Optimizing Logistics In Congested Environment, Resource Planning And Sequencing Activities To Improve Efficiency

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Abstract- *The objective of the paper is to bring out logistics cost by varying the ordering quantity of each material. The project baseline schedule is developed using Primavera from which all the necessary data for the calculations are taken. The entire project is divided into three stages depending upon the interior spaces available for storage and procurement decisions are taken based on the storage space available during each stage. Site logistics cost include material ordering, transporting, finance and layout costs which are calculated for each combination of Ordering quantity using Evolutionary Algorithm. Accordingly, the tool is developed to achieve the main objective to minimize total logistics costs with respect to the constraint, storage space available at each stage of construction. The results obtained also enable the contractor to improve coordination with different parties involved during the construction phase by accurate scheduling of materials to programmed delivery dates.*

Keywords- Logistics Cost, Optimization, Logistics Planning System, Evolutionary Algorithm.

I. INTRODUCTION

Construction logistics involves the planning of efficient transfer of material and equipment from the suppliers to the construction site in a cost-effective way and timely manner. Construction materials need to be supplied and stored on construction sites using timely plans that are dependent on the activities schedule, site space availability, and suppliers' constraints. Construction logistics planning provides an integration framework to coordinate between material supply and storage decisions in order to consider their mutual impacts and interdependencies. Ignoring this coordination between material supply and storage may result in serious project problems. A number of research studies are being conducted to investigate best practices and develop decision support systems for material supply and site storage. Despite the significant contributions of research studies, the mutual interactions and interdependencies between the decisions of material supply and site storage is not studied extensively. To address this research gap, the objective of this thesis is to present the development of a new Construction Logistics Planning tool that is capable of integrating and optimizing the critical planning decisions of material supply and material storage on construction sites. The decisions made have a direct impact on the construction logistics cost that is comprised of ordering, carrying, shortage, finance and layout cost.

The primary result of not planning logistics properly is all too often poor utilization of construction labour, and time and/or cost over runs. A stronger focus on all aspects of logistics and supply chain management does not just improve logistics efficiency – it can greatly improve overall construction project performance in terms of efficiency, cost and programme certainty.

Planning material logistics in a congested construction site is a challenging task because of the scarcity of site space that is needed to accommodate material storage areas in addition to construction activities and temporary facilities. Congested construction sites often don't have sufficient exterior space to accommodate all needed temporary facilities and material storage. As a result, construction managers are driven to utilize interior building spaces that are built over the construction schedule to locate long-term material storage areas. Utilizing interior building spaces is challenging because of the complexity of interior space modelling, and the dynamic constraints of interior space availability and capacities. In addition, the sequence and schedule of indoor construction activities should be carefully considered and altered to provide sufficient material storage space, while maintaining schedule criticality at acceptable levels.

II. PROJECT DETAILS

Design and Construction of balance works of Underground station.

Scope of the project:

- Cut and Cover Station structure
- Emergency exit shafts
- Ventilation shafts
- Ancillary structures
- MEP works (FAS, FPS and E&M)
- A Project details and data collection,

Tender document is collected from project team from which material specifications and different level drawings of the station and other structures are obtained. The working of the tool depends mainly on the assumptions made in the initial stages of calculation. The data are of wide nature that it has to be obtained from different departments and agencies like planning, procurement, mechanical, transporter and material suppliers. Each decision made influences the logistics cost of the project differently. Assumptions are made by the values obtained by site visit and also the values provided by project planner are considered

III. COMMERCIAL TERMS

The commercial terms of the project includes details as follows. The overall scope of works of major items are given in Table-3.1.

- Contract Value : 473.6 crores
- Performance Security: 7.5% of Contract Value
- Mobilization Advance: 20% of Contract Amount
- Retention Amount : 2.5% of Contract Amount
- Price Adjustment : Applicable based on indices published by reserve bank
- Delay Damages : Maximum 10 % of Contract Amount

Table 3.1 Overall Scope of works

S.No.	Station	Excavation (m^3)	Reinforcement (MT)	Concrete (m^3)
1	Site 1	31,995	3,264	17,697
2	Site 2	94,671	4,252	25,814
3	Site 3	1,17,557	4,695	28,770
4	Tunnel	-	-	7,002
	Total	2,44,223	12,211	79,283

A Civil Engineering Structures

- The design life of all civil engineering structures is 120 years minimum unless otherwise specified or agreed upon.
- Adequate measures are taken to ensure120 years of minimum serviceability of civil structures, producing durable concrete. Suitable property enhancers/ blending materials conforming to relevant BIS codes may be used as deemed appropriate and subject to notice by the Employer's Representative.
- The concrete is tested for permeability and ability to resist chloride ion penetration according to ASTM C-1202. Water permeability shall not be more than 10 millimeters and RCPT value shall not exceed 600 coulombs.
- The design life of the above ground building structures including ancillary buildings and vent shafts is 120 years. The properties of concrete and reinforcement used are provided in table 3.2 and 3.3 respectively.

