IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

FLEET DYNAMICS IN LARGE CONSTRUCTION OPERATIONS: A STUDY ON EQUIPMENT UTILIZATION AND COST REDUCTION IN MEGA PROJECTS

Mr. Vaibhav Patil [1]
Research Scholar
Department of Civil Engineering
AJEENKYA D Y Patil School of Engineering
Charholi, Pune, Maharashtra, India

Prof. Ashish Pruthviraj Wagmare[2]
PG Coordinator
Department of Civil Engineering
AJEENKYA D Y Patil School of Engineering
Charholi, Pune, Maharashtra, India

Abstract:-

Efficient management of construction equipment is critical for the successful execution of highway construction projects. Proper fleet management ensures optimal resource utilization, cost control, and timely project completion. This study examines the key factors affecting construction equipment fleet management in highway projects, including equipment selection, maintenance strategies, utilization rates, and cost management. A case study approach is adopted, analysing a real-world highway construction project to identify best practices and challenges in fleet management. The study evaluates equipment productivity, downtime analysis, and the impact of fleet management on overall project performance. Findings highlight the importance of predictive maintenance, real-time monitoring, and data-driven decision-making in improving efficiency. Recommendations are provided to enhance fleet management practices, reduce operational costs, and increase sustainability in highway construction projects.

Keywords: Fleet Management, Highway Construction, Equipment Utilization, Maintenance Strategies, Cost Optimization.

1. Introduction:-

This paper presents the management of construction equipment is a critical component in the successful execution of highway construction projects. Construction equipment accounts for a significant portion of project costs, and its effective management directly influences productivity, project timelines, and overall profitability. Proper fleet management ensures that machinery is optimally utilized, well-maintained, and efficiently allocated to minimize downtime and operational costs.

Highway construction projects, due to their large scale and complexity, require a diverse fleet of equipment, including excavators, bulldozers, graders, pavers, and dump trucks. Managing such a fleet involves strategic planning in equipment selection, maintenance scheduling, fuel consumption optimization, and logistics coordination. Poor fleet management can lead to project delays, cost overruns, and equipment failures, which can negatively impact the project's success.

This study aims to examine the key aspects of construction equipment fleet management in highway projects by analyzing a real-world case study. The research focuses on evaluating fleet performance, maintenance strategies, cost implications, and the role of emerging technologies in improving efficiency. The findings from this study will provide valuable insights for construction managers, engineers, and policymakers to enhance fleet management practices and ensure sustainable project execution.

2. Scope of Paper:

Fleet Management consist of conceptual sub-components such as equipment selection and assignment, equipment optimization, maintenance, production monitoring, material and position monitoring, etc. 1 The scope of this work is limited to equipment optimization and benefit analysis at the site through equipment production analysis. The case selected for the project is a highway construction project where considerable amount earthwork is involved. This project mainly aims to achieve optimum equipment utilization by construction equipment's fleet management.

3. Literature Survey:-

FLEET: Equipment Management Syestem, Amir Tavakoli, Johannes J. Masehi and Cynthia S. Collyard: Amir Tavakoli, Johannes J. Masehi and Cynthia S. collyard have created database of equipment management system named FLEET. FLEET consist of four modules 1.)Inventory management module 2.) Cost, time and production module 3.)Maintenance management module 4.)Report generator module. They conducted a survey of top construction firms for the grasp of facts and figures.

Optimizing Haul Unit Size And Number Based on Loading Facility Characteristics, Douglas D Gransberg: Douglas D Gransberg determined optimum size and number of haul units for an earthmoving project. The optimum level is achieved by modelled way of load growth curve. The model relies on derivation of cost index number (CIN) to determine theoptimum size of hauling unit in the material moving system. The model also provides a means of design the construction equipment fleet over a wide range of material moving system.

Expert System for Equipment selection For Earth –Moving Operations, Serji Amirkhanian and Nancy J. Baker: Serji Amirkhanian and Nancy j. Baker developed a system for selecting earth moving equipment suitable for the particular job. The system uses 930 rules to interpret information concerning project soil condition, operator performance and required earthmoving operation. The systems have to be given various input parameters such as type of soil, swell value, project duration, etc. The system provides user with printed spreadsheet for each type equipment that is being selected.

