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Development of Analytical Framework on Optimization of Construction Equipment for Multiple Infrastructure Projects

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***Abstract*:-- India's gross domestic product (GDP) grew by 7.6 per cent in the year 2015-16, has made India the fastest growing economy in the world. Considering the importance of Infrastructure growth, a critical factor for the continued economic growth of the country, the Ministry of Road Transport and Highway - Government of India has proposed Rs 25 trillion investment in infrastructure for the next three years (2017-2020) duration imparting major share for developing 27 industrial clusters and for road, railway and port connectivity projects.**

Construction equipment plays vital role for development of Infrastructure. Construction equipment's operational cost contributes 36 percent of the total project cost. Hence effective equipment management plays important role in infrastructure project management resulting into the substantial cost saving.

In this research paper we have analyzed two infrastructure (highway development) projects comprising construction of bridges, reinforced earthen wall, culvert and vehicular underpasses. Critical path method is applied for the time and activities scheduling along with construction equipment allocation for both the project. During study float availability is identified as main influencing factor and the same is analyzed to optimize the construction equipment in infrastructure project.

***Key Words:*— Construction, Equipment, infrastructure, Project, Management, Float, Optimization.**

I. INTRODUCTION

India has the second largest road network across the world at 33 Lakhs km. As per National Highway Authority of India Indian road network consist of following:

Category	Length (KM)
Expressways	200
National Highways	96,261
State Highways	1,31,899
Major District Roads	4,67,763
Rural and Other Roads	26,50,000

About 65% of freight and 80% passenger traffic is carried by the roads. National Highways constitute only about 1.7% of the road network but carry about 40% of the total road traffic. Number of vehicles has been growing at an average pace of 10.16% per annum over the last five years. Ministry of Road Transport and Highway - Government of India, has decided to increase the national highway cover from the current 96,000 kilometers to 200,000 kilometers in the country. The project includes development of four-lane and express highways. Creating a world class infrastructure in highways is the top priority. Highway contracts worth US $45 billion between May 2016 and May 2017. Ministry of Road Transport and Highway - Government of India has set an ambitious target of laying more than 40 km of roads every day in 2016-17.

Effective project management is the most important factor to accomplish infrastructure development target set by Government of India. Construction equipment plays vital role in infrastructure construction. In this research paper we have considered two infrastructure (highway development) projects. Project details are as follows:

A. Four laning of NH-4A (NH-748) between Km.118/000 to 125/000 including construction of high level four lane new khandepar bridge at Km.118/800 in the state of Goa.

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B. Construction of Canacona National Highway Bypass from km. 68/00 (chainage 00/00) to km. 85/740 (chainage 7/740) on NH-17 (New NH-66) on P.m section in the state of Goa.

We have applied Primavera 6.0 R8.4 for complete project planning of both the project. Critical path method applied for calculating the time span of the project. Activity with free float identified to carry out analysis reducing the substantial cost towards construction equipment operation for both the projects.

II. LITREATURE REVIEW

We have reviewed various research paper and books buy various authors on highway project management using critical path method. Major finding are as follows:

CPM Analysis of Rolai-Rinjlai Road Construction: Research paper work is based on empirical data of a part of the Rolai-Rinjlai road construction project, in which raw material is available at different quarries providing different options to the contractor. Considering the project as a network, author used CPM technique in an attempt to obtain the critical path of the network and suggested the best approach for acquiring material and construction of road under the stated constraints. Author used crashing to further reduce the project completion time. CPM assumes that each activity has available - all the resources needed to perform the activity in the normal way (or on a crashed basis). In this study, a small amount of overlapping i.e. simultaneously laying the same layer at different spots has provided the slack/float needed to compensate for the "unexpected" delays that inevitably seem to slip into a schedule. Schedule proposed by us provides much shorter completion time as compared to the actual time taken by the project and paves the way for use of CPM scheduling for road construction projects to be a lucrative and viable option.

