International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 08 | Aug 2020 www.irjet.net p-ISSN: 2395-0072

# Time and Cost Optimization of Construction Equipment Fleet for Highway Project

**Sandip Jadhav[1], Amol Thorbole[2]**

*[1]M. Tech. Student Civil - Construction Management, RIT, Maharashtra, India*
*[2]Assistant Professor, RIT, Maharashtra, India*

---

**Abstract -** *Construction equipment are the major resources in infrastructure projects. Construction equipment occupy major portion of project cost, but improper utilization of such resources lead to loss of productivity, ultimately affecting profit. Thus, there is need to optimize these operations to reduce the cost. The present research attempt to design the optimized equipment fleet by studying existing fleet and using optimization for the highway project. It includes an economic analysis of equipment fleet with respect to time and cost. To perform these optimization, production capacity and cost of equipment is taken into consideration. To validate the results, case study of four laning of Sangli - Solapur Section of NH 166 is taken.*

***Key Words***: Construction equipment fleet, cost analysis, productivity analysis, optimization.

## 1. INTRODUCTION

In road construction, equipment plays a major role as earthwork manage major portion of total construction cost, so their cost and productivity has a major role in making the project profitable to the company [4]. Therefore, if accuracy in terms of calculating the operating cost, productivity offered by equipment and feasible way of acquiring equipment is achieved, the project with more precision and economic cost can be planned [6].

Every task of road layer requires different types of equipment and machineries having their own level of application, such as subgrade, granular sub-base, dry lean & pavement quality concrete so each require different set of equipment fleet [3]. The equipment productivity control is undertaken to determine its employment time, the output achieved and its productivity at the site. The main purpose of equipment productivity control is to minimize the wastage in utilization and to minimize the cost [2].

One of the first tasks to be performed on any project, is the development of detailed cost estimates and schedules. The better the historical data available to the estimator, the more accurate the results of his analysis. This includes the actual performance characteristics of specific equipment items as well as determining which type of equipment to use for a particular project. The aim of this work is to perform economic analysis of equipment fleet used in pavement construction. This research has performed economic analysis of existing equipment fleet for selected case study by calculating total owning and operating cost of all equipment.

## 2. CASE STUDY AND DATA COLLECTION

### 2.1 Description of the case study

For data collection, case study of National Highway NH-166 (Package –II) is selected. From project data, condition of existing equipment fleet management is observed. The method of construction in pavement and working of each equipment are thoroughly studied and further cost analysis of each equipment is performed.

The Package-II of the project highway starts at Borgaon (Existing Chainage Km. – 219.956 to Design Chainage Km. - 224.000) in Sangli District and ends at Watambare (Existing Chainage Km. -272.394 to Design Chainage Km 276.000) in Solapur district. The project is located in Maharashtra, India and it is being carried out under Hybrid Annuity Model (HAM) by National Highway Authority of India (NHAI).

### 2.2 Data collection

For primary data collection, data related to each equipment cost was collected for month of 'October 2019' from contractor's records from site. The data of fuel consumption, maintenance cost, labor operating cost and efficiency of equipment was collected for further economic analysis. Then hourly cost of each equipment was calculated.

## 3. COST ANALYSIS OF EQUIPMENT FLEET

The total cost of construction equipment is divided into two components namely ownership cost and operating cost; also referred as O & O cost of the construction equipment. Ownership cost consist of initial cost, salvage value, insurance cost and road taxes.

Operating cost of the equipment is influenced by various parameters namely number of operating hours, location of job site, operating conditions, category of equipment etc. The operating cost consist of maintenance cost, fuel cost, and equipment operator wages.

### 3.1 Ownership cost

Ownership cost is the total cost associated with the construction equipment for owning it irrespective of the equipment is employed or not in the project. The ownership cost consists of the following;

a) Initial cost, b) Salvage value, c) Interest cost or cost of capital investment, d) Insurance cost, e) Road taxes

### 3.2 Operating cost

Operating cost is incurred only when the equipment is operated. The operating cost of the equipment is influenced by various parameters namely number of operating hours, location of job site, operating conditions, category of equipment etc. The operating cost consists of the following;

a) Maintenance cost, b) Fuel cost, c) Equipment operator wages.