Automatic spatio-temporal analysisof construction site equipment operations using GPS data, Nipesh Prdhanga and Jochen Teizer: Nipesh Pradhanga and Jochen Teizer proposed the use of real time positioning data utilizing global positioning system (GPS). The GPS devices continuously record the position of equipment which can help in monitoring construction equipment operations at position. The processing of this data is done on a user interface developed using virtual.

Earthmoving Production Estimation using Linear Regression Techniques, Simon D. smith: Simon D. Smith identified the problem of the occurrence of hauler bunching. He determined that solving such problem by simulation is complex as higher factor that influences the rate at which earthmoving system works. He in fact used the method of multiple regression techniques. He further devised that there is a strong linear relationship between operating conditions and productivity, and developed a deterministic model that will enable earthmoving operations to be planned for many different situations.

Integrated Construction Preventive Maintenance System, C William Ibbs and Kenneth R. Tarveer: C William Ibbs and Kenneth R. Tarveer mentioned that a regular structured maintenance program can be worthwhile investment for many reasons such as reduced field breakdown, more efficient equipment and operator utilization, elimination of unnecessary parts damage, preservation of warranties. They developed a system thatsatisfies the requirement of a well- defined project management program.

Modeling the Dynamics of Heavy Equipment Management Practices and Downtime in Large Highway Contractors, Thanapan Prasertunganian and B.H.W Hadikasumo: Thanapan Prasertunganian and B.H.W Hadikasumo quantified the factors that influence downtime consequences of highway construction equipment based on structural equation modelling. The project they selected was a highway construction projects in Thailand. The SEM model so developed provides a framework for tracing the causes and consequences of downtime and recommend equipment maintenance as a properequipment management practice.

4. Objective of the paper:-

- To Study the highway construction site for current practices of equipment management.
- Perform equipment productivity analysis to optimize the current composition of the earth/material moving fleet.

5. Methodology:-

To study a highway construction site for current practices of equipment management, you can follow a structured approach that includes data collection, observation, and analysis. Below is a step-by-step methodology for conducting this study effectively:

5.1 Define the Scope and Objectives

- Identify the key aspects of equipment management to be studied (e.g., equipment selection, maintenance, utilization, fuel management, cost control).
- Determine the specific highway construction project to be analyzed.
- Set research objectives, such as improving efficiency, reducing downtime, and optimizing costs.

5.2 Data Collection Methods

A] Site Visits and Observations

- Conduct on-site visits to observe real-time equipment operations.
- Document equipment types, usage patterns, and maintenance procedures.
- Assess idle time, equipment breakdowns, and overall efficiency.

B. Interviews and Surveys

- Interview project managers, site engineers, and equipment operators.
- Use structured questionnaires to gather insights on challenges and best practices.
- Focus on aspects like equipment scheduling, procurement, and fleet monitoring.

C. Analysis of Project Records

- Review equipment logs, fuel consumption reports, and maintenance schedules.
- Analyze historical breakdown data to identify patterns and inefficiencies.
- Study rental vs. owned equipment costs and their impact on project budgets.

D. Use of Technology and Software

- Identify whether GPS tracking, telematics, or fleet management software is used.
- Assess how digital tools are improving fleet efficiency and cost control.

5.3 Key Areas of Evaluation

Equipment Utilization Rate: Measure active vs. idle time to determine efficiency.
Maintenance Practices: Evaluate preventive vs. reactive maintenance strategies.
Fuel and Cost Management: Analyze fuel consumption patterns and cost-saving measures.
Safety and Compliance: Assess adherence to safety standards and regulatory compliance.
Impact of Weather and Site Conditions: Understand how external factors affect equipment operations.

5.4 Findings and Recommendations

- Identify inefficiencies and propose strategies for improvement.

- Recommend better scheduling, maintenance, and tracking methods.
- Suggest the adoption of modern fleet management technologies.

