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# Productivity and Cost Assessment of Equipments for Highway Project

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**Abstract:** In the development of infrastructure projects, construction equipment is an important resource. Construction equipment accounts for a large portion of a project's cost, yet inappropriate use of these resources results in a loss of productivity, which has a negative impact on profit. So, in order to save expenses, it's important to optimise these tasks. Up to 36% of the total project costs are spent on construction equipment, which is a critical component of four-lane development. But because there hasn't been enough focus on equipment upkeep, costs have increased by 40%. In this study, the most effective manner to employ construction machinery for the National Highway project is examined. It entails evaluating the equipment's cost, time, and manufacturing output in terms of its benefits. These improvements take into account the production capacity, effective working hours, and equipment expenses. To verify the findings, a case study of the four lanes of section Nh-6 (Jalgaon) of the Chikhali-Tarsod Highway Projects is employed.

**Key Words:** Equipment economics, Productivity, Optimization, etc.

## 1. Introduction

Since earthwork represents a sizable fraction of the overall construction cost, equipment plays a vital role in road construction. Consequently, their cost and productivity are essential in ensuring the project's financial viability for the firm. Therefore, if accuracy is achieved in terms of calculating equipment productivity, ownership and running expenses, and a reasonable manner of acquiring equipment, the project may be designed more precisely and for less money.[1].

Each work of a road layer necessitates a particular set of equipment and machineries, each with its own level of application, such as subgrade, granular sub-base, dry lean, and pavement quality concrete. [2]. Equipment productivity control is carried out to determine the length of time it is in use, the amount of output it produces, and its overall productivity on the project site. The primary goal of equipment productivity control is to reduce cost and waste. [4].

One of the first tasks to be finished on every project is planning the creation of precise cost es timates and schedules. The estimator's access to historical data will improve as the accuracy o f his study's findings increases. This involves determining what kind of equipment to use for

a certain project as well as the actual performance capabilities of particular equipment compo nents.

The ability of a contractor to get a contract and profit from it is determined by factors such as construction methods used and labour and equipment management. Any project requires appropriate planning and calculations before it can be carried out; therefore, if we can achieve accuracy in terms of calculating operational costs, equipment productivity, and a realistic technique of acquiring equipment, we will be able to manage our project more accurately. Despite the fact that scheduled rates are available, we are unaware of or do not pay attention to the factors that play a big role in the calculation of these figures. [5].

The objective of this research paper is to examine the output and economics of various highway building equipment. Hydraulic Excavator (Backhoe Loader), RMC Plant, HMP, Bitumen Paver, and Tandem Road Roller are among the equipments chosen & hence as a outcome, provide obtained results on various factors included in ownership and operating costs on a per working hour basis when equipment is used to its full potential for its intended purpose with an efficiency of 50/60 minutes, as well as per hour productivity that equipment can attain if it is working at an efficiency of 50/60 minutes.

## 2. Research Methodology

The approach used in this research work is divided into two categories.

### 2.1 Methodology for calculation of landed, ownership and operating cost per working hour

Ownership and operation expenses make up the two main components of the overall cost of construction equipment (also known as O & O cost of construction equipment). The cost of ownership includes expenses for depreciation, interest, and insurance (12 percent of book value). The number of running hours, location of the job site, operating conditions, fuel/energ y consumption, and kind of equipment are all elements that affect the equipment's operational cost. It also comprises labour and equipment operator remuneration, as well as maintenance and fuel expenses.The procedures for calculating the cost of equipment are as follows:-

i. A vendor provided information on the landing expenses of the equipment. On the operational life of the equipment (age of the equipment) in hours, data from merchants, IS 11590:1995, and manufacturer performance reports were gathered (Caterpillar Performance Handbook, 2015).

ii. The landed/purchasing cost of equipment is determined by adding the basic cost, the 18 percent GST added to the basic cost, and any shipping or installation fees that were paid by equipment manufacturers, sellers, or owners during the duration of the equipment's life.

iii. Calculation of the net worth of ownership costs that will be covered over the equipment's life cycle.

iv. Data on operating expenses were received from contractors and equipment owners as well as through watching equipment on the Chikhali-Tarsod Highway Project. Maintenance costs and

operator salaries were then converted to a per-working-hour basis. (Assume daily working hours are equal to 10)

v. Finally, by adding all costs, the cost per effective working hour is calculated, allowing for net value coverage.

