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Applying Concept of Operational Research in Construction Industry

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Abstract - Operations Research (OR) is the method of advanced analytical to support complex problem-solving and decision making. The success of OR methods is that it is a systematic approach to solving problems by provide a framework for constructing conceptual and mathematical models finding out the best among all solutions with respect to given measurable parameters (variables), and finding out the best solutions among all problems, In this regards, OR contributes to improving project management by applying different techniques such as Critical Path Methods (CPM) and Project Evaluation Review Technique (PERT), reduce better logistics for quality delivery through network optimization, traffic simulations, decision theory, game bottleneck elimination (game theory), simulations, linear programing, public transport scheduling and planning, monte carlo simulation, transportation problems, etc. In this research paper we are mainly focus on the practical application of linear programming in construction industry.

Key Words: Operational Research, Decision Making, Linear Programming, Simplex Method, Transportation Problem, Monte-Carlo Simulation, Decision Theory.

1. INTRODUCTION

• What is Operational Research?
Encyclopedia of the Chinese Enterprise Management defines operation research as "To make overall arrangement of the limited resources of human, financial and material in the economic system by using analytical, experimental and numerical methods, aiming to provide optimal plans for decision makers to achieve the most effective management".
Approach's (STEPS):
1. Orientation,
2. Problem Definition,
3. Data Collection,
4. Model Formulation,
5. Solution,
6. Model Validation and Output Analysis, and
7. Implementation and Monitoring.

1.1 Linear Programming

In order to develop and apply specific operations, research techniques are accustomed determine the optimal choice, among other several courses of action, including the evaluation of specific numerical values, there's also have to formulate a mathematical model. The term formulation refers to the method of converting the verbal descriptions and numerical data into mathematical expressions , which represents the relationships among relevant decision variables, objective and restrictions, on the utilization of resources like labor, material, time, warehouse space, capital, etc., to many competing activities, like products, services jobs, new equipment, projects etc., on the premise of a given criterion of optimality (George et al, 2000). Application of Software's : The usefulness of this technique is enhanced by the availability of user-friendly computer software such as STORM, TORA, QSB, LINDO, excel solver, @Risk, Various Add-in etc. However, there is no computer software for building an LP model.

1.2 Transportation Problem

The transportation model could be a special class of the applied maths problem. It deals with things within which a commodity is transported from sources to destinations. The target is to be determined the amounts shipped from each source to every destination that minimize the overall shipping cost while satisfying both the provision limit and also the demand requirements. The model assumes that the shipping cost on a given route is directly proportional to the quantity of units shipped thereon route. This industry wants an answer for transportation problems with internal control, managing of fund, and resolving disputes of scheduling production over different time periods for construction materials by using the transportation model. Generally, NWCM, LCM, VAM, MODI, etc method are useful. Application of Software's: The usefulness of this technique is enhanced by the availability software such as Excel solver, AtoZmath.com, etc. .

1.3 Monte-Carlo Simulation

In cost budget management, Project Manager and Engineers can be use Monte Carlo Simulation to better understand project budget and estimate final budget at completion. Monte Carlo simulation has been used in construction projects to better understand certain risks of the project. Application of Software's : The usefulness of this technique is enhanced by the availability of software such as Monte Carlo simulation Add-ins, such as @Risk or Risk+.

1.4 Decision Theory

Decision analysis is an analytical approach by decision making that allows managers to solve problems with uncertainty figures as a prominent factor. A model is developed to represent the decision-making problem, facilitate logical analysis, and produce a recommended course of action. Decision Theory calculation is a creating combination of a events, strategies, payoff table, opportunity loss or regret table. five decision rules (criteria) commonly used in decision process under uncertainty were presented and applied.

