SJC Institute

Operations Management

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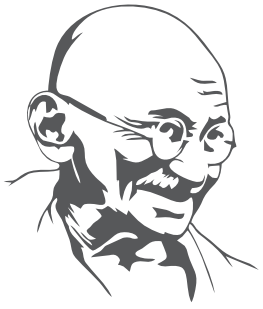
"Live as if you were to die tomorrow. Learn as if you were to live forever."

Mahatma Gandhi



SJC Institute

Our Aim

is to Gift CA/CMAs to Every Family

Welcome Aboard
To Our Goal

Content

Some Chapters are not included here as no questions are asked yet from those chapters.

CHAPTER 1
INTRODUCTION

Chapter 1.1 Scope

Q1 June'23 MTP Set 1, June'23

List down various major decision areas under Production and Operations Management.

Reference

~~Production and Operations Management~~ decision areas

What's **New**

Answer

Major decision areas under Production and Operations Management are:

1. Product selection
2. Facility Location Selection
3. Demand Forecasting
4. Process selection & Layout decision
5. Capacity planning
6. Aggregate Planning, Master production schedule
7. Materials Requirement Planning (MRP)/Manufacturing Resource Planning (MRP I)/ Distribution Resource Planning (DRP) / Enterprise Resource Planning (ERP)
8. Inventory Management
9. Supplier Selection/Sourcing
10. Process Management

Q2 - Scope

Chapter 1.2
Characteristics of Modern Operations Functions

Q1 Dec'23 MTP Set 1

Enumerate the characteristics of Modern Operations functions.

Reference	What's **New**

Answer

Modern Operations Management is characterized by the following :

(a) Technological development Tech dev

(b) Shorter product life cycle PLC

(c) Changing needs and preferences of the customers Customer

(d) Disruptions (market and product) and pressure for innovation Disruption

(e) Globalization Glob

(f) Requirement for supreme service at an affordable price Price / Service

(g) Pressure for optimization of operational cost Optimisn

Chapter 1.3

Recent Trends in Production and Operations Management

Q1 June'23 MTP Set 1

What do you mean by Lean Production?

Reference
Lean Production

What's **New**

Answer

Lean Production

Production systems have become lean production systems which use minimum amounts of resources to produce a high volume of high quality goods with some variety. These systems use flexible manufacturing systems and multi-skilled workforce to have advantages of both mass production and jobs production (or craft production).

Lean Production aims to cut costs by making the business more efficient and responsive to market needs.

Q2 June'23 MTP Set 2

Briefly discuss the scope of Operation Management.

Reference
Scope

What's **New**

Answer

Scope of Operation Management

Operations Management concerns with the conversion of inputs into outputs, using physical resources, so as to provide the desired utilities to the customer while meeting the other organizational objectives of effectiveness, efficiency and adoptability. It distinguishes itself from other functions such as personnel, marketing, finance, etc. by its primary concern for 'conversion by using physical resources'. Following are the activities, which are listed under Production and Operations Management functions:

1. Location of facilities.
2. Plant layouts and Material Handling.
3. Product Design.
4. Process Design.
5. Production Planning and Control.
6. Quality Control.
7. Materials Management.
8. Maintenance Management

Q3 June'23

List down various major decision areas under Production and Operations Management.

Reference

Production and Operations Management

What's **New**

Answer

Major decision areas under Production and Operations Management are:

1. Product selection
2. Facility Location Selection
3. Demand Forecasting
4. Process selection & Layout decision
5. Capacity planning

6. Aggregate Planning, Master production schedule
7. Materials Requirement Planning (MRP)/Manufacturing Resource Planning (MRP I)/ Distribution Resource Planning (DRP) / Enterprise Resource Planning (ERP)
8. Inventory Management
9. Supplier Selection/Sourcing
10. Process Management

CHAPTER 2
OPERATIONS PLANNING

Chapter 2.1

Demand Forecasting

Q1 June'23

The sales of CTV (₹ in Million) of SONTON LTD. for the 5 years are given below :

Year	2014	2016	2018	2020	2022
Sales of CTV (₹ in Million)	18	21	23	27	16

Required:

Estimate the Trend values of Sales of CTV for the years of 2021, 2024 and 2026.

Reference

Trend Values of Sales

What's **New**

Answer

Trend values of Sales of CTV for years:

YEAR 2021	₹ 21.30 Million
YEAR 2024	₹ 21.60 Million
YEAR 2026	₹ 21.80 Million

Q2 Postal Test Papers

From the following time series data of sale project the sales for the next three years.

Years	2015	2016	2017	2018	2019	2020	2021
Sales (₹000 units)	80	90	92	83	94	99	92

Soln to Q1

Let the st line trend eqn be:-

$$Y = a + bX$$

where Y = Trend value, y = Sales

$X = \frac{x - \text{Origin}}{\text{Scale}}$:

x = yrs

Origin: 2018

Scale: 1yr

a & b are constants & can be obtained by solving these eqns:-

(i) $\Sigma y = na + b\Sigma x$

(ii) $\Sigma xy = a\Sigma x + b\Sigma x^2$

Table can be constructed as below:-

y	x	X	Xy	X^2
Sales	yrs			

18	2014	-4	-72	16
21	2016	-2	-42	4
23	2018	0	0	0
27	2020	2	54	4
16	2022	4	64	16
105		0	4	40

$\therefore$ (i) $105 = 5a + b \times 0$ (ii) $4 = a \times 0 + b \times 40$

$\therefore a = 21$ $b = 0.10$

$\therefore$ Eqn: $\boxed{Y = 21 + 0.10X}$

Fv	$x\left(\frac{x - \text{origin}}{\text{scale}}\right)$	Sales (M) $Y = 21 + 0.1X$
Yr		
2021	3	$21 + 0.1 \times 3 = 21.3$
2024	6	$21 + 0.1 \times 6 = 21.6$
2026	8	$21 + 0.1 \times 8 = 21.8$

Reference

Time Series - Method of Least Squares - Odd No. of years

What's **New**

Sales Forecast

Answer

Computation of trend values of sales

Year	Time deviations from 2004	Sales (₹ 000 units)	Squares of time deviation	Product of time deviation and sales
	X	Y	X^2	XY
2015	–3	80	9	– 240
2016	–2	90	4	– 180
2017	–1	92	1	– 92
2018	0	83	0	0
2019	+1	94	1	+ 94
2020	+2	99	4	+ 198
2021	+3	92	9	+ 276
n = 7	$\Sigma X = 0$	$\Sigma Y = 630$	$\Sigma X^2 = 28$	$\Sigma XY = +56$

Regression equation of Y on X:

$Y = a + bX$

To find the values of a and b

$$a = \frac{\Sigma Y}{n} = \frac{630}{7} = 90$$

$$b = \frac{\Sigma XY}{\Sigma X^2} = \frac{56}{28} = 2$$

Hence regression equation comes to $Y = 90 + 2X$.

With the help of this equation we can project the trend values for the next three years, i.e. 2022, 2023 and 2024.

$Y_{2008} = 90 + 2(4) = 90 + 8 = 98$ (000) units.

$Y_{2009} = 90 + 2(5) = 90 + 10 = 100$ (000) units.

$Y_{2010} = 90 + 2(6) = 90 + 12 = 102$ (000) units.

Q3 Dec'23 MTP Set 1

With the help of following data project the trend of sales for the next five years:

origin 2018.5, scale = 0.5

Years	2016	2017	2018	2019	2020	2021
Sales (in lakhs)	100	110	115	120	135	140

Reference
Time Series - Method of Least Squares - Even No. of years

What's **New**
Sales Forecast

Even.

Answer

Computation of trend values of sales

$X = \frac{x - \text{origin}}{\text{scale}}$

Year	Time deviations from the middle of 2004 and 2005 assuming 6 months = 1 unit	Sales (in lakh ₹)	Squares of time deviation	Product of time deviation and sales
	X	Y	X^2	XY
2016	-5	100	25	-500
2017	-3	110	9	-330
2018	-1	115	1	-115
2019	+ 1	120	1	+120
2020	+ 3	135	9	+ 405
2021	+ 5	140	25	+ 700
n = 6	$\Sigma X = 0$	$\Sigma Y = 720$	$\Sigma X^2 = 70$	$\Sigma XY = 280$

Regression equation of Y on X:

$Y = a + bX$

(i) $\Sigma y = na + b\Sigma x$

$720 = 6a + b \times 0$

$a = 120$

(ii) $\Sigma Xy = a\Sigma x + b\Sigma x^2$

$280 = a \times 0 + b \times 70$

$b = 4$

To find the values of a and b

$$a = \frac{\Sigma Y}{n} = \frac{720}{6} = 120$$

$$b = \frac{\Sigma XY}{\Sigma X^2} = \frac{280}{70} = 4$$

Hence regression equation comes to $Y = 120 + 4X$

$\therefore Y = 120 + 4x$

Sales forecast for the next years, i.e., 2022-26

Yr	X	$Y = 120 + 4x$
22	7	$120 + 7 \times 4 = 148$
23	9	$120 + 9 \times 4 = 156$
24	11	= 164
25	13	= 172
26	15	= 180

$Y_{2022} = 120 + 4\,(+7) = 120 + 28 = ₹\ 148$ lakhs

$Y_{2023} = 120 + 4\,(+9) = 120 + 36 = ₹\ 156$ lakhs

$Y_{2024} = 120 + 4\,(+11) = 120 + 44 = ₹\ 164$ lakhs.

$Y_{2025} = 120 + 4\,(+13) = 120 + 52 = ₹\ 172$ lakhs.

$Y_{2026} = 120 + 4\,(+15) = 120 + 60 = ₹\ 180$ lakhs.

Chapter 2.2
Capacity Planning

Q1 June'23 MTP Set 1

Discuss in brief the types of capacity planning.

Reference
Capacity Planning

What's **New**

Answer

Capacity planning is mainly of two types:

(i) **Long-term capacity plans** which are concerned with investments in new facilities and equipments. These plans cover a time horizon of more than two years.

(ii) **Short-term capacity plans** which takes into account work-force size, overtime budgets, inventories etc.

Capacity refers to the maximum load an operating unit can handle. The operating unit might be a plant, a department, a machine, a store or a worker. Capacity of a plant is the maximum rate of output (goods or services) the plant can produce.

Q2 Postal Test Papers

A manager has to decide about the number of machines to be purchased. He has three options i.e., purchasing one, or two or three machines. The data are given below.

Number of machine	Annual fixed cost	Corresponding range of output
One	₹ 12,000	0 to 300
Two	₹ 15,000	301 to 600
Three	₹ 21,000	601 to 900

Variable cost is ₹ 20 per unit and revenue is ₹ 50 per unit

(a) **Determine** the break-even point for each range

(b) If projected demand is between 600 and 650 units **how** many machines should the manager purchase?

Reference

Break-Even Point

What's **New**

Marginal Costing

Answer

(i) Break-even point

Let Q be the break even point.

FC = Fixed cost, R = Revenue per unit, VC = Variable cost

At, BEP,

TR = FC + TVC

or, Revenue p.u × Q = FC + VC p.u. × Q

Q (R – VC) = FC

$$Q = \frac{FC}{R - VC}$$

Let Q1 be the break-even-point for one machine option

Then, $Q_1 = \frac{1200}{(50 - 20)} = \frac{1200}{30} = 400$ units

(Not within the range of 0 to 300)

Let Q_2 be the break-even-point for two machines option.

Then, $Q_2 = \frac{1500}{(50 - 20)} = \frac{1500}{30} = 500$ units

(within the range of 301 to 600)

Let Q_3 be the break-even-point for three machines option.

Then, $Q_3 = \frac{21000}{(50 - 20)} = \frac{21000}{30} = 700$ units

(with in the range of 601 to 900)

(ii) The projected demand is between 600 to 650 units.