For case study, equipment which are most cost effective are selected and considered for further analysis. These equipment are studied for finding out owning and operating cost. The various costs associated with equipment for calculating total owning and operating cost are calculated below.

The annual ownership cost of each equipment is calculated by considering purchase cost, life of equipment, insurance cost and road taxes associated with it.

**Table -1:** Annual Ownership Cost

| Sr. No | Equipment Type | Purchase Cost (Rs.) | Life (yrs) | Annualized Purchase Cost (Rs.) | Insurance Premium (Rs.) | Road Taxes | Total Ownership Cost (Rs.) |
|---|---|---|---|---|---|---|---|
| 1 | Back Hoe Loader | 2,000,000 | 10 | 353,968.33 | 8665 | 17680 | 380,313.33 |
| 2 | Dozer | 9,185,902 | 10 | 1,625,759.19 | 6538 | - | 1,632,297.19 |
| 3 | Excavator | 5,600,000 | 8 | 1,127,295.91 | 2653 | - | 1,129,948.91 |
| 4 | Excavator Breaker | 5,550,000 | 8 | 1,117,230.77 | 3237 | - | 1,120,467.77 |
| 5 | Excavator Mine | 10,797,000 | 6 | 2,626,108.08 | 4568 | - | 2,630,676.08 |
| 6 | Excavator Mine Breaker | 6,277,600 | 6 | 1,526,873.77 | 4454 | - | 1,531,327.77 |
| 7 | Motor Grader | 11,000,000 | 10 | 1,946,825.81 | 18800 | - | 1,965,625.81 |
| 8 | Slip Form PQC Paver SP 1200 | 96,250,000 | 6 | 23,410,475.40 | 53086 | - | 23,463,561.40 |
| 9 | Slip Form PQC Paver SP 500 | 54,720,000 | 6 | 13,309,311.31 | 24562 | - | 13,333,873.31 |
| 10 | Soil Compactor | 2,488,633 | 10 | 440,448.63 | 1197 | - | 441,645.63 |
| 11 | Tandem Roller | 2,639,250 | 6 | 641,933.48 | 1240 | - | 643,173.48 |
| 12 | Texture Curing TCM 180 | 76,650,147 | 6 | 18,643,287.07 | 13312 | - | 18,656,599.07 |
| 13 | Tipper Mine | 3,838,000 | 8 | 772,600.31 | 27914 | 24512 | 825,026.31 |
| 14 | Tipper 10 Wheeler | 1,973,000 | 8 | 397,170.51 | 27914 | 24512 | 449,596.51 |
| 15 | Transit Mixer | 1,700,000 | 6 | 413,483.72 | 12655 | 24752 | 450,890.72 |
| 16 | Vogele DLC Paver | 18,648,000 | 10 | 3,300,400.69 | 8815 | - | 3,309,215.69 |
| 17 | Water Tanker | 435,000 | 8 | 87,566.74 | 19222 | 24512 | 131,300.74 |
| 18 | Wheel Loader | 3,263,826 | 10 | 577,645.52 | 10539 | 25412 | 613,596.52 |

The equipment salvage cost of each equipment is calculated by considering purchase cost, life of equipment and annualized salvage value associated with it. Summary of the equipment salvage cost per hour for equipment which are major cost effective is given below.