Wald's MaxiMin or MiniMax
Hurwicz's
Maximax or MiniMin
Savage's
Laplace's, etc

Application of Software's: Generally, Microsoft Excel is Used for the solving out Decision Theory

2. PRACTICAL APPLICATION:

2.1. Linear Programming:

2.1.1 Graphical Method:

Rajasthan Municipal Water System distributes drinking water through the gravitational method leads to problem as a inadequate in pressure, which could be solved by introducing mechanical pump booster station at a various building housing area. The pressure expected by a gravitational method is 6 kg/cm^2 and by mechanical pumping station put at 9 kg/cm^2. In this case study 2 area A & B is taken into consideration, where 'A' is a 'Paramanand Colony' and 'B' is a 'Santoshi Bhar' area. A & B are expected to get combined pressure not more than limit of 15 & 12 kg/cm^2 respectively. Pressure combinations for A & B are show below. Find out minimum pressure required in the municipality.

Table -1: Pressure

	Gravitational Method (kg/cm^2)	Mechanical Booster (kg/cm^2)
A	0.25	3
B	0.40	4

From the case study , the following formulation can be made.
(i) Objective Function is
$Q = 6X_1 + 9X_2$

(ii) $0.25X_1 + 3X_2 \leq 15$ .... 'A' - Paramanand Colony Constant
$0.40X_1 + 4X_2 \leq 12$ .... 'B' – Santoshi Bhar Constant

(iii) Non – Negativity Constant,
$X_1, X_2 \geq 0$

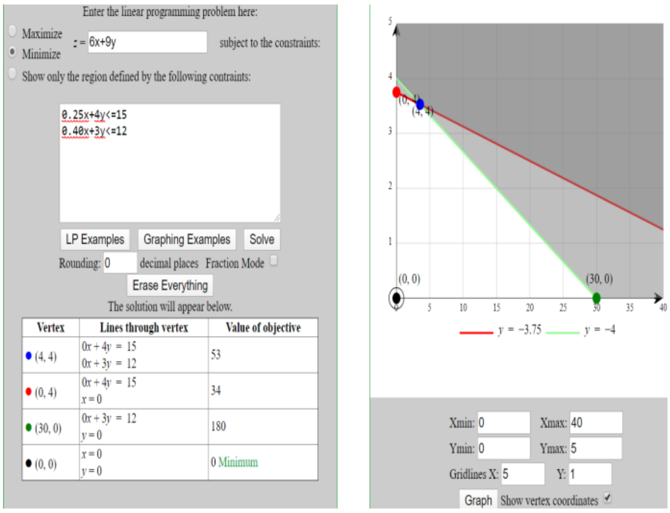

Fig 1: Graphical Solution

2.1.2 Simplex Method:

The following data was required for residential building work. The building has G+5 building located at Ahmedabad. 3 floor construction had been completed. The building estimate is Rs. 3 crores.

Table -2: Required Data

Raw Material Needed	Quantity of Whole Structure
Manpower	157
Cement (50kg)	180
Sand (Cft)	515
Brick	20,657

Table -3: Each Floor Requirement

	Ground Floor (Per Day)	First Floor (Per Day)	Second Floor (Per Day)
Manpower	19	15	13
Cement	27	22	18
Sand	85	76	63
Brick	3120	2850	2232

Table -4: Profit

Floor	Profit
Ground Floor	11,15,900
First Floor	9,75,700
Second Floor	4,15,450

From the case study , the following formulation can be made.
(i) Objective Function is
MAX $Z = 11{,}15{,}900X_1 + 9{,}75{,}700X_2 + 4{,}15{,}450X_3$
(ii) Subject to

$19X_1 + 15X_2 + 13X_3 \leq 157$ ……. Manpower
$27X_1 + 22X_2 + 18X_3 \leq 180$ ……. Cement
$85X_1 + 76X_2 + 63X_3 \leq 515$ ……. Sand
$3120X_1 + 2850X_2 + 2232X_3 \leq 20657$ ……. Brick
(iii) Non – Negativity Constant,
$X_1, X_2, X_3 \geq 0$

Optimal solution: p = 6761040; x = 6.05882, y = 0, z = 0

Solve Examples Erase everything

Hide tableaus (faster).
Show tableaus.
Show tableaus and intermediate solutions.
Tableau mode: decimal fraction integer Rounding: 6 significant digits

