Estimated repair and maintenance cost of sugarcane (Saccharum spp.) harvester

Estimativa do custo com reparo e manutenção de colhedora de cana-de-açúcar (Saccharum spp.)

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Abstract
Brazil is the largest sugarcane producer worldwide. Harvester’s repair and maintenance cost is high, and it is more representative than that of fuel. Equipment maintenance costs mainly comprise spare parts, third-party services and manpower. In addition, it is also closely related to the intense use of the equipment and to the increased mechanized operations. The current study aims to evaluate the proposals used to estimate the total costs associated with repair and maintenance of sugarcane harvesters. The initial value and useful life in hours of the equipment were used in the calculations. For the development of this work was adopted the data modeling, using methodological proposals and their results were generated using the Excel® spreadsheet. Among the proposals considered, two are according with reality because it reaches the useful life in hours at a cost of US$ 396,059.75, which corresponds to the initial value of the equipment. The longer worked hours increased total repair and maintenance costs. The equipment must not be used when it reaches its lifespan limit in hours.

Additional keywords: agricultural mechanization; data modeling; fleet renewal; income; management.

Resumo
O Brasil é o maior produtor mundial de cana-de-açúcar. A colhedora apresenta alto custo com reparo e com manutenção, sendo este mais representativo que o custo com combustível. O custo de manutenção da máquina é formado basicamente por peças, serviço de terceiros e mão-de-obra. Além disso, ele tem uma estreita relação com a intensidade no uso do equipamento e aumento das operações mecanizadas. Objetivou-se com o presente trabalho avaliar as propostas para estimar o custo total com reparo e manutenção global de colhedora de cana-de-açúcar. Considerou-se para o seu cálculo o valor inicial e vida útil em horas da máquina. Para o desenvolvimento do trabalho foi adotado a modelagem de dados, utilizando propostas metodológicas e seus resultados foram gerados, empregando-se a planilha eletrônica do Excel®. Entre as propostas consideradas, duas estão de acordo com a realidade, porque alcançar a vida útil em horas a um custo de US$ 396,059,75, que corresponde ao valor inicial do equipamento. O aumento das horas trabalhadas eleva o custo total com reparo e manutenção. O equipamento não deverá ser utilizado quando alcançar a vida útil em horas.

Palavras-chave adicionais: Gerenciamento; mecanização agrícola; modelagem de dados; renda; renovação de frota.

Introduction
Sugarcane cultivation to agribusiness in Brazil encompasses cultivated area of 9.11 million hectares and estimated total production of 694.50 million tons for the 2016-2017 crop, Conab (2016). According to Santos et al. (2014b), harvesters are the highest-cost equipment 75.51% in the sugarcane mechanical harvesting system, whereas agricultural tractors represent 24.49% of its costs. According to Santos et al. (2014b), equipment repair and maintenance cost (RMC) is the most representative one 40.41% and it is followed by fuel cost 34.27%. According to Banchi et al. (2008c), the harvester’s
RMC is 33.00% and the cost with lubricants represents 4.00% of the total.

Faria & Silva (2015) evaluated the effects of the modification of maintenance scheduled on the equipments of the mechanized harvesting system of sugarcane and concluded that there was a reduction in the number of harvesters, tractor set and transhipment, keeping the quantity of processed raw material and reducing the maintenance rate of harvesters, from 10.0% to 3.5%. Calcante et al. (2013) conducted studies on grain harvesters’ RMC and their results showed costs of 20.80% in the harvesting platform, 6.40% in the threshing mechanism, 10.6% in the hydraulic system, 32.10% in transmission and 7.30% in worn parts.

Abubakar et al. (2013) conducted studies to determine the RMC composition of agricultural tractors and they obtained the equivalent to 79.60% of the total variable cost. Khodabakhshian & Shakeri (2011) analyzed three tractor types and concluded that the cost with spare parts ranged from 67.95 to 71.35% and that with the mechanic’s wage ranged from 14.54 to 18.39%. Ashfarnia et al. (2014) studied the breakdowns and concluded that the electrical system showed the highest expenses, and it was followed by the cooling and the hydraulic systems.

The mathematical or computational modeling is a practical tool adopted to create scenarios to assess the RMC of the agricultural machinery. Khoub Bakht et al. (2009) suggested a mathematical model for tractors and found the following values: spare parts 66.72%, operator’s wage 18.54%, lubricants and oil filters 12.01%, and fuel 2.73%. Rashidi & Ranjbar (2010); Niari et al. (2012) developed a model for tractors and found the following values: lubricants 7.20%, mechanic’s wage 23.50% and spare parts 69.30%. Rohani et al. (2011) developed a computer model to solve tractor’s RMC issues regarding accuracy, speed, practicality and low cost.

According to Banchi et al. (2006a,b), sugarcane harvesters’ RMC formation occurs due to specific spare parts, specialized manpower and to repairs performed by third parties. However, according to Lips & Burose (2012), the equipment’s RMC is also strongly influenced by its intense use, lifespan and by wear in mechanical components. In addition, according to Quadros & Malinovsky (2012), the cost rises depending on the relation between the equipment’s RMC and the increased mechanized operations.

The RMC of agricultural machinery is also related to maintenance type. According to Balastreire (1987), preventive maintenance takes under consideration expenses with lubricating oils and filters. However, corrective maintenance depends on the operator’s skill and on field conditions, and its cost is more difficult to be measured. Mialhe (1974) mentions that repairing the equipment is essential; however, mechanical labor, replacement of broken parts, spare parts, among others should be included in the costs. Thus, the current study aims to evaluate different proposals to estimate total repair and maintenance costs with sugarcane harvesters.