### 2.2 Methodology for evaluation of productivity per working hour

All of the methodologies and procedures are based on R.L Peurifoy, Clifford J. Schexnayder, and Avid Shapira's book "Construction Planning, Equipment, and Methods," published by Tata McGraw-Hill Companies in 2010. [6].

### 2.3 Equipment performance

The ratio of per hour Ownership and Operating costs in rupees, as well as equipment productivity in m3/hr., is used to calculate equipment performance.

## 3. Data Collection

### 3.1 Description of the case study

The case study of National Highway NH-6 (Package - IIA) is chosen for data collecting. The project highway's Package-II A begins in Chikhali in Buldhana district and runs for 62.7 km, from kilometre 360.000 to km 422.700.

The project will be carried out by the National Highway Authority of India in the State of Ma harashtra using hybrid annuities (DBOT annuities) (NHAI).

The current state of equipment management is revealed as a result of this research. The method of bituminous pavement construction and the operation of each piece of equipment are extensively studied, and further output and cost analysis, such as values for landed cost, ownership cost, operating cost, maintenance cost, and so on, are collected from equipment working on project sites and construction equipment sellers.
Each piece of equipment's operation and the method used to build bituminous pavement are t horoughly studied, and additional output and cost analysis, including values for landed cost, ownership cost, operating cost, maintenance cost, and so on, are gathered from sellers of cons truction equipment and equipment used on project sites.The Chikhali-Tarsod highway construction project's equipment observation yields information for calcul ating equipment productivity, including bucket capacity of excavators, volume of concrete/as phalt produced by plants, average speed of paver & roller to be maintained, and effective wor king hours for hydraulic excavators, RMC, Hot Mix Plant, speed of bitumen paver & road rol ler, among other things.

### 3.2 Data collection

Data on each equipment production and cost was acquired from the contractor's records from site for primary data collection during the months of October 2020 to May 2021. For further

output and economic analysis, data on fuel consumption, maintenance costs, labour operating costs, and equipment working hours were gathered. The cost of each type of equipment was then computed on an hourly basis, as shown below.

## 4. Result Analysis

In highway projects, one resource is usually assigned to each action and is referred to as the dynamic resource. The productivity of the entire project is determined by the performance of the equipment, and the ultimate output becomes the resource's output. This section includes result analysis for production (Theoretical output, Effective production / Practical output & Net Production) & cost of five equipments like Hydraulic Excavator (Backhoe Loader), RMC Plant, HMP, Bitumen Paver & Tandem Road Roller for the month of October 2020- May 2021.

### 4.1 Performance of Hydraulic Excavator (Backhoe Loader) Productivity:

The excavator's productivity is crucial since it is the dynamic equipment in utmost soil and granular layers where finishing is essential. The NH-6 project's data has been evaluated, and its productivity and cost have been assessed.

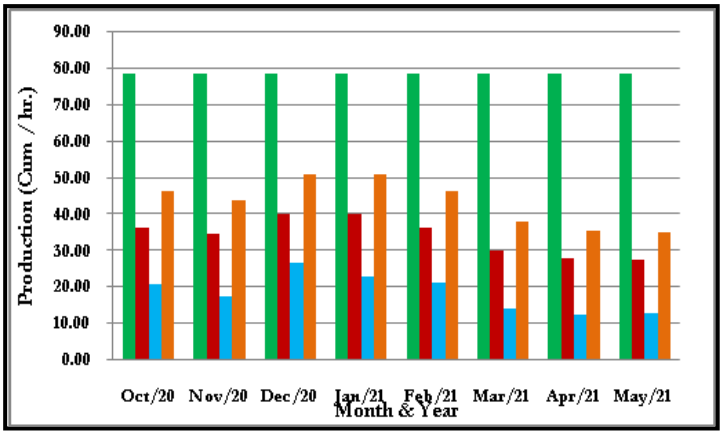


**Figure 1. Performance of Excavator**

The theoretical Output for Hydraulic Excavator is 78.75 m3/hr. From October 2020 to May 2021, the net production rates of one excavator range from 12.52 m3/hr. to 26.71 m3/hr., whereas from March to May 2021, the excavator performs below the drift of the entire set.