6. Excavation Case:-

Various excavation works were undertaken at the site. Hump cutting excavation was the major work undertaken. The material excavated from the hump was non cohesive soil, generally used for backfilling. Bad patch excavation also is the secondary excavation undertaken. Black cotton soil and expansive soil is generally excavated from the bad patch. Non cohesive muroom is replaced at the at bad patch excavated pit. Following the summary of various cases with excavation site, type of material, quantity of excavation and dumping site with the practised fleet composition used on the site:

Case	Excavation Site	Dump Site	Fleet Composition
Case 1	Road hump cutting @ 20/800 to 20/870 (Murrom- 2986 m^3)	Dumping Site @ 12/300 for backfilling	1.)TATA Hitachi EX-210
			2.)14.9 m^3 TATA TIPPER – 2 Nos.
			3.)18.52 m^3 MAN CLA TIPPER – 1 No.
Case 2A	Road hump cutting @ 14/690 to 14/810 (Murrom- 943 m^3)	Dumping site @ 12/300 for backfilling	1.)TATA Hitachi EX-210
			2.)18.52 m^3 MAN TIPPER - 4 Nos.
Case 2B	Road hump cutting @ 14/690 to 14/810 (Blasted Rock- 3071 m^3)	Dumping site @ 12/300 for backfilling	1.)TATA Hitachi EX-210
			2.)18.52 m^3 MAN TIPPER - 4 Nos.
Case 3	Bad patch Excavation @ 63/620 to 64/390 LHS (BC soil- 1732 m^3)	Dump @ 2.9 km away from excavation site.	1.)TATA Hitachi EX-210
			2.)18.52 m^3 MAN TIPPER - 1 No.

Image: - Site Excavation

Image:- Site Excavation

Image: - Site Excavation

Image: - Site Excavation

Image: - Site Excavation

6.1 Equipment Productivity Analysis:

Production of each equipment involved in the fleet is manipulated as actual and theoretical using the performance charts and other parameters such as distance, speed, number of trips, capacity, etc. using various mathematical formulae. The unit of measure for the production is always quantity of material excavated or moved on hourly basis i.e. m3/hr. various parameters are required to manipulate productivity of each equipment. Following are the parameters required for the productivity calculations:

6.2 Capacity:

The capacity of each equipment is denoted in m3 measure such as the bucket capacity in excavator or body capacity in case of tipper. This is found out by standard dimensions of each equipment given by the manufacturing company. But there are chances for minor modifications done after the purchase of equipment's by the owner. The dimensions may also change due deformations during the operation of any equipment. Thus for this reason actual measurements of each equipment are taken to know the exact cubic capacity of each equipment. The equipment's are generally filled at its heaped capacity and not at its struck volume. The struck capacity is that volume actually enclosed by the bucket, while for the heaped capacity an angle of repose is considered. According to standard conditions angleof repose 2:1 slope is considered.

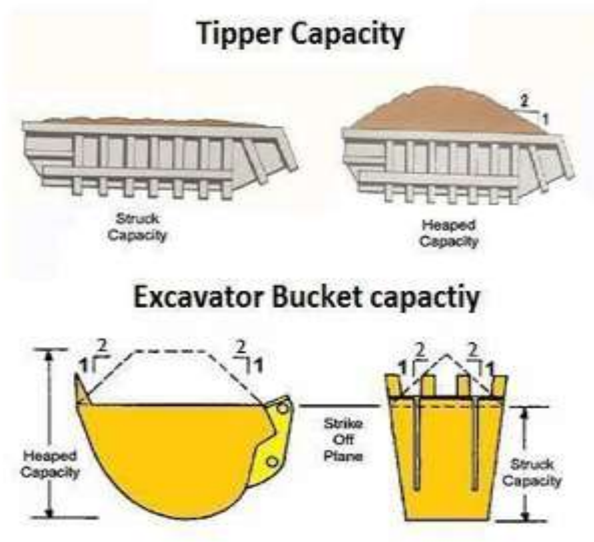


Table:- Illustrative Struck and Heaped Capacity of Volumetric Measures

Table 7.1: Avg. Loading time

<u>Avg. Loading Time = 36.68 min</u>

The speed at which plant loads the tipper is calculated as follows:

Sr. No.	Equipment	Dimensions (LxWxH)	Struck Capacity (m^3)	Heaped Capacity (m^3)
1	Tata Tipper 1613	3.65 X 1.96 X 1.04 m	7.44	9.3
2	MAN CLA 25220	5.19 X 2.10 X 1.36 m	14.82	18.52
3	Tata Haiwa 2518	4.78 X 1.96 X 1.28 m	11.99	14.95
4	Tata Ex 210no.8 bucket	Width 1023 mm	-	0.9*
5	Tata Ex 210no.9 bucket	Width 1023 mm	-	0.9*
6	L&t 70 bucket	Width 650 mm	-	0.3*
7	Volvo 140 bucket	Width 875 mm	-	0.45*
8	Vibratory roller SD110	Width 7'7" = 2346 mm	-	-
*Heaped capacity according to specifications of the manufacturer for respective bucket width				

7. Asphalt Case: -Fleet Management in asphalt laying case is done by tipper assignment according to mathematical calculations. The Asphalt laying process is cyclic process which includes the processes as per the following diagram

Loading Time for 18.5 m^3 truck by Asphalt Plant	
Obs. No.	Time (min:sec)
1	39:00
2	35:25
3	40:05
4	35:15
5	34:55
6	35:00
7	36:15
8	37:05
9	35:40
10	37:45
Average	36.68 min

Loading Speed=18.5/36.38= 0.504 m^3/ hr.
Dump time:-

Figure: Asphalt Laying Process Chain

Continuous paving operations depend on balancing paver production with plant production. The critical choke points in the operation which must be analysed and managed, are the loading of haul units at the plant and haul unit – paver link.

Asphalt Laying Equipment Fleet:

1. Asphalt Plant: Atlas Industries Make Drum Mix Plant (DM-50)
2. Hauling Equipment: 18.5 m^3 capacity MAN 25220 truck - 6
3. Paver/Finisher: Apollo ap-600
4. Roller: Case 752

7.1 loading Time:

The Time required to load one 18.52 m^3 tipper by the asphalt plant is recorded and Avg. time required is calculated as follows:

Time required to fully dumping 18.5 m^3 truck into 4.5m^3 hopper of the paver

Bituminous Macadam	
Obs. No.	Dump Time (min)
1	37
2	40
3	39
4	42
5	36
Average	38.8 min

Table 7.2: Dump time for Bituminous Macadam

Bituminous Carpet	
Obs. No.	Dump Time (min)
1	28
2	29
3	25
4	28
5	30
Average	28 min

Table 7.3: Dump time for Bituminous Carpet

Average paving speed achieved:

Bituminous Macadam= $\frac{paving\ length\ achieved\ per\ truck}{Avg.dump\ period} = \frac{88.06}{38.8} = 2.26$ metre/min.

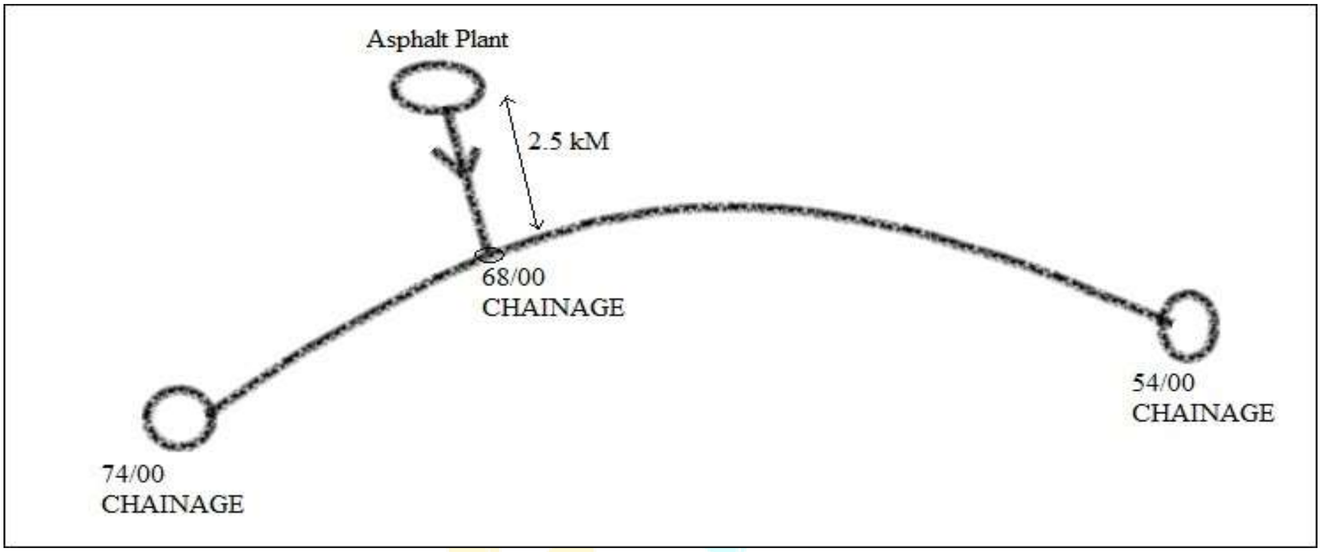
Bituminous Carpet= $\frac{paving\ length\ achieved\ per\ truck}{Avg.dump\ period} = \frac{151.02}{28} = 5.39$ metre/min.