The break even point for single machine option (i.e., 400 units) is not feasible because it exceeds the range of volume that can be produced with one machine (i.e., 0 to 300).

Also, the break even point for 3 machines is 700 units which is more than the upper limit

of projected demand of 600 to 650 units and hence not feasible. For 2 machines option the break even volume is 500 units and volume range is 301 to 600.

Hence, the demand of 600 can be met with 2 machines and profit is earned because the production volume of 600 is more than the break even volume of 500. If the manager wants to produce 650 units with 3 machines, there will be loss because the break even volume with three machines is 700 units. Hence, the manager would choose two machines and produce 600 units.

Chapter 2.3

Facility Location and Layout

Q1 Postal Test Papers

Suppose, an E-Commerce company wants to open Central order fulfilment center in Kolkata South in West Bengal. The possible locations are say L_1, L_2, and L_3. The company form a group of experts. The team identifies say 4 factors such as F_1, F_2, F_3, and F_4 to evaluate L_1 to L_3.

Weighted Rating of Factor & Location

Factors	Weight	Alternatives		
		L1	L2	L3
F1	0.3	10	9	7
F2	0.2	7	3	10
F3	0.1	7	5	10
F4	0.4	6	8	5

Identify the best location.

Reference
Location

What's **New**
Factor Rating Method

Answer

For L_1 : $0.3 \times 10 + 0.2 \times 7 + 0.4 \times 6 = 3 + 1.4 + 0.7 + 2.4 = 7.5$

As per the weighted score Location L_1 is the best location

Chapter 2.4

Resource Agreement Planning

Q1 June'23

Discuss with appropriate examples, various properties of aggregate planning.

Reference	What's New
Resource Aggregate Planning, Demand Forecasting	

Answer

Properties of Aggregate Planning:

To facilitate the production manager the aggregate planning must have the following characteristics:

(i) Both out put and sales should be expressed in a logical overall unit of measuring. For example, an automobile manufacturing company can say 1000 vehicles per year, without giving the number of each variety of vehicle. Similarly a paint industry can say 10,000 litres of paint and does not mention the quantities of each variety of colour.

(ii) Acceptable forecast for some reasonable planning period, say one year.

(iii) A method of identification and fixing the relevant costs associated with the plant. Availability of alternatives for meeting the objective of the organisation. Ability to construct a model that will permit to take optimal or near optimal decisions for the sequence of planning periods in the planning horizon.

(iv) Facilities that are considered fixed to carry out the objective

Chapter 2.5
Economic Batch Quantity

Q1 June'23 MTP Set 1

Define EBQ

Reference

Economic Batch Quantity

What's **New**

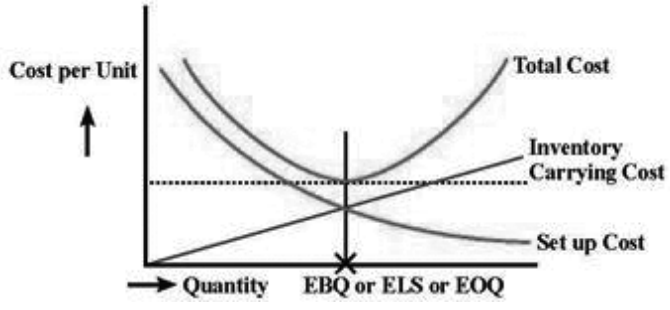
Answer

EBQ: In inventory management, Economic Batch Quantity (EBQ) is a measure to determine the quantity of units that can be produced at the minimum average costs in a given batch.

If S is the set up cost per set up also known as Ordering Cost, 'C' is the production cost per unit produced and I is the inventory carrying or holding changes (%) and A is the annual demand for the item in units, then,

Economic Batch Quantity (EBQ)

$$\sqrt{\frac{2AS}{C}} = \sqrt{\frac{2\times(\text{Annual demand in unit})\times(\text{Set up Cost per set up})}{(\text{Production Cost per unit})\times(\text{Inventory carrying charges (Percentage)})}}$$



Economic Batch Quantity

→ Not good

Q2 June'23 MTP Set 1

Solve the ABC analysis of the following table.

Annual Usage of Inventory by value

Item Number	Annual Rupee Usage (₹)	Percentage of total value (%)
22	95,000	40.69
68	75,000	32.12
27	25,000	10.71
03	15,000	6.43
82	13,000	5.57
54	7,500	3.21
36	1,500	0.64
19	800	0.34
23	425	0.18
41	225	0.10
TOTAL	**₹2,33,450**	**100%**

Cum %: 40.69, 72.81, 83.52, 89.95, 95.52, 98.73, 99.37, 99.71, 99.89, 99.99

A, B, C

Reference

ABC Analysis

What's **New**

Answer

ABC analysis is an inventory management technique that determines the value of inventory items based on their importance to the business. It groups item into three categories (A, B & C) based on their level of value within a business.

Classification	Item no.	Annual Rupee Usage	% of total
A	22,68	1,70,000	72.9%
B	27,03,82	53,000	22.7%
C	54,36,19,23,41	10,450	4.5%

Q3 Postal Test Paper

The monthly requirement of raw material for a company is 3000 units. The carrying cost is estimated to be 20% of the purchase price per unit, in addition to ₹ 2 per unit. The purchase price of raw material is ₹ 20 per unit. The ordering cost is ₹ 25 per order.

(i) You are **required** to find EOQ.

(ii) **What** is the total cost when the company gets a concession of 5% on the purchase price if it orders 3000 units or more but less than 6000 units per month

(iii) **What** happens when the company gets a concession of 10% on the purchase price when it orders 6,000 units or more?

(iv) **Which** of the above three ways of orders the company should adopt?

Reference
EOQ

What's **New**
Price Break Problem per month

Answer

We are given that,

A = Annual demand = 3,000 × 12 = 36,000 units per annum ;

S = Ordering Cost = ₹ 25;

C = Inventory carrying cost = 2 + 20% of ₹ 20 = 2 + 4 = ₹ 6

i) $EOQ = \sqrt{\frac{2AS}{C}} = \sqrt{\frac{2 \times 36000 \times 25}{6}} = \sqrt{3,00,000} = 548$ units (approx.)

Total cost = Ordering Cost + Cost of purchasing the material + Storage cost

= (36,000 / 548) × 25 + (36,000 × 20) + (548/2) × 6

[∵ Storage cost = Average Inventory × Inventory carrying cost]

= ₹ 1642.33 + 7,20,000+ 1,644 = ₹ 7,23,286 = $\frac{EOQ}{2} \times 6$]

ii) When the company has an option to order between 3000 and 6000 units, the EOQ should be calculated with a reduction in price by 5% (due to concession);

The purchase price = 95% of ₹ 20 = ₹ 19.

A = 36,000 units per annum; S = ₹ 25; C = 2 + 20% of 19 = 2 + 3.80 = ₹ 5.80

$$EOQ = \sqrt{\frac{2 \times 36000 \times 25}{5.80}} = \sqrt{\frac{18,00,000}{5.80}} = 557 \text{ units app.}$$

Total cost = (36,000/557) × 25 + (36,000 × 19) + (557/2) × 5.80

= ₹ (1,615.79 + 6,84,000 + 1,615.30) = ₹ 6,87,231.09

For monthly order quantity being 3000 units or more but less than 6000 units

EOQ = 557 units

Total cost = (36,000/557) × 25 + (36,000 × 19) + (557/2) × 5.80

= ₹ (1,615.79 + 6,84,000 + 1,615.30) = ₹ 6,87,231.09

$$\text{No. of orders per year} = \frac{\text{Yearly demand}}{EOQ} = \frac{36000}{557} = N \text{ (let)}$$

$$\text{No. of orders per month} = \frac{N}{12} = \frac{36000 / 557}{12} = 5.385 = 6 \text{ (say)} = N^*$$

Quantity to be orderd per month = N* × EOQ = 6 × 557 = 3342 units

This quantity lies in the range of 3000 to 6000 units

Hence the EOQ (557 units) can be considered to be a feasible quantity for availing 5% discount on Purchase Price.

iii) When the company orders more than 6,000 units purchase price = 90% of ₹ 20 (because 10% concession)

= ₹ 18; A = 36,000 units per annum; S = ₹ 25; C = 2 + 20% of ₹ 18

= 2 + 3.60 = 5.60

$$EOQ = \sqrt{\frac{2AS}{C}} = \sqrt{\frac{2 \times 36000 \times 25}{5.60}} = 567 \text{ units app.}$$

For monthly order quantity more than or equal to 6000 units

EOQ = 567 units

$$\text{No. of orders per year} = \frac{36000 / 567}{12} = 5.29 = 6 \text{ (say)} = N^*$$

Quantity to be ordered per month = N* × EOQ = 6 × 567 = 3402 units

This quantity does not lie in the range of 6000 or more units.

Hence the EOQ (567 units) can not be considered as feasible quantity for availing 10% discount on Purchase Price.

To understand the effect of 10% on Total Cost, we consider the minimum value of price break quantity of this range i.e. 6000 units to be the optimum order quantity and calculate.

Total Cost as follows —

TC = Ordering Cost + Cost of Purchasing the material + Storage Cost

$$= \frac{36000}{6000} \times 25 + 36000 \times 18 + \frac{6000}{2} \times 5.60$$

$$= 150 + 648000 + 16800 = ₹\ 6,64,950$$

iv) Hence the total cost will be minimum (₹ 6,64,950) if orders are placed in lot size of 6000 units.

CHAPTER 3

DESIGNING OF OPERATIONAL SYSTEMS AND CONTROL

Chapter 3.1 Product Design

Q1 June'23 MTP Set 2

What does Product Design do?

Reference

What's **New**

Answer

The activities and responsibilities of product design include the following:

(i) Understand and translate the requirements of the customers (Voice of the Customers) into a set of technical requirements (Voice of the Process) for design and execution planning and processes.

(ii) Differentiate the existing products to stretch the product life cycle

(iii) Developing new products

(iv) Providing inputs required for the formulation of the quality goals

(v) Help in cost optimization

(vi) Building and testing model prototypes

(vii) Documentation of the design specifications

Chapter 3.2 Product Life Cycle

Q1 Postal Test Paper

What is product life cycle. Describe various stages of product life cycle.

Reference

Product life cycle

What's **New**

Answer

Likewise, the business organizations and human beings, each product has a life that goes through various phases or cycles. All these cycles during the usable life of a product is collectively called as Product Life Cycle (PLC). A typical PLC has five stages:

(a) **Introduction phase:** During this phase the product (either completely new product or a new variant of the existing product) gets introduced in the market for the first time. For the introduction of the new products in the market, at this stage, the volume stays low, sales are low and effect of learning curve is not realized. Hence, the return on investment is low. This phase is featured by higher level of expenditure in the promotional campaigns. The pricing depends on the innovativeness of the product, nature of the target customer segment and most often discounts are given to entice the potential customers.

(b) **Growth phase:** In this stage, the company focuses on rapid revenue generation and market growth. During this phase, the product sales intend to cover up the fixed cost and bring down the overhead costs while utilizing the learning in the previous stage. Promotional and advertising strategy is decided according to the level of the growths. The objective is to hold the existing customers and create new customers.

(c) **Maturity phase:** This phase is characterized by saturation in the market place. This is a critical phase for the organizations. In the earlier stage (i.e., growth) the objective of the company is to achieve fast growth while in this stage the company wants to flatten the curve to slow down the movement toward fall down.

Further, at this stage the organizations infuse variety and differentiation in the products most often to start a new PLC from hereon for finding out a niche market. At this stage,

organizations get engaged in aggressive promotional and pricing programs. Profit margin is comparatively lower at this stage.

(d) **Decline phase:** After maturity, the products start losing their attractiveness in the market and sales get falling down. Profit margin becomes increasingly narrower. The organizations take a call to scrap the product and focus on cost consolidation. Sometimes, organizations come up with revival planning with product differentiation and promotional strategy to improve the sales.