The range of effective production (Prod. Qty. /actual working hours) of the excavator is found to be 40.28 m3/hr. with a standard deviation of 27.78 m3/hr. The efficiency of excavators (Effective Production/Theoretical Production) x 100 ranges from 35.28 % to 51.15 %. Excavator utilization ranges from 44.71 % to 68.17 % (Actual Working Hours / Planned Available Hours) × 100. Variability in job conditions, type of soil, soil conditions, climate situation, and vary in the nature of the task can all be responsible for the fluctuation in production rate.

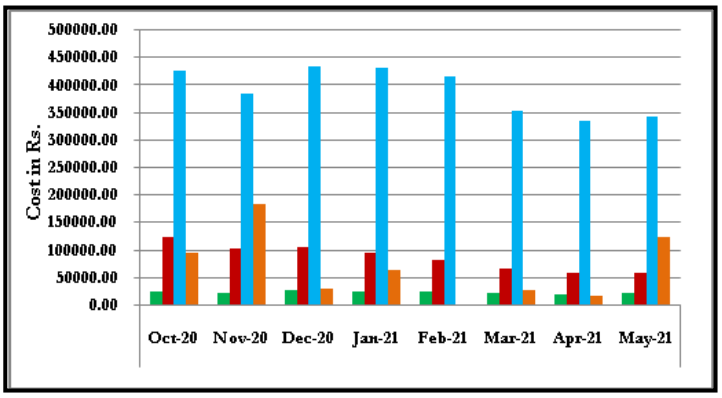


**Figure 2. Cost Components of Excavator**

The key components of the cost of performance for four excavators at the NH-6 project are operating costs, which range from Rs.3,35,704.17 to Rs. 4,34,098.20/- and an average of Rs.3,90,663.18/- for continuous excavation activity.

With an average of Rs.85,934.56/- and a range of Rs.81,601.11/- to Rs.1,24,128.16/-, the backhoe loader is the second biggest contributor to cost of performance.

Other costs include landing charges, which range from Rs. 19,216.24/- to Rs. 24,939.79/-, with an average of Rs.22390.54/-, and maintenance costs, which range from Rs.16,520.55/- to Rs. 1,82,009.00/-, with an average of Rs.66318.38/-

## 4.2 Performance of Ready Mix Concrete Plant:

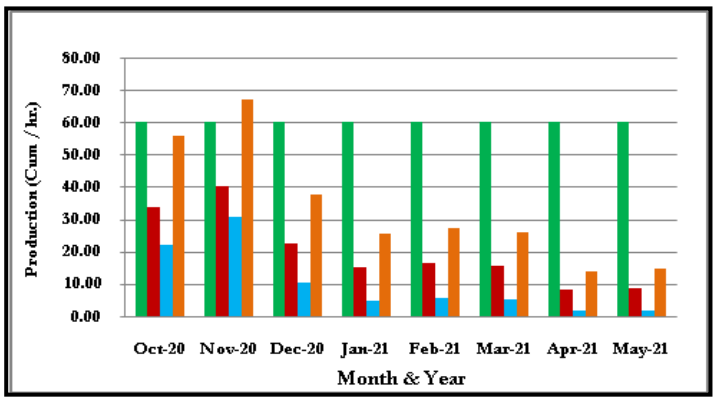


**Figure 3. Performance of RMC Plant**

The theoretical Output for RMC Plant is 60 m3/hr. The net production rates of RMC plant is vary from 1.80 m3/hr. to 30.85 m3/hr from a period of October 2020- May 2021 while from month January 2021 performs of RMC plant relatively below the drift of the whole set.

