were determined for each criteria group. The summarizing of determined weights of criteria and sub-criteria are presented in Table 1

Table 1. Weights of criteria and sub-criteria.

CRITERIA	WEIGHT	SUBCRITERIA	WEIGHT
Technical experience	0.328	Civil works	0.194
		Electrical	0.015
		Mechanical	0.072
		Landscaping	0.015
		Site works	0.032
Performance record	0.290	Completing project on schedule	0.072
		Effectiveness of quality control system	0.073
		Effectiveness of cost control system	0.072
		Quality of finished products	0.073
Financial stability	0.086	Profitability	0.017
		Availability of credit	0.052
		Dept volume	0.017
Management and employees qualification	0.076	No. of projects that experienced failure in last 10 years	0.060
		Experience of manager	0.008
		Labour force	0.008
Capacity	0.037	No. of projects contractor works on now	0.006
		Capacity to add this project	0.008
		Status of current projects	0.023
Safety record	0.033	Strengths of safety program	0.009
		No. of accidents in the last 5 years	0.021
		Availability of safety training for new employees	0.003
Operation and equipment	0.150	Capabilities of technical field personal	0.148
		Suitable equipment resources	0.002

Next, information on evaluation of each criteria and subcriteria of each of five contractors was collected. Criteria evaluation was chosen according to their performance record and other information.

Based on Saaty [16] scale, decision making matrix for problem solution was prepared.

Finally, Table 2 provides overall scoring of each contractor on different criteria. Scoring of each contractor based on different criteria was counted with „Expert Choice".

In the Table 2, all optional values are the biggest values:

$$K_j = \sum_{i=1}^{m} \frac{x_{ij} w_i}{\sum_{j=1}^{n} x_{ij}} . \quad (1)$$

Where:

w_i - weight of sub criteria; x_{ij} - evaluation of i-th contractor according to the j-th criterion; $i = \overline{1,m}$; $j = \overline{1,n}$; m - number of criteria; n - number of contractors.

Table 2. Overall scoring of contractors.

CRITERIA	SUBCRITERIA	CONTRACTOR				
		Contr. 1	Contr. 2	Contr. 3	Contr. 4	Contr. 5
Technical experience	Civil works	0.097	0.097	0.019	0.048	0.048
	Electrical	0.008	0.008	0.015	0.002	0.004
	Mechanical	0.038	0.038	0.025	0.009	0.019
	Landscaping	0.007	0.007	0.015	0.002	0.004
	Site works	0.017	0.017	0.033	0.008	0.008
Performance record	Completing project on schedule	0.016	0.016	0.073	0.007	0.016
	Effectiveness of quality control system	0.037	0.018	0.037	0.005	0.018
	Effectiveness of cost control system	0.018	0.018	0.037	0.005	0.009
	Quality of finished products	0.037	0.037	0.073	0.009	0.018
Financial stability	Profitability	0.004	0.017	0.017	0.002	0.004
	Availability of credit	0.013	0.051	0.013	0.005	0.005
	Dept volume	0.002	0.002	0.002	0.002	0.004
	No. of projects that experienced failure in last 10 years	0.011	0.06	0.06	0.005	0.06

Management and employees qualification	Experience of manager	0.009	0.004	0.009	0.001	0.004
	Labor force	0.002	0.002	0.002	0.001	0.002
Capacity	No. of projects contractor work on now	0.006	0.001	0.001	0.006	0.001
	Capacity to add this project	0.007	0.002	0.001	0.007	0.001
	Status of current projects	0.005	0.011	0.011	0.005	0.005
Safety record	Strengths of safety program	0.001	0.001	0.002	0.00	0.00
	No. of accidents in the last 5 years	0.021	0.021	0.002	0.005	0.002
	Availability of safety training for new employees	0.00	0.00	0.003	0.00	0.00
Operation and equipment	Capabilities of technical field personal	0.023	0.023	0.047	0.011	0.011
	Suitable equipment resources	0.023	0.023	0.054	0.004	0.009
Total		0.402	0.474	0.551	0.149	0.252

According to Table 2 most suitable contractor would be contractor No. 3 as it scored the highest rate (0.551), the least good contractor for building swimming pool would be contractor No. 4 as it scored the lowest rate (0.149).

5. Conclusions

1. Most of construction management problems are MCDM problems. Countering complexity of a problem to be solved four optimization methods can be used: multi-criteria, oriented cost, mono objective, multi objective. Elimination, optimization and probabilistic methods could be used by project managers when making decisions. Multi-criteria aspect is significant when making construction management decisions.

2. The nine-stage model for solving decision making problems in construction have been suggested. Based on the literature overview and opinion of experts set of criteria was determined: a) technical experience; b) performance recourses; c) financial stability; d) management performance and employees qualification; e) capacity; f) safety record; g) operation and equipment.

3. The proposed model was used to choose contractor for construction of swimming pool. After analysing all alternatives, the best contractor with total score 0.551 had been chosen

MOORE'S & JOHNSON'S PROCEDURE

What Is Moore's Law?