Chapter 3.3 Process Planning and Selection

Q1 Dec'23 MTP Set 1

Define Process Strategy? The Classical way of Categorizations includes 4 types of layouts – **Discuss**

Reference | What's **New**

Answer

Process Strategy

A process strategy is a decision taken by the organization vis-à-vis selection of the processes for converting the input (i.e., resources) into output (i.e., finished products and services as required by the customers) in line with the product specifications. A typical process strategy depends on long-term efficiency and productivity, resource availability, flexibility, cost and benefits, quality of the products and lead time. Accordingly, the process strategy stands on the following premises:

(a) Trade-off between Make (in house conversion, fully or partial) or Buy (outsourcing, fully or partial) decisions

(b) Degree of capital intensity that decides the optimum balance between level of automation and manual operations

(c) The extent of flexibility required in the process (i.e., the flexibility in the positioning and functioning of the machines, works stations and requisite skills for layout decisions)

Accordingly, the facilities are designed while having three focus areas such as

(a) Process focused: The facility is designed in a process centric way. Accordingly, the equipment, machines and work stations are organized. Each process is capable of carrying a wide range of activities (aka intermittent processes) and flexible enough to adopt frequent changes. This type of arrangement allows a higher level of customization, i.e., product flexibility. This type of system is also known as job shop production. Example of products: Aircraft

(b) Product focused: The facility is planned in a product centric way to allow a higher level of standardization. The products in higher volume (with lower variety) are produced to give economies of scale and learning benefits for better facility utilization rate. Examples of products: steel, glass, paper, electric bulbs, chemicals and pharmaceutical products. This type of arrangements is suited for continuous flow and batch production.

However, this type of structure incurs a higher amount of fixed cost.

(c) Repetitive Focus: This structure utilizes the benefits of the above-mentioned arrangements. It uses modular production. This type of structure is also known as assembly production. Examples include automobile process, household appliances etc.

Process Layout Selection

Process layout aims to identify the necessary arrangement of facilities such as equipment/ machines, material, people, and work stations for

(a) facilitating the production efficiently

(b) minimizing unnecessary movements and transportation

(c) efficient material handling

(d) effective design and organizations of the work stations

(e) identification and removal of the bottlenecks/ constraints

(f) effective utilization of the spaces.

The underlying objective is to provide the value added products and services to the end customers while minimizing the waste in the process and hence, optimizing the operational cost and resource utilization.

The classical way of categorization includes four types of layouts

(a) process layout

(b) product layout

(c) Group layout(combination layout)

(d) Fixed position layout

(a) Process layout or functional layout: It organizes the work stations in such a way that similar type of machines and services (i.e., facilities) are located together. Therefore, each such sub-facility is specialized in performing a particular activity of the whole conversion process. This type of layout is suitable for low volume, high variety products produced by job shop, batch production and other non-repetitive processes.

Examples: Furniture, restaurants etc.

(b) Product layout or line layout: In this type of layout, the facility is organized as per the logical/sequential flow of the activities performed to produce the products. This type of

layout is used for high volume and continuous production where level of customization is low. Typical examples include assembly line or mass production used in consumer electronics, automobile sectors etc.

(c) Group (combination) layout: This combines the features of both the previously mentioned layouts. In this layout the individual processes are replicated at multiple cells wherein each cell is equipped with all facilities to complete the corresponding process. This type of layout is suitable for cellular manufacturing that minimizes the cost of transportation and material handling.

(d) Fixed position or Project layout: In this type of layouts, main facilities are fixed at specified locations while the materials, people and work stations move as per the requirements to those locations. This type of layout is of single use and suitable for highly customized (ETO type) products. Examples: Air Craft, Ships

Each production system is uniquely suited to produce a particular mix and volume of products.Each production system provides different levels and a unique set of the manufacturing outputs: cost, quality, performance, delivery, flexibility and innovativeness.One of the tasks of the manufacturing strategy is to select the best production system for each product or product family.

Chapter 3.4 Design Thinking

Q1 June'23 MTP Set 2

Briefly explain the five stages of Design Thinking?

Reference | What's **New**

Answer

The Five Stages of Design Thinking

The Hasso Plattner Institute of Design at Stanford (aka the d.school) describes design thinking as a five-stage process. These stages are not always sequential, and teams often run them in parallel, out of order and repeat them in an iterative fashion.

Stage 1: Empathize—Research Users Needs

Empathy is crucial to a human-centered design process such as design thinking because it allows to set aside assumptions about the world and gain real insight into users and their needs.

Stage 2: Define — State Users' Needs and Problems

It's time to accumulate the information gathered during the Empathize stage. Then analyze observations and synthesize them to define the core problems. These definitions are called problem statements.

Stage 3: Ideate — Challenge Assumptions and Create Ideas

The solid background of knowledge from the first two phases means one can start to "think outside the box", look for alternative ways to view the problem and identify innovative solutions to the problem statement. Brainstorming is particularly useful here.

Stage 4: Prototype—Start to Create Solutions

This is an experimental phase. The aim is to identify the best possible solution for each problem found.

Stage 5: Test—Try Your Solutions Out

Evaluators rigorously test the prototypes. Although this is the final phase, design thinking is iterative: Teams often use the results to redefine one or more further problems. So, one can return to previous stages to make further iterations, alterations and refinements – to find or rule out alternative solutions.

Overall, one should understand that these stages are different modes which contribute to the entire design project, rather than sequential steps. Goal throughout is to gain the deepest understanding of the users and what their ideal solution/product would be.

CHAPTER 4

APPLICATION OF OPERATION RESEARCH - PRODUCTION PLANNING AND CONTROL

Chapter 4.1

Optimum Allocation of Resources - LPP

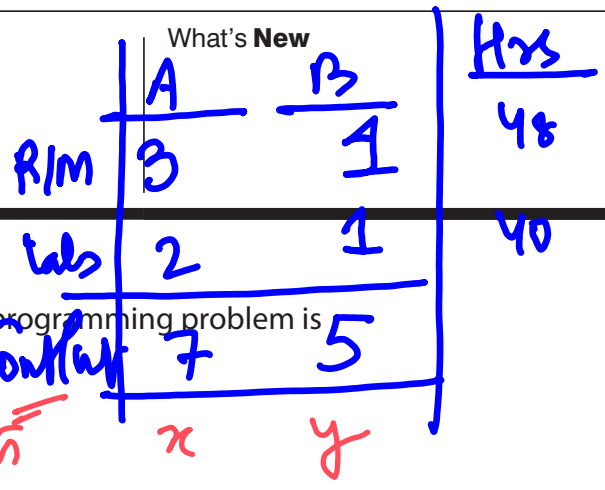
Q1 June'23 MTP Set 1

One unit of Product A contributes ₹ 7 and requires 3units of raw material and 2 hours of labour. One unit of Product B contributes ₹ 5 and requires 1 unit of raw material and 1 hour of labour. Availability of Raw Material at present is 48 units and hence there are 40 hours of labor.

Formulate it as Linear Programming Problem.

Reference
Linear Programming

What's **New**



Answer

The mathematical formulation of the linear programming problem is

Maximise $Z = 7x_1 + 5x_2$

Subject to $3x_1 + x_2 \leq 48$

$2x_1 + x_2 \leq 40$

$x_1, x_2 \geq 0$

Where x_1 and x_2 denote the number of units of product A and B respectively.

Max Z = 7x + 5y

Subj to :- RM => 3x + 4y ≤ 48

Lab => 2x + y ≤ 40

Non => x, y ≥ 0

Q2 June'23 MTP Set 2

The products P, Q and R are being produced in a plant having profit margin as ₹3, ₹5 and ₹4 respectively. The A, B and C are of scarce supply and the availability is limited to 8, 15 and 10 units respectively. Specific consumption is indicated in the table below:

	P	Q	R	Available units
A	2	3	-	8
B	3	2	4	15
C	-	2	5	10
PM/unit	3/-	5/-	4/-	

Write down the problem mathematically for maximization of profit margin.

Reference: **LP Formulation**

What's **New**

Answer

Let x_1 be the no. of units of product P

Let x_2 be the no. of units of product Q

Let x_3 be the no. of units of product R

Objective function: Max. $Z = 3x_1 + 5x_2 + 4x_3$

Subject to constraints:

$2x_1 + 3x_2 \leq 8$ (Constraint on availability of Raw Material 'A')

$3x_1 + 2x_2 + 4x_3 \leq 15$ (Constraint on availability of Raw Material 'B')

$2x_2 + 5x_3 \leq 10$ (Constraint on availability of Raw Material 'C')

And $x_1, x_2, x_3 \geq 0$ (Non negativity constraint)

Q3 Postal Test Paper

A Bank is in the process of formulating its loan policy. Involving a maximum of ₹ 600 Million. Table below gives the relevant types of loans. Bad debts are not recoverable and produce no interest receive. To meet competition from other Banks the following policy guidelines have been set. At least 40% of the funds must be allocated to the agricultural and commercial loans. Funds allocated to housing must be at least 30% of all loans given to personal, car, Housing. The overall bad debts on all loans may not exceed 0.06.

Type of loan	Interest Rate %	Bad Debts (Probability)
Personal	17	0.10
Car	14	0.07
Housing	11	0.05
Agricultural	10	0.08
Commercial	13	0.06

Formulate a linear program Model to determine optimal loan allocations.

Reference	What's **New**
LP Formulation	**Loan Allocations**

Answer

Let x_1 be the amount allocated for personal loan

Let x_2 be the amount allocated for car loan

Let x_3 be the amount allocated for Housing loan

Let x_4 be the amount allocated for agricultural loan

Let x_5 be the amount allocated for Commercial loan

Objective Function: Max Z

$= 0.17x_1 + 0.14x_2 + 0.11x_3 + 0.1x_4 + 0.13x_5 - (0.10x_1 + 0.07x_2 + 0.05x_3 + 0.08x_4 + 0.06x_5)$

$= (0.17 - 0.10)x_1 + (0.14 - 0.07)x_2 + (0.11 - 0.05)x_3 + (0.1 - 0.08)x_4 + (0.13 - 0.06)x_5$

$= 0.17x_1 + 0.07x_2 + 0.06x_3 + 0.02x_4 + 0.07\,x_5$

Subject to constraints

(i) $x_1 + x_2 + x_3 + x_4 + x_5 \le 600$ Millions (Constraint on total loan amount)

(ii) $x_4 + x_5 \ge 0.4\,(x_1 + x_2 + x_3 + x_4 + x_5)$ (Constraint due to policy set for Agricultural and Commercial Loan)

(iii) $x_3 \ge 0.5\,(x_1 + x_2 + x_3)$ (Constraint due to policy set for Housing Loan)

(iv) $0.1x_1 + 0.07x_2 + 0.05x_3 + 0.08x_4 + 0.06x_5 \le 0.06\,(x_1 + x_2 + x_3 + x_4 + x_5)$ (Constraint on limit of overall bad debt)

(v) $x_1, x_2, x_3, x_4, x_5 \ge 0$ (Non negativity constraint)

Q4 June'23

A factory of SPON LTD. manufacturers 3 products which are processed through 3 different production stages. The time required to manufacture one unit of each of the three products and the daily capacity of the Stages are given in the following table:

State	Time/ Unit in minutes			Stage capacity (minutes)
	Product 1	Product 2	Product 3	
1	1	2	1	430
2	3	-	2	460
3	1	4	-	420
Profit/Unit	₹3	₹2	₹5	

Required :

Develop a linear programming model to determine how many products to be manufactured to maximize profit.

Let the no of Product 1, 2 & 3 be x_1, x_2 & x_3 no respectively.