The range of effective production of the RMC plant is found to be 40.30 m3/hr. with a standard deviation of 8.30 m3/hr. The efficiency of RMC plant is ranging from 13.83 % to 67.17 %. The utilization range of RMC plant (Actual Working Hours / Planned Available Hours) x 100 is vary from 20.58 % to 76.54 %. Variability in job circumstances, maintenance, weather conditions, and the nature of the task can all contribute to the fluctuation in output rate.

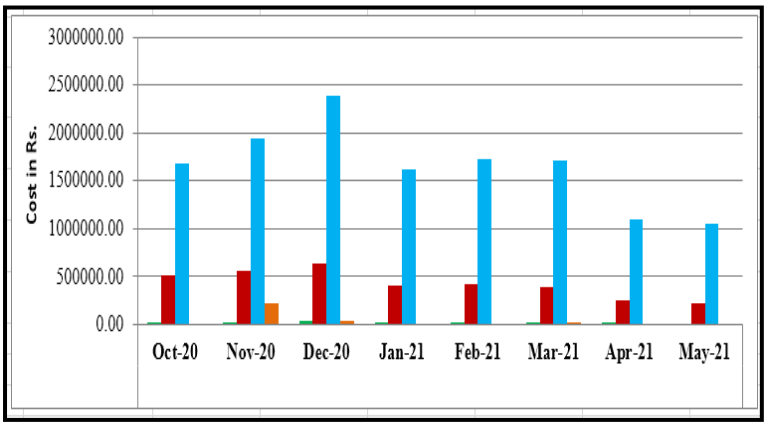


**Figure 4. Cost Components of RMC Plant**

From the cost components data of RMC Plant at NH-6 project, the larger components of the cost is operating cost with the range of Rs. 10,44,170.43/- to Rs. 23,90,857.53/- & average of Rs. 16,52,225.57/- as the continuous work of RMC Plant. The ownership cost of the RMC Plant is the next key contribution of cost components with an average of Rs. 4,25,938.34/- with a range from Rs. 2,29,306.72/- to Rs. 6,35,773.40/-. The other costs include landed cost is vary from Rs. 15,268.26 /- to Rs. 34,960.05/- & average of Rs.24,150.97/- and maintenance cost is ranging from Rs. 1750.00/- to Rs. 2,19,261/- with average cost of Rs. 35,998.26/-. The major variation is observed in costs from March 2021- May 2021.

### 4.3 Performance of Bitumen Paver:

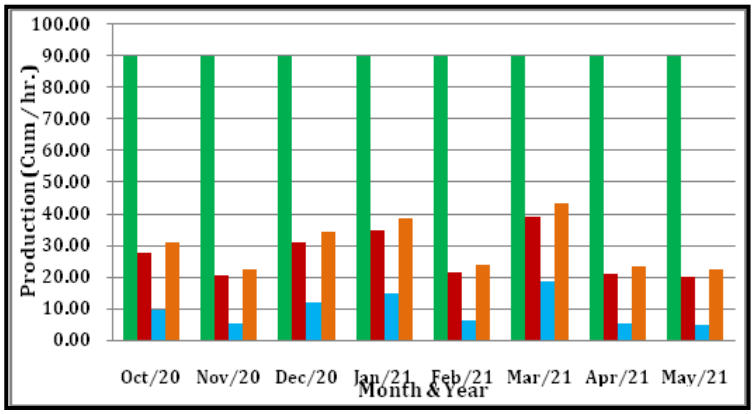


**Figure 5. Performance of Bitumen Paver**

The theoretical Output for Bitumen Paver is 90 m3/hr. From October 2020 to May 2021, the net production rates of Bitumen Paver range from 4.98 m3/hr. to 18.65 m3/hr.

The Bitumen Paver's effective production range is 38.86 m3/hr., with a standard divergence of 20.09 m3/hr. Bitumen Paver's efficiency ranges from 22.33 % to 43.18 %. Bitumen Paver's utilization ranges from 24.81 % to 47.98 %. Variability in job conditions, paving specifications, maintenance, weather, and the nature of the task can all be responsible for the fluctuation in production rate.

