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Construction Cranes Parametric Cost Estimating

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Abstract–Nowadays, there are several methodologies to estimate construction equipment costs, largely developed by manufacturers. This paper provides an evaluation method to determine economics between renting equipment or utilizing purchased equipment.

This paper aims to present a new approach to estimating ownership and operating costs of large cranes and other load hoist equipment utilized in construction and assembly of industrial facilities projects in compliance with Brazilian legislation.

This methodology has been based on international parameters to calculate operational costs (such as maintenance costs) to achieve the lowest possible cost per hour while ensuring top machine performance and efficiency. For this, it has been necessary to define a selection of specimens for this study, setting a price quotation system. Through the researched information, and the parameters set, the relevance of the results associated with the mechanical availability and operational efficiency of each type of cranes was observed.

The crane depreciation method utilized is based on various factors: the length of the lifetime, the market conditions, brand reputation, and general conditions of intended use.

The results of the costs per hour were converted to costs per month. These results were compared with those available in the rental market, excluding markup.

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Introduction

Nowadays, there are several methodologies to estimate construction equipment costs, largely developed by manufacturers. These provide an adequate evaluation to determine economics between renting equipment or owning equipment.

The goal of these suggested methods is to be able to estimate with a reasonable degree of accuracy how much a machine will cost per hour. The result can be termed as cost of utilization and it is influenced by the following factors:

- purchase cost (including attachments)
- ownership period
- available operating time (hours)
- capital interest rate (%)
- maintenance factors (K)
- fuel consumption rates for flywheel horsepower-hour (gal/fwhp-hr)

It is applicable to equipment such as excavators, bulldozers, wheel loaders, and transport vehicles. It is also widely utilized for cost estimates of agricultural equipment. However, there is no evidence or studies on the application of a deterministic method for calculating operating costs for cranes and other load-lifting equipment. Other equipment (i.e. welding machines) do not have references for the cost calculation.

It is generally accepted in cost engineering practices that such machines will always be available at job sites over the whole period of implementation, i.e., cranes.

Cranes, from the perspective of the owner, are an important initial investment, and they have been a very profitable product, because of their long life and their fast return. However, there are difficulties for banks and insurance companies in measuring the return on investment.

In general, the cost of equipment is one of the largest categories of outlay for the contractor. It is a cost that is subject to many variables and uncertainties. Two issues must be carefully addressed for equipment owners to optimize the utilization costs of their machines:

1. How much does it cost to operate the crane in a project?
2. What are the optimal working conditions to maximize the economic life of a crane?

The process of selecting a specific type of crane for use in the construction of a project requires knowledge of the cost associated with machine operation on the site. In selecting the appropriate machine, the contractor seeks to obtain the lowest possible cost of unit production. When bidding projects and developing cost estimates, it is essential to know the cost of owning and operating costs (expressed in dollars per hour).

This paper aims to present a new approach to the methodology of estimating ownership and operating costs of large cranes and loading equipment utilized in the construction and erection of industrial plant projects in accordance with Brazilian legislation.

It also seeks to define the criteria for the correct application of the method in cost estimates. The methodology presented here is guided by systematic data collection, use of economic engineering techniques, and parameters for load-lifting operations with cranes.

Parametric Model

The determination of cost per hour involves the application of parameters that approximate the real costs. It aims to identify and estimate partial costs through available data of the machines and the knowledge of cost engineers.

The initial development of the methodology will define which items should be considered for the parametric calculation of utilization cost per hour of a configuration of a crane that is used in load-lifting services in construction and assembly works.

The assumption is to incorporate only costs related to owning and operation. Costs for the mobilization and erection of the equipment are not covered in this study.

The purpose of the method is to develop cost per hour for uptimes and downtimes in compliance with local laws.

Therefore, the price of equipment will be understood on fixed and variable costs of equipment in operation measured by the cost of hours worked and unproductive time.

Conceptual Basis

Uptime and Downtime Definitions

The time of use of equipment considers concepts of mechanical availability and operational efficiency which provides an evaluation of the construction planning in terms of uptime and downtime.