7.4 Haul and Return Time:-

Avg. hauls speed: 0.32 kM/min.

Avg. returns speed: 0.36 kM/min

Figure: Layout of site



Bituminous Macadam Cycle Time						
Chainage	**Avg. Distance**	**Haul Time (min)**	**Return Time (min)**	**Loading time (min)**	**Dump Time (min)**	**Total Cycle Time (min)**
54 - 55	16	50.00	44.44	36.68	38.8	169.92
55 - 56	15	46.88	41.67	36.68	38.8	164.02
56 - 57	14	43.75	38.89	36.68	38.8	158.12
57- 58	13	40.63	36.11	36.68	38.8	152.22
58- 59	12	37.50	33.33	36.68	38.8	146.31
59 - 60	11	34.38	30.56	36.68	38.8	140.41
60 - 61	10	31.25	27.78	36.68	38.8	134.51
61- 62	9	28.13	25.00	36.68	38.8	128.61
62 - 63	8	25.00	22.22	36.68	38.8	122.70
63 - 64	7	21.88	19.44	36.68	38.8	116.80
64 - 65	6	18.75	16.67	36.68	38.8	110.90
65 - 66	5	15.63	13.89	36.68	38.8	104.99
66 - 67	4	12.50	11.11	36.68	38.8	99.09
67 - 68	3	9.38	8.33	36.68	38.8	93.19
68 - 69	4	12.50	11.11	36.68	38.8	99.09
69 - 70	5	15.63	13.89	36.68	38.8	104.99
70 - 71	6	18.75	16.67	36.68	38.8	110.90
71 - 72	7	21.88	19.44	36.68	38.8	116.80
72 - 73	8	25.00	22.22	36.68	38.8	122.70
73 - 74	9	28.13	25.00	36.68	38.8	128.61

Table 7.4: Cycle Time of 18.5 m^3 tipper for Bituminous Macadam

Bituminous Carpet Cycle Time						
Chainage	**Avg. Distance**	**Haul Time (min)**	**Return Time (min)**	**Loading time (min)**	**Dump Time (min)**	**Total Cycle Time (min)**
54 - 55	16	50.00	44.44	36.68	28	159.12
55 - 56	15	46.88	41.67	36.68	28	153.22
56 - 57	14	43.75	38.89	36.68	28	147.32
57- 58	13	40.63	36.11	36.68	28	141.42
58- 59	12	37.50	33.33	36.68	28	135.51
59 - 60	11	34.38	30.56	36.68	28	129.61
60 - 61	10	31.25	27.78	36.68	28	123.71
61- 62	9	28.13	25.00	36.68	28	117.81
62 - 63	8	25.00	22.22	36.68	28	111.90
63 - 64	7	21.88	19.44	36.68	28	106.00
64 - 65	6	18.75	16.67	36.68	28	100.10
65 - 66	5	15.63	13.89	36.68	28	94.19
66 - 67	4	12.50	11.11	36.68	28	88.29
67 - 68	3	9.38	8.33	36.68	28	82.39
68 - 69	4	12.50	11.11	36.68	28	88.29
69 - 70	5	15.63	13.89	36.68	28	94.19
70 - 71	6	18.75	16.67	36.68	28	100.10
71 - 72	7	21.88	19.44	36.68	28	106.00
72 - 73	8	25.00	22.22	36.68	28	111.90
73 - 74	9	28.13	25.00	36.68	28	117.81