**Table -2:** Equipment Salvage Cost

| Sr. No | Equipment Type | Purchase Cost (Rs.) | Life (yrs) | Salvage Value (Rs.) | Annualized Salvage Cost (Rs.) |
|---|---|---|---|---|---|
| 1 | Back Hoe Loader | 2,000,000 | 10 | 200,000.00 | 11,396.83 |
| 2 | Dozer | 9,185,902 | 10 | 918,590.20 | 52,345.09 |
| 3 | Excavator | 5,600,000 | 8 | 560,000.00 | 45,529.59 |
| 4 | Excavator Breaker | 5,550,000 | 8 | 555,000.00 | 45,123.08 |
| 5 | Excavator Mine | 10,797,000 | 6 | 1,079,700.00 | 133,046.81 |
| 6 | Excavator Mine Breaker | 6,277,600 | 6 | 627,760.00 | 77,356.18 |
| 7 | Motor Grader | 11,000,000 | 10 | 1,100,000.00 | 62,682.58 |
| 8 | Slip Form PQC Paver SP 1200 | 96,250,000 | 6 | 9,625,000.00 | 1,186,047.54 |
| 9 | Slip Form PQC Paver SP 500 | 54,720,000 | 6 | 5,472,000.00 | 674,291.13 |
| 10 | Soil Compactor | 2,488,633 | 10 | 248,863.30 | 14,181.27 |
| 11 | Tandem Roller | 2,639,250 | 6 | 263,925.00 | 32,522.35 |
| 12 | Texture Curing TCM 180 | 76,650,147 | 6 | 7,665,014.70 | 944,526.94 |
| 13 | Tipper Mine | 3,838,000 | 8 | 383,800.00 | 31,204.03 |
| 14 | Tipper 10 Wheeler | 1,973,000 | 8 | 197,300.00 | 16,041.05 |
| 15 | Transit Mixer | 1,700,000 | 6 | 170,000.00 | 20,948.37 |
| 16 | Vogele DLC Paver | 18,648,000 | 10 | 1,864,800.00 | 106,264.07 |
| 17 | Water Tanker | 435,000 | 8 | 43,500.00 | 3,536.67 |
| 18 | Wheel Loader | 3,263,826 | 10 | 326,382.60 | 18,598.64 |

The hourly ownership cost of each equipment is calculated by considering annual ownership cost, annual salvage value and monthly working hours associated with it. Summary of the hourly ownership cost per hour for equipment which are major cost effective is given below.

**Table -3:** Hourly Ownership Cost

| Sr. No | Equipment Type | Annual Ownership Cost (Rs.) | Annual Salvage Value (Rs.) | Total Annual Ownership Cost (Rs.) | Monthly Ownership Cost (Rs.) | Hourly Ownership Cost (Rs.) |
|---|---|---|---|---|---|---|
| 1 | Back Hoe Loader | 380,313.33 | 11,396.83 | 368,916 | 30,743.04 | 102.48 |
| 2 | Dozer | 1,632,297.19 | 52,345.09 | 1,579,952 | 131,662.67 | 438.88 |
| 3 | Excavator | 1,129,948.91 | 45,529.59 | 1,084,419 | 90,368.28 | 301.23 |
| 4 | Excavator Breaker | 1,120,467.77 | 45,123.08 | 1,075,345 | 89,612.06 | 298.71 |
| 5 | Excavator Mine | 2,630,676.08 | 133,046.81 | 2,497,629 | 208,135.77 | 693.79 |
| 6 | Excavator Mine Breaker | 1,531,327.77 | 77,356.18 | 1,453,972 | 121,164.30 | 403.88 |
| 7 | Motor Grader | 1,965,625.81 | 62,682.58 | 1,902,943 | 158,578.60 | 528.60 |
| 8 | Slip Form PQC Paver SP 1200 | 23,463,561.40 | 1,186,047.54 | 22,277,514 | 1,856,459.49 | 6,188.20 |
| 9 | Slip Form PQC Paver SP 500 | 13,333,873.31 | 674,291.13 | 12,659,582 | 1,054,965.18 | 3,516.55 |
| 10 | Soil Compactor | 441,645.63 | 14,181.27 | 427,464 | 35,622.03 | 118.74 |
| 11 | Tandem Roller | 643,173.48 | 32,522.35 | 610,651 | 50,887.59 | 169.63 |
| 12 | Texture Curing TCM 180 | 18,656,599.07 | 944,526.94 | 17,712,072 | 1,476,006.01 | 4,920.02 |
| 13 | Tipper Mine | 825,026.31 | 31,204.03 | 793,822 | 66,151.86 | 220.51 |
| 14 | Tipper 10 Wheeler | 449,596.51 | 16,041.05 | 433,555 | 36,129.62 | 120.43 |
| 15 | Transit Mixer | 450,890.72 | 20,948.37 | 429,942 | 35,828.53 | 119.43 |
| 16 | Vogele DLC Paver | 3,309,215.69 | 106,264.07 | 3,202,952 | 266,912.64 | 889.71 |
| 17 | Water Tanker | 131,300.74 | 3,536.67 | 127,764 | 10,647.01 | 35.49 |
| 18 | Wheel Loader | 613,596.52 | 18,598.64 | 594,998 | 49,583.16 | 165.28 |