Reference

Linear Programming

What's New

Answer

Let x_1 be the no. of units of Product 1

Let x_2 be the no. of units of Prudct 2

Let x_3 be the no. of units of Prudct 3

Objective Function :

Max $Z = 3x_1 + 2x_2 + 5x_3$

Subject to Constraints :

$x_1 + 2x_2 + x_3 \leq 430$ (Constraints on Stage Capacity (in mins) of State 1)

$3x_1 + 2x_3 \leq 460$ (Constraints on Stage Capacity (in mins) of State 2)

$x_1 + 4x_2 \leq 420$ (Constraints on Stage Capacity (in mins) of State 3)

And $x_1, x_2, x_3 \geq 0$ (Non-negativity Constraint)

Obj func

Max $Z = 3x_1 + 2x_2 + 5x_3$

Subj to

(1) $x_1 + 2x_2 + 1x_3 \leq 430$

(2) $3x_1 + 2x_3 \leq 460$

(3) $1x_1 + 4x_2 \leq 420$

(4) NNA :- $x_1, x_2, x_3 \geq 0$

Chapter 4.2 Job Evaluation, Job Allocation Assignment

Q1 Dec'23 MTP Set 1

A supervisor in his workshop is considering how he should assign the four jobs that are to be performed, to four of the workers under him. He wants to assign the jobs to the workers such that the aggregate time to perform the jobs is the least. Based on previous experience, he has the information on the time taken by the four workers in performing these jobs and the same is given in the table below.

Time Taken (in minutes) by 4 Workers

Worker	Job			
	A	B	C	D
1	46	40	51	68
2	57	42	63	55
3	49	53	48	64
4	41	45	61	55

Solve the assignment problem for optimal solution using Hungarian Method

Reference

What's **New**

Soln: Pre initial check :- No. of rows = 4
No. of columns = 4
∴ Balanced

Row Minimum

6	0	11	28
15	0	21	13
1	5	0	16
0	4	20	14

Col Minimum

~~6~~	0	~~11~~	~~15~~
~~15~~	0	~~21~~	~~0~~
~~1~~	~~5~~	~~0~~	~~3~~
~~0~~	~~4~~	~~20~~	~~1~~

$n = 4$

$\therefore$ optimum

Boxing the zeroes

	A	B	C	D
1	6	[0]	11	15
2	15	~~0~~	21	[0]
3	1	5	[0]	3
4	[0]	4	20	1

Workers	Jobs	Time
W1	B	40
W2	D	55
W3	C	48
W4	A	41
		184

Q2 Postal Test Paper

Four jobs can be processed on four different machines, with one job on one machine. Resulting profits vary withassignments. They are given below:

		Machines			
		A	B	C	D
Jobs	I	42	35	28	21
	II	30	25	20	15
	III	30	25	20	15
	IV	24	20	16	12

Find the optimum assignment of jobs to machines and the corresponding profit.

Reference

Maximise Profit

What's **New**

1. Pre initial check
Rows = 4
Colm = 4
∴ Bal problem

Answer

Relative Loss Matrix

Jobs \ M/cs	A	B	C	D
I	0	7	14	21
II	12	17	22	27
III	12	17	22	27
IV	18	22	26	30

2. Opp loss Matrix (42 - given data)

As this is a problem of Maximisation, the same is converted to one of Minimisation by forming a Relative Loss Matrix where all the elements of the given matrix are subtracted from the highest element of the matrix (which is 42 in this case)

0 7 14 21
12 17 22 27
12 17 22 27
18 22 26 30

Matrix after Row Operation

Jobs \ M/cs	A	B	C	D
I	0	7	14	21
II	0	5	10	15
III	0	5	10	15
IV	0	4	8	12

3. Row Minimise

0 7 14 21
0 5 10 15
0 5 10 15
0 4 8 12

4. Colm Minimise

Matrix after Column Operation

Jobs \ M/cs	A	B	C	D
I	0	3	6	9
II	0	1	2	3
III	0	1	2	3
IV	0	0	0	0

Here minimum no. of horizontal and vertical straight lines to cover all the zeros = 2 ≠ Order of the matrix (4)

So the solution is non optimal.

Improved Matrix (Non Optimal)

Jobs \ M/cs	A	B	C	D
I	0	2	5	8
II	0	0	1	2
III	0	0	1	2
IV	1	0	0	0

Here minimum no. of horizontal and vertical straight lines to cover all the zeros = 3 ≠ Order of the matrix (4)

So the solution is non optimal.

Further Improved Matrix [Optimal Solution (i)]

Jobs \ M/cs	A	B	C	D
I	[0]	2	4	7
II	~~0~~	[0]	~~0~~	1
III	~~0~~	~~0~~	[0]	1
IV	2	1	~~0~~	[0]

Here minimum no. of horizontal and vertical straight lines to cover all the zeros = 4 = Order of the matrix.

So the solution is optimal.

Further Improved Matrix (Optimal Solution-ii)

Jobs \ M/cs	A	B	C	D
I	[0]	2	4	7
II	~~0~~	~~0~~	[0]	1
III	~~0~~	[0]	~~0~~	1
IV	2	1	~~0~~	[0]

Assignment as per Soution (i)			Assignment as per Soution (ii)		
Jobs	M/cs	Profit (₹)	Jobs	M/cs	Profit (₹)
I	A	42	I	A	42
II	B	25	II	C	20
III	C	20	III	B	25
IV	D	12	IV	D	12
Total	–	₹ 99	Total		₹ 99

Chapter 4.3

Scheduling and Queuing Models

Q1 June'23 MTP Set 1

Faber's Car wash & Dry is an automatic five minutes' operation with a single bay. On a typical Saturday Morning, cars arrive at a mean rate of eight per hour, with arrivals tending to follow a Poison Distribution.

Find

i) The average number of cars in line.

ii) The average time cars spend in line and service.

Reference

Single Channel

What's New

Answer

Arrive Rate = $\lambda = 8$ cars per hour

Service Rate = $\mu = 1$ per 5 minutes, or 12 per hour

Av. no. of cars waiting in line = $L_q = \frac{\lambda^2}{2\mu(\mu-\lambda)} = \frac{8^2}{2(12)(12-8)} = 0.667$ Car

Av. time cars spend in line and service = $W_s = \frac{L_q}{\lambda} + \frac{1}{\mu} = \frac{0.667}{8} + \frac{1}{12} = 0.167$ hours, or 10 minutes.

Q2 June'23 MTP Set 2

Customers arrive at a bakery at an average rate of 16 per hour on weekday mornings. The arrival can be described by a Poisson distribution with a mean of 16. Each clerk can serve a customer in an average of three minutes; This time can be described by an exponential distribution with a mean of 30 Minutes.

a. **What** are the arrival and service rates?

b. **Compute** the average number of customers being served at any time.

c. **Suppose** it has been determined that the average number of customers waiting in line is 3.2. compute the average number of customers in the system (i.e., waiting in line or being served), the average time customers wait in line, and the average time in the system.

d. **Determine** the system utilization for M = 1, 2 and 3 servers.

Reference
Single Channel

What's **New**

Answer

a. The arrival rate is given in the problem: λ = 16 customers per hour. Change the service time to a comparable hourly rate by first restating the time in hours and then taking its reciprocal. Thus, (3 minutes per customer)/(60 minutes per hour) = 1/20 = 1/μ. Its reciprocal is μ = 20 customers per hour = Service Rate.

b. Average no. of customers being served at any time.

r = λ/μ = 16/20 = 0.80 customer.

Formulas for basic single-server model

Performance Measure	Equation
Average number in line/queue	$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)}$
Probability of zero units in the system	$P_o = 1 - \left(\frac{\lambda}{\mu}\right)$
Probability of n units in the system	$P_n = P_o\left(\frac{\lambda}{\mu}\right)^2$

Probability of less than n units in the system	$P_{<n} = 1 - \left(\frac{\lambda}{\mu}\right)^n$

c. Given: $L_q = 3.2$ customers

$L_s = L_q + r = 3.2 + 0.80 = 4.0$ customers

Average time customers wait in line

$= W_q + \frac{L_q}{\lambda} = \frac{3.2}{16} = 0.20$ hour, or 0.20 hour × 60 minutes/hour = 12 minutes

W_s = Average time customers wait in system $= W_q + \frac{1}{\mu}$

Waiting time in line plus service

$0.20 + \frac{1}{20}$ hour, or 15 minutes

d. System utilization is $\rho = \frac{\lambda}{M \times \mu}$

For M = 1, $\rho = \frac{16}{1(20)} = 0.80$

For M = 2, $\rho = \frac{16}{2(20)} = 0.40$

For M = 3, $\rho = \frac{16}{3(20)} = 0.27$

Note that as the system capacity increases, the system utilization for a given arrival rate decreases.

Single server, exponential service time, M/M/1

The simplest model involves a system that has one server (or a single crew). The queue discipline is first-come, first-served, and it is assumed that the customer arrival rate can be approximate by a Poisson distribution and service time by a negative exponential distribution. There is no limit on length of queue.

Q3 Postal Test Paper

Workers come to tool store room to enquire about special tools (required by them) for accomplishing a particularproject assigned to them. The average time between two arrivals is 60 seconds and the arrivals are assumed to be in Poisson distribution. The average service time (of the tool room attendant) is 40 seconds.

Determine:

(i) average queue length,

(ii) average length of non-empty queues,

(iii) average number of workers in system including the worker being attended,

(iv) mean waiting time of an arrival,

(v) average waiting time of an arrival who waits.

Reference

Single Channel -Queue

What's **New**

Answer

Here, Arrival Rate = $\lambda = \frac{60}{60}$ per second = 1 per minute

Service Rate = $\mu = \frac{60}{60}$ per second = 1.5 per minutes

(i) Average queue length:

$$L_q = \frac{\lambda}{\mu} \times \frac{\lambda}{(\mu - \lambda)} = \frac{1}{1.5} \times \frac{1}{(1.5 - 1)} = \frac{1}{0.75} = \frac{4}{3} \text{ workers}$$

(ii) Average length of non-empty queues

$$L_n = \frac{\mu}{\mu - \lambda} = \frac{1}{(1.5 - 1)} = 3 \text{ workers}$$

(iii) Average number of workers in the system

$$L_s = \frac{\lambda}{\mu - \lambda} = \frac{1}{(1.5 - 1)} = 2 \text{ workers}$$

(iv) Mean waiting time of an arrival

$$W_q = \frac{\lambda}{\mu} \times \frac{\lambda}{(\mu - \lambda)} = \frac{1}{1.5} \times \frac{1}{(1.5 - 1)} = \frac{4}{3} \text{ minutes}$$

(v) Average waiting time of an arrival who waits

$$W_n = \frac{1}{\mu - \lambda} = \frac{1}{(1.5 - 1)} = 2 \text{ minutes}$$

Q4 June'23

Below table shows the time remaining (number of days until due date) and the work remaining (number of days still required to finish the work) for 5 jobs which were assigned the letters A to E as they arrived to the shop.

Job	Number of days until due date	Number of days of work remaining
A	6	3
B	4	8
C	2	5
D	8	6
E	7	2

Required :

Sequence the jobs according to priority established by

(i) Early Due Date (EDD) Rule

(ii) Least Slack (LS) Rule

(iii) Longest Processing Time (LPT) Rule

(iv) Critical Ratio Rule

Reference

Sequencing

What's **New**

Answer

(i) Earliest Due Date (EDD) Job First : C-B-A-E-D : 2-4-6-7-8

(ii) Least Slack Rule

Job	No. of days until due date	No. of days work remaining	Slack days
A	6	3	3
B	4	8	-4
C	2	5	-3
D	8	6	2
E	7	2	5

* Slack Days = No. of days until due date - No. of days work remaining.

(iii) Longest Processing Time (LPT) : B - D - C - A - E : 8 - 6 - 5 - 3 - 2

(iii) Critical Ratio Rule :

Job	No. of days until due date	No. of days work remaining	Critical Ratio
A	6	3	6/3 = 2
B	4	8	4/8 = 0.5
C	2	5	2/5 = 0.4
D	8	6	8/6 = 1.333
E	7	2	7/2 = 3.5

- C B D A E

Chapter 4.4

Simulation and ~~Line Balancing~~

Q1 June'23

TANEESA, acar rental Agency has collected the following parameters on the demand for five-seater vehicles over the past 50 days.