A Study on Resource Planning in Highway Construction Projects: In this research paper authors used Microsoft project to schedule the BRTS Vishakhapatnam for planning of construction equipment. Author have compared actual resource planning against the ideal resource planning for the project. Planning of BRTS Road Project by using Microsoft Project 2007 for 013 KMS and Existing Carriage indicate poor planning of resources. Also equipment assign for total project is less as compared to required number. From the planning of BRTS highway project after allocating resources to various activities, we come to know if Equipments and manpower is provided as per required data which is analyze by using Microsoft Project-2007 as compare to actual used on site. It will help to complete project on time with specified duration as per contract.

Project Management: A project is a temporary endeavor undertaken to create a unique product or service. The three main most important project characteristics include uniqueness, temporary, and predefined goals. About 44 important activities have to be performed by a project manager during the project's life cycle. These activities are grouped in the five processes groups discussed as follows: Project Initiation is the phase of formally authorizing a new project. This phase links the project to the ongoing work of the performing organization. Projects are typically authorized as a result of one or more of the following: a market demand, a business need, a customer request, a technology advance or a social need.
Executing processes coordinate people and other resources, such as equipment and material, to carry out the plan in order to perform the project. Monitoring and controlling processes ensure the high-quality achievements of the project plan and updating it when necessary. Closing processes formalize acceptance of the project by its customers and other stakeholders and bring it to an orderly conclusion.

Critical Path Method: The Project Management Body of Knowledge (PMBOK), an internationally recognized collection of processes and knowledge areas accepted as best practice for the project management profession, defines the critical path as "the sequence of scheduled activities that determines the duration of the project." It is the longest sequence of tasks in a project plan that must be completed on time in order for the project to meet its deadline. If there is a delay in any task on the critical path, then your whole project will be delayed. Although many projects have only one critical path, some projects may have multiple critical paths.

Float: Float is the amount of time an activity, network path, or project can be delayed from the early start without changing the completion date of the project. Float denotes

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)
Vol 1, Issue 8, December 2016

the flexibility range within which the activity start and finish time may fluctuate without affecting the total project duration.

- ***Total Float***: It is the time span by which the starting or finishing of an activity can be delayed without affecting the overall completion time of the project.

- ***Free Float***: It is that duration by which an activity can be delayed without delaying any other succeeding activity. Free float is the portion of total float. This concept is based on all activities start at their earliest times.

- ***Independent Float***: It is the excess time available if the preceding activity ends as late as possible and the succeeding activity start as early as possible.

- ***Interfering Float***: Interfering float is the difference between the total float and free float.

- ***Research Gap***: After reviewing various research paper and books on highway project management, we found that critical path method applied for calculating project completion period, resource optimization, cost control, risk assessment etc. Neither float management nor construction equipment sharing aspect is being discussed in any of the research.

We strongly feel that float management and construction equipment sharing can play very important role in infrastructure project management. Hence we have considered free float for sharing of major construction equipment between two highway and bridge development project in Goa. Primavera 6.0 R8.4 applied for scheduling and identification of free float in both the project.

III. FLEET OF CONSTRUCTION EQUIPMENT

Major construction equipment and their rate are as follows:

Table – 1: Major Equipment Rate

Sr. No.	Name of Equipment	Rate Per Hour (INR)
1	Batching and Mixing Plant 30 cum capacity	1940
2	Hot mix Plant - 120 TPH capacity	15100
3	Hot mix Plant - 100 TPH capacity	11167
4	Hot mix Plant - 60 to 90 TPH capacity	8930
5	Hot mix Plant - 40 to 60 TPH capacity	1950
6	Piling Rig with Bentonite Pump	4200
7	Crane 5 – 10 – 15 – 20 - 40 Tonne	536
8	Crane 80 tonnes	1200
9	Dozer D - 80 - A 12	3030
10	Dozer D - 50 - A 15	2145
11	Integrated Stone Crusher 100THP	6000
12	Integrated Stone Crusher 200 HP	12000
13	Hydraulic Excavator of 1 cum bucket	1000
14	Transit Mixer 4.0/4.5 cum	820
15	Transit Mixer 3.0 cum	700
16	Tipper - 5 cum	438
17	Tandem Road Roller	800
18	Smooth Wheeled Roller 8 tonne	700
19	Truck 5.5 cum per 10 tonnes	200
20	Vibratory Roller 8 tonne	1163
21	Wet Mix Plant 60 TPH	1400
22	Paver Finisher Hydrostatic with sensor or mechanical control 100 TPH	2000
23	Kerb Casting Machine	50
24	Mechanical Broom Hydraulic	410
25	Motor Grader 3.35 mtr blade	436
26	Mobile slurry seal equipment	790
27	Hydraulic Chip Spreader	171
28	Front End loader 1 cum bucket capacity	800
29	GSB Plant 50 cum	1224
30	Emulsion Pressure Distributor	640
31	Wet Mix Plant 100 TPH	8847
32	Wet Mix Plant 75 TPH	6610
33	Vibrating Pile driving hammer complete with power unit and accessories.	1200
34	Piling rig Including double acting pile driving hammer (Hydraulic rig)	6250
35	Jack for Lifting 40 tonne lifting capacity.	1200
36	Bitumen Pressure Distributor	760
37	Bitumen Boiler oil fired	522
38	Concrete Paver Finisher with 40 HP Motor	2500
39	Pneumatic Road Roller	727
40	Pneumatic Sinking Plant	3094

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International Journal of Science, Engineering and Management (IJSEM)
Vol 1, Issue 8, December 2016

41	Pot Hole Repair Machine	2145
42	Pre stressing Jack with Pump & access	140
43	Ripper	1878
44	Rotavator	450
45	Compressor with guniting equipment along with accessories	500
46	Plate compactor	63
47	Batching and Mixing Plant 15 - 20 cum capacity	1520
48	Cement concrete batch mix plant @ 75 cum per hour (effective output)	3245
50	Road marking machine	90
51	Tractor	370
52	Tractor with Rotevator	200
53	Tractor with Ripper	200
54	Belt conveyor system	800
55	Cold milling machine @ 20 cum per hour	500
56	Drum mix plant for cold mixes of appropriate capacity but not less than 75 tonnes/hour.	1200
57	Epoxy Injection gun	200
58	Induction, DE induction and erection of plant and equipment including all components and accessories for pneumatic method of well sinking.	15000
59	Joint Cutting Machine with 2-3 blades (for rigid pavement)	50
60	Truck Trailor 30 tonne capacity	300

IV. PROJECT A: NH 4A FOUR LANNING WITH TWO GRADE SEPARATOR AND KHANDEPAR HIGH LEVEL BRIDGE

Project Title: Four laning of NH-4A (NH-748) between Km.118/000 to 125/000 including construction of high level four lane new khandepar bridge at Km.118/800 in the state of Goa.

Location: Ponda – Goa.

Client: Ministry of Road Transport and Highways – Government of India.