The equipment maintenance cost of each equipment is calculated by considering monthly maintenance cost, average daily and monthly working hours associated with it. Summary of the equipment maintenance cost per hour for equipment which are major cost effective is given below.

**Table -4:** Equipment Maintenance Cost

| Sr. No | Equipment Type | Monthly Maintenance Cost (Rs.) | Avg. Daily Working Hours | Monthly Working Hours | Hourly Maintenance Cost |
|---|---|---|---|---|---|
| 1 | Back Hoe Loader | 71,466 | 6.91 | 207.43 | 344.53 |
| 2 | Dozer | 131,165 | 1.33 | 39.90 | 3,287.34 |
| 3 | Excavator | 30,359 | 9.50 | 284.89 | 106.56 |
| 4 | Excavator Breaker | 21,010 | 8.01 | 240.32 | 87.42 |
| 5 | Excavator Mine | 24,787 | 14.46 | 433.82 | 57.14 |
| 6 | Excavator Mine Breaker | 4,670 | 9.59 | 287.68 | 16.23 |
| 7 | Motor Grader | 141,261 | 6.96 | 208.93 | 676.12 |
| 8 | Slip Form PQC Paver SP 1200 | 1,322,634 | 2.79 | 83.57 | 15,826.39 |
| 9 | Slip Form PQC Paver SP 500 | 120,185 | 2.71 | 81.43 | 1,475.96 |
| 10 | Soil Compactor | 349 | 4.22 | 126.64 | 2.76 |
| 11 | Tandem Roller | 5,907 | 4.10 | 123.00 | 48.02 |
| 12 | Texture Curing TCM 180 | 2,332 | 2.53 | 75.75 | 30.79 |
| 13 | Tipper Mine | 44,978 | 8.80 | 264.00 | 170.37 |
| 14 | Tipper 10 Wheeler | 20,717 | 100.38 | 3,011.43 | 6.88 |
| 15 | Transit Mixer | 5,901 | 71.50 | 2,145.00 | 2.75 |
| 16 | Vogele DLC Paver | 760,233 | 5.11 | 153.21 | 4,961.89 |
| 17 | Water Tanker | 7,501 | 5.90 | 177.14 | 42.34 |
| 18 | Wheel Loader | 93,494 | 5.87 | 176.00 | 531.22 |

The hourly fuel cost of each equipment is calculated by considering standard fuel consumption at liters/hour, weekly and monthly fuel consumption, monthly average mileage and fuel cost per liters associated with it. Summary of hourly fuel cost per hour for equipment which are major cost effective is given below.

