METHOD IN PLANNING CONSTRUCTION MACHINERY REPLACEMENT

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Summary: *One basic criteria for determining the replacement time of construction machinery is based on the age , that is, the increase in operating costs of the machine with time. The key factor which determines and justifies replacement at a given time is the magnitude of operating costs. This analysis will show a method for replacement planning and sale of machines in a future time period.*

Keywords: *construction machinery, costs, machine replacement.*

1. INTRODUCTION

As the basis for a a variety of financial planning and capital budgeting decisions, machine replacement planning is an extremely important part of long-term business planning. There are many criteria by which a decision can be reached for the replacement of machinery. In the majority of cases, the basic criteria is based on the operating costs of the machine during its working life. "How much does it really cost me?" and "How long do I keep it?" are two question for which there is no precise answer to in practise. However, these answers are crucial for the economic justification to maintain ownership of construction machinery. If a machine is owned and operated for a short period of time then owning costs arising from high early depreciation dominate the calculation and give rise to high hourly rates. On the other hand, if the machine is kept for too long then hourly operating and maintence costs tend to increase.
The optimal economic ownership period or "sweet spot" in practice is recognised as the period when the sum of hourly owning and operating costs have been minimsed. In other words the sweet spot is determined as the period when the machine has worked

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long enough to reduce owning costs, but not long enough to experience unnecessary or unusually high operating costs.

2. CALCULATING COSTS OVER TIME

Determining the period when operating hourly costs (sweet spot) are at a minimun and calculating the peak of construction machinery costs requires a detailed understanding of owning and operating costs and how these vary over the life time of a machine. There are several important factors to consider:
1. Owning and operating costs, by their own nature, are very different;
2. Hourly owning costs decrease over time;
3. Hourly operating costs increase over time;
4. Hourly cost calculations are overly sensitive to changes in input parametres.
The relationship between cost per hour and machine age is extremely complex and is based on numerous assumptions which need to always be confirmed in practise. To obtain the correct results requires calculating hourly costs during the working life of the machine. This is only possible if a correct prediction is made about the work life of the machine and the anticipated hourly periods of operation during every year of utilisation. A detailed presentation of the process is shown in [1].
In order to analyse the change in operating costs of a machine during utlilisation requires an analysis of how individual costs change during the operating life of a machine. Total direct lifecycle costs is the sum of primary resource costs (Eos) and operating costs (Eex) enlarged by the coefficient non-utilisation, D, that is, the costs a machine incurs in downtime according to the formula:

$$Ch = (Eos + Eex) * (1 + Down) \tag{1}$$

where:
Ch - total of hourly costs,
Eos - primary resource costs
Eex - operating costs
$Down$ - percentage of non-utilisation

Primary resource costs represent owning costs. They include the sum of depreciation costs(*Eam), investment maintence costs (Eio) and interest and insurance costs. (Ekios).
Operating costs represent the costs of construction machine operations. They are the sum of energy sources and lubricant costs (Ee, Emaz), labour costs (Ers), repair parts costs (Eh) and current maintence costs.(Eto). A detailed calculation of these costs is shown in document [2].
Total costs are calculated according to the formula in (1). Costs which are rarely included in the calculation, but nonetheless have a significant impact on total operating hourly costs, include costs incurred when the machine is inoperable due to a malfunction and non-utilisation at the building site.
Over time, primary resource costs (owning costs) decrease, but total operating costs increase.Their sum, combined with cost of non-utilisation over time, is simply presented by the U-shaped curve.In the first years of operation cost decrease, reach a minimum,

and after this, costs begin to increase and continues to do so until the end of work life of the machine. Changes in costs over time are graphically displayed in Figure 1.