Moore's Law refers to Moore's perception that the number of transistors on a microchip doubles every two years, though the cost of computers is halved. Moore's Law states that we can expect the speed and capability of our computers to increase every couple of years, and we will pay less for them. Another tenet of Moore's Law asserts that this growth is exponential.

- Moore's Law states that the number of transistors on a microchip doubles about every two years, though the cost of computers is halved.[1]
- In 1965, Gordon E. Moore, the co-founder of Intel, made this observation that became Moore's Law.[2]
- Another tenet of Moore's Law says that the growth of microprocessors is exponential.

In operations research, Johnson's rule is **a method of scheduling jobs in two work centers**. Its primary objective is to find an optimal sequence of jobs to reduce makespan (the total amount of time it takes to complete all jobs). It also reduces the amount of idle time between the two work centers.

ECONOMIC COMMON CYCLE SCHEDULING (ECC SCHEDULING).

The economic lot and delivery scheduling problem is to simultaneously determine the production sequence of several assembly components at a supplier and the delivery interval of those components to the customer. The customer, an assembly facility, is assumed to use the components at a constant rate. The objective is to find the production sequence and delivery interval that minimize the holding, setup, and transportation cost for the supply chain. Previous solutions to the problem assume a constant production rate for each component and that all components are of acceptable quality. These assumptions ignore volume flexibility and quality cost. Volume flexibility permits a system to adjust the production rate upwards or downwards within wide limits. Also, component quality may deteriorate with larger lot sizes and decreased unit production times. We can develop an algorithm for solving the economic lot and delivery scheduling problem for a supplier using a volume flexible production system where component quality depends on both lot sizes and unit production times. We can test the performance of the algorithm and illustrate the models with numerical examples.

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DEPARTMENT OF ARCHITECTURE

UNIT – III –Construction Operations Management– SARA5301

MODULE 13 SCM

SCM

The origins of supply chain management (SCM) lie in the manufacturing industries. The armoury practices of the late-19th century, and later the production methods of Henry Ford in the 1920s, created the SCM system that remains largely unchanged today. The central focus is on the production process of goods through the control of material flows.

Large efficiency gains can be achieved through managing the interfaces between organisations. Latham and Egan recognised this as being relevant to construction in their respective reports.

SCM exists alongside and overlaps with many other management approaches including:

- Lean thinking.
- Business process reengineering (BPR).
- Mass customization

What is supply chain management?

Supply chain management in construction

Contents

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Introduction

The origins of supply chain management (SCM) lie in the manufacturing industries. The armoury practices of the late-19th century, and later the production methods of Henry Ford in the 1920s, created the SCM system that remains largely unchanged today. The central focus is on the production process of goods through the control of material flows.

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SCM exists alongside and overlaps with many other management approaches including:

- Lean thinking.
- Business process reengineering (BPR).
- Mass customisation.

What is supply chain management?

'Supply' is the flow of resources used to satisfy a demand, such as materials, labour, information, skills, and so on. It can also refer to competencies, and represent combinations of resources. Commodity suppliers tend to be more price focused, whilst strategic suppliers are more quality/delivery focused.

'Chains' represents the notion of links within and between both resources and competencies. They are based upon relationships between people and organisations, and processes within and between organisations.

'Management' is the exercise of formal authority within a structured organisational setting that is directed towards aims and objectives through the efforts of other people using systems and procedures.

Supply chain management requires a holistic perspective and a view of organisations as parts of a process. It requires the ability to look beyond organisational boundaries, and a recognition of the interdependence of organisations.

Most definitions of supply chain management share generic characteristics:

- Holistic.
- Networks.
- Relationship-focused.
- Attitudinal.
- Responsibility of managing chain.
- Necessity for change of culture.

The need for SCM in construction

Managing the supply chain involves understanding the breakdown and traceability of products and services, organisations, logistics, people, activities, information and resources that transform raw materials into a finished product that is fit for its purpose.

Buildings are becoming increasingly complex, and require more design input by specialist suppliers. At the same time there is increasing fragmentation of the industry as can be seen from the growth of specialist suppliers/contractors, the proliferation of products and the fragmentation of design and control activities.

The supply chain is relatively unstable, and the industry is project-based with defined start and end points, and a traditional separation between design and construction. Demand is treated as a

series of competitively tendered prototypes constructed by temporary coalitions. This all has an impact on organisational relationships.

Project relationships are short term and have defined start and end points, they are usually informal/ad-hoc and focused on the project not the business. Relationships between competencies vary from project to project. The resulting lack of continuity prevents the innovation and improvement of process as well as the development of more complex relationships. The client may also have an impact on the procurement route and choice of strategic suppliers.

MODULE 14 INVENTORY MANAGEMENT

Inventory management

Inventory management system involves procurement, storage, identification, retrieval, transport and construction methods. Each is indelibly linked to safety, productivity and schedule performance. The main objective is to analyze the inventory management control adopted and the effective utilization of inventory at the construction site. ABC analysis is one of the conventionally used approaches to classify the inventories and the case study of a company is collected. The tracking and locating of materials in construction jobsites has increase a great concern among construction entities. The improper handling and storage of materials in construction site has made it difficult to track and locate materials when the time they are needed. These findings may reflect the main factors that will affect the inventory management system which able to achieve the improved efficiency of project management and to reduce the waste of materials in the respective region of construction industries.