**Table -5:** Hourly Fuel Cost

| Sr. No | Equipment Type | Standard Consumption (Liters/hour) | Weekly Fuel Consumption of October | | | | Monthly Avg. Mileage (Liters/hour) | Fuel Cost (Rs.67/Liter) | Average Fuel Cost (Rs.) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2-8 Oct | 9-15 Oct | 16-22 Oct | 23-29 Oct | | | |
| 1 | Back Hoe Loader | 5 | 5.16 | 4.69 | 5.00 | 5.08 | 4.98 | 333.83 | 328.43 |
| 2 | Dozer | 22 | - | - | 22.58 | - | 22.58 | 1,512.86 | 1,512.86 |
| 3 | Excavator | 15.5 | 13.62 | 14.10 | 13.32 | 14.55 | 13.90 | 931.13 | 974.42 |
| 4 | Excavator Breaker | 14 | 12.15 | 11.77 | 11.61 | 11.67 | 11.80 | 790.60 | 876.95 |
| 5 | Excavator Mine | 20 | 18.34 | 17.89 | 18.78 | 17.59 | 18.15 | 1,216.05 | 1,226.27 |
| 6 | Excavator Mine Breaker | 15 | 13.69 | 13.66 | 13.63 | 14.35 | 13.83 | 926.78 | 895.62 |
| 7 | Motor Grader | 12 | 10.81 | 11.71 | 11.18 | 10.74 | 11.11 | 744.37 | 724.96 |
| 8 | Slip Form PQC Paver SP 1200 | 18 | 22.17 | 15.99 | 9.70 | 19.21 | 16.77 | 1,123.42 | 963.82 |
| 9 | Slip Form PQC Paver SP 500 | 12 | 8.91 | - | 9.93 | - | 9.42 | 631.14 | 631.14 |
| 10 | Soil Compactor | 9 | 9.45 | 10.42 | 10.16 | - | 10.01 | 670.67 | 631.79 |
| 11 | Tandem Roller | 8 | 7.29 | 7.78 | 6.81 | - | 7.29 | 488.65 | 460.74 |
| 12 | Texture Curing TCM 180 | 4 | | 3.11 | 3.00 | 3.08 | 3.06 | 205.24 | 202.79 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | Tipper Mine | 6 | 7.59 | 7.66 | 8.53 | 8.49 | 8.07 | 540.52 | 479.42 |
| 14 | Vogele DLC Paver | 12 | 10.41 | 11.91 | 11.53 | 12.86 | 11.68 | 782.39 | 782.39 |
| 15 | Water Tanker | 5 | 5.42 | 6.13 | 3.23 | - | 4.93 | 330.09 | 344.26 |
| 16 | Wheel Loader | 10 | - | 8.46 | 8.88 | 10.19 | 9.18 | 614.84 | 633.82 |

The hourly labor cost of each equipment is calculated by considering labor type, monthly wages, labor cost per hour associated with it. Summary of hourly labor cost per hour for equipment which are major cost effective is given below.

**Table -6:** Hourly Labor Cost

| Sr. No | Equipment Type | Labor Type | Monthly Wages (Rs.) | Labor Cost (Rs./hour) | Total Labor Cost (Rs./hour) |
|---|---|---|---|---|---|
| 1 | Tipper | Driver | 15,000 | 50.00 | 50.00 |
| 2 | Excavator | Operator | 25,000 | 83.33 | 123.33 |
| | | Helper | 12,000 | 40.00 | |
| 3 | Backhoe Loader | Operator | 18,000 | 60.00 | 60.00 |
| 4 | Dozer | Operator | 18,000 | 60.00 | 60.00 |
| 5 | Transit Mixer | Operator | 20,000 | 66.67 | 66.67 |
| 6 | Motor Grader | Operator | 25,000 | 83.33 | 123.33 |
| | | Helper | 12,000 | 40.00 | |
| 7 | Slip Form PQC Paver | Operator | 35,000 | 116.67 | 316.67 |
| | | 4- Helper | 60,000 | 200.00 | |
| 8 | Soil Compactor | Operator | 18,000 | 60.00 | 60.00 |
| 9 | Tandem Roller | Operator | 18,000 | 60.00 | 60.00 |
| 10 | Texture Curing Machine | Operator | 25,000 | 83.33 | 133.33 |
| | | Helper | 15,000 | 50.00 | |
| 11 | DLC Paver | Operator | 30,000 | 100.00 | 200.00 |
| | | 2 - Helper | 30,000 | 100.00 | |
| 12 | Wheel Loader | Operator | 15,000 | 50.00 | 50.00 |
| 13 | Water Tanker | Operator | 12,000 | 40.00 | 40.00 |

The equipment efficiency of each equipment is calculated by considering weekly working hours, average daily hours and hourly working shift of associated with it. Summary of equipment efficiency for equipment which are major cost effective is given below.