The mechanical availability (MA) is defined as the percentage of scheduled service time that the machine is mechanically able to perform productive work, not considering the time that the machine is in repair or maintenance. It is a quantity that indicates how long a machine is in perfect condition and completely usable. It can be expressed in equation (1).

$$\mathrm{MA} = \frac{\mathrm{AMT}}{\mathrm{UPT}} \times 100 = \frac{\mathrm{AMT}}{(\mathrm{AMT+MP})} \times 100$$ **Equation 1**

where:

MA = mechanical availability ratio (%)
AMT = available mechanical time, in hours
UPT = useful potential time, in hours
MP = maintenance period, in hours.

Operational efficiency (OE) is defined as the percentage of time worked effectively in relation to the scheduled time of service. It can be understood as the time that equipment works effectively. It can be expressed in equation (2).

$$\mathrm{OE} = \frac{\mathrm{WET}}{\mathrm{AMT}} \times 100 = \frac{\mathrm{UP}}{(\mathrm{UP+C})} \times 100$$ **Equation 2**

where:
OE = operational efficiency ratio (%)
WET = worked effectually time, in hours
AMT = available mechanically time, in hours
UP = uptime, in hours
C = constraint during the operation, in hours

Therefore, the time of utilization can be defined by the relationship between uptimes and downtimes through the utilization factor (UF) which is the product of mechanical availability with operational efficiency, as shown in equation (3).

$$\%\mathrm{UF} = \mathrm{MA} \times \mathrm{OE}$$ **Equation 3**

Figure 1 expresses the relationship between uptime and downtime time of utilization of equipment.

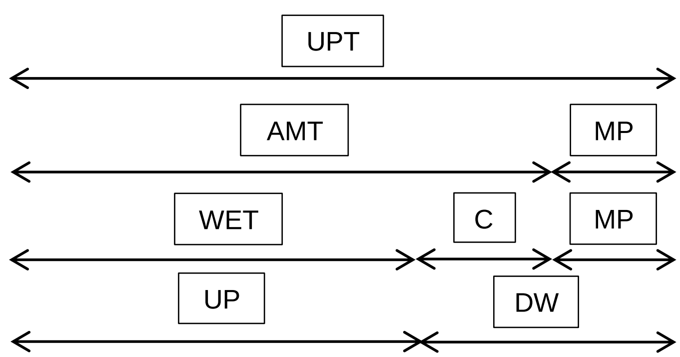


Figure 1–Useful Time

<u>Cost of Utilization</u>

The costs occurring in the utilization of equipment can be classified into three groups:

- ownership costs

- operating costs
- maintenance costs.

The ownership cost group can also be called fixed costs, and this group makes up the cost category related to depreciation and investment interest. For equipment mounted on a truck, in compliance with Brazilian legislation, insurance and vehicle taxes are added to this group.

Other groups represent variable costs according to the operating conditions defined in the use of the equipment. They consist of the cost category related to consumable materials in the operation, such as consumption of fuel, lubricants, grease, filters, operating labor costs, undercarriage costs, and costs of mechanical maintenance.

Therefore, the general expression of the cost of utilization of equipment is given in equation (4).

$$C = \frac{P-S}{Na} + \frac{i}{a}\left[(P-S)\frac{N+1}{2N} + S\right] + (C_{mat} + C_{labor}) + \frac{k \times P}{N \times a}$$ **Equation 4**

where:
P = purchase cost
S = salvage value
N = useful life, in years
a = available hours per year
i = annual interest rate
C_{mat} = consumable materials cost (included fuel)
C_{mat} = operating labor cost
k = factor of repair mechanics

During the downtime, the machine is at the disposal of the operation, however, is not being used. To calculate the actual cost in this period, disregard the incidence of the cost of consumables and the costs of mechanical repairs. Thus, the expression of the cost of utilization is given in equation (5) and is called downtime cost.

$$C_d = \frac{P-S}{Na} + \frac{i}{a}\left[(P-S)\frac{N+1}{2N} + S\right] + C_{labor}$$ **Equation 5**

Scope

This paper considers crane types and settings most used in onshore industrial construction projects. This evaluation is limited to new cranes only, to minimize the impact of obsolescence due to technological upgrading. It also considered manufacturers with global operations in the crane market.