B. Cut and Cover Structures,

- Cut-and-cover structures include all stations, station entrances/exits, vent shafts, pedestrian subways, utilities, services and the like other than bored tunnels that are required to be constructed below ground surface under this contract.
- The cut-and-cover structure is proposed to be a rigid box section with permanent walls as external wall support system, beam-slab and column forming the internal structural framing. The roof slab shall support the soil and vehicular surcharge while the passenger and plant loads are carried by the concourse slab.
- The track and platform loads is supported by the base slab. The permanent walls shall resist the lateral earth and hydrostatic pressures in addition to the surcharge.
- The completed stations, station entrances, vent shafts and pedestrian subways shall comply with water-tightness criteria mentioned in specifications.
- It can be carried out in two approaches either top-down or bottom-up approach. Roof slab is done first allowing traffic to resume quicker in top down approach whereas bottom up is conventional but needs a lot more space for construction activities.
- In top down method, rebar couplers are left in diaphragm wall with development length and welded to plunge column which are exposed during slab construction.
- In plunge column, steel section in put inside drill bore and cover concrete of low strength is done which can be removed on later date.

C. Flooring,

The Major types of flooring used in this package are:

- Granular: In rooms M09, M10 made of M20 Grade concrete. Grooves are made at every 2m and sealant is filled to act as expansion joints.
- Granite: All public areas
- Ceramic tiles: Toilet areas
- False floor: Station controller room, ticketing room which has a lot of utilities going around below the floor.

IV. METHODOLOGY

Bill of quantities is calculated from the available tender drawings of each levels of metro station. Project baseline schedule is developed and all the necessary data for the calculations are taken from the schedule. Material demand profile gives the material requirement for each activity at each stage of the project. Entire project is divided into three stages depending upon the interior spaces available for storage according to which procurement decisions are taken. Material footprint schedule has to be calculated as per the density of the material which gives the load it will exert on the floor and also the volume which gives the amount of space it will occupy inside the storage area. At each stage of construction, the total space available for material storage is calculated from the floor plans and the dates between which spaces are available for storage is found out from the baseline schedule. The maximum inventory levels at each stages of construction are given by the difference between cumulative demand and supply of each material. This varies with respect to the fixed ordering quantity of the material since longer ordering period will generate larger inventories.

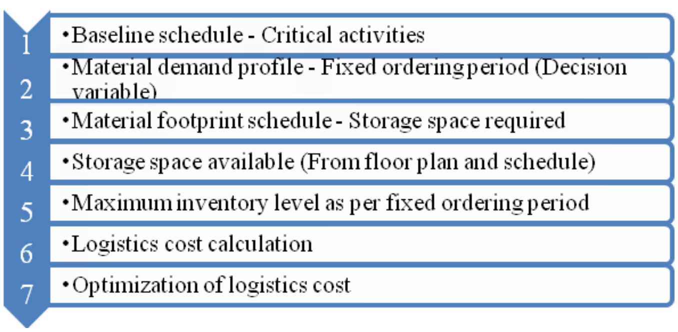

Figure 4.1 Research Methodology

A. Logistics Cost,

Logistics cost is the sum total of all the individual cost incurred in different stages of procurement of any material. Each cost involved in logistics is explained in detail. The understanding of relationship between each cost and the ordering quantity is essential for minimizing the total logistics cost. The components of logistics cost are shown in figure 4.2.

TLC = PC+DC+FC+SC+LC ………. (eq.4.1)

Where,

TLC = Total logistics cost
PC= Purchase cost
DC= Delivery cost
FC= Finance cost
SC= Stock-out cost
LC=Layout cost

Layout cost (LC) represents the travel costs of resources between site facilities and storage areas and the costs of site layout reorganization over the project duration. The layout cost is composed of three main cost components: materials handling cost (MHC), resources travel cost (RTC), and site reorganization cost (SRC). The materials handling cost is calculated by using the estimated quantity of materials that needs to be transported from each storage area to every site facility in all stages and the travel cost rates of handling crews that are represented by their handling capacity and identifies the quantity of material that can be transported in one crew trip, crew hourly cost rate and crew travel speed.