Daily demand	5	6	7	8	10
No. of days	4	10	16	14	6

The agency has only 7 cars currently.

[**Given:** Random numbers: 15, 48, 71, 56, 90]

Required:

(1) Using the Random numbers stated supra, **develop** 5 days of demand for the car rental agency.

(2) **Calculate** the average number of cars rented per day for the 5 days.

(3) **Assess** how many rentals will be lost over the 5 days.

Reference

Simulation

What's New

Refer to Q1 by No.

Random Interval

DD	No. of days	Pb	CPb	CP × 100	R.I
5	4	0.08	0.08	08	00 - 07
6	10	0.20	0.28	28	08 - 27
7	16	0.32	0.60	60	28 - 59

8	14	0.28	0.88	88	60 – 87
10	6	0.12	1	100	88 – 99
	50				

Simuln Work Sheet

Days	RN	(i) Simulated dd	(ii) Cars Rented	(Range of dd & avail)	(iii) Rental lost
1	15	6	6		–
2	48	7	7		–
3	71	8	7		1
4	56	7	7		–
5	90	10	7		3
		Avg	6.8		4

Q2 Dec'23 MTP Set 1

A confectioner sells confectionery items. Past data of demand per week in hundred kilograms with frequency is given below:

Demand/Week	0	5	10	15	20	25
Frequency	2	11	8	21	5	3

Using the following sequence of random numbers, **generate** the demand for the next 10 weeks. Also **find** out the average demand per week.

Random numbers	35	52	13	90	23	73	34	57
	35	83	94	56	67	66	60	

Reference

Average Demand

What's New

Frequency

Answer

Table - I

Random No. Range Table for demand				
Demandper week	**Frequency(f)**	**Probability (p = f ÷ Σf)**	**Cumulative Probability**	**Range† of Random Nos.**
0	2	.04	.04	00-03
5	11	.22	.26	04-25
10	8	.16	.42	26-41
15	21	.42	.84	42-83
20	5	.10	.94	84-93
25	3	.06	1.00	94-99
	∑ f = 50	**1.00**		

As the given Random Nos. are of 2 digits, the ranges of Random Nos. has also been considered to have 2 digits only. Also the range of Random Nos. corresponds to cumulative probability values which lies between 0 & 1 and can be correlated as nos. between 00 and 99.

Table - II

Simulated Values for next 10 weeks		
Weeks	**Random Nos.**	**Demand**
1	35*	10*
2	52	15

3	13	5
4	90	20
5	23	5
6	73	15
7	34	10
8	57	15
9	35	10
10	83	15
Total	**–**	**120**

*From Table (I), Random No. 35 appears in the range of 26-41. Also the demand for this range is 10.

Average weekly demand $= \frac{120}{10} = 12$

CHAPTER 5

PROJECT MANAGEMENT, MONITORING AND CONTROL

Chapter 5.1 Project Planning

Q1 Dec'23 MTP Set 1

What is Project Management? Project Quality Management consists of four process – **Discuss**

Reference

What's **New**

Answer

A project is defined as a sequence of activities undertaken for getting a set of tasks done to achieve the desired business goals successfully. Project Management centres on planning and managing everything involved in delivering a Project.

What is a project?

A project is defined as a one-time activity with a series of tasks that produces a specific outcome to achieve organizational goals.

Projects are a set of interdependent tasks that have a common goal. No matter what the project is, each project is broken down into objectives and what needs to be done to achieve them, ensuring that the project stays on track and is completed as per plan.

The primary constraints of a project are:

- Time – the schedule for the project to reach completion
- Cost – the budget allocated for the project to meet its objectives and complete it on time
- Scope – the specific deliverables of the project
- Quality – the standard of the outcome of the project

The main principle of project quality management is to ensure the project will meet or exceed stakeholder's needs and expectations.

Project Quality management consists of four main processes:

- Quality Definition
- Quality Assurance
- Quality Control
- Quality Improvements.

Quality Definition:

Quality management implies the ability to anticipate situations and prepare actions that will help bring the desired outcomes. The goal is the prevention of defects through the creation of actions that will ensure that the project team understands what is defined as quality.

Quality Assurance:

Quality Assurance is a process to provide confirmation based on evidence to ensure to the donor, beneficiaries, organization management and other stakeholders that product meet needs, expectations, and other requirements. It assures the existence and effectiveness of process and procedures tools, and safeguards are in place to make sure that the expected levels of quality will be reached to produce quality outputs.

Quality Control

Quality control is the use of techniques and activities that compare actual quality performance with goals and define appropriate action in response to a shortfall.

Quality Improvements:

Quality improvement refers to the application of methods and tools to close the gap between current and expected levels of quality by understanding and addressing system deficiencies and strengths to improve, or in some cases, re-design project processes.

Chapter 5.2
PERT and CPM

Q1 June'23 MTP Set 1

The activities involved in a PERT Project are detailed in the adjoining table:

t_o = optimistic, t_m = most likely time, and t_p = pessimistic time

Job	Duration (days)		
i – j	t_o	t_m	t_p
1-2	3	6	15
2-3	6	12	30
3-5	5	11	17
7-8	4	19	28
5-8	1	4	7
6-7	3	9	27
4-5	3	6	15
1-6	2	5	14
2-4	2	5	8

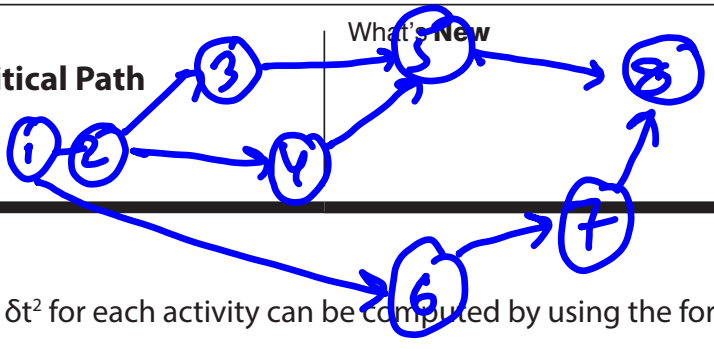
(i) **Draw** a network diagram.

(ii) **Identify** the critical path after estimating and examining the earliest and latest event time for all nodes.

Reference

Network Diagram, Critical Path

What's New

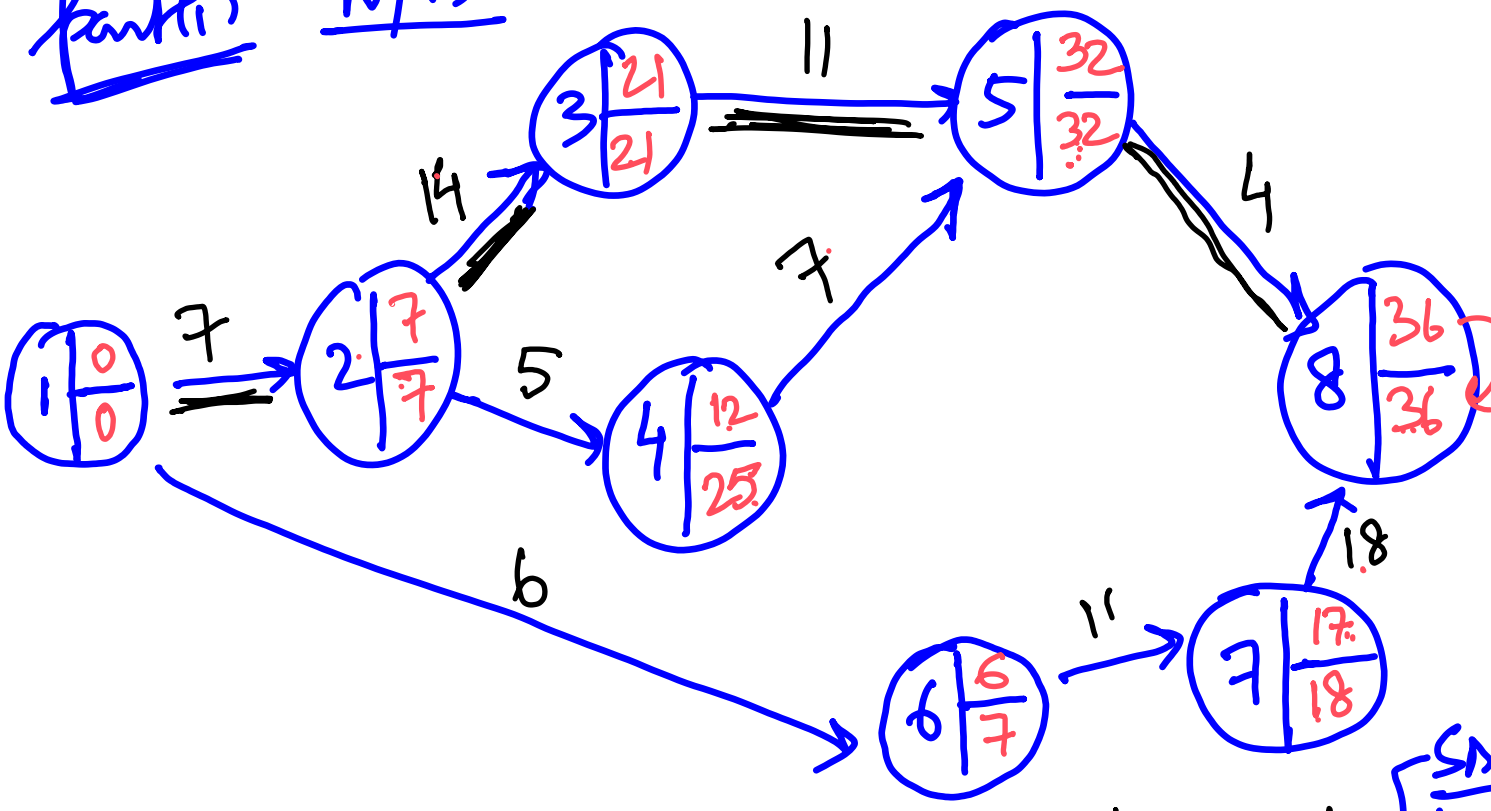


Answer

(i) Mean time t_e and variance δt^2 for each activity can be computed by using the formulae

$$t_e = \frac{1}{6}(t_o + 4tm + t_p) \text{ and } \delta t^2 = [\frac{1}{6}(t_p - t_o)]^2$$

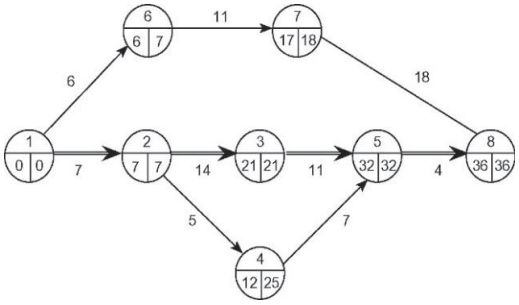
Example N/D



Activity	to	tm	tp	$t_e = \frac{t_o + 4t_m + t_p}{6}$
1-2	3	24	15	7
2-3	6	48	30	14
3-5	5	44	17	11
7-8	4	76	28	18
5-8	1	16	7	4
6-7	3	36	27	11
4-5	3	24	15	7
1-6	2	20	14	6
2-4	2	20	8	5

Example The CP is - 1-2-3-5-8, Expected duration 36

Activity	1-2	2-3	3-5	7-8	5-8	6-7	4-5	1-6	2-4
t_e	7	14	11	18	4	11	7	6	5
δ_t^2	4	16	14	16	1	16	4	4	1



(ii) Earliest event times and latest event times for each node are computed and are shown in the network above. The critical path is 1→ 2 → 3 → 5 → 8.