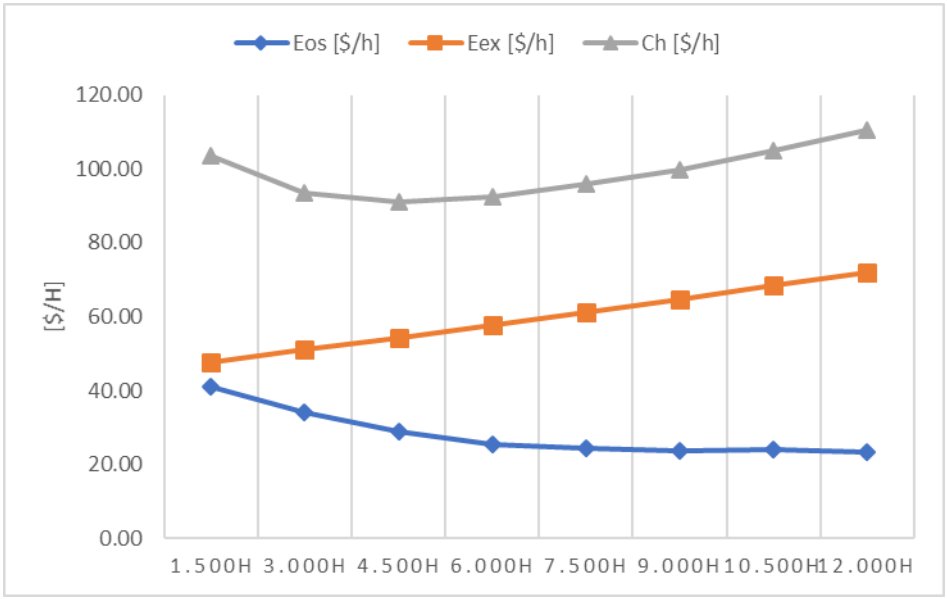

Figure 1 Changes in owning costs, operating costs and total costs during the work life cycle of a machine

According to Vorster [3], before analysing total operating costs during the work life of a machine, it is necessary to consider the following data:

- Magnitude of the minimum point – It is necessary to determine what are the minimum total operating costs of construction machines;
- The timing of the minimum point - This is important data which shows how long the machine should be kept in ownership in order to minimise the sum of decreasing owning and increasing operating costs
- The shape of the curve – This information confirms and quantifies the sensitivity of the cost calculation on either shortening or lengthening the life of the machine and makes it possioble to set ranges or zones used as a basis for machine replacement planning.

One of the most important uses of this calculation is to compare the real cost to the optimal planning point for the replacement of machinery. Machine replacement planning is extremely important strategically for construction companies as it forms the basis for financial resource planning and capital budgeting decisions.

3. METHODOLGY IN FLEET REPLACEMENT PLANNINN

Fleet replacement planning is based on the economic price of a machine. This can be divided into five steps:

1. Determine the curve and changes in operating hourly costs during utilisation
2. Define acceptable age cost zones, that is, determine the moment when the machine should be replaced (sold, shelved….)
3. Rank and group machines according to age
4. Plan utilisation of every machine over time according to expected work hours
5. In accordance with costs groups, plan replacement and acquirement of new