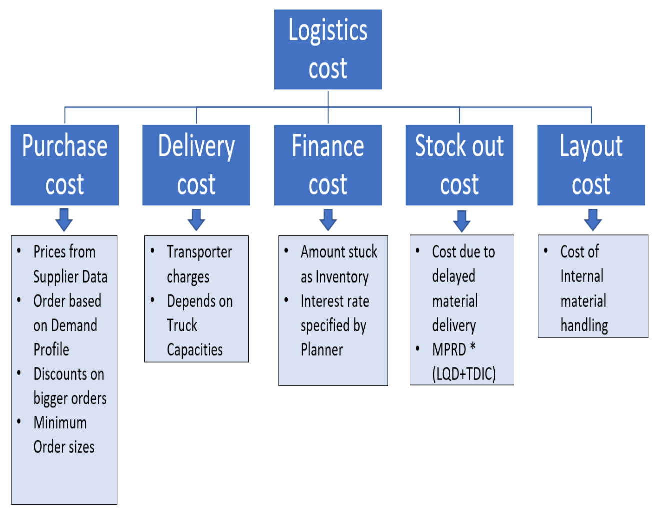

Figure 4.2 Logistics cost compounds

B. Optimization Logistics Cost,

The objective is to optimize the total logistics cost by minimizing the function given by the sum of individual costs by changing the decision variables in fixed ordering quantity of each material in each stage of construction against the critical constraint as the storage space available for material.

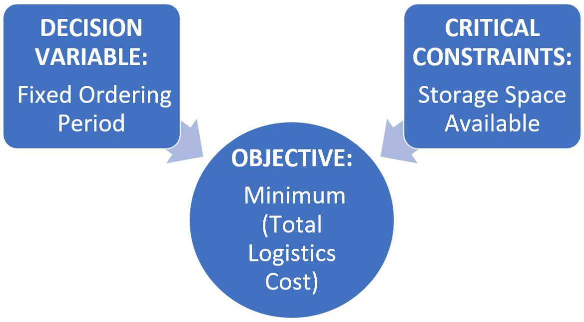

Figure 4.3 Optimization of Logistics Cost

V. RESULTS AND DISCUSSIONS

The activity details are prepared along with their dependencies and the baseline scheduling is done using Primavera. The activity details are given in table 5.1.

Table 5.1 Activity table

S. No .	Activity	Duration	Predecessor	Relation	Lag
1	Slab concreting	120	-	-	-
2	Blockwork	80	1	SS	21
3	Transoms and Mullions	60	2, 2	SS, FF	5, 10
4	Plastering	30	3, 9	FS, FS	10, -15
5	Floor tiles	60	3, 9	SS, SS	14, 30
6	Painting	30	4, 9	FS, FS	-
7	False ceiling	21	5, 6, 9	FS, FS, FS	-
8	Supply of equipment	30	2	SS	5
9	Installation of equipment	90	8	FS	-
10	Testing and commissioning	45	9	FS	-
11	Fixing light fixtures	30	7, 10	FS, FS	-

The dates for each activity, critical path along with floats available for each activity are obtained from the schedule. All the critical activities are shown in red colour in Gantt chart as shown in figure 6.1.

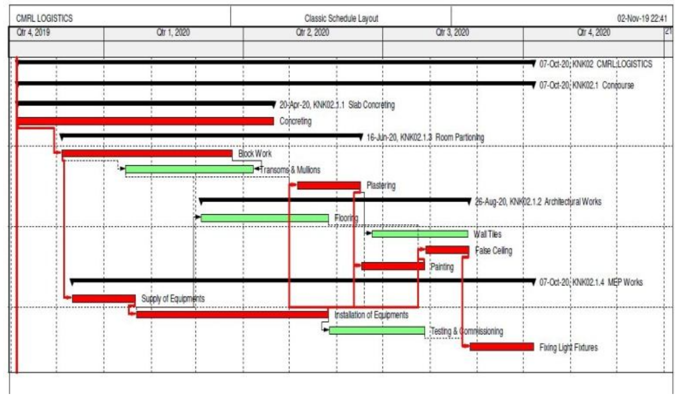

Figure 5.1 Gantt chart of activities

Construction schedule is divided into three stages based on the storage space available for material storage and the type of activity to be carried out and the material requirement for the same.

A. Supplier Data Interpretation,

For each material required for activities under consideration, data collected from suppliers regarding the purchase rates and the discounts that can be obtained in terms of scalable purchases. Minimum ordering quantity is specified for each material is specified. In case of daily requirement of a material is more than that of minimum quantity, the quantity required for a day has to be ordered which would mean just-in-time delivery.

B. Fixed Ordering Quantity,

Fixed ordering quantity is the quantity that replenishes the inventory at the beginning of fixed intervals when new orders are acquired to cover the demand for the succeeding intervals. During the construction phase, the values are updated at each stage to generate optimal logistics plans to consider any changes in schedule, site layout, or procurement decisions that may occur.