Expected time for completion of the project, E (T) = 7 + 14 + 11 + 4 = 36 days.

Project variance is obtained by summing variances of all the critical activities

i.e., $\sigma t^2 = 4 + 16 + 4 + 1 = 25$ days.

Q2 June'23 MTP Set 1

A Project consists of seven activities. Activities P, Q, R runs simultaneously. The relationships among the various activities is as follows:

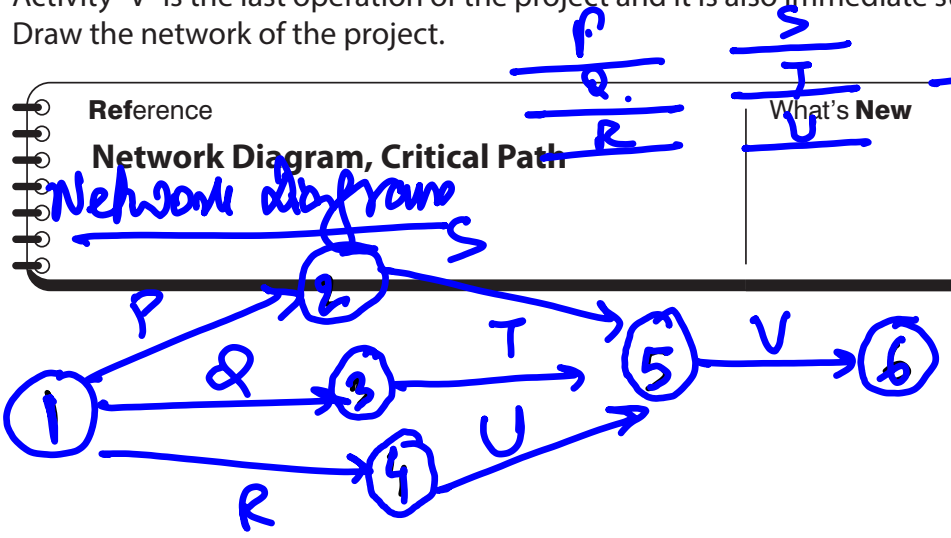
Activity	Immediate Successor
P	S
Q	T
R	U

Activity "V" is the last operation of the project and it is also immediate successor to S, T and U. Draw the network of the project.

Reference

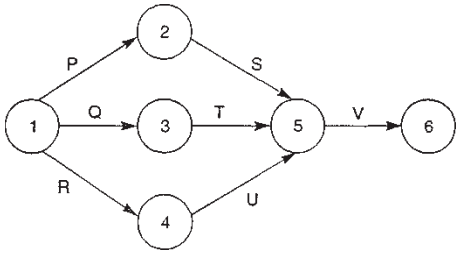
Network Diagram, Critical Path

What's **New**



Answer

Network of the Project:



Q3 June'23

A marketing organization is planning a questionnaire survey on behalf of their client to assess market potential of instant foods. The following activities are involved in this project:

Task	Description	Precedence	Duration(days) Optimistic	Most(likely)	
A.	Design questionnaire	–	2	3	4
B.	Sample design	–	6	10	20
C.	Testing of questionnaire and refinements	–	2	4	6
D.	Recruiting interviewers	B	2	3	10
E.	Training of interviewers	D,A	1	1	1
F.	Allocation of interviewers to territories	B	4	5	6
G.	Conducting interviews	C,E,F	5	12	25
H.	Evaluation of results	G	6	10	20

Find the expected duration and variance of each task.

(a) Draw an arrow diagram (network) of the project.

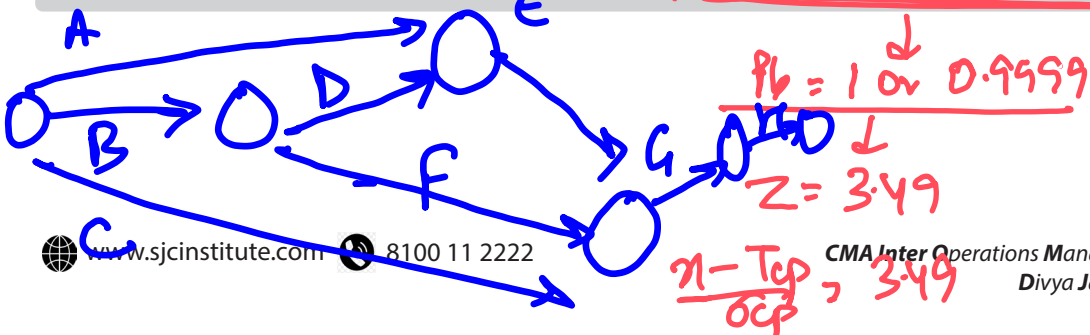
(b) Calculate EST, EFT, LST, LFT & TF

(c) Identify the critical path.

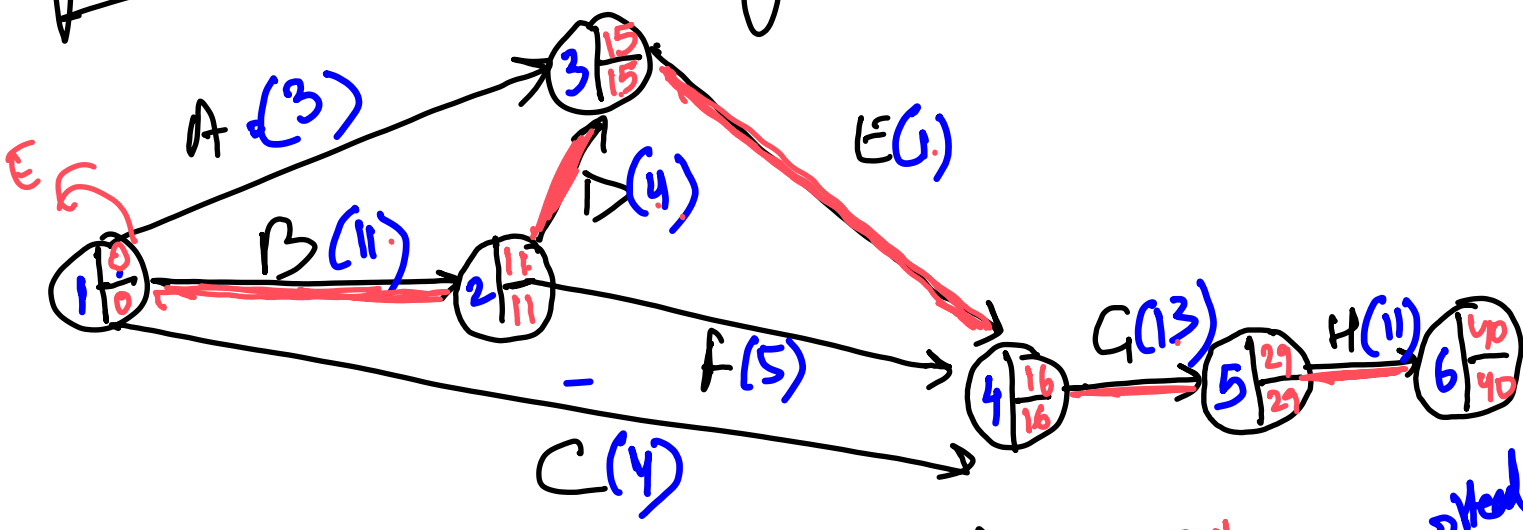
(d) Find the critical path duration of the project.

(e) What percentage of the project will be complete in 44 days?

(g) Find the no of day by which approximately 100% of the project will be completed



part(a) Network Diagram



part(b)

$t_e = \frac{t_o + 4t_m + t_p}{6}$ $\quad SD = \frac{t_p - t_o}{6}$ $\quad Var = (SD)^2$

E → Tail, L → Head

Activity		Dura t_o	$4t_m$	t_p	t_e	SD	Var	EST	EFT	LST	LFT	TF
	TE - HE							E→D	E→D	L←D	L←D	
A	1-3	2	12	4	3	0.33	0.11	0	3	12	15	12
B	1-2	6	40	20	11	2.33	5.44	0	11	0	11	0
C	1-4	2	16	6	4	0.67	0.44	0	4	12	16	12
D	2-3	2	12	10	4	1.33	1.78	11	15	11	15	0
E	3-4	1	4	1	1	0	0	15	16	15	16	0
F	2-4	4	20	6	5	033	0.11	11	16	11	16	10
G	4-5	5	48	25	13	3.33	11.11	16	29	16	29	0
H	5-6	6	40	20	11	2.33	5.44	29	40	29	40	0

part(c) CP = 1-2-3-4-5-6

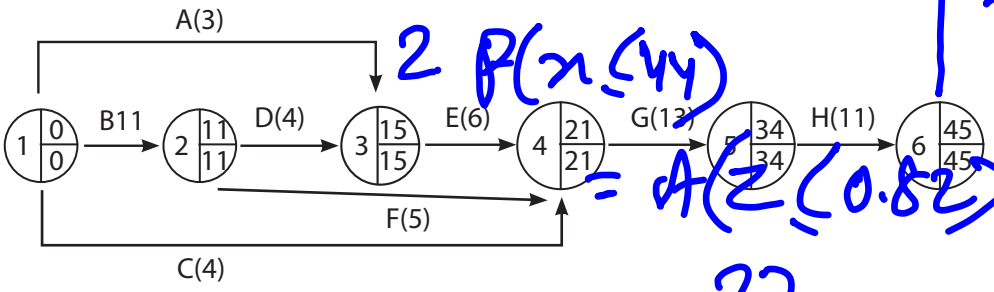
(d) CP Dura = 40

Reference
CPM & PERT

What's **New**

Answer

Part (a) Network Diagram



Part (b)

Activity	Name	to	4tm	tp	te	$(SD)^2$	EST	LFT	EFT	LST	TF
1-3	A	2	12	4	3	0.11	0	5	3	12	12
1-2	B	6	40	20	11	5.44	0	11	11	0	0
1-4	C	2	16	6	4	0.44	0	21	4	17	17
2-3	D	2	12	10	4	1.78	11	15	15	11	0
3-4	E	1	4	1	6	0	15	21	21	15	0
2-4	F	4	20	6	5	0.11	11	21	16	16	5
4-5	G	5	48	25	13	11.11	21	34	34	21	0
5-6	H	6	40	20	11	5.44	34	45	45	34	0

Part (c)

Critical Path = 1-2-3-4-5-6

Part (d)

Critical Path Duration = 45

Part (e)

Pb of completion of work in 44 days

Variation of Critical Path

= 5.44 + 1.78 + 0 + 11.11 + 5.44 = 23.77

SD of CP

= $\sqrt{23.77}$ = 4.88

1. Duration (x) = 44
2. $Z = \frac{x - TCP}{SD \text{ of } CP}$

   $Z = \frac{44 - 45}{488} = -0.20$
3. $P(x \leq 44) = A(z \leq -0.20) = 42.07\%$

Part (f)

No. of days in which 100% of the project will be completed.