### Material and methods

The current study took under consideration an Elaborate Scenario (ES) using a sugarcane harvester with initial value of US$ 250,000.00, estimated lifespan of 30,000 hours, in a Reference Mill (RM) with area of 22,000 ha, mean yield of 80.00 t ha⁻¹, and estimated price per ton of sugarcane delivered in the field rather than in the mill of 13.40 US$ t⁻¹, according to UDOP (2015).

For the development of this work was adopted the data modeling, using methodological proposals and their results were generated using the Excel® spreadsheet. The methodology that met the aim of the study is in line with the proposals adapted from Asabe (2011) and Banchi et al. (2008a,b).

The total repair and maintenance cost of the harvester (TRMCA) was calculated using the proposal adapted from Asabe (2011), equation 1.

\[
TRMCA = [(RMF \times lv) \times (Wh / ULh)]
\]

Wherein: TRMCA is the total repair and maintenance cost of the harvester (US$), RMF is the repair and maintenance factor, in decimal, lv is the initial value (US$), Wh is the worked hours (h) and ULh is the useful life in hours (h).

The repair and maintenance factor (RMF) used for the equipment in this proposal meets that of Asabe (2011).

The proposal by Banchi et al. (2008a) was developed using primary (raw) data obtained from two harvester models, in eleven sugarcane mills. This proposal was modified to define the total repair and maintenance cost of the harvester (TRMCBA), equation 2.

\[
TRMCBA = [(0.00678 \times 10^{Wh} + 25.83873) \times Wh]
\]

Wherein: TRMCBA is the total repair and maintenance cost of the harvester (US$) and Wh is the worked hours (h).

The proposal by Banchi et al. (2008b) was developed using primary (raw) data from harvesters manufactured between 1997 and 2007, in 8 sugarcane mills. The aforementioned proposal was adjusted to determine the total repair and maintenance cost of the harvester (TRMCBB), equation 3.

\[
TRMCBB = [lv \times (4 \times 10^{-6}Wh^2 + 3 \times 10^{-6}Wh)]
\]

Wherein: TRMCBB is the total repair and maintenance cost of the harvester (US$), lv is the initial value (US$) and Wh is the worked hours (h).

The proposal by Santos (2011); Santos et al. (2014a, 2015) was developed to set the gross and net income from the sugarcane harvest performed in one mill. The percentage of raw material loss was taken under consideration in the gross income and the mechanized harvesting cost was taken under consideration in the net income. The proposal has been adapted to calculate the gross crop income (GCI), by taking under consideration the association between the harvested sugarcane production (SP) and
the price per ton (PT), equation 4.

\[ \text{GCI} = \text{SP} \times \text{PT} \]  \hspace{1cm} (4)

Wherein: GCI is the gross crop income (US$), SP is the sugarcane production (t) and PT is the price per ton of sugarcane (US$ t⁻¹).

The proposal has been modified to determine the net crop income (NCI), by taking under consideration the difference between the gross crop income (GCI) and the total repair and maintenance cost of the harvester (TRMC), equation 5.

\[ \text{NCI} = \text{GCI} - \text{TRMC} \]  \hspace{1cm} (5)

Wherein: NCI is the net crop income (US$) and TRMC is the total repair and maintenance cost of the harvester (US$).

Results and discussions

Figure 1 shows the total repair and maintenance cost of the sugarcane harvester in the Mill Reference (RM) Elaborate Scenario. The proposal adapted from Asabe (2011) shows linear growth, although the cost does not reach the initial equipment value even with 30,000 h and it underestimates this value. On the other hand, the proposals adapted from Banchi et al. (2008a,b) show polynomial growth and reach the initial equipment value of US$ 396,119.50 and US$ 396,000.00 with 13,500 and 16,500 h, respectively, thus resulting in difference of 3,000 h and in 0.03% of the initial equipment value.

![Figure 1 - Total repair and maintenance cost of the harvester in function on its estimated lifespan.](image)

When the harvester reached 20,000 and 30,000 worked hours in the proposals by Banchi et al. (2008a,b), the cost was US$ 807,193.75 and US$ 1,719,290.50; US$ 550,000.00 and US$ 1,125,000.00, respectively, corresponding to 203.78% and 434.03%; 220.00 and 450.00%, which was higher than the initial equipment value. It proves the economic infeasibility of using the equipment after it reached its lifespan in hours. Thus, since the gross crop income of the Reference Mill was US$ 23,584,000.00, the cost impact on the income was 3.42 and 7.29%; 2.33 and 4.77%.

The Elaborate Scenario shows that the critical “Z” point indicates the median harvester cost, which is 15,000 hours of lifespan and US$ 396,059.75, among the proposals adapted from Banchi et al. (2008a,b).

Thus, the net crop income of the Reference Mill was US$ 23,187,940.25 due to the total harvested sugarcane production of 1,760,000 t. However, the critical point refers to the fleet control, which should be taken under consideration by the mills, since it informs when the equipment has reached its lifespan in hours. Therefore, it should be no longer used. Instead, the harvester should be replaced by another one; otherwise, it would lead to high costs.

Conclusions

The longer worked hours increased the cost with the equipment, despite the evaluated proposal.

When the cost is equivalent to the initial equipment value, it means that the equipment reached its lifespan in hours.

The mills should adopt an excellent management method for fleet control in order to determine the machinery renewal critical point.

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