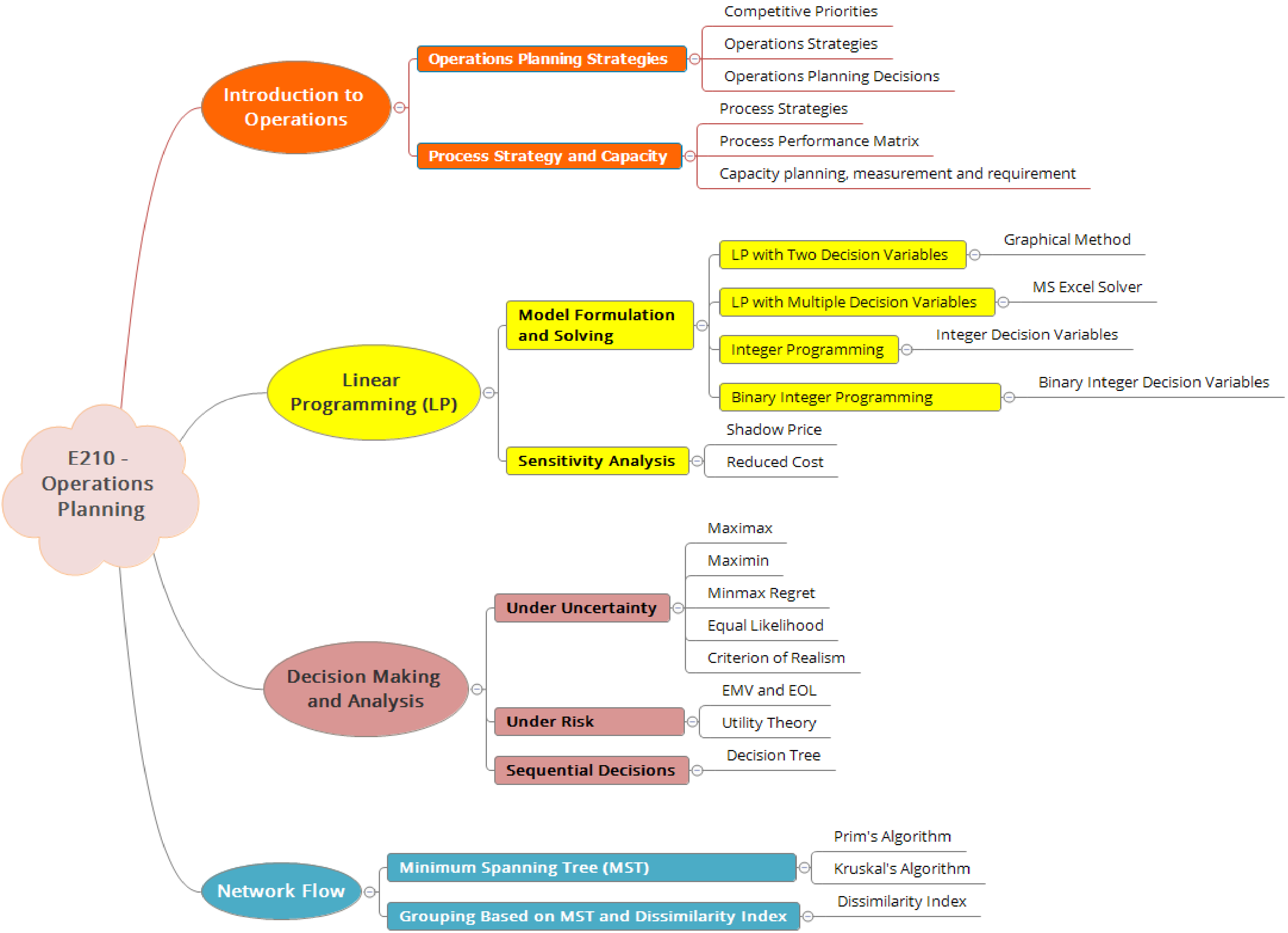
Problem 06

Crane Operators Scheduling – Part I

E210 – Operations Planning

SCHOOL OF ENGINEERING

E210 Operations Planning Topic Tree



Service Scheduling Problem

- Service scheduling problem considers the planning and scheduling of the activities involved in service industry.
- The activities can be:
  - A meeting that has to be attended by certain people
  - A game that has to be played between two teams
  - A flight leg that has to be covered by a plane
  - A personnel position that must be occupied in a given time period (today's problem).
- Characteristics of Service Scheduling Problem
  - Customer service requests are random and customers do not want to wait → provide capacity for services
  - No inventory of services → services are 'on-demand'
  - Service scheduling are multi-faceted, involving employees, customers and equipment