(i) $x = a$ (Let)

(ii) $Z = \frac{x - T_{CP}}{\sigma_{CP}}$

$3.4 = \frac{a - 45}{4.88}$

(iii) $P(x \leq a) = A(Z \leq \text{value}) = 100\%$

(i.e., when $Z = 3.4$, area of $z \leq 3.4$ is1 or 100% (given value)

$\therefore \quad 3.4 = \frac{x - 45}{4.88}$

$16.59 = x - 45$

$\therefore \quad x = 61.59$

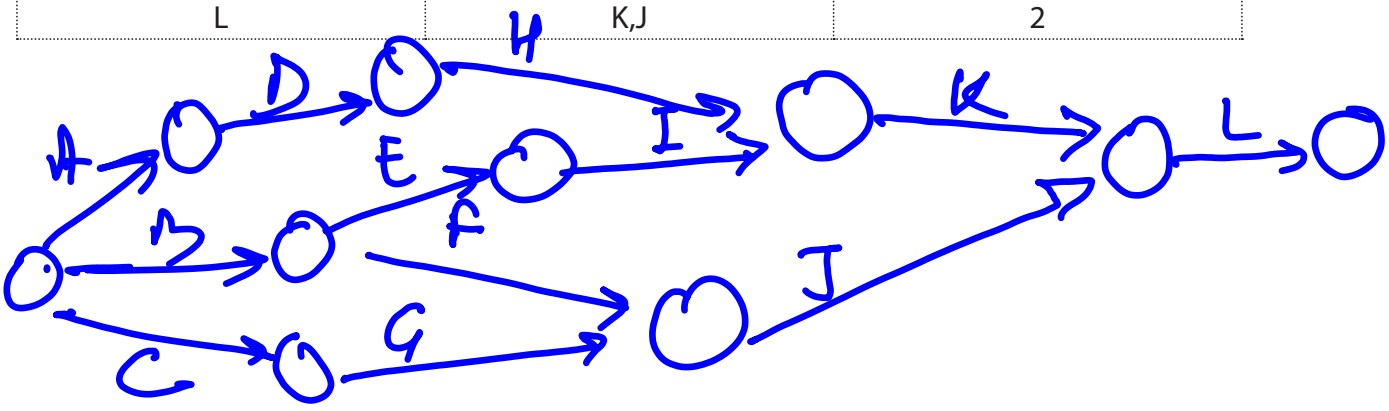
$\therefore$ Pb of completion of project with 100% chance is when duration is 6159 days.

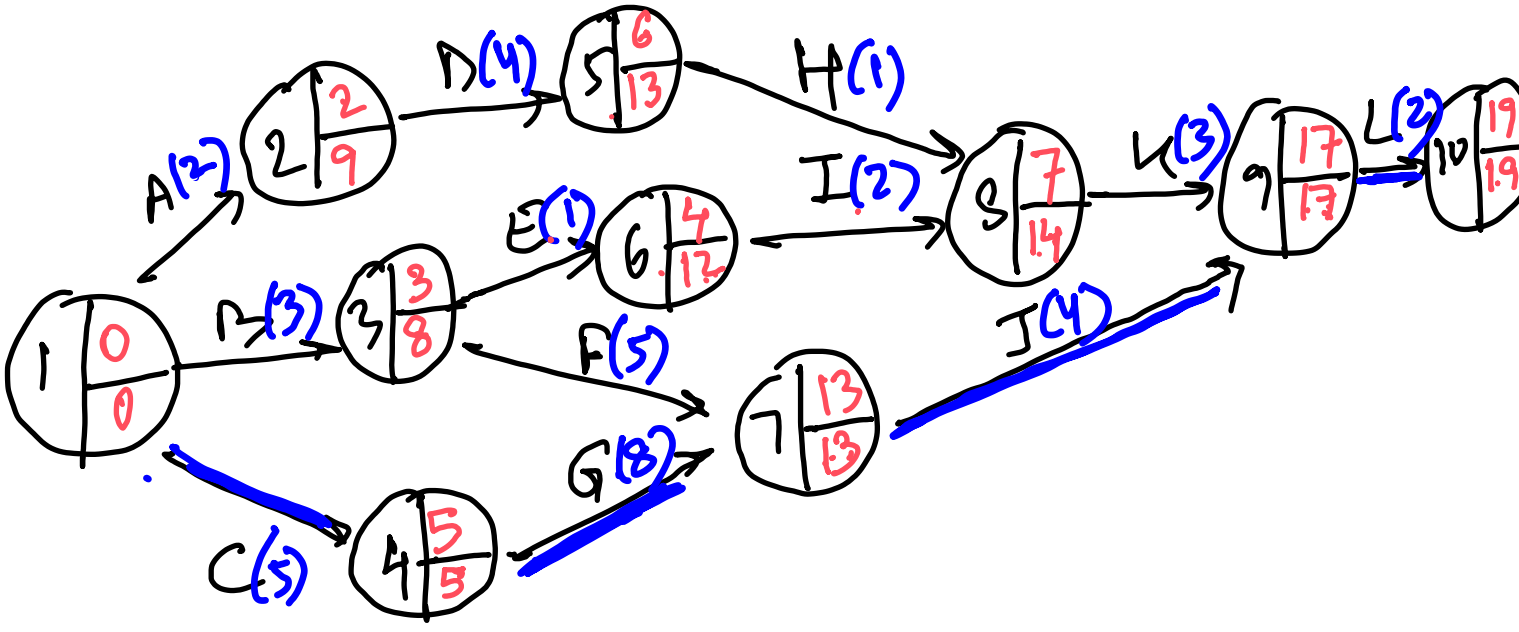
Q4 Dec'23 MTP Set 1

Draw the network for the following activities and find the Critical Path and Total duration of the project.

Activity	Predecessor	Duration (months)
A	-	2
B	-	3
C	-	5
D	A	4
E	B	1
F	B	5
G	C	8
H	D	1

I	E	2
J	F,G	4
K	H,I	3
L	K,J	2





∴ CP is ⇒ 1-4-7-9-10 or C-G-J-L

The duration is 19 days

CHAPTER 6

ECONOMICS OF MAINTENANCE AND SPARES MANAGEMENT

Chapter 6.1

Replacement of Machine

Q1 June'23 MTP Set 2

A firm is using a machine whose purchase price is ₹15,000. The installation charges amount to ₹3,500 and the machine has a scrap value of ₹1,500 because the firm has a monopoly of this type of work. The maintenance cost in various years is given in the following table:

Year	1	2	3	4	5	6	7	8	9
Maintenance Cost (₹)	260	760	1100	1600	2200	3000	4100	4900	6100

The firm wants to determine after how many years should the machine be replaced on economic considerations, assuming that the machine replacement can be done only at the year end.

Reference

Optimum Replacement Period

What's New

Answer

Cost of machine, C = ₹ 15,000 + ₹ 3,500 = ₹ 18,500

Scrap value, S = ₹ 1,500.

Year	Maintenance Cost, M_1 (₹)	Cumulative Maintenance Cost, ΣM_1 (₹)	Cost of Machine – Scrap Value (₹)	Total Cost $T_{(n)}$ (₹)	Annual Cost $A_{(n)}$ (₹)
(i)	(ii)	(iii)	(iv)	(v)= (iii)+(iv)	(vi)=(v)/n
1	260	260	17,000	17,260	17,260
2	760	1,020	17,000	18,020	9,010
3	1,100	2,120	17,000	19,120	6,373
4	1,600	3,720	17,000	20,720	5,180
5	2,200	5,920	17,000	22,920	4,584
6	3,000	8,920	17,000	25,920	4,320
7	4,100	13,020	17,000	30,020	4,288*
8	4,900	17,920	17,000	34,920	4,365
9	6,100	24,020	17,000	41,020	4,557

Lowest average cost is ₹4,288 approx., which corresponds to n = 7 in above table. Thus machine needs to be replaced every 7th year.

Chapter 6.2

Spare Parts Management

Q1 MTP Set 1 Dec'23

A Public transport system is experiencing the following number of breakdowns for months over the past 2 years in their new fleet of vehicles:

Number of breakdowns	0	1	2	3	4
Number of months this occurred	2	8	10	3	1

Each break down costs the firm an average of ₹ 2,800. For a cost of ₹ 1,500 per month, preventive maintenance can be carried out to limit the breakdowns to an average of one per month.

Which policy is suitable for the firm? Support your answer with needful calculations and justifications.

Reference | What's **New**

Breakdown vs Preventive Maintenance

Answer

Converting the frequencies to a probability distribution and determining the expected cost/ month of breakdowns we get:

No. of breakdowns (x)	Frequency in months (f)	Probability p = f / Σf	Expected no. of breakdowns (px)
0	2	0.083	0.000
1	8	0.333	0.333
2	10	0.417	0.834
3	3	0.125	0.375
4	1	0.042	0.168
			Total 1.710

Expected Breakdown cost per month; Expected cost = 1.710 × ₹ 2,800 = ₹ 4,788.

Preventive maintenance cost per month: -

Average cost of one breakdown/month	= ₹ 2,800
Maintenance contract cost/month	= ₹ 1,500
Total	= ₹ **4,300**

Thus, preventive maintenance policy is suitable for the firm.

INTERMEDIATE EXAMINATION

June 2023

P–9(OMSM)
Syllabus 2022

OPERATIONS MANAGEMENT AND STRATEGIC MANAGEMENT

Time Allowed: 3 hours | Full Marks: 100

The figures in the margin on the right side indicate full marks.
All Sections are Compulsory. Each section contains instructions regardning the number of questions to be answered within the section.
All working notes must form part of the answer.
Wherever necessary, candidates may make appropriate assumptions and clearly State them in the respective answer.

Section–A
Operations Management

Answer Question No. 1 *which is compulsory and* any three *from* Question Nos. 2, 3, 4 and 5.

1. (a) **Choose the correct answer from the given alternatives (You may write only the Roman numeral and the Alphabet chosen for your answer):** 1×8=8

(i) With reference to the aspects of customer service under Operations Management, if Primary consideration focuses on "Movement of a given, requested or acceptable specification", it's corresponding Principal function will be:

(A) Manufacture
(B) Transport
(C) Supply
(D) Service

(ii) Which one of the following forecasting is more useful in production planning?

(A) Short-term
(B) Medium-term
(C) Long-term
(D) None of the above

(iii) In which one of the following layouts, similar type of machines and services (i.e. facilities) are located together?

(A) Product or Line layout
(B) Process layout
(C) Group layout
(D) Fixed layout

(iv) Point-rating method is closely associated with
(A) Transportation
(B) Simulation
(C) Queuing system
(D) Job Evaluation

(v) The ratio of Actual Production to the Standard Production is referred to as:
(A) Standardization
(B) Simplification
(C) Productivity
(D) Actual Yield

(vi) Which one of the following is the project management software program?
(A) MS PowerPoint
(B) MS Excel
(C) MS Project
(D) MS Access

(vii) The type of spare parts which although acknowledged to have a long life or a small chance of failure, would cause a long shoutdown of equipment because it would take a long time to get a replacement for them, are known as
(A) Insurance spares
(B) Rotable spares
(C) Regular spares
(D) Capital spares

(viii) Which of the following is not the method used for Operations Research problems?
(A) Analytical method
(B) Simulation method
(C) Trail and error method
(D) None of the above

(b) **State whether the following statements are 'true' or 'false' (You may write only the Roman numeral and whether 'True' or 'False' without copying the statements into the answer books):** 1×4=4

(i) The term Operations Management is more used for a system where tangible goods are produced. F

(ii) Aggregate planning is an Intermediate term planning decision. T

(iii) The first and foremost stage of Design Thinking is Prototype. F

(iv) The ISO Standards are reviewed every 10 years and revised if needed. F

5 yrs

SUGGESTED ANSWERS TO QUESTIONS

SECTION – A

1(a)

(i) (B) Transport

(ii) (A) Short-Term

(iii) (B) Process Layout

(iv) (D) Job Evaluation

(v) (C) Productivity

(vi) (C) MS Project

(vii) (D) Capital Spares

(viii) (D) None of the Above

1(b)

(i) False

(ii) True

(iii) False

(iv) False

1(c)

(i) Resources

(ii) Network

(iii) Breakdown

2(a)

1. Product Selection
2. Facility Location Selection
3. Demand Forecasting
4. Process Selection & Layout Decision
5. Capacity Planning
6. Aggregate Planning, Master production schedule
7. Materials Requirement Planning (MRP) / Manufacturing Resource Planr (MRP1) / Distribution Resource Planning (DRP) / Enterprise Resource Planr (ERP)
8. Inventory Management
9. Supplier Section / Sourcing
10. Process Management
11. Quality Management
12. Maintenance
13. Warehousing / Transportation
14. Reverse Logistics

In Addition, an operations manager is also responsible for working capital management, skill – Management etc.