It is a well-known truth that the various stages of a roadway project are extremely interdependent. As we can see from the above section of the report, the excavator's performance has deteriorated, and it was already below average, which worked as a barrier to the next stage of the bitumen paver not working on a larger scale (range).

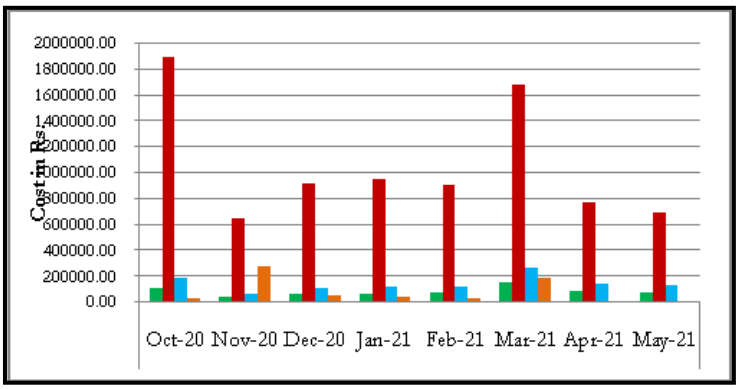


**Figure 6. Cost Components of Bitumen Paver**

The major parts of the cost of performance for two Bitumen Pavers at the NH-6 project include ownership costs, which range from Rs. 7,73,453.77/- to Rs. 18,84,382.23/-, with an average of Rs.10,56,539.39/- as the continuous work of Bitumen Paver. The Bitumen Paver's operating cost is the next largest contributor to cost of performance, with an average of Rs.1,45,749.64/- and a range of Rs. 70,163.89/- to Rs. 2,68,360.05/-. Other costs include landed charges, which range from Rs.42,027.40/- to Rs. 161320.55/- and average Rs.87449.32/-, and maintenance costs, which range from Rs.5370.00 to Rs.2,78,000.00 and average Rs.77,388.97/-. The major variation is observed in costs from March 2021- May 2021.

## 4.4 Performance of Hot Mix Plant:

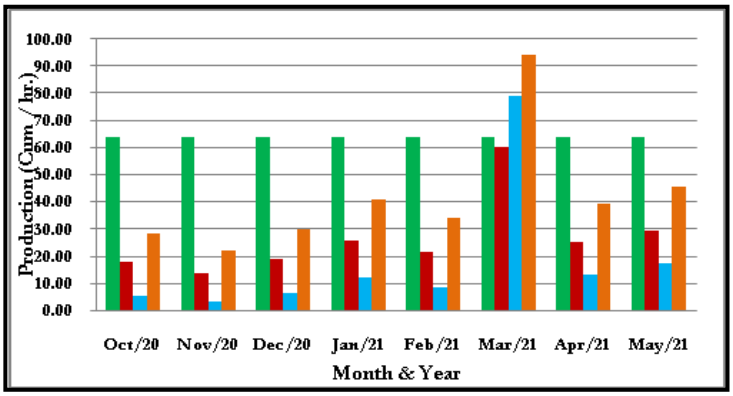


**Figure 7. Performance of HMP**

The theoretical Output for HMP is 64 m3/hr. From October 2020 to May 2021, the net production rates of HMP range from 3.77 m3/hr. to 78.98 m3/hr. HMP works on paver's demand, and paver's particular lower effective production produced a significant drop in the period from October 2020 to February 2021.

The range of effective production of the HMP is found to be 60.40 m3/hr. with a standard divergence of 14.20 m3/hr. The efficiency of HMP of the HMP is ranging from 22.19 % to 94.38 %. The utilization range of HMP is vary from 26.54 % to 130.77 %. Fluctuation in job conditions, presence of moisture, maintenance, climate situation, and Vary in the nature of the job can all be responsible for the variation in output rate.