Tableau 1:

	x	y	z	s1	s2	s3	s4	p	
s1	19	15	13	1	0	0	0	0	157
s2	27	22	18	0	1	0	0	0	180
s3	85	76	63	0	0	1	0	0	515
s4	3120	2850	2232	0	0	0	1	0	20657
p	-1115900	-975700	-415450	0	0	0	0	1	0

Tableau 2:

	x	y	z	s1	s2	s3	s4	p	
s1	0	-1.98824	-1.08235	1	0	-0.223529	0	0	41.8824
s2	0	-2.14118	-2.01176	0	1	-0.317647	0	0	16.4118
x	1	0.894118	0.741176	0	0	0.0117647	0	0	6.05882
s4	0	60.3529	-80.4706	0	0	-36.7059	1	0	1753.47
p	0	22045.9	411629	0	0	13128.2	0	1	6761040

Fig -2: Simplex Solution

A organization plans on building a maximum of 11 new stores in a Gandhinagar city. They will construct these stores in one among of three sizes for every location 1. A convenience store 24x7 2. Standard and 3. An expanded service store. The convenience store is estimated Rs. 15 Crore to build and 80 employees to operate. The standard store requires Rs. 10 Crore to build and 50 employees to operate. The expanded-services store requires Rs. 18 Crore to build and 60 employees to operate. The organization can be arrange Rs. 50 Crores in construction capital, and 250 employees to staff the stores. On the average, the convenience store nets Rs. 5 Crores annually, the standard store nets Rs. 2.5 Crore annually, and the expanded-services store nets Rs. 4 Crore annually. How many of each should they build to maximize their revenue? formulate, LPP model Maximization of allocation.

From the case study , the following formulation can be made.

(i) Objective Function is

$MAX\ Z = 5X_1 + 2.5X_2 + 4X_3$

(ii) Subject to

$X_1 + X_2 + X_3 \leq 11$

$15X_1 + 10X_2 + 18X_3 \leq 50$

$80X_1 + 50X_2 + 60X_3 \leq 250$

(iii) Non – Negativity Constant,

$X_1, X_2, X_3 \geq 0$

	X1	=	No. of convenience store			
	X2	=	No. of standard stores			
	X3	=	No. of expanded service store			
	X1=	2.77778	X2=	0	X3=	0.46296
	Conven.	Stand.	Exp. Serv.		Limit	
Construct	15	10	18		50	
Staffing	80	50	60		250	
Revenue	5	2.5	4			
Constraints			3.240740741	<=	11	
			50	<=	50	
			250	<=	250	
Maximize			15.74074074			

Fig -3: Excel Solver Solution

In Sabarmati River, the accessible water was allocated for the requirement of daily household consumption, electric power generation, and irrigation among 3 communities. The water allocated per annum per capita for all uses in theses three communities are $68m^3$, $62m^3$ and $58m^3$. The allocation of water were based on the critical factors of fertilized land area, population of communities, industrialization. The population of the communities are 3850, 5300 & 2400 respectively. Power supply capacities of 100W, 120W & 85W. While the land areas of irrigation are 90 hectares, 85 hectares and 70 hectares respectively. Allowable allocation limits of more than 6000 peoples, less than 200W and 125 hectares were stipulated for the purposes. Assume non-negativity condition. Using the above information, formulate, LPP model, Maximization of allocation.

From the case study , the following formulation can be made.

(i) Objective Function is

$MAX\ Z = 68X_1 + 62X_2 + 58X_3$

(ii) Subject to

$3850X_1 + 5300X_2 + 2400X_3 \geq 6000$
$100X_1 + 120X_2 + 85X_3 \leq 200$
$90X_1 + 85X_2 + 70X_3 \geq 125$