Contractor: **M. VENKATA RAO INFRA PROJECTS PVT. LTD (MVR)**

Project Start Date: 01.01.2016

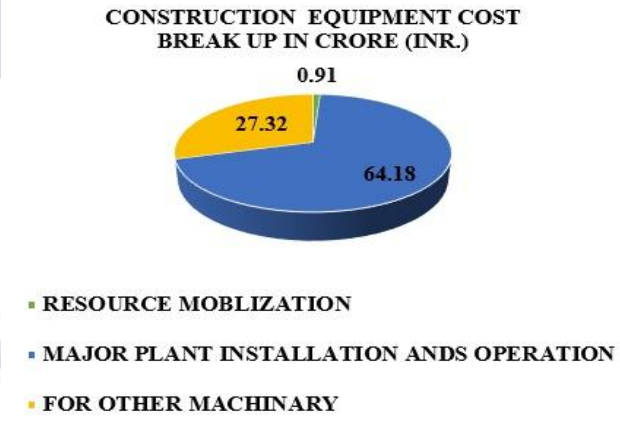
Project Finish Date: 22.01.2019

Project Detail: Project consist of construction of service / slip road on LHS and RHS for total length of 13.586 KM, 106 m long Khandepar high level bridge, 400 m long grade separator at Ponda, 30 m long grade separator at Amigos junction, 4 vehicular underpass, widening of 26 culverts, 4 box culver and junction improvement at 9 location.

Cost Of The Project: RS. 241 CRORE

Construction Equipment Operation Cost: Rs. 92 Crore.

Weightage Construction Equipment Operation Towards Total Cost: **38%**



V. PROJECT B: CANACONA NATIONAL HIGHWAY BYPASS AND THREE BRIDGE

Project Title: Construction of Canacona National Highway Bypass from km. 68/00 (chainage 00/00) to km. 85/740 (chainage 7/740) on NH-17 (New NH-66) on P.m section in the state of Goa.

Location: Canacona – Goa.

Client: Ministry of Road Transport and Highways – Government of India.

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Contractor: **M. VENKATA RAO INFRA PROJECTS PVT. LTD (MVR)**

Project Start Date: 01.01.2016

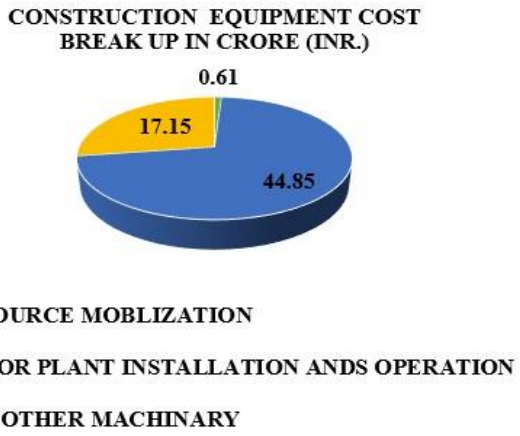
Project Finish Date: 13.02.2018

Project Detail: Project consist of construction of 7.74 km four lane road as Canacona bypass, 500 m long bridge at Galgibag, 450 m long bridge at Talpona, 100 m long bridge at Mashe, 21 new culvert and 1720 m long reinforce earth wall.

Cost Of The Project: Rs. 180 Crore

Construction equipment operation cost:
Rs. 63 Crore.

Weightage Construction Equipment Operation Towards Total Cost: 35%



VI. FRAMEWORK TO OPTIMIZE CONSTRUCTION EQUIPMENT FOR PROJECT A AND B

Project A: NH 4A FOUR LANNING WITH TWO GRADE SEPARATOR AND KHANDEPAR HIGH LEVEL BRIDGE and PROJECT B: CANACONA NATIONAL HIGHWAY BYPASS AND THREE BRIDGE considered for optimization of construction equipment. In this project we have analyzed the potential construction equipment sharing strategy under following heads:

Total Cost For Project A And B:
241 + 180 = Rs. 421 Crore

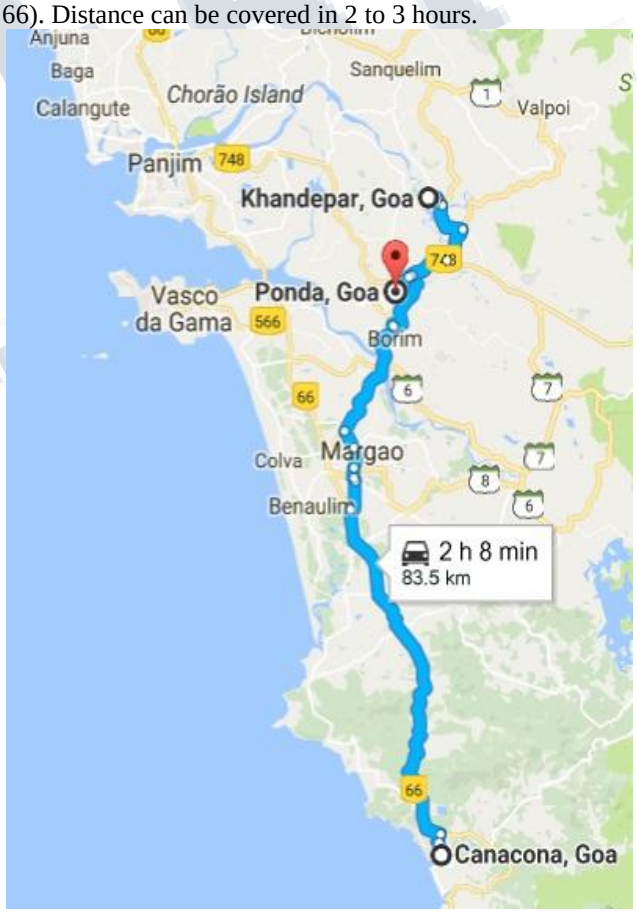
Total Cost Towards Construction Equipment Operation For Project A And B: 92 + 63 = Rs. 155 Crore

Weightage Construction Equipment Operation Towards Total Cost For Project A And B: 37%

Major Plant Installation And Operation Cost For Project A And B: 64 + 45 = Rs. 109 Crore

WEIGHTAGE OF MAJOR PLANT INSTALLATION AND OPERATION COST FOR PROJECT A AND B: 70%

Project Connectivity: Distance between Project A & Project B is 83.5 KM. Project are very good road connectivity by NH-4A (NH-748) and NH-17 (New NH-66). Distance can be covered in 2 to 3 hours.



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Vol 1, Issue 8, December 2016

Concept Of Construction Equipment Sharing For Project A And B: We have used critical path method to prepare construction schedule for the project A and B.

Free Float Analysis

Project A:

Nh 4A Four Lanning With Two Grade Separator And Khandepar High Level Bridge

SR. NO.	ACTIVITY DECSCRIPTION (AT DIFFERENT CHAINAGE)	FREE FLOAT (IN DAYS)
A	**13.586 KM NH 4AWidening**	
1	Earthwork & Sub-grade	595
2	Bituminous Concrete (BC)	3 TO 409
B	**Widening of existing culvert and new box culvert construction**	
1	Miscellaneous works: (Stone Pitching, Painting of Head walls. etc)	1
2	Excavation	49
C	**Vehicular Underpass**	
1	Excavation	2
D	**Bridge Construction**	
1	Superstructure - Pier Head	30
2	Superstructure - T Arm (Casting)	80
3	Superstructure - T Arm (Launching)	30 - 663

Project B:

Canacona National Highway Bypass And Three Bridge

SR. NO.	ACTIVITY DECSCRIPTION (AT DIFFERENT CHAINAGE)	FREE FLOAT (IN DAYS)
A	**7.74 KM NH 17 Construction**	
1	Bituminous Concrete (BC)	14 TO 160
	Granular Sub-base (GSB)	1 TO 7
	Wet Mix Macadam (WMM)	3 TO 5
	Dense Bitumen Macadam (DBM)	5
B	**New Culvert Development**	
1	Miscellaneous works: (Stone Pitching, Painting of Head walls. etc)	1 TO 506
2	Excavation	41
C	**Reinforce Earth Wall**	
1	Excavation	2
D	**Bridge Construction**	
1	Superstructure - Pier Head	18
2	Superstructure - T Arm (Casting)	48
3	Superstructure - T Arm (Launching)	42 - 538

From above two table it is clearly visible that free float is available to various activities of both the project. Hence start and finish date cab be adjusted according to float availability, and construction equipment can be shared for these activity.

Cost saving depends on specific activities with free float.