**Table -7:** Equipment Efficiency

| Sr. No | Equipment Type | Weekly Hours for October Month | | | | Avg. Daily Hours | Hourly Shift/day | Avg. Efficiency |
|---|---|---|---|---|---|---|---|---|
| | | 2-8 Oct | 9-15 Oct | 16-22 Oct | 23-29 Oct | | | |
| 1 | Back Hoe Loader | 53.70 | 46.90 | 55.20 | 37.80 | 6.91 | 10 | 0.62 |
| 2 | Dozer | 0.00 | 0.00 | 9.30 | 0.00 | 1.33 | 2 | 0.66 |
| 3 | Excavator | 90.60 | 68.10 | 65.40 | 41.80 | 9.50 | 20 | 0.45 |
| 4 | Excavator Breaker | 60.00 | 90.30 | 62.00 | 12.00 | 8.01 | 20 | 0.46 |
| 5 | Excavator Mine | 120.30 | 122.00 | 106.90 | 55.70 | 14.46 | 20 | 0.64 |
| 6 | Excavator Mine Breaker | 81.50 | 77.90 | 78.30 | 30.80 | 9.59 | 20 | 0.41 |
| 7 | Motor Grader | 44.50 | 49.00 | 65.20 | 36.30 | 6.96 | 20 | 0.31 |
| 8 | Slip Form PQC Paver SP 1200 | 6.00 | 75.00 | 10.00 | 29.00 | 2.79 | 10 | 0.56 |
| 9 | Slip Form PQC Paver SP 500 | 23.00 | 0.00 | 15.00 | 0.00 | 2.71 | 10 | 0.27 |
| 10 | Soil Compactor | 31.50 | 31.30 | 25.10 | 30.30 | 4.22 | 10 | 0.41 |
| 11 | Tandem Roller | 31.40 | 23.40 | 31.30 | 0.00 | 4.10 | 10 | 0.40 |
| 12 | Texture Curing TCM 180 | 0.00 | 40.55 | 9.34 | 20.81 | 2.53 | 20 | 0.15 |
| 13 | Tipper Mine | 44.90 | 76.90 | 68.90 | 55.70 | 8.80 | 20 | 0.41 |
| 14 | Tipper 10 Wheeler | 980.00 | 664.00 | 464.00 | 0.00 | 100.38 | 20 | 0.58 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15 | Transit Mixer | 383.00 | 337.00 | 651.00 | 631.00 | 71.50 | 20 | 0.50 |
| 16 | Vogele DLC Paver | 54.00 | 35.00 | 40.00 | 14.00 | 5.11 | 10 | 0.51 |
| 17 | Water Tanker | 40.80 | 16.30 | 66.90 | 0.00 | 5.90 | 10 | 0.41 |
| 18 | Wheel Loader | 0.00 | 47.30 | 49.30 | 26.60 | 5.87 | 10 | 0.59 |

Finally, the hourly owning and operating cost of each equipment is calculated by considering ownership cost, labor cost, maintenance cost and fuel cost associated with it. Summary of the owning and operating cost per hour for equipment which are major cost effective is given below.