1. INTRODUCTION

The term inventory refers to the goods or materials used by a firm for the purpose of production and sale. It also includes the items, which are used as supportive materials to facilitate production. Nearly 60% of money is allotted for the inventory in a project. Inventory constitutes one of the important items of current assets, which permits smooth operation of production and sale process of a firm. Inventory management is that aspect of current assets management, which is concerned with maintaining optimum investment in inventory and applying effective control system so as to minimize the total inventory cost. Materials

Management is related to planning, procuring, storing and providing the appropriate material of right quality, right quantity at right place in right time so as to co-ordinate and schedule the production activity in an integrative way for an industrial undertaking. Inventory Management is simply the process by which an organization is supplied with the goods and services that it needs to achieve its objectives of buying, storage and movement of materials. Inventory is seen as incurring costs, or waste, instead of adding and storing value, contrary to traditional accounting. Inventory management is the supervision of non-capitalized assets (inventory) and stock items. A component of supply chain management, inventory management supervises the flow of goods from manufacturers to warehouses and from these facilities to point of sale. A key function of inventory management is to keep a detailed record of each new or returned product as it enters or leaves a warehouse or point of sale.

1.1material Management

Construction material constitutes a major cost component in any construction project. The total cost of installed material may be 50% or more of the total cost. The goal of material management is to ensure that the materials are available at their point of use when needed hence, efficient procurement of material represents a key role in the successful completion of the work. Materials management is a critical component of the construction industry. As such, organizations need to understand the effects of proper materials management techniques on the effectiveness of project execution. Extensive literature and reports deplore the lack of efficiency and productivity in the construction industry. Too often, construction projects suffer from delays, budget overruns, and claims. A properly implemented materials management program can achieve the timely flow of materials and equipment to the jobsite, and thus facilitate improved work face planning, increased labor productivity, better schedules, and lower project costs.

1.2 Concept Of Just In Time

Just in Time (JIT) production is a manufacturing philosophy which increases speed of production. JIT Concept is, ―Company produces only what is needed, when it is needed and in the quantity that is needed‖. The company produces only what the customer requests, to actual orders, not to forecast. JIT can also be defined as producing the necessary units, with the required quality, in the necessary quantities, at the last safe moment. It means that company can manage with their own resources and allocate them very easily.

MODULE 15 ECONOMIC ORDER QUANTITY (EOQ)

EOQ

The economic order quantity (EOQ) refers to the ideal order quantity a company should purchase in order to minimize its inventory costs, such as holding costs, shortage costs, and order costs. EOQ is necessarily used in inventory management, which is the oversight of the ordering,

storing, and use of a company's inventory. Inventory management is tasked with calculating the number of units a company should add to its inventory with each batch order to reduce the total costs of its inventory.

The EOQ model seeks to ensure that the right amount of inventory is ordered per batch so a company does not have to make orders too frequently and there is not an excess of inventory sitting on hand. It assumes that there is a trade-off between inventory holding costs and inventory setup costs, and total inventory costs are minimized when both setup costs and holding costs are minimized.

- The economic order quantity (EOQ) refers to the ideal order quantity a company should purchase in order to minimize its inventory costs.
- A company's inventory costs may include holding costs, shortage costs, and order costs.
- The economic order quantity (EOQ) model seeks to ensure that the right amount of inventory is ordered per batch so a company does not have to make orders too frequently and there is not an excess of inventory sitting on hand.
- EOQ is necessarily used in inventory management, which is the oversight of the ordering, storing, and use of a company's

inventory.

The Formula for Economic Order Quantity (EOQ)

$$EOQ = \sqrt{\frac{2 \times S \times D}{H}}$$

where:

S = Setup costs (per order, generally including shipping and handling)

D = Demand rate (quantity sold per year)

H = Holding costs (per year, per unit)

In construction industry the problem of exceeding the overall estimated budget often arises and it seems quite challenging to be precise all the time. Its need to overcome such problems for that the proper use of inventory control or material planning is needed which is achieved by inventory management. In any construction project the working capital consist of 60- 70% material cost of the total cost of the project. A properly implemented materials management program can achieve the timely flow of materials and equipment to the job site and thus facilitate improved workforce planning, increased labor productivity, better schedules and lower project costs. The main objective is to select the Qualitative analysis technique such as Economic order Quantity (EOQ), Break Even Analysis (BEP) and to maintain sufficient stock of raw material and Control investment in inventories and give pragmatic suggestion for Future work. Thus, the cost effectiveness can be achieved.