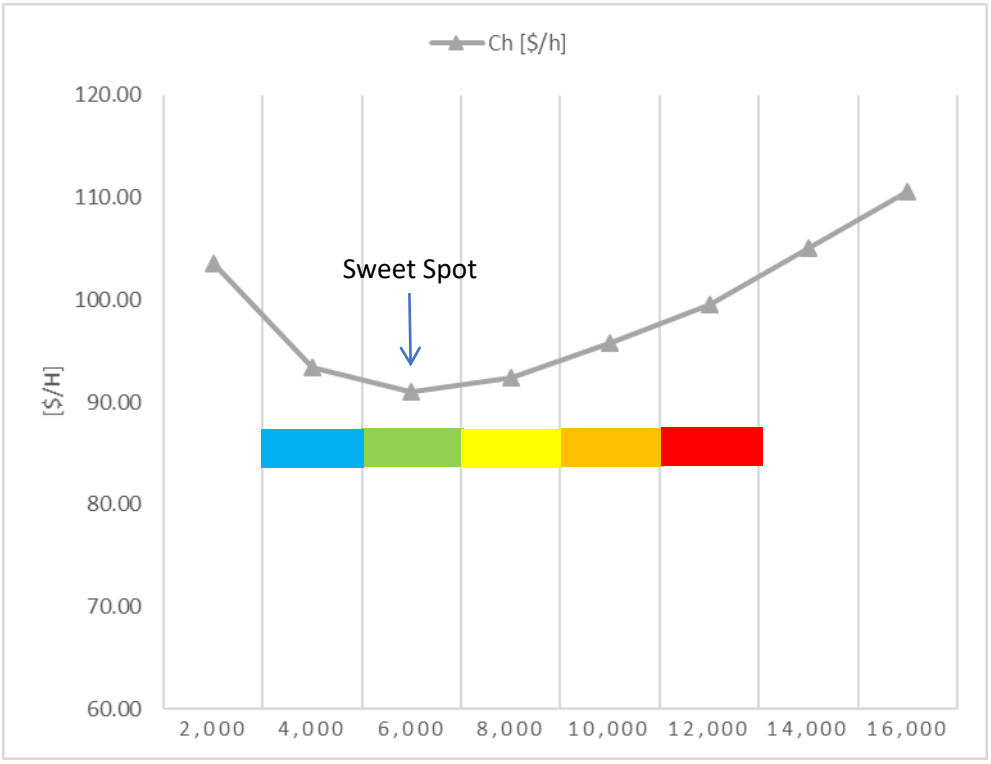

Figure 3. Position and magnitude of sweet spot and division of cost zones.

4. EXAMPLE OF FLEET REPLACEMENT PLANNING

By way of illustrating this methodology, an analysis of a replacement plan for a fleet of 11 machines in varying age zones has been given (from 3,010 working hours to 11,450 working hours). The plan is shown in Figure 3. Every machine has been assigned an hourly per annum plan in the range from 1,500 to 2,100 hours.. In the column *Current*

Age the number of working hours which a machine will have by the end of 2018 is shown..
Figure 3 shows the cost curve over time as calculated using the formula [1]. The position of the Sweet Spot is 5.000 working hours. Working under the assumption that such a curve is acceptable for all machines, the cost curve zone can be grouped into five zones.

- Blue zone - below 4,000 hours. The machines are young and have not yet reached their minimum point.. In this zone, *Ownership Cost* is still significant, while operating costs have not risen.
- Green zone – from 4,000 to 6,000 hours,(1,000 hours each side of the Sweet Spot) . This is the most economical zone - operating costs in this zone are at a minimum.
- Yellow zone - from 6,000 to 8,000 hours. Machines in this zone are slightly past the minimum and are becoming expensive to operate due to increasing operating costs.
- Orange zone – from 8,000 to 10,000 hours. Machines in this zone are clearly becoming more expensive due to rising repair costs and increasing fuel costs.
- Red zone – from 10,000 to 12,000 hours. Machines in this zone are clear candidates for replacement due to high operating costs which dominate while *Ownership Cost* are less and less.

All machines have been grouped according to their work life in the column *Current Age* (Figure 3). This column represents the age of machines at the end of 2018. Years are expressed in the number of working hours. In accordance with the division of cost zones, 2 machines are eligible for the red zone and are being planned for sale. The number of working hours by the end of 2019 is represented by the sum total of working hours for the current year, 2018, and planned hourly operations per annum (*Hours per year*). In the column for 2019., the two machines which were in the red zone in 2018 have been sold and two new ones have been bought. The same process is repeated for the following year. The total age of machine, expressed in the number of working hours of machines, in this way, remains relatively stable. Also the average age of machines is relatively stable and ranges from 5,876 hours to 7,180 hourse, that is, it is mainly in the yellow cost zone..