S.No.	Material	UOM	Stage-1	Stage-2	Stage-3
1	Granite Tiles	Sqm	0	160	0
2	False Ceiling	Sqm	0	0	600
3	CI Pipes	Rm	96	48	0
4	GI pipes	Rm	128	96	0
5	Acrylic paint	Sqm	0	0	450
6	Block work	Cum	275	50	0
7	Kota stone	Sqm	0	120	0

C. Maximum Inventory Level,

The maximum inventory levels at each stages of construction is given by the difference between cumulative demand and supply of each material. Cumulative demand is calculated from the baseline schedule developed for the project. High inventory levels tend to raise the working capital which will reflect in logistics cost as finance cost.

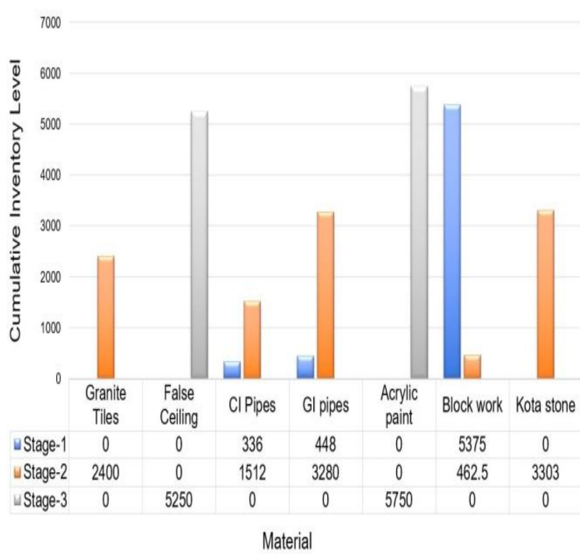

Figure 6.2 inventory levels at each stage

VI. SUMMARY AND CONCLUSION

The combination of FOQ of each material and the corresponding costs at each stage is shown below.

Table 6.1 Optimized Logistics Cost in stage 1

No.	Material	FOQ	Purchase cost	Delivery cost	Finance cost	Layout cost	Logistics cost
1	Granite tiles	0	0	0	0	0	0
2	False ceiling	0	0	0	0	0	0
3	CI pipes	96	76752	15000	3211	1728	96691
4	GI pipes	128	10240	15000	883	3840	29963
5	Acrylic paint	0	0	`0	0	0	0
6	Block work	275	3023438	168000	623781	322500	4137718
7	Kota stone	0	0	0	0	0	0
				Total logistics cost			4264373
				Storage space available			3142
				Storage space needed			2156

Table 6.2 Optimized Logistics Cost in stage 2

No.	Material	FOQ	Purchase cost	Delivery cost	Finance cost	Layout cost	Logistics cost
1	Granite tiles	160	360000	540000	135000	576000	1611000
2	False ceiling	0	0	0	0	0	0
3	CI pipes	48	826560	236250	334785	18144	1415739
4	GI pipes	96	104960	157500	89674	39360	391494
5	Acrylic paint	0	0	0	0	0	0
6	Block work	50	2890625	171000	283200	277500	3622325
7	Kota stone	120	42572	152250	53625	88080	336527
				Total logistics cost			7377085
				Storage space available			988
				Storage space needed			445

Table 6.3 Optimized Logistics Cost in stage 3

N o.	Materi al	F O Q	Purc hase cost	Deliv ery cost	Fina nce cost	Lay out cost	Logis tics cost
1	Granite tiles	0	0	0	0	0	0
2	False ceiling	60 0	47250	8160 0	1127 4	126 00	1527 24
3	CI pipes	0	0	0	0	0	0
4	GI pipes	0	0	0	0	0	0
5	Acrylic paint	45 0	32036	8100 0	1444 3	345 00	1619 79
6	Block work	0	0	0	0	0	0
7	Kota stone	0	0	0	0	0	0
				Total logistics cost			3147 04
				Storage space available			1002
				Storage space needed			36

A SUMMARY OF LOGISTICS COST,

- Scenario with minimum total logistics cost is chosen using evolutionary algorithm.
- In stage-2, site inventory levels are minimum.
- Internal storage space availability is minimum in stage-2 and hence very few combinations are found to match constraints criteria.
- Just-in-time delivery is proved to be more advantageous than scale on purchase during execution phase.
- Risk is maximum in JIT delivery.
- Stock-out cost and possible delay in project schedule to be included in next phase.
- Procurement decisions influences project cost to maximum extent during execution phase.
- No external storage facility is needed.
- Minimum ordering quantity specified by suppliers happened to be optimized values since supplied specifies economic quantity in terms of production and transportation and the effect of various costs are shown in table 6.4.

B CONCLUSION,

The percentage of optimization achieved using the construction logistics planning method during each stage of construction are shown in table 6.4

Table 6.4 Percentage of optimization

Description	Stage-1	Stage-2	Stage3
Total logistics cost before optimization	4904029	8852502	349321
Total logistics cost after optimization	4264373	7377085	314704
Cost savings	639656	1475417	34617
Percentage of optimization	13.04	16.67	9.91

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