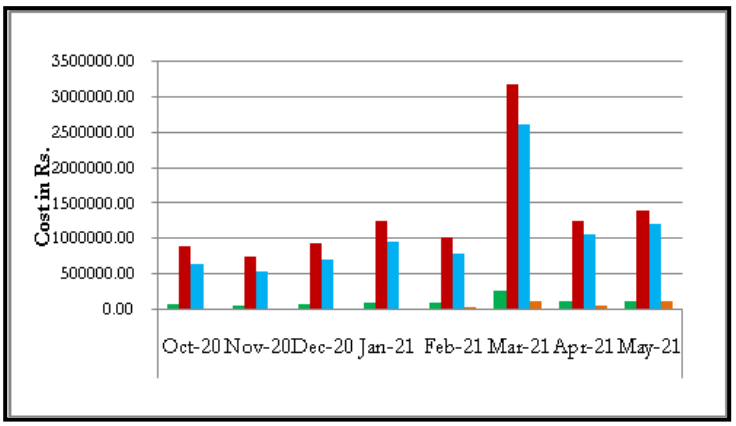


**Figure 8. Cost Components of HMP**

According to HMP's cost of performance data for the NH-6 project, the major parts of the cost of performance include ownership costs, which range from Rs. 7,37,503.52/- to Rs. 31,77,533.57/-, with an average of Rs.13,30,191.18/-.

The HMP's operating costs are the next largest contributor to cost of performance, averaging Rs.10,58,994.56/- with a range of Rs.532641.67/- to Rs.2622204.30/-. Other costs include landed costs, which range from Rs. 50500.23/- to Rs. 248841.70/-, with an average of Rs.1,00,451.54/-; and maintenance costs, which range from Rs.0.00/- to Rs.1,12,265.00/-, with an average of Rs.39,488.50/-. Costs show the most variance between March and May 2021.

## 4.5 Performance of Tandem Roller

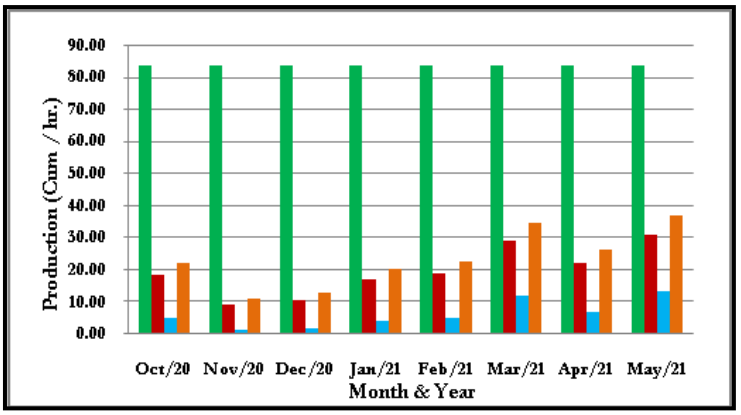


**Figure 9. Performance of Tandem Roller**

The theoretical Output for Tandem Roller is 83.33 m3/hr. From October 2020 to May 2021, Tandem Roller's net output rates range from 1.21 m3/hr. to 13.58 m3/hr. By bringing it close

to completion, the roller applies the last layer of work. Due to a lag in previous activities, two of the three rollers were inactive for an extended length of time, necessitating repair.

With a typical deviation of 9.17 cum/hr. the Tandem Roller's effective production range is found to be 30.71 m3/hr. The Tandem Roller's efficiency ranges from 11.00 percent to 36.86 percent. Tandem Roller's utilization rate ranges from 13.20 percent to 44.23 percent. Variability in task circumstances, wetness, lift thickness, number of roller passes, maintenance, weather, and the type of the project all contribute to the fluctuation in production rate.