(iii) Non – Negativity Constant,
$X_1, X_2, X_3 \geq 0$

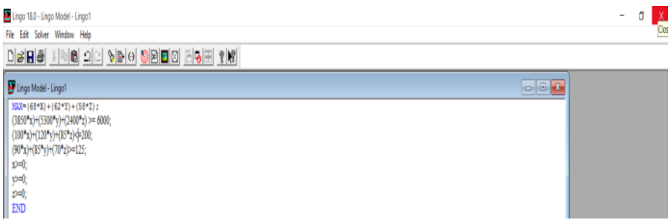

Fig -4: Lingo Input

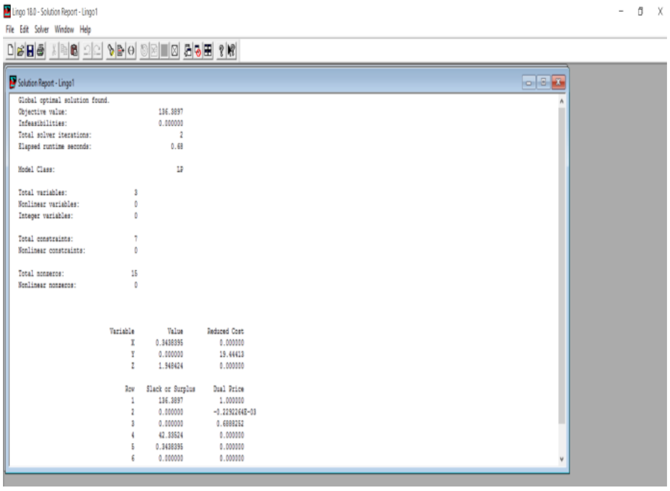

Fig -5: Lingo Output

2.2 Transportation Problem:

A Ready-Mix Concrete Supplier has 3 batching plant are required to supply concrete to four projects. The unit cost of transportation from a batching plant are listed in a cost matrix. The capacity of production of batching plant and requirement of concrete on a projects per day are also listed. Optimize the problem by using NWCM, LCM, VAM & RAM.

Table -5: Transportation Problem Table

Batching Plant	Project (Rs.)				Capacities (Cum)
	P1	P2	P3	P4	
BP1	50	80	60	30	120
BP2	25	30	70	40	100
BP3	60	50	40	60	80
Requirement	50	70	40	60	

	D_1	D_2	D_3	D_4	D_{dummy}	Supply
S_1	50(50)	80(70)	60	30	0	0
S_2	25	30	70(40)	40(60)	0	0
S_3	60	50	40	60	0(80)	0
Demand	0	0	0	0	0	

Initial feasible solution is

	D_1	D_2	D_3	D_4	D_{dummy}	Supply
S_1	50 (50)	80 (70)	60	30	0	120
S_2	25	30	70 (40)	40 (60)	0	100
S_3	60	50	40	60	0 (80)	80
Demand	50	70	40	60	80	

Fig -6: North-West Corner Method

Minimum Transportation Cost = (50*50)+(80*70)+(40*70)+(80*40) = 13,300 Rs.

	D_1	D_2	D_3	D_4	D_{dummy}	Supply
S_1	50	80	60	30(40)	0(80)	0
S_2	25(50)	30(50)	70	40	0	0
S_3	60	50(20)	40(40)	60(20)	0	0
Demand	0	0	0	0	0	

Initial feasible solution is

	D_1	D_2	D_3	D_4	D_{dummy}	Supply
S_1	50	80	60	30 (40)	0 (80)	120
S_2	25 (50)	30 (50)	70	40	0	100
S_3	60	50 (20)	40 (40)	60 (20)	0	80
Demand	50	70	40	60	80	

Fig -7: Least Cost Method

Minimum Transportation Cost = (25*50)+(30*50)+(50*20)+(40*40)+(30*40)+(60*20) = 7750 Rs.

<table>
<tr><th></th><th>D_1</th><th>D_2</th><th>D_3</th><th>D_4</th><th>D_{dummy}</th><th>Supply</th><th>Row Penalty</th></tr>
<tr><td>S_1</td><td>50(20)</td><td>80</td><td>60(40)</td><td>30(60)</td><td>0</td><td>120</td><td>30 | 20 | 20 | 20 | 20 | 30 |</td></tr>
<tr><td>S_2</td><td>25(30)</td><td>30(70)</td><td>70</td><td>40</td><td>0</td><td>100</td><td>25 | 5 | 15 | -- | -- | -- |</td></tr>
<tr><td>S_3</td><td>60</td><td>50</td><td>40</td><td>60</td><td>0(80)</td><td>80</td><td>40 | -- | -- | -- | -- | -- |</td></tr>
<tr><td>Demand</td><td>50</td><td>70</td><td>40</td><td>60</td><td>80</td><td></td><td></td></tr>
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</table>

Fig -8: Vogel's Approximation Method

Minimum Transportation Cost = (25*50)+(30*50)+(50*20)+(40*40)+(30*40)+(60*20) = 7750 Rs.