I. INTRODUCTION

Construction is second largest economic activity in India, next only to agriculture. The amount of money invested in and the jobs provided by construction industry are much larger than any other industry in India. Construction plays a critical role in all development sectors like agriculture, irrigation, energy, transportation, communication, manufacturing, housing, civil infrastructure and social services. The scope and volume of the construction industry can be directly linked with size and population of the country. In India, the construction industry

employs a very large workforce probably next only to agriculture. Thus, the construction industry is an important industry for economic development. In Construction Industry the problem of exceeding the estimated budget often arises and it seems quite difficult to be precise all the time. To overcome such problems the use of proper inventory control or material planning is needed which is achieved by inventory management. In any construction project the working capital of the material comprises of 60-70% of the total cost of the project.

MODULE 16 LOGISTICS MANAGEMENT

Logistics management in construction

Logistics management is the process of planning, implementing and controlling supply chain resources, generally from the point of origin, such as raw material accumulation, to the point of destination, i.e. delivering goods to the correct location on the construction site.

Effective logistics management is important can enhance efficiency and productivity, having a positive overall impact on cost and time. For example, good logistics management ensures the workforce are able to carry out required activities without delays caused by materials being delivered to site.

Logistics management involves the integrating of many activities:

- Resource assessment.
- Lead time assessment.
- Supply and demand planning.
- Sourcing and procurement.
- Production planning and scheduling.
- Packaging and assembly.
- Inventory management and order fulfilment.
- Inbound and outbound transport management.
- Warehousing.
- Materials handling.
- On site vehicle and plant management.
- Customer services.
- Waste management.

Having a timeline of project stages planned in advance, with a full inventory of materials and tools required, is a key part of logistics management. Due to the complexity of the process, and the interaction of many supply streams, dedicated simulation software can be used to model, analyse, visualise and optimise logistics.

In addition to keeping the construction programme on-schedule, other advantages of good logistics management include:

- Cost savings and waste reduction as productivity is enhanced.
- Logistical planning on site enables materials to be stored correctly which improves efficiency and reduces the potential for damage
- Sites can be kept safe, clean and easy to move around.
- Deliveries can be received and handled promptly.

VALUE ENGINEERING

Value engineering is based on a methodology developed by Lawrence Miles, who worked for the General Electric Company in the USA during the Second World War. Because of the war, there were shortages of materials and certain finished products. However, manufacturing was running at maximum capacity, and ideas were needed to expand production.

Commonly used value techniques are now be defined as:

- Value Management (VM). The full range of value techniques available. This is a higher order title and is not linked to a particular project stage at which value techniques may be applied.
- Value Planning (VP). Value techniques applied during the planning phases of a project.
- Value Engineering (VE). Value techniques applied during the design or 'engineering' phases of a project.
- Value Analysis (VA). Value techniques applied retrospectively to completed projects to analyse or audit the project's performance.

VE is a technique directed toward analyzing the functions of an item or process to determine "best value", or the best relationship between worth and cost. In other words, "best value" is represented by an item or process that consistently performs the required basic function and has the lowest life-cycle cost. In this context, the application of VE in facilities construction can yield a better value when construction is approached in a manner that incorporates environmentally-sound and energy-efficient practices and materials.

Because "costs" are measurable, "cost reduction" is often thought of as the sole criterion for a VE application and indeed it is primarily addressed in this document. However, the real objective of VE is "value improvement" and that may not result in an immediate cost reduction

VE is a systematic, low-cost approach to assessing the "value" of a project. Typically, VE on projects can be used to gain the following benefits [2]:

- Cost reductions;
- time savings (schedule savings)
- quality improvements;
- isolation of design deficiencies.

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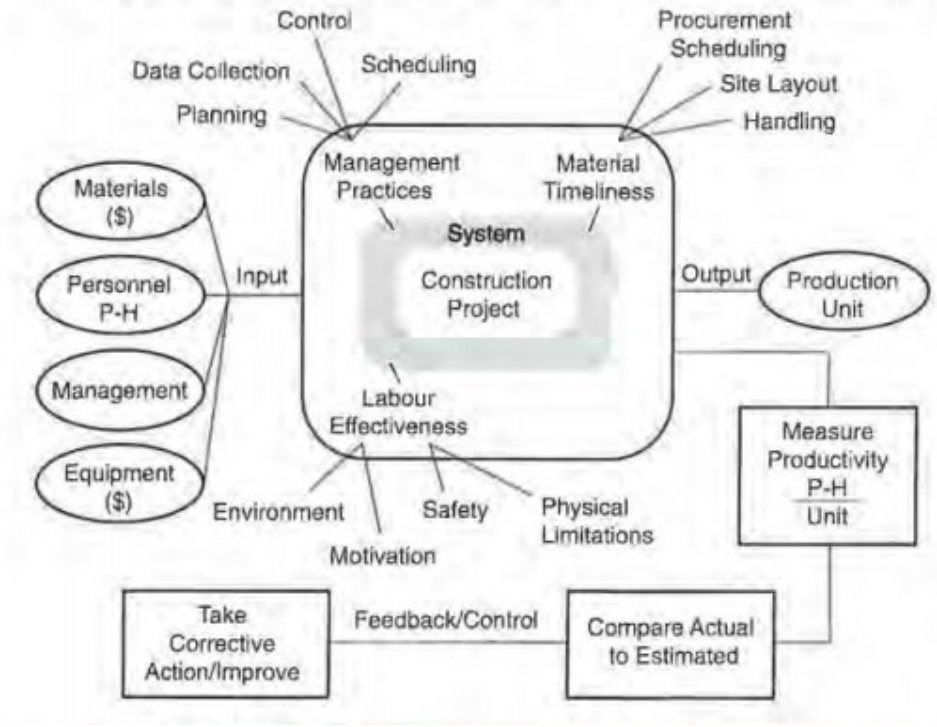
MODULE 17 PRODUCTIVITY