Service Scheduling Systems

- Appointment system
  - Controls customer arrivals for service
- Reservation system
  - Estimates demand for service, reservation of resources such as trucks, time slots, meeting rooms.
- Scheduling the workforce
  - Manages capacity for service, such as the assignment of shifts in call centers, hospitals.

Objectives & Constraints of Service Scheduling

- Objectives –

  for example: meet service level, minimize cost, workload balancing.

- Constraints –

  for example: work schedule, shift hours, personal constraints, rest hours, minimum number of supervisors, service requirement

Practical Issues with Employee Scheduling - Others

- Employee leave, availability, preferences
- Employee recruitment and retention
- Skill level, service quality – uneven skills across shifts
- Poor communication between shifts
- Managing festive and seasonal workloads, etc ….

Practical Issues with Employee Scheduling – Employment Act

Singapore Employment Act :

- A shift worker is allowed to work up to 12 hours a day, provided that the average working hours each week do not exceed 44 over a continuous three week period.
- An employee is generally not required to work more than six consecutive hours without a break.
- A part-time employee is one who is under a contract of service to work less than 35 hours a week

http://www.mom.gov.sg/employment-practices/hours-of-work-overtime-and-rest-days

Recall: Assumptions of Linear Programming

- The ***Certainty*** assumption:
  - Each model parameter is known with certainty.
  - Model parameters here refer to objective function coefficients, right-hand side values of model constraints, and constraint coefficients.
- The ***Proportionality*** assumption:
  - The contribution to the objective function (left-hand side of each constraint) from each decision variable is proportional to the value of the decision variable.
- The ***Additivity*** assumption:
  - Total contributions to the objective function (left-hand side of each constraint) is the sum of individual contributions from each variable.
- The ***Continuity*** assumption:

  Is this always true???
  - Variables can take on any value within a given feasible range

Integer Programming

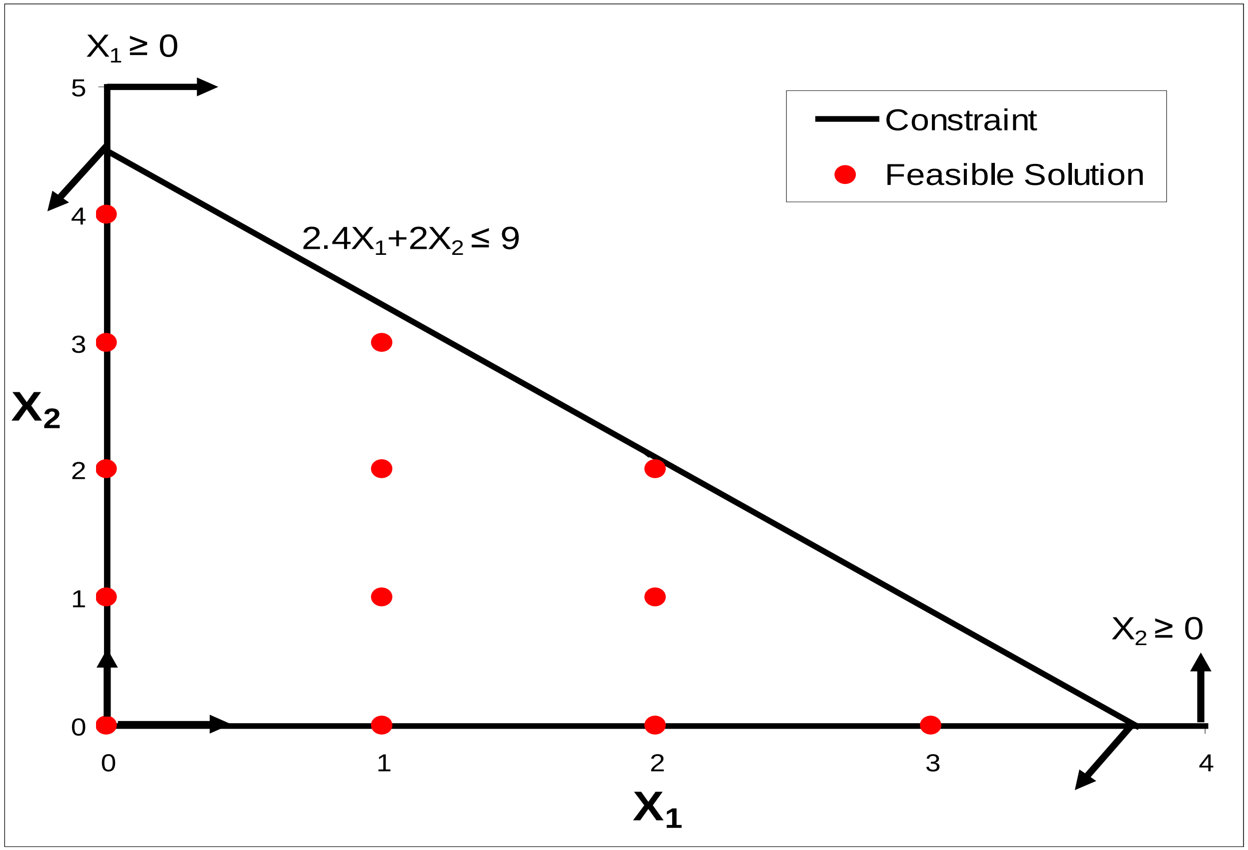
- Many engineering, industrial and financial applications involve integer requirements; especially when fractional values are infeasible for the variables.