INTERMEDIATE EXAMINATION

MODEL QUESTION PAPER

PAPER - 9

OPERATIONS MANAGEMENT AND STRATEGIC MANAGEMENT

SET 1

June'23

Time Allowed: 3 Hours **Full Marks: 100**

The figures in the margin on the right side indicate full marks.

Where considered necessary, suitable assumptions may be made and clearly indicated in the answer.

SECTION – A : [OPERATIONS MANAGEMENT]

Answer Question No. 1 which is compulsory and any three from Questions Nos. 2, 3, 4 & 5

1. (a) Choose the correct alternatives: **1×8=8**

(i) Operations management is concerned essentially with the utilization of resources. Utilisation of resources means

a. Obtaining maximum effect from resources
b. Minimizing loss of resources
c. Minimising under utilization or waste of resources
d. All the above

(ii) In a linear programming model feasible solution is

a. The basic solution to the general L.P. problem
b. Any solution that also satisfies the non-negative restrictions of the general L.P. problem
c. A solution which optimize (maximize or minimize) the objective function of a general L.P. problem
d. A basic solution to the system of equation if one or more of the basic variables become equal to zero.

(iii) Multiple shift operation enhances

a. Firm's Capacity utilisation
b. Demand for firm's product
c. Firm's labour turnover
d. Firm's channel conflict

(iv) Which of the following is not a method for solving Assignment problem?

a. Complete Enumeration method
b. Hungarian method
c. Simplex method
d. Natural method

(v) Of all paths through the network, the critical path
   a. has the maximum expected time
   b. has the minimum expected time
   c. has the maximum actual time
   d. has the minimum actual time

vi) It is the basis for decisions regarding capacity planning, facilities (or plant) layout, equipment and design of work systems. This is
   a. Process Design
   b. Process Planning
   c. Process Strategy
   d. Process Selection

vii) 'Z' chart is a chart used in:
   a. Programme control
   b. Job control
   c. Cost control
   d. Quality control

viii) The most obvious reason for product design is
   a. To offer new products to sustain in the market
   b. To offer new products to fulfil changing preferences of customers
   c. To offer new products to remain competitive in the market
   d. To offer new products to cope with changing regulations in the market

(b) Fill in the blanks **1×4=4**

1. Design thinking is a ---------- stage process.
2. ---------- organizes the workstations in such a way that similar type of machines and services i.e., facilities are located together.
3. ---------- encompasses all the activities that are performed to produce the final products as per the specifications in line with the requirements of the customers.
4. ---------- is the maximum amount by which duration time of an activity can be increased without increasing the total duration time of the project.

(c) State whether the following statements are True/False. **1×3=3**

1. Gantt Chart is a principal tool used in scheduling.
2. One of the limitations of Gantt Chart is that it does not clearly indicate the details regarding progress of activities.
3. Preventive maintenance ensures greater safety to workers.

Time Allowed: 3 Hours **Full Marks: 100**

The figures in the margin on the right side indicate full marks.
Where considered necessary, suitable assumptions may be made and clearly indicated in the answer.

SECTION – A : [OPERATIONS MANAGEMENT]

Answer Question No. 1 which is compulsory and any three from Questions Nos. 2, 3, 4 & 5

1. (a)

(i)	(d)
(ii)	(b)
(iii)	(a)
(iv)	(d)
(v)	(a)
(vi)	(b)
(vii)	(a)
(viii)	(c)

(b)

(i)	Five
(ii)	Process layout /Functional layout
(iii)	Process Design
(iv)	Total float

(c)

(i)	True
(ii)	True
(iii)	True

2. (a) (i) **Lean Production**

Production systems have become lean production systems which use minimum amounts of resources to produce a high volume of high quality goods with some variety. These systems use flexible manufacturing systems and multi-skilled workforce to have advantages of both mass production and jobs production (or craft production).

Lean Production aims to cut costs by making the business more efficient and responsive to market needs.

INTERMEDIATE EXAMINATION
MODEL QUESTION PAPER
PAPER - 9
OPERATIONS MANAGEMENT AND STRATEGIC MANAGEMENT

SET 2
TERM – JUNE 2023

Time Allowed: 3 Hours **Full Marks: 100**

The figures in the margin on the right side indicate full marks.
Where considered necessary, suitable assumptions may be made and clearly indicated in the answer.

SECTION – A : [OPERATIONS MANAGEMENT]

Answer Question No. 1 which is compulsory and any three from Questions Nos. 2, 3, 4 & 5

1. (a) Choose the correct alternatives: **1×8=8**

(i) The Starting point of Production cycle is:
- a. Product design
- b. Production Planning
- c. Routing
- d. Market research.

(ii) Negative float signifies
- a. Reduction in target time to finish the work in time
- b. Adjustment of target time to finish the work before schedule
- c. Reduction in target time to crash the critical path
- d. Adjustment of target time to maintain the most likely time of activities

(iii) On which of the following areas ISO 9003 is applicable?
- a. Procurement
- b. Production
- c. Installation
- d. Servicing

(iv) One of the product examples for line layout is:
- a. Repair workshop
- b. Welding shop
- c. Engineering College
- d. Cement

(v) One of the important charts used in Programme control is:
- a. Material chart
- b. Gantt chart
- c. Route chart
- d. Inspection chart

(vi) Most suitable layout for continuous production is
   a. Line layout
   b. Process layout
   c. Group technology
   d. Matrix layout

(vii) The method used in scheduling a project is:
   a. A schedule of breakdown of orders
   b. Outline Master Programme
   c. PERT & CPM
   d. Schedule for large and integrated work.

(viii) JIT stands for
   a. Just in time purchase
   b. Just in time production
   c. Just in time use of materials
   d. Just in time order the material.

(b) Fill in the blanks **1×4=4**

(i) A _____ is defined as a onetime activity with a series of tasks that produces a specific out come to achieve organizational goals.

(ii) _____ signified the freedom for rescheduling or to start the job.

(iii) The investment on machines in a straight line layout is _____ than the investment on machines in a functional layout.

(iv) To evaluate the work done by preventive maintenance, _____ derived at from the total time of stoppage of the machine for scheduled and unscheduled maintenance work.

(c) State whether the following statements are True/False. **1×3=3**

1. Job evaluation is used to measure absolute job worth.
2. Training boosts employee morale.
3. EFT (Earliest Finish Time) is the sum of the earliest start time plus the time of duration for any event.

2. (a) Briefly discuss the scope of Operation Management.

(b) A company planning to manufacture a household cooking range has to decide on the location of the plant. Three locations are being considered viz., Patna, Ranchi, and Dhanbad. The fixed costs of the three location are estimated to be ₹30 lakh, ₹50 lakh, and ₹25 lakh per annum respectively. The variable costs are ₹300, ₹200 and ₹350 per unit respectively.

Time Allowed: 3 Hours **Full Marks: 100**

The figures in the margin on the right side indicate full marks.
Where considered necessary, suitable assumptions may be made and clearly indicated in the answer.

SECTION – A : [OPERATIONS MANAGEMENT]

Answer Question No. 1 which is compulsory and any three from Questions Nos. 2, 3, 4 & 5

1. (a)

(i)	(d)
(ii)	(a)
(iii)	(b)
(iv)	(d)
(v)	(b)
(vi)	(a)
(vii)	(c)
(viii)	(b)

(b)

(i)	Project
(ii)	Slack
(iii)	higher
(iv)	downtime

(c)

(i)	False
(ii)	True
(iii)	True

INTERMEDIATE EXAMINATION **SET - 1**

MODEL ANSWERS **TERM – DECEMBER 2023**

PAPER – 9 **SYLLABUS 2022**

OPERATIONS MANAGEMENT AND STRATEGIC MANAGEMENT

Time Allowed: 3 Hours **Full Marks: 100**

The figures in the margin on the right side indicate full marks.

SECTION – A

1. Multiple Choice Questions: **[15 x 2 = 30]**

(i) The starting point of Production cycle is
- (A) Product design
- (B) Production planning
- (C) Routing
- (D) Market Research

(ii) Which one of the following is NOT the advantage of Preventive Maintenance?
- (A) Better product quality
- (B) Greater safety of workers
- (C) Increased breakdowns and downtime
- (D) Fewer large-scale repairs

(iii) Consider the following item that is being managed using a fixed time period model with Safety Stock:
Weekly Demand – 50 units;
Review Cycle – 3 weeks;
Safety Stock – 30 units.
What is the average inventory level?
- (A) 100 units
- (B) 25 units
- (C) 105 units
- (D) None of these.

(iv) The type of production control which is typically found where a particular bottleneck machines exists in the process of manufacturing is
- (A) Block control
- (B) Load control
- (C) Flow control
- (D) Batch control

(v) Which one of the following ISO standards concerns minimization of harmful effects to the environment caused by the operations by the organization?
- (A) ISO 9001
- (B) ISO 14000
- (C) ISO 9002
- (D) ISO 9004

(vi) A Ltd., a large scale industry manufactures Product K of 24 units per shift of 8 hours. The standard time per unit is 15 minutes. What is the productivity of the per shift of 8 hours?

(A) 50%
(B) 60%
(C) 75%
(D) 80%

(vii) Arrangement of machine depending on sequence of operations happen in:

(A) Process Layout
(B) Product Layout
(C) Hybrid Layout
(D) Group Technology Layout

(viii) Buffer stock is built to cater for

(A) Fluctuating load
(B) Machine breakdown
(C) Import substitution
(D) Diversification

(ix) The objective function of a LPP is $Z = 3x_1 + 2x_2$. If $x_1 = 10$ and $x_2 = 5$, then the value of Z is:

(A) 35
(B) 40
(C) 45
(D) 50

(x) What describes the categories of activities within and around an organization, which together create a product or service?

(A) SWOT analysis
(B) BCG framework
(C) Value chain
(D) Brain storming

(xi) A _____ is a business unit in a growing market, but has yet with high market share.

(A) cash cow
(B) dog
(C) question mark
(D) star

(xii) _____ specifies what is to be accomplished by focusing on the end result.

(A) Output control
(B) Behavior control
(C) Premise control
(D) Implementation control

(xiii) The test is a catch-all category, indicating that the structure must fit legal, stakeholder, trade union or similar constraints.

(A) The Feasibility Test
(B) The People Test
(C) The Parenting Advantage Test
(D) The Specialised Cultures Test

(xiv) Which among the following is not a characteristic of Big Data?

(A) Variety
(B) Volume
(C) Velocity
(D) Invariability

(xv) _____ is similar to referral programs.

(A) Influencer marketing
(B) Affiliate Marketing
(C) Pay-per-click
(D) Content marketing

Answer:

(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)	(xii)	(xiii)	(xix)	(xv)
D	C	C	B	B	C	B	A	B	C	C	A	A	D	B

SECTION – B

Answer any 3 questions out of 4 questions given. Each question carries 14 marks.
[3 x 14 = 42]

2. (a) Enumerate the characteristics of Modern Operations functions **[7]**

(b) Define Process Strategy? The Classical way of Categorizations includes 4 types of layouts – Discuss **[3 + 4=7]**

Answer:

(a) Today's production system is characterised by the following features:

1. **Manufacturing as Competitive Advantage:** Unlike the past, today plants have excess capacities, competition is mounting and firms look and competitive edge and firms intend to exploit the potential. Total Quality Management (TQM), Time- Based Competition, Business Process Re-engineering (BPRE), Just-in-Time (JIT), Focused Factory, Flexible Manufacturing Systems (FMS), Computer Integrated Manufacturing (CIM), and The Virtual Corporation are but only some techniques which the companies are employing to gain competitive advantage.

2. **Services Orientation:** Service sector is gaining greater relevance these days. The production system, therefore, needs to be organised keeping in mind the peculiar requirements of the service component. The entire manufacturing needs to be geared to serve (i) intangible and perishable nature of the services, (ii) constant interaction with clients or