Productivity improvement in construction is best understood when the construction process is visualized as a complete system as shown in Figure 1.1. The system is made up of the construction project to which material, personnel, equipment, management, and money are inputs. They are consumed by the system in the process of producing the construction unit. Control of the system is achieved by collecting and processing information about the rates at which production is attained.

Figure 1.1 Framework for productivity improvement



1. Introduction

The measure of the rate at which work is performed is called “productivity”. It is a ratio of production output to what is required to produce it. The measure of productivity is defined as a total output per one unit of a total input. In construction, the output is usually expressed in weight, length, or volume, and the input resource is usually in cost of labor or man-hours. There are many standards available in the construction industry for contractors as reference values for

purposes of construction cost estimation. These standards may vary in values but most are similar in principle. This writing explores labor factoring and how advances in technology are making management of labor productivity more predictable. The use of technology can expose inefficiencies, enable visualization of problem areas, and improve construction planning accuracy, as well as provide documentation and visualization to support or defend change order requests and construction claims.

2. Labor Impacts on Construction Planning

The American Association of Cost Engineers defines productivity as a "relative measure of labor efficiency, either good or bad, when compared to an established base or norm." This white paper focuses on the ability to create, change, and manage labor factors affecting productivity in construction planning. While trying to benchmark productivity is difficult as an absolute value, many sources are available for benchmarking trends from historical data collected, which are made available from many trade and professional associations. These include the US Department of Labor, US Bureau of Labor Statistics, Contractors Associations, independent contractors, universities, and other organizations. Although there are numerous lists of labor factors from different groups, most are very common to many lists and carry a similar range of impacts on labor productivity. Every year, owner operators, engineering, procurement, and construction (EPC) companies, and contractors are hit with billions of dollars in construction claims as a result of inefficiency factors impacting labor. Good construction planning should consider and track labor factors in the original work scope to accurately reflect all the conditions that were used to estimate and fund the project, as well as to eliminate or minimize the impact on productivity, which will directly affect the construction costs. It should also include changes in work scope that look at labor impacts as part of the sequence and planning of any work. Technology such as Intergraph® SmartPlant® Construction can help work planners manage and control labor impacts by providing users the ability to add and adjust labor factors for their project. It also allows users to visualize and animate work packages with the ability to change the sequence of work packages in order to eliminate or reduce labor factoring. In addition, SmartPlant Construction can create work package documentation to support or defend construction claims associated with labor factoring

3. Unique Projects

No two construction projects are exactly the same and vary in many ways such as design, size, capacity, utilities, location, orientation, and so on. When projects are planned and budgeted based on historical data, it is important to consider the differentiators and variables unique to the project and factor them accordingly. All projects are unique and have some variables. Even those with the exact same design will have some differentiators, including:

- Design or capacity
- Varying site conditions such as soil,drainage, and so on
- Weather conditions such as climate andtemperature
- Season changes

 Manpower and labor conditions, such asunion versus open shop, and skilled versus unskilled labor

 Experience factors such as learning curve and legacy data from previous projects

 Intangible factors such as morale, fatigue, and attitude, which leads to absenteeism, turnover, and crew size inefficiency

 Site access

 Unplanned errors and omissions, work stoppages, delays, and so on

 Source and location of power and utilities

 Governmental or regulatory requirements

 Material source, supply, and codes

 Different project team and supervision

 Proximity to transport and logistics

MODULE 18 VSM

Value stream mapping (VSM) is a tool used within the field of Project Management to visualize and improve the overall flow process of a product or service from raw material all the way to the customer. It has its origin at TOYOTA, being a part of their lean management tools, where it is known as “material and information flow mapping”. VSM helps document all the activities required to complete a request from a customer. It includes people who normally manage individual functions or processes, and makes the overall flow of material and information across the entire process visible. In addition, it brings alignment to the organization, by involving the people who in fact do the work, and provides a platform for improvement and implementation. VSM is dynamic tool, since its continuously updated as the processes is being improved. VSM differs from the traditional tool; process/flow maps, by having a process focus, rather than a product focus. It provides a holistic view of how thing work, with a costumer perspective. VSM generates security within the organisations, which is essential to success. Insecurity often result in withhold of important information about the flow and processes, and will consequent lead to delay and loss of value. One vital gain from applying VSM, is that it provides a common language when talking about processes, and allowing people to operate solely based on facts.