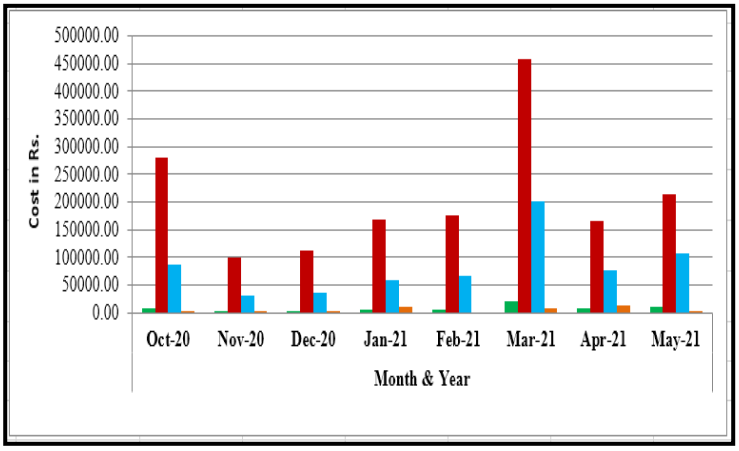


**Figure 10. Cost Components of Tandem Roller**

The major parts of the cost of performance for three Tandem Roller at the NH-6 project are ownership cost, which ranges from Rs. 1,00,158.29/- to Rs. 4,57,924.27 /- and an average of Rs.2,09,249.71 /- as the continuous work of Tandem Roller. The Tandem Roller's operating cost is the next largest contributor to cost of performance, at Rs. 83782.77/- on average, with a range of Rs. 32235.19/- to Rs. 202455.20/-. Other costs include landed charges, which range from Rs. 3293.10/- to Rs. 20,781.67/-, with an average of Rs. 8580.43/-, and maintenance costs, which range from Rs. 0.00/- to Rs. 13600.00/-, with an average of Rs. 5002.25/-. Costs show the most variance between March and May 2021.

## 5. Conclusions

The equipment seen on highway project sites is usually divided into two categories: driving and non-driving.

1. The average actual production rates of the hydraulic excavator (backhoe loader) equipments are found to be close to 30.92 m3/hr, which is lower than the theoretical production rate of 78.75 m3/hr.
2. Given that the RMC Plant and the Hot Mix Plant at the project site have a capacity of 60 m3/hr and 64 m3/hr, respectively, the average effective production rate of the two plants must be close to 14.93 m3/hr and 21.41 m3/hr.
3. In a similar vein, it is determined that the Bitumen Paver & Tandem Roller's average effective production rates in a project site are around 49.85 m3/hr & 46.67 m3/hr, respectively, despite the fact that their theoretical production rates are 90 m3/hr & 83.33 m3/hr.

4. 4. The performance discrepancy is obvious when comparing the equipments' availability and utility factors. The average level of equipment usage, which ranges from 25 to 55 percent, indicates that the equipment is not functioning well or being maintained inside the site.
5. The effect of Covid 19 on the construction sector has been continuous, resulting in workforce shortages and delays in planned operations, with a pronounced impact between October 2020 and May 2021. As a result, over the same time period, equipment performance has been below average.
6. As the second wave of Covid 19 arrived, and the worst part is that we were in no way prepared for it and were hoping it wouldn't, the total cost of the equipment is largely proportional to the landed cost, with ownership cost, operating cost, and maintenance cost having more variation due to working hours. In reality, the impact of the second wave in metro regions and urban areas was greater than the impact of the first wave in terms of increasing the number of Covid patients. Therefore, it accounts for the majority (50–60%) of the costs.