Table 7.5: Cycle Time of 18.5 m^3 tipper for Bituminous Carpet

7.5 Analysis

7.5.1 Bituminous Macadam

$$\text{Time the paver requires a truck} = \frac{\textit{paving length achived}}{\textit{paving speed}} = \frac{88.09\ mtr/truck}{2.26 mtr/min} = 38.97 \text{ min}$$

Thus paver requires a truck load after every 38.97 min.

$$\text{Number of trucks required} = \frac{\textit{truck cycle time}}{38.97}$$

Chainage	Cycle Time (min)	No. of tipper =cycle time/38.97	No. of tippers Required	Tippers actually used
54 - 55	169.92	4.36	5	6
55 - 56	164.02	4.21	5	6

56 - 57	158.12	4.06	5	6
57- 58	152.22	3.91	4	6
58- 59	146.31	3.75	4	6
59 - 60	140.41	3.60	4	6
60 - 61	134.51	3.45	4	6
61- 62	128.61	3.30	4	6
62 - 63	122.70	3.15	4	6
63 - 64	116.80	3.00	3	6
64 - 65	110.90	2.85	3	6
65 - 66	104.99	2.69	3	6
66 - 67	99.09	2.54	3	6
67 - 68	93.19	2.39	3	6
68 - 69	99.09	2.54	3	6
69 - 70	104.99	2.69	3	6
70 - 71	110.90	2.85	3	6
71 - 72	116.80	3.00	3	6
72 - 73	122.70	3.15	4	6
73 - 74	128.61	3.30	4	6

Table 7.6: Bituminous Macadam Tipper Analysis

7.5.2 Bituminous Carpet

$$\text{Time the paver requires a truck} = \frac{\text{paving length achived}}{\text{paving speed}} = \frac{151.02\ \text{mtr/truck}}{5.39\ \text{mtr/min}} = 28.01\ \text{min}$$

Thus paver requires a truck load after every 28.01 min.

$$\text{Number of trucks required} = \frac{\text{truck cycle time}}{28.01}$$

Chainage	Cycle Time (min)	No. of trucks = cycle time/28.01	No. of tippers Required	Tippers actually used
54 - 55	159.12	5.68	6	6
55 - 56	153.22	5.47	6	6

56 - 57	147.32	5.26	6	6
57- 58	141.42	5.05	6	6
58- 59	135.51	4.84	5	6
59 - 60	129.61	4.63	5	6
60 - 61	123.71	4.42	5	6
61- 62	117.81	4.21	5	6
62 - 63	111.90	4.00	4	6
63 - 64	106.00	3.78	4	6
64 - 65	100.10	3.57	4	6
65 - 66	94.19	3.36	4	6
66 - 67	88.29	3.15	4	6
67 - 68	82.39	2.94	3	6
68 - 69	88.29	3.15	4	6
69 - 70	94.19	3.36	4	6
70 - 71	100.10	3.57	4	6
71 - 72	106.00	3.78	4	6
72 - 73	111.90	4.00	4	6
73 - 74	117.81	4.21	5	6

Table 7.7: Bituminous Carpet Tipper Analysis

From the above table it is observed that number of tippers used in bituminous macadam and carpet laying are used in excess than required

7.6 Results:

The 18.52 m^3 tipper used for hauling asphalt have O&O cost 660.77 Rs./hr. considering 8hrs. Working per day, the cost saving per day is calculated. The results are compared between practised fleet and optimized fleet as follows

Bituminous Macadam				
Chainage	**Cost Of Hauling per Day (8hrs.Working x Cost/Hr.)**		**% Saving in Cost**	**Average % Saving In Cost**
	Practised Fleet (Rs./day)	**Optimized Fleet (Rs./day)**		

54 - 55	31716.96	26430.8	16.67	38.33 %
55 - 56	31716.96	26430.8	16.67	
56 - 57	31716.96	26430.8	16.67	
57- 58	31716.96	21144.64	33.33	
58- 59	31716.96	21144.64	33.33	
59 - 60	31716.96	21144.64	33.33	
60 - 61	31716.96	21144.64	33.33	
61- 62	31716.96	21144.64	33.33	
62 - 63	31716.96	21144.64	33.33	
63 - 64	31716.96	15858.48	50.00	
64 - 65	31716.96	15858.48	50.00	
65 - 66	31716.96	15858.48	50.00	
66 - 67	31716.96	15858.48	50.00	
67 - 68	31716.96	15858.48	50.00	
68 - 69	31716.96	15858.48	50.00	
69 - 70	31716.96	15858.48	50.00	
70 - 71	31716.96	15858.48	50.00	
71 - 72	31716.96	15858.48	50.00	
72 - 73	31716.96	21144.64	33.33	
73 - 74	31716.96	21144.64	33.33	