VSM generic formulation

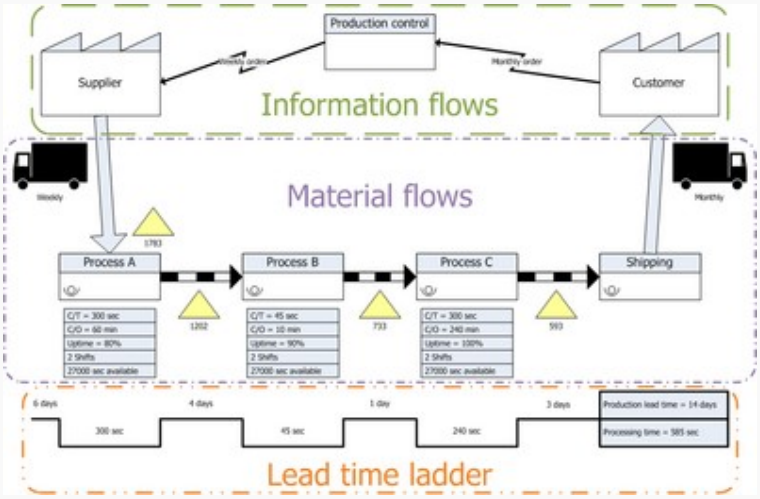


Figure 1: Value stream map.

Value stream mapping (VSM) originated in the manufacturing industry. It was developed by Toyota Motors Corporation, being a part of their Lean management tools. The Lean management philosophy is to identify and eliminate every activity in the design, production and supply chain management related processes that does not create value for a costumers point of view. Generally it is characterized as a process-improving management philosophy, that seeks to minimize the waste without decreasing the productivity.

Let's first define what a "Value stream" is. The formal definition is as follows: "All the steps both value added and non-value added, required to take a product or service from row material to the waiting arms of the customer".

Value stream mapping (VSM) is used to both analyse and design the flow of material and information, that is required to bring a product or service to the end customer. It is a visual tool that provides a holistic view of the overall process, and thus a platform for strategically improvement and adding value to the costumers. It has also been used to initiate a systemic implementation of the Lean production tools. The goal is to design an “ideal state”, also known as the “future state” by analyzing the “current state”. The current state presents how the process is at the time of making the VSM. This is very important due to the dynamic nature of VSM. An enormous amount of waste or in Japanese (Muda) is often present within the a work flow system. This waste is identified by reflecting the current state. The future state represents the state where the all the identified waste has been eliminated.

The general mapping of a current state is presented in Figure 1, showing the three key points:

- Information flow
- Material flow
- Lead time ladder

The overall lead time of the product or service is an important part of a VSM. Usually significant amount of non-value added activity or waste is found, and takes an enormous amount of time. Having identified the wastes, a future state can be designed where the wastes are eliminated, often applying additional Lean tools to achieve it. Standardized symbols are used when mapping a process state, to obtain a common language for communicating through the VSM

VSM in the construction industry

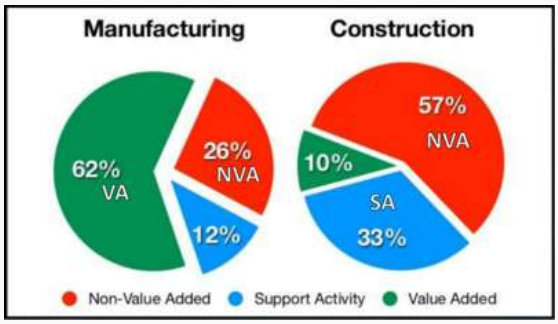


Figure 2: Construction industry vs. Manufacturing industry.

The construction industry in terms of productivity, quality and efficiency, is often characterized as a backward industry, that fails to innovate compared to other industries. The Lean Thinking philosophy way introduced to the construction industry in 1993, and some successful implementations has been achieved. The major difference between the manufacturing- and construction industry is uniqueness related to a building project. Unlike, for instance in the car industry, the assembly line has been used since it's first implementation in the early 20th century. This automation of a standardized product cannot directly be implemented in the building industry due to the unique nature of building projects. However increasing automation is seen in constituent parts of construction project, as in pre-fabrication of concrete elements. This has furthermore been shown reduce both energy consumption and cost. The Construction Industry Institute states that only 10% are value added inputs and striking 57% are waste. This is compared to the manufacturing industry where 62% is value added and 26% is waste. The lack of performance in the construction industry compared to other industries, has been directly related to the low rate of innovation.

Another issue is the competition for building project, mainly in the public projects, which is cost centered. The cheapest bid wins the project, and under these circumstances bidders invest very little amount of time, money and vitality in advance. These statistics are a major motivation, for studying and identifying the wastage, which is frequently present in the industry. Consequently how to apply Lean tools and techniques to reduce the wastage. Examples of value adding activities are pouring concrete, erecting steel or installing the roof. Examples of waste are

excessive material handling, design errors, conflict between contractors, ineffective supply chain and rework.