- Examples : Number of trucks, number of workers, Yes/No decision

- Integer programming problem types include
  - General integer problem: decision variables are integers
  - 0-1 binary problem: decision variables are binary (0 or 1)
  - Mixed integer problem: some decision variables are integer, while others can be continuous.

Integer Programming

- For integer programming problems, the feasible region is not continuous.



Example of a graphical representation of a two-variable Integer Programming problem

Solving Integer Programming Problems

- It appears to be mathematically correct and convenient to simply round off a fractional solution to the closest integer solution.
- In general, this does not work reliably:
  - The rounded-off solution may be infeasible.
  - The rounded-off solution may not be optimal
- It is more difficult to solve an integer linear programming problem (the algorithms are more complex and more computing time and power are required).

Some Integer Programming Applications

- Capital Investment Analysis
  - Whether or not to invest a fixed amount into building a facility or acquiring some equipment
- Designing production and distribution network
  - Selection of sites as part of logistics network
- Shipment dispatching
  - Vehicle routing and scheduling
- Airline operations
  - Fleet assignment & crew scheduling

Problem 06
Suggested Solution

The Operators Scheduling Problem at RedDot Port

- RedDot Port operates several shifts (including both Type I and Type II shifts) a day.

- The number of crane operators required by each shift is dependent on vessel arrival time and the number of containers to be handled (loading/unloading) at different periods of a day.

- The objective is to determine the right number of operators on each shift to minimize the overall personnel cost while providing satisfactory customer service level, the possible minimum vessel turnaround time in this case.

Today's Problem: Integer Programming (IP) Model Formulation

- **Decision Variables** : Number of operators scheduled on each shift

- **Objective function** : Minimise daily personnel cost

- **Constraints:**
  - Operators in Type I shift + operators in Type II shift at each period >= operators required at each period

  - The ratio between operators assigned to Type I shift and total operators on duty during peak time periods is at least 3 : 10.

Today's Problem: IP Formulation

Decision Variables:

Let Xi be the number of operators on a Type I shift i (i = 1, 2 and 3) and Yj be the number of operators on a Type II shift j (j = 1, 2 and 3).

Objective Function:

Minimize daily personnel cost = $120*X1+$120*X2+$136*X3 +$180*Y1+ $184*Y2+$188*Y3

Constraints:

Operator requirement at each time period:

e.g. 11 operators required between 1700 - 1900: X2 + Y1 + Y2 >= 11

The ratio between operators assigned to Type I shift and total operators on duty during peak time periods:

e.g. Operators in Type I shift must be at least 3/10 of the total operators on duty between 1300 - 1400: 7X1 - 3(Y1 + Y2) >= 0

Constraints needed for the decision variables:

All decision variables should be non-negative and **integer**.

This special case of Linear Programming where decision variables are required to be integers is called Integer Programming.