The development of long term strategy of machine replacement consists of a moderate mix around machines in all zones which have a suitable average age. In figure 7.4 it can be deduced that three machines are in the red zone.. If two machines are sold and immediately two new ones are purchased then a mix like in column C is obtained.. If this is not done then 4 enter the red zone and the firm will be confronted with a major problem in machine planning replacement in the following year.
If existing machines were replaced with new ones, the average age of machines would be significantly higher (shown in figure 4). In this case, the machines would rapidly (as early as 2020) enter the red cost zone and their operating costs would be expensive.

			Expected age at the end of:			
Unit ID:	**Hours per year**	**Current age**	**2019**	**2020**	**2021**	**2022**
A450	1500	11,450	<Sell			
A310	1500	10,220	<Sell			
A371	1800	9,100	10,600	<Sell		
A455	1800	7,230	9,030	10,830	<Sell	
A230	2000	6,800	8,800	10,800	<Sell	
U5620	1800	6,540	8,340	10,140	<Sell	
U5630	1500	6,050	7,550	9,050	10,550	<Sell
U5635	1800	4,550	6,350	8,150	9,950	11,750
U5624	2000	4,020	6,020	8,020	10,020	<Sell
A556	2000	3,580	5,580	7,580	9,580	11,580
A548	1800	3,010	4,810	6,610	8,410	10,210
U5478	1500	Buy>	1,500	3,000	4,500	6,000
U5470	1500	Buy>	1,500	3,000	4,500	6,000
U5210	1800		Buy>	1,800	3,600	5,400
A479	1800			Buy>	1,800	3,600
A589	2000			Buy>	2,000	4,000
A698	2000			Buy>	2,000	2,000
A969	2000				Buy>	2,000
A968	2100				Buy>	2,100
	Total age:	72,550	70,080	78,980	66,910	64,640
	Average age:	6,595	6,371	7,180	6,083	5,876

Figure 3. Plan machine replacement over a four year period

Unit ID:	**Hours per year**	**Current age**	**2019**	**2020**	**2021**	**2022**
A450	1500	11,450	12,950	14,450	15,950	17,450
A310	1500	10,220	11,720	13,220	14,720	16,220
A371	1800	9,100	10,600	12,400	14,200	16,000
A455	1800	7,230	9,030	10,830	12,630	14,430
A230	2000	6,800	8,800	10,800	12,800	14,800
U5620	1800	6,540	8,340	10,140	11,940	13,740
U5630	1500	6,050	7,550	9,050	10,550	12,050
U5635	1800	4,550	6,350	8,150	9,950	11,750
U5624	2000	4,020	6,020	8,020	10,020	12,020
A556	2000	3,580	5,580	7,580	9,580	11,580
A548	1800	3,010	4,810	6,610	8,410	10,210
	Total age:	72,550	91,750	111,250	130,750	150,250
	Average age:	6,595	8,341	10,114	11,886	13,659

Figure 4. Plan machine replacement over a four year period if no sale of old and buying of new machines is done.

5. CONCLUSION

Apart from the age of fleet, there are other factors which influence machine replacement planning. For example, the number of different machines that a firm owns gives the firm opportunities to gain work. The average age of machines and the level of investment in replacing machines enables the firm to remain productive and be competitive in the future. The magnitude of the fleet and the age of the fleet are two very different things. One relates to the present, while the other to the future. Both are very important and deserve more attention.

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PRIMER METODE ZA PLANIRANJE ZAMENE GRAĐEVINSKIH MAŠINA

Rezime: *Jedan od osnovnih kriterijuma za zamenu građevinske mašine baziran je na njenoj starosti, odnosno, koštanju radnog časa mašine povećanom do neprihvatljive vrednosti. Trenutak zamene mašine i iznos troškova koje mašina stvara su od ključnog značaja za ekonomsku opravdanost vlasništva nad građevinskom mašinom. U radu je prikazana metoda kojom se planira kupovina i prodaja mašina u budućem periodu.*

Ključne reči: *Građevinske mašine, troškovi, zamena mašina*