MODULE 19 JIT

ELIMINATE INVENTORY WASTE AND MORE WITH JUST IN TIME CONSTRUCTION DELIVERY

JIT Delivery, or just in time in construction, is an inventory management approach designed to eliminate waste by "receiving goods only as they [are needed] for production processes." While JIT delivery is most often correlated with combating the issue of inventory waste, it is also perfectly applicable to the elimination of D.O.W.N.T.I.M.E and all of the 8 wastes of lean construction.

In construction processes, inventory waste is generally the result of unnecessary stockpiling of materials due to over-estimating and over-ordering. But it can also include and lead to the unnecessary use of said materials, thus translating to a whole host of wasted effort, time, and material.

The concept of just in time in construction is derived from the Toyota company's revolutionary system of lean manufacturing; where production input is determined on the basis of actual demand. As with many factory-based lean manufacturing principles, JIT delivery is becoming increasingly assimilated into lean construction methodologies.

In a construction scheduling context, JIT requires alignment and balance between project items that are considered "long lead" and those that are more readily available. As a result, specialized Supply Chain Management (SCM) personnel are required for ensuring that all materials are present and readily available when needed. This means that the SCM must factor lead times into the process, creating a system where materials are pulled, rather than pushed through the process.

Estimating material needs and "pushing" them through a project is inefficient and prone to error, often resulting in wasted effort, time, money, and supplies.

The JIT method also requires that suppliers and contractors collaborate at a higher level than in regular construction methods and it requires that all project supplies are up to standard. This helps to prevent project delays due to unusable materials and helps to ensure that contractors deliver a higher quality product with reduced defects and maintenance needs over the life of the product.

MODULE 20 BREAK EVEN POINT

BEP

In simple words, the break-even point can be defined as a point where total costs (expenses) and total sales (revenue) are equal. The origins of break-even point can be found in the economic concepts of "the point of indifference." Calculating the break-even point of a company has proved to be a simple but quantitative tool for the managers. The break-even analysis, in its simplest form, facilitates an insight into the fact about revenue from a product or service incorporates the ability to cover the relevant production cost of that particular product or service or not. Moreover, the break-even point is also helpful to managers as the provided info can be used in making important decisions in business, for example preparing competitive bids, setting prices, and applying for loans.

$$Break\ Even\ Point\ (N) = \left(\frac{\text{Fixed costs}}{\text{Price per unit} - \text{Variable costs}}\right)$$

MODULE 21 KANBAN

"Kanban" is the Japanese word for "visual cards" and is a Lean tool developed in the automotive industry for JIT production. The Kanban acts as a work order without which work should not start, and has also been used as a material process flow technique for the pull replenishment logic system. The Kanban is usually used in the construction material procurement process by organizing orders, acting as a visual tool for the improvement of communication among all stakeholders, and insuring that the right amount of the right item is delivered at the right time. This paper seeks to promote the use of the Kanban as a work order for the construction production process, and as a construction process control tool. There are two types of Kanban described in this paper: the ordering Kanban, and the receipt Kanban. The Kanban is also useful as safety control tool because safety information is included on each Kanban. Due to the Kanban's ability to increase communication, and to decrease the number of accidents, one of the most important findings of these case studies: the use of the Kanban in construction production and safety control is highlighted.

MODULE 22 WORK SAMPLING

Labor productivity has a major impact on whether a construction project is completed on time and within budget. Therefore, it is important for construction managers to improve the conditions that affect labor productivity on their jobsites. Work sampling is a method that evaluates the amount of productive, supportive, and non-productive time spent by the trade workers engaged in performing their assigned work activities. It also helps identify any trends affecting labor productivity.
Work sampling was used by an insulation and waterproofing contractor located in the southeast on a hospital project to identify areas where action could be taken to improve labor productivity. There is a need for a course of action for implementing a work sampling study on a jobsite . Construction companies are constantly searching for ways to improve labor productivity. Since labor is one of the greatest risks in a construction contract it must be controlled and continuously improved. The construction company with the most efficient operations has a greater chance to make more money and deliver a faster construction project to the project owner (Orth & Jenkins, 2003). There are several factors that affect labor productivity on a jobsite such as weather conditions, workers' skill level, overcrowding of work crews, construction methods used, and material delivery/storage/handling procedures (Jenkins & Orth, 2003). Several methods exist for measuring and analyzing worker productivity. These methods include work sampling, audio-visual methods, and the method productivity delay model. This study attempted to isolate areas of potential labor productivity improvement by observing the labor force using work sampling. Work sampling is a method that evaluates the amount of productive, supportive, and non-productive time spent by the trade workers engaged in performing their assigned work activities. Work sampling also helps identify any trends affecting labor productivity.

This paper presents the guidelines used by the authors to develop and implement a work sampling study for work performed on a hospital construction project. This particular study took place during July 2004 and was used to evaluate the work conducted by the company's three profit centers: fireproofing, waterproofing, and insulation on a hospital project in the southeastern United States. The authors believe that work sampling is a useful method for analyzing site productivity, providing solutions for existing productivity problems, and establishing a baseline for comparing future studies, due to the value of information obtained from this study. Although the focus is on applying work sampling techniques to a hospital construction project, the guidelines presented in this paper may be modified to conduct such a study on any type construction project.