**Table -8:** Hourly Owning & Operating Cost

| Sr. No | Equipment Type | Ownership Cost (Rs.) | labor Cost (Rs.) | Fuel Cost (Rs.) | Maintenance Cost (Rs.) | O & O Cost (Rs.) |
|---|---|---|---|---|---|---|
| 1 | Back Hoe Loader | 97.57 | 60.00 | 333.83 | 344.53 | 835.93 |
| 2 | Dozer | 438.88 | 60.00 | 1512.86 | 3,287.34 | 5,299.08 |
| 3 | Excavator | 301.23 | 123.33 | 931.13 | 106.56 | 1,462.25 |
| 4 | Excavator Breaker | 298.71 | 123.33 | 790.60 | 87.42 | 1,300.06 |
| 5 | Excavator Mine | 693.79 | 123.33 | 1216.05 | 57.14 | 2,090.30 |
| 6 | Excavator Mine Breaker | 403.88 | 123.33 | 926.78 | 16.23 | 1,470.22 |
| 7 | Motor Grader | 528.60 | 123.33 | 744.37 | 676.12 | 2,072.42 |
| 8 | Slip Form PQC Paver SP 1200 | 6,188.20 | 316.67 | 1123.42 | 15,826.39 | 23,454.68 |
| 9 | Slip Form PQC Paver SP 500 | 3,516.55 | 316.67 | 631.14 | 1,475.96 | 5,940.32 |
| 10 | Soil Compactor | 118.74 | 60.00 | 670.67 | 2.76 | 852.17 |
| 11 | Tandem Roller | 169.63 | 60.00 | 488.65 | 48.02 | 766.30 |
| 12 | Texture Curing TCM | 4,920.02 | 133.33 | 205.24 | 30.79 | 5,289.38 |
| 13 | Tipper Mine | 213.70 | 50.00 | 540.52 | 170.37 | 974.59 |
| 14 | Tipper 10 Wheeler | 113.62 | 50.00 | 199.56 | 6.88 | 370.06 |
| 15 | Transit Mixer | 112.55 | 66.67 | 444.59 | 2.75 | 626.56 |
| 16 | Vogele DLC Paver | 889.71 | 200.00 | 782.39 | 4,961.89 | 6,833.99 |
| 17 | Water Tanker | 108.63 | 40.00 | 330.09 | 42.34 | 521.06 |
| 18 | Wheel Loader | 158.22 | 50.00 | 614.84 | 531.22 | 1,354.27 |

## 4. PRODUCTIVITY ANALYSIS

The equipment which are major cost effective in existing fleet are considered for further analysis. Hence, production of these equipment is calculated to perform detailed economic analysis of existing fleet. The details of production calculations of these equipment are given below.

### 4.1 Excavator Dumper Production Calculation

The highway site at Ch. 244 + 750 to 244 + 950 having bucket size of 1.30 cy and 3 dumpers used of 10 cum. Work is in progress from Ch. 244 + 900 to dump site at 246+400 (Borrow area), having lead of 3.0 km and height of cut is 2.5 m.

1) Bucket size = 1.3 cy.
2) Material = sandy gravel soil,
So fill factor = 110 % … Table 9.4 (CEPM, Purifoy)
3) Cycle time = 15 sec … Table 9.5 (CEPM, Purifoy)
4) Check depth of cut – O.K.
5) Production = (Bucket size x Fill factor x Efficiency) / cycle time
= 1.30 cy x 1.1 x 27/ (15 sec/ 60) min/hr.
= 154.44 lcy/hr.
6) Convert production to tons/hr.
Hence, Production = (154.44 x 2260 lb/cy) / 2000 lb/ton
= 174.51 tons/hr
7) Match Excavator to available dumper
Loading time dumper = no. of bucket passes x hoe cycle time
No. of bucket passes = Payload Hauler/ Payload Bucket
= 1.3 cy x 1.1

= 1.43 cy
Ideal no of passes = 13 cy / 1.43 cy
= 9.09 … Take 9
But, actual no. of passes = 12
Total loading time –
For 9 passes = 2.25 min.
For 12 passes = 3.0 min.
8) Haul time = 12.9 min
9) Return time = 5.6 min
Dump time = 2.0 min
10) Truck cycle time =
For 9 passes, truck cycle time = 22.75 min
For 12 passes, truck cycle time = 23.5 min
Dumpers required = Truck cycle time/ truck load time
For 9 passes, No of dumpers = 22.75/ 2.25 = 10
For 12 passes, No of dumpers = 23.5/ 3.0 = 8
11) Production =
For 9 passes, 2.25 min, Production (excavator) = 27 min/hr x (1.3 x 10 cum)
= 156 lcy/hr … (Optimized Fleet)
For 12 passes, 3.0 min, Production (excavator) = 27 min/hr x (1.3 x 10 cum)
= 117 lcy/hr … (Actual Fleet)
For 9 passes, 10 no, 22.75 min Production (dumper) = 27 min/hr x 13 cy x 10
= 154.28 lcy/hr
For 12 passes, 8 no, 23.5 min Production (dumper) = 27 min/hr x 13 cy x 8
= 119.48 lcy/hr