Today's Problem: IP Formulation

Decision variables:

X1 – Number of operators on Type I shift 1 (0700-1500)

X2 – Number of operators on Type I shift 2 (1500-2300)

X3 – Number of operators on Type I shift 3 (2300-0700)

Y1 – Number of operators on Type II shift 1 (0700-1900)

Y2 – Number of operators on Type II shift 2 (1300-0100)

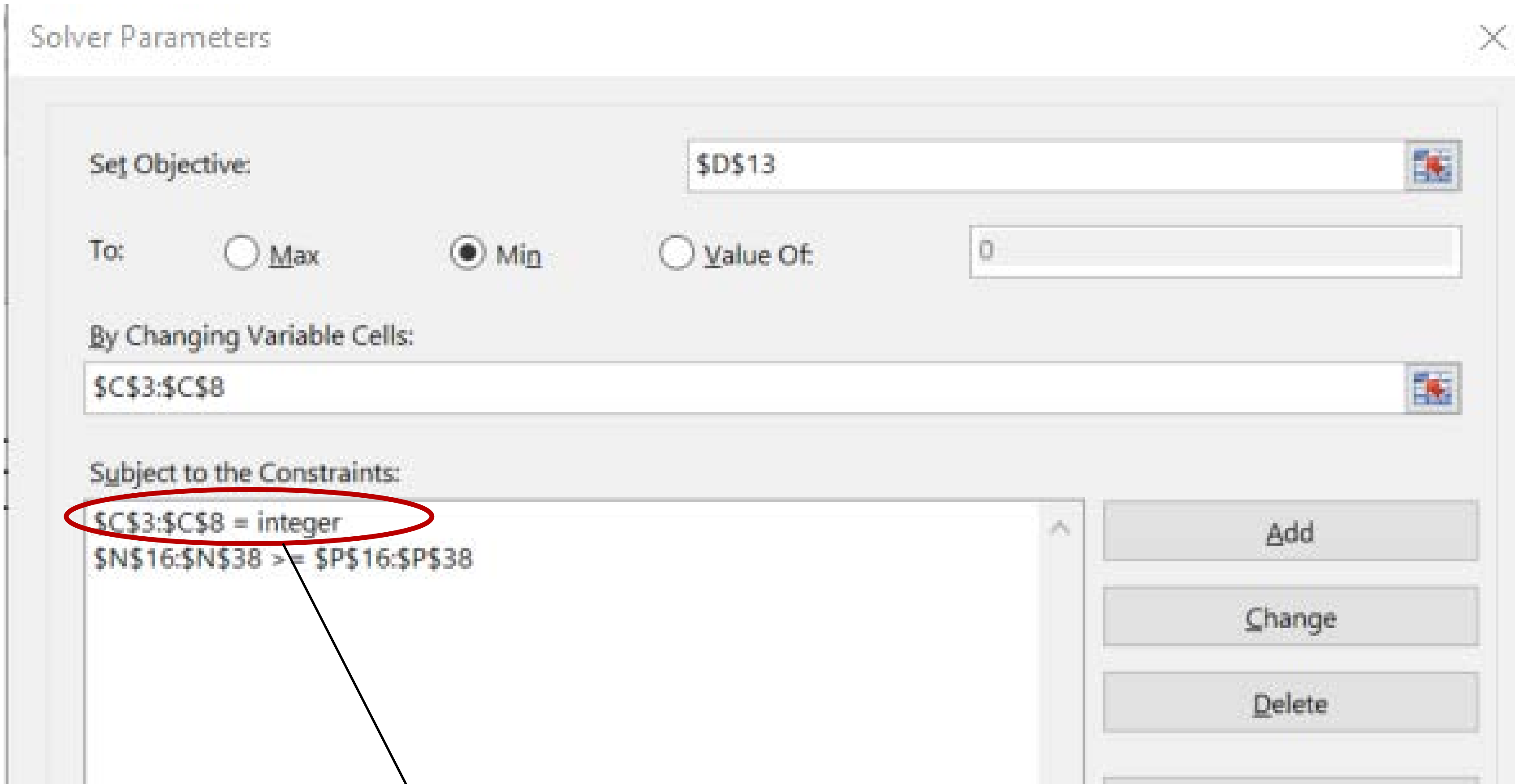
Y3 – Number of operators on Type II shift 3 (1900-0700)