The families or groups of cranes listed in Table 1 below, was based on the Sobratema Equipment Guide 2014-2016, as this is the equipment which manufacturers typically operate in Brazil.

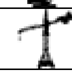
Crane Type	Mounted	Boom	Model
All-terrain (AT)	All-wheel truck	Telescopic	
Truck-crane (TC)	Truck	Telescopic	
Rough terrain (RT)	Undercarriage	Telescopic	
Crawler crane	Undercarriage	Telescopic	
Crawler crane	Undercarriage	Truss	
Tower crane	Concrete slab	Variable	

Table 1–Group of Cranes

Criteria Usage

The process of selecting a particular type of machine for use in the preparation of a project requires knowledge of the associated costs.

Crane Capacity Index (CCI)

One of the criteria used for selecting cranes for this study was the application of the Crane Capacity Index (CCI), developed by the European Association of Abnormal Road Transport and Mobile Cranes (ESTA), to guide the choice of a crane for investors, rental companies, and owners. The CCI is in Te.m² and is calculated as follows:

- radius
- lifting height
- capacity.

The base formula for the CCI is presented in equation (6) as follows.

$$\mathrm{CCI} = \frac{\mathrm{average}(\mathrm{R} \cdot \mathrm{máx}(\mathrm{LH} \times \mathrm{Cap}))}{100}$$ **Equation 6**

where:
R = radius, in meters (m)
LH = lifting height, in meters (m)
Cap = capacity, in metric tons (Te).

To clarify calculations, these base dimensions, for example, are presented in Figure 2. A is the distance between crane center and pivot point main boom, B is the height of crane pivot point and C is the sheaves distance.

The CCI for each of the selected cranes is shown in the table below. The selection criterion was to select the crane with the largest CCI from the cranes of the same type and nominal capacity. The overview results are presented in Table 3.

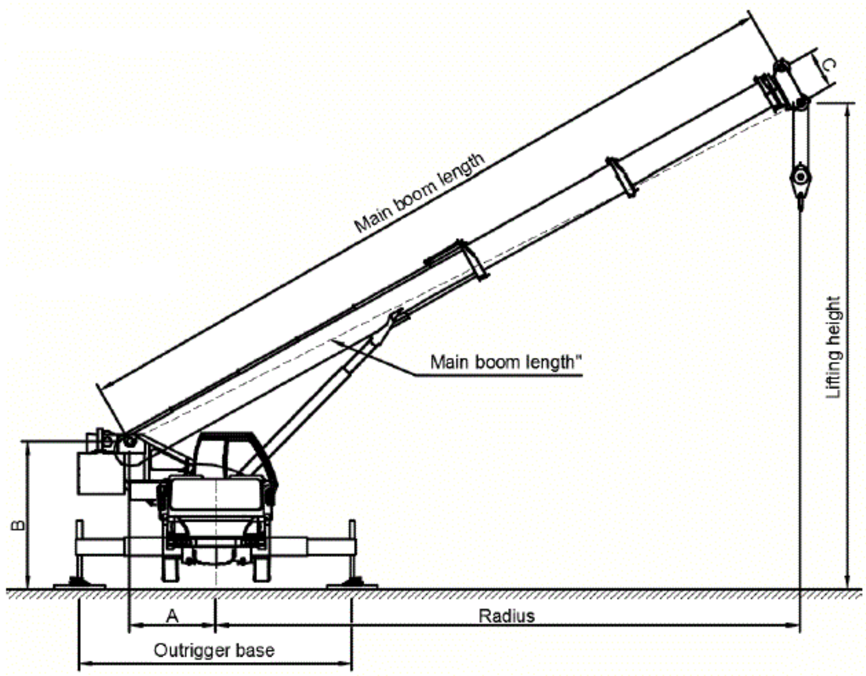


Figure 2–Base Dimensions for CCI Calculation

Manufacturer	Model Type	Capacity	CCI
Liebherr	LTM 1030-2.1	30	14.62
Terex	AC 35	35	14.55
Tadano	HK 40	40	18.95
Liebherr	LTM 1040-3.1	45	22.12
Liebherr	LTM 1050-3.1	50	23.53
Liebherr	LTM 1055-3.2	55	32.06
Tadano	HK 65	60	35.30
Tadano	ATF 65G	65	32.37
Liebherr	LTM 1080-1	70	44.00
Grove	GMK 4075	75	37.27
Grove	GMK 4080-1	80	46.83
Tadano	ATF 90G-4	90	58.00
Grove	GMK 5095	95	67.88
Liebherr	LTM 1100-5.2	100	75.08