### 4.2 Tandem Roller Production

Roller passes = 8 … (98.88% compaction achieved)
Production = (W x S x L x E x 16.3) / n
Compaction width W = 7.22 ft.
S = average rolling speed in miles/hr
= 3.1 miles/hr
n = no of passes = 8,
E = 0.40,
L = Lift thickness = 10 inch …. Table 5.3 CEPM, Purifoy
Production = (7.22 ft x 3.1 miles/hr x 10 inch. x 0.40 x 16.3) / 8
= 182.41 lcy/hr.

### 4.3 Soil Compactor Production

Speed of Compactor S = 5 kmph,
Compacted Lift Thickness L = 254 mm,
No. of passes n = 4 and efficiency E= 0.41,
Compaction Width W = 1.68 m
Production of Soil Compactor = (W x S x L x E) / n
= (1.68 m x 5 kmph x 254 mm x 0.41) / 4
= 218.694 cum / hr.

### 4.4 Grader Production

6 passes are made for each layer i.e. (Mixing, Levelling and final shaping)
For 1 km stretch,
Speed of grader S = 5 kmph i.e. 3.1 mph
Distance Travelled by grader D = 500 m i.e. 0.31 miles
No of passes N = 6, and efficiency E = 0.31,
Blade Length W = 3.7 m i.e. 12.136 ft.
Grader time = (N x D) / (S x E)

= (6 x 0.31) / (3.1 x 0.31)
= 1.93 hr …… Avg. Total time

Production of Grader = (5280 x S x W x E) / 9
= (5280 x 3.1 mph x 12.136 ft x 0.31) / 9
= 6838.73 Sq.m / hr.

## 5. RESULT

From productivity analysis, production of onsite equipment fleet for major cost effective equipment is mentioned below.

**Table -9:** Productivity Analysis

| Sr. No. | Equipment Type | Production (Rs.) |
|---|---|---|
| 1 | Excavator Dumper | 156 lcy/hr. |
| 2 | Tandem Roller | 182.41 lcy/hr. |
| 3 | Soil Compactor | 218.694 cum / hr. |
| 4 | Grader | 6838.73 Sq.m/hr. |

## 6. CONCLUSION

From productivity analysis performed, actual excavator-dumper fleet using 10 dumpers and 12 bucket passes has production Rs. 117 lcy/hr. But, optimized production is found for 8 dumpers and 9 bucket passes which is Rs. 156 lcy/hr. Roller production for achieving 98.88 % compaction is Rs. 182.41 lcy/hr. Compactor production is found on site is Rs. 218.694 cum / hr. Grader production for 2 hr. grader time is Rs. 6838.73 Sq.m/hr.

## REFERENCES

[1] Govindan Kannan (2011): "Field Studies in Construction Equipment Economics and Productivity" Journal of Construction Engineering & Management ASCE, 137(10), 823-828
[2] Ilias Naskoudakisa, (2016): "A thematic review of main researches on construction equipment over the recent years" Journal of Procedia Engineering, 164, 206 – 213
[3] M. Waris, et al (2014): "Criteria for the selection of sustainable onsite construction equipment" International Journal of Sustainable Built Environment, 3, 96–110
[4] Manuel Parente (2016): "A novel integrated optimization system for earthwork tasks" Journal of Transportation Research Procedia, 14, 3601 – 3610
[5] Sabah Alkass, (1998): "Expert System for Earthmoving Equipment Selection in Road Construction" Journal of American Society of Civil Engineers, 114(3), 426-440
[6] Venkatesh M.P. (2019): "Improvement of Manpower and Equipment Productivity in Indian Construction Projects" International Journal of Applied Engineering Research, 14(2), 404-409