Work Sampling

Work sampling is a series of instantaneous observations, "snap shots," of work in progress taken randomly over a period of time (Jenkins & Orth, 2003)." This method provides information on the amount of time workers spend performing productive, supportive, and non-productive work (Jenkins & Orth, 2003). Work sampling is a technique that provides valuable information to a construction manager regarding areas of low productivity that need corrective action (Thomas & Napolitan, 1999). Work sampling's main advantage is that it allows for simultaneous monitoring of labor productivity in a variety of trades (Noor 1998). When monitoring more than one trade, the observer(s) need to distinguish the different trades so observations are not incorrectly categorized. Work sampling can be conducted by anyone with basic knowledge of both construction and work sampling methods. However, the authors suggest that the person(s) conducting the work sampling study be a neutral party and not employed by the company being evaluated. This will help to reduce bias of the study and reflect the actual conditions of jobsite labor productivity.

In conducting a work sampling study, the observer(s) start at a random time and follow a pre-planned route throughout the jobsite. As each trade worker is encountered, the observer categorizes and records the activity of the individual based on the instant the observer came into contact with the trade worker. Categories of work are classified as being productive, supportive, or non-productive. By definition, the categorization of the activity performed by each individual trade worker at the time they are observed is considered to be a "work sample". Productive work is defined as direct, hands-on activity to physically construct the project, such as insulating a pipe or painting a door. Supportive work is defined as any activity used to support the productive work such as measuring a pipe or stirring paint. Non-productive is defined as wasted time spent on the jobsite that can be recovered as productive time such as waiting for instructions, starting late or quitting early on a work activity.

The study continues until observer(s) record the pre-determined number of samples. The data obtained for a work sampling study will become more reliable as the quantity of work samples increases. Statistical tables relaying the quantity of samples required for a high probability of accuracy are available to help determine the required number of samples (Adrian & Adrian, 1995). At the conclusion of the study, all observed work samples are compiled together and analyzed. Recommendations for improving productivity are then based upon these findings. While collecting data it is important to take work samples throughout the entire day or shift (Thomas & Daily, 1983). If the observer does not take into account the time at the beginning and end of the day or before and after lunch then the data will show an inflation of productive work by eliminating set up times and times when workers are putting tools away (Thomas & Daily, 1983).

MODULE 23 FORECASTING

Considerable research efforts have been made to improve the effectiveness of time and cost control of engineering, procurement and construction (EPC) projects (Alshibani, 1999; Moselhi, 1993; Ji Li, 2004; Fleming and Koppelman, 2005). However, through a study conducted in collaboration with large Canadian engineering, procurement and construction management (EPCM) firm, along with related materials from literature, areas of improvement in current process of progress reporting and forecasting final cost (FFC) can be identified.

These areas include:
1) implementation of earned value method (EVM) on forecasting cost and time in large size EPC projects in practical manner,
2) trade-off between practicality and theory,
3) proper visualized reporting on construction progress using multi-media,
4) progress measurement and consolidated progress for EPC projects.

This paper presents a methodology and a prototype model that address the above cited limitations. The developed model has 3 interesting features: 1) it improves the accuracy of trending and FFC in a practical simple way, 2) it facilitates progress measurement and consolidation for overall EPC progress reporting, and 3) it provides visualized progress reports from the cost and time control point of view. Numerical examples are presented to illustrate the essential features.

- **Linear-regression analysis**—A straight-line mathematical model to describe the functional relationships between independent and dependent variables.
- **Standard error of the estimate**—A measure of variability around the regression line.
- **Coefficient of correlation**—A measure of the strength of the relationship between two variables.
- **Coefficient of determination**—A measure of the amount of variation in the dependent variable about its mean that is explained by the regression equation.
- **Multiple regression**—An associative forecasting method with > 1 independent variable.

Multiple regression forecast: $\hat{y} = a + b_1x_1 + b_2x_2$ (4-17)

- The regression equation is one way of expressing the nature of the relationship between two variables. Regression lines are not "cause-and-effect" relationships. They merely describe the relationships among variables. The regression equation shows how one variable relates to the value and changes in another variable.

- Another way to evaluate the relationship between two variables is to compute the coefficient of correlation . This measure expresses the degree or strength of the linear relationship

- Unlike time-series forecasting, associative forecasting models usually consider several variables that are related to the quantity being predicted. Once these related variables have been found,

- a statistical model is built and used to forecast the item of interest. This approach is more powerful than the time-series methods that use only the historical values for the forecast variable.

- Many factors can be considered in an associative analysis. For example, the sales of Dell

- PCs may be related to Dell's advertising budget, the company's prices, competitors' prices and promotional strategies, and even the nation's economy and unemployment rates. In this case, PC sales would be called the dependent variable , and the other variables would be called independent variables . The manager's job is to develop the best statistical relationship between PC sales and the independent variables . The most common quantitative associative forecasting model is linear-regression analysis .

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