	D_1	D_2	D_3	D_4	D_{dummy}	Supply
S_1	50 (20)	80	60	30 (60)	0 (40)	0
S_2	25 (30)	30 (70)	70	40	0	0
S_3	60	50	40 (40)	60	0 (40)	0
Demand	0	0	0	0	0	

Initial feasible solution is

	D_1	D_2	D_3	D_4	D_{dummy}	Supply
S_1	50 (20)	80	60	30 (60)	0 (40)	120
S_2	25 (30)	30 (70)	70	40	0	100
S_3	60	50	40 (40)	60	0 (40)	80
Demand	50	70	40	60	80	

Fig -9: Russel's Approximation Method

Minimum Transportation Cost = (50*20)+(25*30)+(30*70)+(40*40)+(30*60) = 7250 Rs.

2.3 Monte-Carlo Simulation:

Consider the case of dealer of certain construction product for which probability distribution of daily demand and the probability distribution of the lead time, both develop empirically by observation, probability distribution of daily demand.

Table -6: Unit Demand & Probability

Unit Demand	3	4	5	6	7	8	9	10	11	12
Probability	0.02	0.08	0.11	0.16	0.19	0.13	0.10	0.08	0.07	0.06

Table -7: Probability Distribution of Lead Time

Lead Time	2	3	4	5
Probability	0.2	0.3	0.35	0.15

The ordering cost is known to be Rs. 80 per order, the holding cost per unit is estimated of Rs. 2, while unit shortage cost, representing the loss in profit is Rs. 20 per unit per day. The dealer is anxious to know for specific reorder quantities, what would be the total inventory cost (made up by ordering, holding and shortage cost) and thereby selecting an appropriate combination of two of this sum we shall be evaluate, a simulation plan which calls for re-order quantity of 40 unit and re-order level of 20 units with a beginning inventory balance of 30 units. Give the results for 40 days. Random Number for lead time: 47,74,25,21,47,69,9,86

R.N	Demand	Probability	Cum Probability	R.N. Interval	
47	3	0.02	0.02	0	1
74	4	0.08	0.1	2	9
25	5	0.11	0.21	10	20
21	6	0.16	0.37	21	36
47	7	0.19	0.56	37	55
69	8	0.13	0.69	56	68
9	9	0.1	0.79	69	78
80	10	0.08	0.87	79	86
	11	0.07	0.94	87	93
	12	0.06	1	94	99
	Lead Time				
	2	0.2	0.2	0	19
	3	0.3	0.5	20	49
	4	0.35	0.85	50	84
	5	0.15	1	85	99

Fig -10: R.N Interval Distribution

Day	Random Number	Demand	Random Number	Lead Time	Receipt 30	Balance	Order Cost	Holding Cost	Shortage Cost
0						30			
1	68	8				22		44	
2	13	5	47	3		17	80	34	
3	9	4	Please insert random number			13		26	
4	20	5	Please insert random number			8		16	
5	73	9			40	39		78	
6	7	4				35		70	
7	92	11				24		48	
8	99	12	74	4		12	80	24	
9	93	11	Please insert random number			1		2	
10	18	5	Please insert random number			0		0	80
11	24	6	Please insert random number			0		0	120
12	22	6			40	34		68	
13	7	4				30		60	
14	29	6				24		48	
15	57	8	25	3		16	80	32	
16	33	6	Please insert random number			10		20	
17	49	7	Please insert random number			3		6	
18	65	8			40	35		70	
19	92	11				24		48	
20	98	12	21	3		12	80	24	
21	0	3	Please insert random number			9		18	
22	57	8	Please insert random number			1		2	
23	12	5			40	36		72	
24	31	6				30		60	
25	96	12	47	3		18	80	36	
26	85	10	Please insert random number			8		16	
27	72	9	Please insert random number			0		0	20
28	91	11			40	29		58	
29	77	9	69	4		20	80	40	
30	37	7	Please insert random number			13		26	
31	34	6	Please insert random number			7		14	
32	11	5	Please insert random number			2		4	
33	27	6			40	36		72	
34	10	5				31		62	
35	59	8				23		46	
36	33	6	9	2		17	80	34	
37	87	11	Please insert random number			6		12	
38	72	9			40	37		74	
39	73	9				28		56	
40	79	10	80	4		18	80	36	