Table 2–Overview of Selected Cranes by CCI

Request for Quotation

The price quotation process of acquisition was carried out with the selected manufacturers according to the system presented below.

System

The currency chosen was the US dollar and the acquisition value should include all taxes and additional charges with CIF shipping to the city of Rio de Janeiro, Brazil. The acquisition values obtained refer to the purchase cash payment.

Two methods are chosen for the calculation of the depreciation time: the linear function method and the method of average annual investment.

The machine depreciates every year to a constant value for the life. This method is simple and is in compliance with tax Brazilian rules.

The second approach to the calculation of the portion of the depreciation cost uses the average value of the machine multiplied by the cost of the capital rate. This will incorporate the monetary portion of the capital interest plus installment of straight-line depreciation results in the cost of ownership of equipment.

Definition of Useful Life and Salvage Value

In practice, it is quite difficult to safely establish the time when a useful life has been reached. The correct and realistic determination of the number of probable years of life is dependent on data provided by the settlement. Some manufacturers have developed data tracking systems for the operation, mechanical repairs, and technological modifications.

It is known that during the life of the equipment maintenance costs grow over time due to natural wear.

The salvage value of a crane relies on various factors:

- brand reputation
- model size
- model type (e.g., luffing, horizontal jib, self-erecting)
- year of manufacturing
- level of technology (kind of drives, control system, safety features, other options)
- general conditions of intended use.

The chart below in Figure 3 shows the salvage values of tower cranes in comparison with their cost amortization.

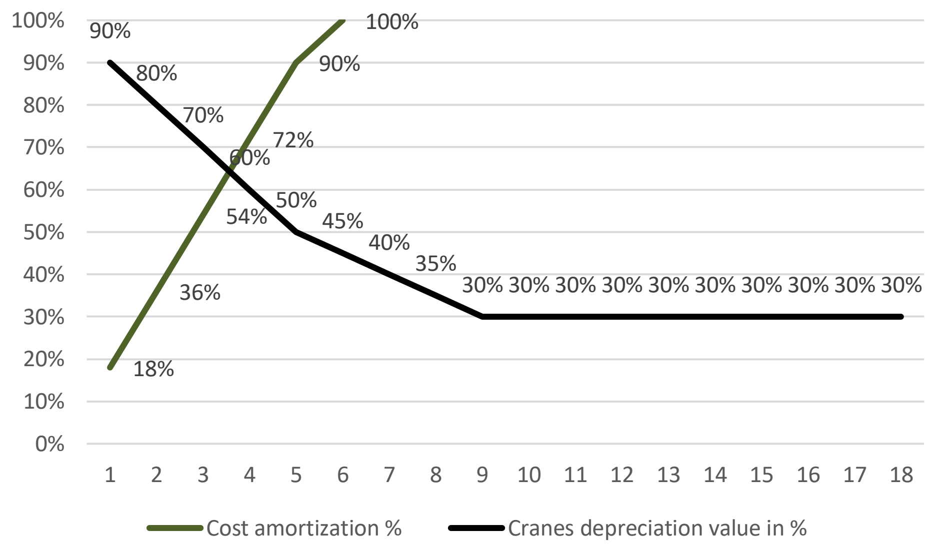


Figure 3–Crane Depreciation /Cost Amortization in %

Conclusion

The method brought results that maximizes efficiency by ensuring that realistic costs are charged by both the rental market and the construction companies. This should also be fully applicable in public budgets aimed at the economics and the performance of the buildings of government investments.

The present study can be extended to other equipment, such as welding machines, tests, and measurement instruments. It is necessary to evaluate its applicability by defining the mandatory parameters that must be considered.

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