Table 7.8: Bituminous Macadam avg. cost saving

Bituminous Carpet				
Chainage	**Cost Of Hauling per Day (8hrs.Working x Cost/Hr.)**		**% Saving in Cost**	**Average % Saving In Cost**
	Practised Fleet (Rs./day)	**Optimized Fleet (Rs./day)**		
54 - 55	31716.96	31716.96	0	
55 - 56	31716.96	31716.96	0	
56 - 57	31716.96	31716.96	0	
57- 58	31716.96	31716.96	0	
58- 59	31716.96	26430.8	16.67	
59 - 60	31716.96	26430.8	16.67	

60 - 61	31716.96	26430.8	16.67	23.33 %
61- 62	31716.96	26430.8	16.67	
62 - 63	31716.96	21144.64	33.33	
63 - 64	31716.96	21144.64	33.33	
64 - 65	31716.96	21144.64	33.33	
65 - 66	31716.96	21144.64	33.33	
66 - 67	31716.96	21144.64	33.33	
67 - 68	31716.96	15858.48	50.00	
68 - 69	31716.96	21144.64	33.33	
69 - 70	31716.96	21144.64	33.33	
70 - 71	31716.96	21144.64	33.33	
71 - 72	31716.96	21144.64	33.33	
72 - 73	31716.96	21144.64	33.33	
73 - 74	31716.96	26430.8	16.67	

Table 7.9: Bituminous Carpet avg. cost saving

Conclusion: -

Optimizing the use of construction equipment in large-scale projects and mega operations plays a critical role in reducing overall project costs. Effective equipment management not only enhances productivity but also minimizes idle time, maintenance costs, and operational inefficiencies. Studies and practical observations indicate that by strategically optimizing equipment usage, project costs can be reduced by approximately **23% to 38%**. This significant cost saving highlights the importance of adopting modern fleet management practices, leveraging data analytics, and ensuring proper planning and scheduling of machinery throughout the project lifecycle.

References:-

1. Amir Tavakoli, Johannes J. Masehi and Cynthia S. collyard, FLEET Equipment Management Syestem, Journal of Management in Engineering, Vol.6 1990, 211-220.
2. Douglas D Gransberg, Optimizing Haul Unit Size And Number Based on Loading Facility Characteristics, Journal of Construction Engineering and Management, 1996, 248-253.
3. Serji Amirkhanian and Nancy J. Baker, Expert System for Equipment selection For Earth –Moving Operations, Journal of Construction Engineering and Management, 1992, 318-331.
4. Nipesh Prdhanga and Jochen Teizer, Automatic spatio-temporal analysisof construction site equipment operations using GPS data, Automation in Construction, 2013, 107-122.
5. Simon D. smith, Earthmoving Production Estimation using Linear Regression Techniques, Journal of Construction engineering and Management, 1999, 133-141.

6. C William Ibbs and Kenneth R. Tarveer, Integrated Construction Preventive Maintenance System, Journal of Construction engineering and Management, 1984, 43-59.
7. Thanapan Prasertunganian and B.H.W Hadikasumo, Modeling the Dynamics of Heavy Equipment Management Practices and Downtime in Large Highway Contractors, Journal of Construction engineering and Management, 2009, 939-947.
8. Y.R.Anbhule and Prof. M.B.Kumthekar , 3D Equipment Management system for Highway Construction Projects : Conceptual Design, Journal of Mechanical and Civil Engineering, 2013, 1-4
9. Saeed Karshenas , Truck Capacity Selection For Earthmoving, Journal of Construction engineering and Management, 1989, 212-227
10. Mohamed Marzouk and Osama Moselhi, Multiobjective Optimization of Earthmoving Operations, Journal of Construction engineering and Management, 2004, 105-113.