Order Cost	Holding Cost	Shortage Cost
640	1456	220

Fig -11: Simulation in Microsoft Excel

Order Cost = 640 Rs. Holding Cost = 1456 Rs., Shortage Cost = 220 Rs.

2.4 Decision Theory:

A cement bag wholesale store is selling 50 kg cement bag for 270 Rs. It purchased the cement for 264 Rs. per bag. Since some of the bags are about to reach its expiry date and can be sell at low margin profit for 220 Rs. each at the end of 3 months. According to past experience, the actual demand for cement bags are in between 470 to 500 Bags.

Profit = 6 Rs., Loss in Profit = 44 Rs.

Table -8: Event & Strategies (Demanded & Purchased)

E1	470	A1	470
E2	471	A2	471
…	…	…	…
E15	500	A15	500

Table -9: Payoff Table

EVENT		ACT			
		A1	A2	...	A31
		470	471	...	500
E1	470	2820	2776	...	1500
E2	471	2820	2826	...	1550
...	...	...	...	...	...
E31	500	2820	2826	...	3000

Table -10: Opportunity Loss Table (Regret Table)

EVENT		ACT			
		A1	A2	...	A31
		470	471	...	500
E1	470	0	44	...	1320
E2	471	6	0	...	1276
...	...	...	...	...	...
E31	500	180	174	...	0

- **Decision Rules:**

Table -11: Laplace Principle: Average of Each Column/No. of Each Column

470	471	472	473	...	500
A1	A2	A3	A4	...	A31
2820	2824	2827	2828	...	2250

Ans: 473: 2828: A4

Table -12: Mini-Max or Maxi-Min: Minimum of Each Column

470	471	472	473	...	500
A1	A2	A3	A4	...	A31
2820	2776	2732	2688	...	1500

Ans: 470: 2820: A1

Table -13: Maxi-Max or Mini-Min: Maximum of Each Column

470	471	472	473	...	500
A1	A2	A3	A4	...	A31
2820	2826	2832	2838	...	3000

Ans: 500: 3000: A31

Table -14: Harwicz's Principle: (α = 0.6)

ACT	MAX	MIN	CRITERIAN VALUE α*(Max Value) + (1- α)*(Min Value)
A1	2820	2820	2820
A2	2826	2776	2806
...	...	...	...
A31	3000	1500	2400

Ans: 470: 2820: A1

Table -15: Savage Principle: Principle of Mini-Max Regret)

470	471	472	473	...	500
A1	A2	A3	A4	...	A31
180	174	168	162	...	1320

Ans: 473: 162: A4

Table -16: Summery

Laplace Principle	473	Bags
Mini-Max or Maxi-Min Principle	470	Bags
Maxi-Min or Mini-Min Principle	500	Bags
Harwicz Principle	470	Bags
Savage Principle	473	Bags
Taking Average of 5 Principle	477	Bags

3. CONCLUSION

Operational Research techniques were shown to be useful not only for solving management problems, but also for solving many problems arising at all the levels of the construction process. Today, in the construction sector, the "decision maker" has to provide functionally, formally and economically derived optimal solutions; concluding that the Operational Research view point is applicable as well to the tasks and interrelationships of the participants in the construction problems and also gives beneficiary in all the way possible. OR techniques had been approved and studied by other sectors before, but this technique had resulted in providing great experience in and off construction field.

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