Today’s Problem: IP Formulation

Description of Constraints	Constraints	LHS	Sign	RHS
Type_I shift and total operators ratio between 1200 - 1300	7X1 - 3Y1 >= 0	28	>=	0
Type_I shift and total operators ratio between 1300 - 1400	7X1 - 3(Y1 + Y2) >= 0	7	>=	0
Type_I shift and total operators ratio between 1400 - 1500	7X1 - 3Y2 >= 0	28	>=	0
Type_I shift and total operators ratio between 1500 - 1600	7X2 - 3(Y1 + Y2) >= 0	0	>=	0
Type_I shift and total operators ratio between 1600 - 1700	7X2 - 3Y1 >= 0	21	>=	0
7 staff between 0700 to 1000	X1 + Y1 >= 7	14	>=	7
7 staff between 1000 to 1100	X1 >= 7	7	>=	7
7 staff between 1100 to 1200	Y1 >= 7	7	>=	7
8 staff between 1200 to 1300	X1 + Y1 >=8	14	>=	8
8 staff between1300 to 1400	X1 + Y1 + Y2 >= 8	21	>=	8
8 staff between 1400 to 1500	X1 + Y2 >= 8	14	>=	8
11 staff between 1500 to 1600	X2 + Y1 + Y2 >= 11	20	>=	11
11 staff between 1600 to 1700	X2 + Y1 >= 11	13	>=	11
11 staff between 1700 to 1900	X2 + Y1 + Y2 >= 11	20	>=	11
11 staff between 1900 to 2000	Y2 + Y3>= 11	11	>=	11
10 staff between 2000 to 2100	X2 + Y3 >= 10	10	>=	10
10 staff between 2100 to 2200	X2 + Y2 + Y3 >= 10	17	>=	10
10 staff between 2200 to 2300	X2 + Y2 >= 10	13	>=	10
6 staff between 2300 to 0100	X3 + Y2 + Y3>= 6	15	>=	6
6 staff between 0100 to 0200	X3 + Y3 >= 6	8	>=	6
4 staff between 0200 to 0300	X3 >= 4	4	>=	4
4 staff between 0300 to 0400	Y3 >= 4	4	>=	4
4 staff between 0400 to 0700	X3 + Y3>=4	8	>=	4

All Xi (i = 1, 2 and 3) and Yj (j = 1, 2 and 3) are non-negative and integer

Today's Problem: Integer Requirement on Decision Variables



Using Integer Programming to find the Integer Solution:
Define constraints for integer decision variables in MS Excel Solver.

Today’s Problem: IP solution

	Rates	Decision Variables Qty	0700 0800	0800 0900	0900 1000	1000 1100	1100 1200	1200 1300	1300 1400	1400 1500	1500 1600	1600 1700	1700 1800	1800 1900	1900 2000	2000 2100	2100 2200	2200 2300	2300 0000	0000 0100	0100 0200	0200 0300	0300 0400	0400 0500	0500 0600	0600 0700
Type_I (0700 - 1500)	$120.00	7	X1																							
Type_I (1500 - 2300)	$120.00	6									X2															
Type_I (2300 - 0700)	$136.00	4																	X3							
Type_II (0700 - 1900	$180.00	7	Y1																							
Type_II (1300 - 0100	$184.00	7							Y2																	
Type_II (1900 - 0700	$188.00	4													Y3											
Staff required			7					8			11					10			6			4				

Objective Min. Z = \$120*X1+\$120*X2+\$136*X3 +\$180*Y1+ \$184*Y2+\$188*Y3

= $\boxed{\$5,404}$

Today's Problem: Without the Integer Requirement

The solution may be in decimals. If the solution is rounded to the nearest integers, the solution may not be feasible.