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## References

1. Mr. Akash Ashok Jagtap, Prof. Dipak P. Patil, “Study On Resource Productivity of A Highway Project”, International Journal Of Advance Scientific Research And Engineering Trends, Volume 5, Issue 9, September 2020, pp.12-18.
2. Sandip Jadhav, Amol Thorbole, “Time and Cost Optimization of Construction Equipment Fleet for Highway Project”, International Research Journal of Engineering and Technology (IRJET), Volume: 07 Issue: 08 | Aug 2020, pp. 3913-3920.
3. Venkatesh M.P. and Saravana Natarajan P.S., “Improvement of Manpower and Equipment Productivity in Indian Construction Projects”, International Journal of Applied Engineering Research, ISSN 0973-4562 Volume 14, Number 2 (2019) pp. 404-409.
4. Ashish Singla, Dr. Pardeep Kumar Gupta, “Cost and Productivity Analysis of Equipments for Flexible Pavement- a Case Study”, International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 07 | July-2016, pp.965-969.
5. N. Shyamananda Singh, “Construction Equipment Productivity and Cost Economics in Highway Projects: Case Study Part I (Site Specific Study)”, International Journal of Advanced Research in Engineering and Technology (IJARET), Volume 9, Issue 3, May June 2018, pp. 154–162.
6. H. T. Kadivar, “Case Study on Output/Productivity of Pneumatic Tired Vibratory Roller (Earth Compaction Equipment) under Different Job and Management Conditions”, IJSTE

- International Journal of Science Technology & Engineering, Volume 3, Issue 04, October 2016, pp. 89-91.
7. M. Waris, Mohd. ShahirLiew, Mohd. FarisKhamidi, AraziIdrus, "Criteria for the selection of sustainable onsite construction equipment", Gulf Organization for Research and Development International Journal of Sustainable Built Environment, (2014) 3, pp. 96-110.
8. A. Hassanein and O. Moselhi, "Planning and Scheduling Highway Construction", Journal of Construction Engineering and Management © ASCE, September/October 2004, pp.638-646.
9. Khaled El-Rayes and Amr Kandil, "Time-Cost-Quality Trade-Off Analysis for Highway Construction", Journal of Construction Engineering and Management © ASCE / April 2005, pp.477-486.
10. M. Manikandan, Prof. M. Adhiyaman, Dr. K.C.Pazhani A, "Study and Analysis of construction equipment management used in construction projects for improving productivity", International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 03, Mar-2018, pp. 1297-1303.
11. Priyanka Methe, Mahaboobali Nadaf, Rashmi J.V., K. P. Thejaswi, "Identification of factors influencing equipment productivity in construction projects", International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 06, June-2018, pp. 379-384.
12. Y. R. Anbhule and Prof. M. B. Kumthekar, "3D Equipment Management System for Highway Construction Projects: Conceptual Design", IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), 2019, ISSN: 2278-1684, PP: 01-03.
13. Saurabh Rajendra Kadam, Prof. Dhananjay S Patil, "Construction Equipment Fleet Management: Case Study of Highway Construction Project", International Journal of Science and Research (IJSR), Volume 4 Issue 6, June 2015, pp. 2558-2564.
14. Pavan pal, Dr. Mukesh Pandey, "Factor Affecting Construction Cost and Time in road project, International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 08 | Aug -2017, pp. 1557-1560.
15. Premjith.S.P, Monisha Manoharan, "Analysis of Equipment Maintenance Operation and Repair in a Construction Industry", International Journal of Engineering and Management Research, Volume-7, Issue-2, March-April 2017, pp. 18-23.
16. Govindan Kannan (2011): "Field Studies in Construction Equipment Economics and Productivity" Journal of Construction Engineering & Management ASCE, 137(10), pp. 823-828.
17. Peurifoy Robert L, Clifford J. Schexnayder, Aviad Shapira (2010), "Construction Planning, Equipment and Methods", Tata McGraw-Hill Companies, Edition 7.
18. Mr. Ghanasham C. Sarode & Dr. Pankaj P.Bhangale, "Assessment Equipment Productivity For Highway Project", Journal of Emerging Technologies and Innovative Research (JETIR), April 2021, Volume 8, Issue 4, pp. 730-737.
19. IRC: 90-2010 – "Guidelines for Selection, Operation & Maintenance of Bituminous Hot Mix Plant".

20. Mitchell, Z., (1998). “A statistical analysis of construction equipment repair costs using field data and the cumulative cost model.” Ph.D. dissertation, Virginia Polytechnic Institute and State Univ., Blacksburg, VA.
21. IS 11590:2000 – “Guidelines for working out Unit rate cost of Construction Equipment used for River Valley Project”.

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