Cost Saving Towards Major Plant Installation And Opetration: Total Rs. 109 Crore incurred towards major plant installation and operation cost for project A and B, which is 70% of construction equipment budget and 25% of total project cost. By analyzing both the project characteristic and location, it is found that common set plant installation required. Hence project B CANACONA NATIONAL HIGHWAY BYPASS AND THREE BRIDGE can utilize plant installed for the project A NH 4A FOUR LANNING WITH TWO GRADE SEPARATOR AND KHANDEPAR HIGH LEVEL BRIDGE. This strategy will be resulting in cost saving of Rs. 45 Crore.

VII. EXPERT INTERVIEW

We have interviewed GENERAL MANAGER - M. VENKATA RAO INFRA PROJECTS PVT. LTD (MVR), comments are "Construction equipment plays vital role in project delivery. Sharing of construction equipment is one of the most important strategy to counter time and cost overrun. Construction equipment optimization model like this will not only control the time and cost but also result in substantial cost saving in multiple infrastructure project."

VIII. CONCLUSION

Construction equipment are the primary requirement of all infrastructure project. Effective management of construction equipment ensured timely delivery of infrastructure project within the contractual cost. In this research paper we have carried out the potential of construction equipment sharing model between two highway and bridge project in Goa. We have used critical path method. Primavera 6.0 R8.4 applied for schedule preparation. Activity with free float considered for sharing of construction equipment. Free float utilization will be resulting in substantial cost saving for the project. Considering both the project weightage of

construction equipment is 37% of the total cost. Cost towards major plant installation and operation turns around 25% of the total project cost. In this case project B CANACONA NATIONAL HIGHWAY BYPASS AND THREE BRIDGE can utilize plant installed for the project A NH 4A FOUR LANNING WITH TWO GRADE SEPARATOR AND KHANDEPAR HIGH LEVEL BRIDGE. This strategy will be resulting in cost saving of Rs. 45 Crore. Construction equipment optimization is very important for success of infrastructure project. Float management and construction equipment sharing strategy is one of the most important step towards professional project management practice to deliver the infrastructure project within contractual time and budget.

REFERENCES

[1] National Highway Authority of India (Ministry of Road Transport and Highway – Government of India)

[2] "Construction Planning, Equipment and Meyhods" by "Robert L. Peurifoy, Cliff J. Schexnayder, Aviad Shapira", McGraw Hill Publication; 2007 edition.

[3] "Downtime model development for construction equipment management" by "Mr. Madhav Prasad Nepal and Mr. Moonseo Park (Assistant Professor at National University of Singapore, Singapore)". Journal - Engineering, Construction and Architectural Management – 2004

[4] "Heavy Equipment Management Practices and Problems in Thai Highaway Contractor" by "Thanapun Prasertrungung and B.H.W. Hadikusumo at Asian School of Technolgy, Thailand", Journal - Engineering, Construction and Architectural Management -2007.

[5] "Construction and Project Management for Engineers, Architects, Planners and Builders" by "K.G. Krishnamurthy and S. V. Ravindra", CBS (1 December 2008) "Construction Management and Equipment" by "Saurabh K. Soni", S.K. Kataria & Sons Publication; 2014 edition.

[6] "Roads ministry targets laying over 40 km of roads every day in 2016 - 17" by Rajat Arora, The Economic Times.

[7] A Guide to the PROJECT MANAGEMENT BODY OF KNOWELEDGE (PMBOKR GUIDE) by PMI Gloabal Standard.

[8] "CPM Analysis of Rolai-Rinjlai Road Construction" by Khurana Sunita and Banerjee Snigdha (School of Statistics, Devi Ahilya University, Indore, M.P., India) at Research Journal of Mathematical and Statistical Sciences-2013.

[9] "A Study on Resource Planning in Highway Construction Projects" by K Swarna Kumari and J Vikranth at PYDAH College of Engg. & Tech.,JNTUK,Andhrapradesh.