	Rates	Decision Variables Qty	
Type_I (0700 - 1500)	$120.00	7	X1
Type_I (1500 - 2300)	$120.00	5	X2
Type_I (2300 - 0700)	$136.00	4	X3
Type_II (0700 - 1900)	$180.00	7	Y1
Type_II (1300 - 0100)	$184.00	5	Y2
Type_II (1900 - 0700)	$188.00	6	Y3

Period	0700 0800	0800 0900	0900 1000	1000 1100	1100 1200	1200 1300	1300 1400	1400 1500	1500 1600	1600 1700	1700 1800	1800 1900	1900 2000	2000 2100	2100 2200	2200 2300	2300 0000	0000 0100	0100 0200	0200 0300	0300 0400	0400 0500	0500 0600	0600 0700
Staff required	7					8			11					10			6			4				

Objective Min. Z = $120*X1+$120*X2+$136*X3 +$180*Y1+ $184*Y2+$188*Y3

= $\boxed{\$5,292}$

Violation of required ratio constraint

Description of Constraints	**Constraints**	LHS	Sign	RHS
Type_I shift and total operators ratio between 1200 - 1300	7X1 - 3Y1 >= 0	28	>=	0
Type_I shift and total operators ratio between 1300 - 1400	7X1 - 3(Y1 + Y2) >= 0	13	>=	0
Type_I shift and total operators ratio between 1400 - 1500	7X1 - 3Y2 >= 0	34	>=	0
Type_I shift and total operators ratio between 1500 - 1600	7X2 - 3(Y1 + Y2) >= 0	-1	>=	0
Type_I shift and total operators ratio between 1600 - 1700	7X2 - 3Y1 >= 0	14	>=	0

Today's Problem: Without the Integer Requirement

The solution may be in decimals. If the solution is rounded to the next whole numbers, the solution may not be optimal.

	Rates	Decision Variables Qty	
Type_I (0700 - 1500)	$120.00	7	X1
Type_I (1500 - 2300)	$120.00	6	X2
Type_I (2300 - 0700)	$136.00	4	X3
Type_II (0700 - 1900)	$180.00	7	Y1
Type_II (1300 - 0100)	$184.00	5	Y2
Type_II (1900 - 0700)	$188.00	7	Y3

Period	0700 0800	0800 0900	0900 1000	1000 1100	1100 1200	1200 1300	1300 1400	1400 1500	1500 1600	1600 1700	1700 1800	1800 1900	1900 2000	2000 2100	2100 2200	2200 2300	2300 0000	0000 0100	0100 0200	0200 0300	0300 0400	0400 0500	0500 0600	0600 0700
Staff required	7				8				11					10			6			4				

Objective Min. Z = $120*X1+$120*X2+$136*X3 +$180*Y1+ $184*Y2+$188*Y3

= $\boxed{\$5,600}$

When the solution is rounded to the next whole numbers, 36 operators are needed, 1 more operator on Type II shift needed than the optimal solution. The total daily personnel cost increased from $5,404 to $5,600.

Today's Problem: Recommendations

- Operators on Type I shift to be scheduled at each of the shifts: 7, 6 and 4 respectively.
- Operators on Type II shift to be scheduled at each of the shifts: 7, 7 and 4 respectively.
- Total personnel cost per day=$5,404.
- If Mindy just assign all 36 operators available equally in each shift
  - ➢ The solution may not be feasible

Description of Constraints	Constraints	LHS	Sign	RHS
Type_I shift and total operators ratio between 1200 - 1300	7X1 - 3Y1 >= 0	24	>=	0
Type_I shift and total operators ratio between 1300 - 1400	7X1 - 3(Y1 + Y2) >= 0	6	>=	0
Type_I shift and total operators ratio between 1400 - 1500	7X1 - 3Y2 >= 0	24	>=	0
Type_I shift and total operators ratio between 1500 - 1600	7X2 - 3(Y1 + Y2) >= 0	6	>=	0
Type_I shift and total operators ratio between 1600 - 1700	7X2 - 3Y1 >= 0	24	>=	0
7 staff between 0700 to 1000	X1 + Y1 >= 7	12	>=	7
7 staff between 1000 to 1100	X1 >= 7	6	>=	7
7 staff between 1100 to 1200	Y1 >= 7	6	>=	7

  - ➢ The solution is also not optimal, the total daily personnel cost will increase by:

    6*(120+120+136+180+184+188) - 5404 = $164

Learning Objectives

At the end of the lesson, students should be able to:

- Solve a typical manpower scheduling problem in a service company based on Integer Programming.
- Explain the multiple facets of manpower scheduling: involving employees, customers and equipment.
- Identify objectives of manpower scheduling – meet service level, minimize cost.
- Identify and formulate constraints in terms of service and manpower policy requirements.

Overview of E210 Operation Planning Module