METHODOLOGY PROPOSAL FOR IDENTIFYING LIFE-CYCLE COSTS (LCC) OF MULCHERS OF UNDESIRABLE GROWTH

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Management of life-cycle costs is an approach that leads to sustainable development and effective use of company's resources. By using the life-cycle cost method analysis - LCC creates a foundation for complex evaluation of costs of a product from its conceptions to the end of its life-cycle. In the introduction, we present a general scheme of a life-cycle cost analysis and calculation of costs. The analytical part includes a description of two types of analysed equipment - mulchers-AHWI FM 600 profi and Seppi m_ Midifrost dt 250. Specific relevant criteria were identified that can be used to evaluate life-cycle costs (LCC) of the above-mentioned equipment. Further, we outlined results of data collection and primary evaluation of this data. The goal is to create a platform for economic evaluation of increase in life-cycle of analysed initial and adjusted equipment based on specifically proposed methods.

KEYWORDS

Life-Cycle Costs (LCC), Mulcher of Undesirable Growth, Relevant Costs

1 INTRODUCTION

Today in the global economy and due to various other market pressures, the procurement decisions of many products are not entirely made on initial acquisition costs but on their total life cycle costs; in particular is the case of expensive products. Many studies performed over the years indicate that the product ownership cost soften exceed procurement costs. In fact, the product ownership cost (i.e., logistics and operating cost) can vary from 10 to 100 times the procurement cost. Even the assertion of the ownership cost being high could be detected from the overall annual budgets of various organizations. Life cycle cost of a product may simply be described as the sum of all costs incurred during its life span, i.e., the total of procurement and ownership costs [Venkannavar 1999].

Management of life-cycle costs consists of an approach leading to sustainable development and effective use of company's resources. The life-cycle cost analysis method – LCC, provides a base for complex evaluation of costs of a product from its conception until termination of its life- cycle. Life-cycle costs were defined by the IEC in 1989 as total costs to a user of a specific system or equipment for its purchase and installation, as well as costs for using and upkeep during its life-cycle. The life-cycle can be a so called maximum life-cycle of a product, which includes period of its conception, development, preparation for production, production, use and disposal [Westkaempfer 2002]. The EN 60300-3-3 norm is a good tool for monitoring and qualification of amounts for various costs, which are absorbed by the user and which are considerably affected by the products' quality (especially by reliability of production). The above mentioned norm is recommended for work with information on life-cycle costs. Its purpose is to optimize results in various phases of the life-cycle or a specific technical system, by dividing costs into six groups:

- costs for concept development and parameter setting phase,
- costs for draft phase and system development,
- costs for evaluation of a (production) system,
- costs for system installation at user's facility,
- costs for system use and maintenance, and
- costs for liquidation of a system.

One should monitor especially the first three costs, to be able to uncover (e.g. with the use of model of process costs) possibility how to lower costs, which at first sight are covered by system development, however in the end are absorbed by the user as part of the final sale price. Experience has shown that a developer can influence costs of the life-cycle by up to 90%, especially in pre-production phases [Nenadal 2008].

Cierna [Cierna 2006] indicates the importance of monitoring costs of a life-cycle:

- with their help, we can in the product development stage influence characteristics of its use, which are important in the scope of costs of its life-cycle,
- they allow one to compare different product designs, when criteria of appropriateness are minimal costs during a life-cycle, and
- play an integral role in the design review phase.

The aim of the article is to show importance of evaluation of product life-cycle costs used by forestry technologies, which are subject of our study. Further, the article aims to create a database of relevant terms for economic evaluation of a process to increase life-cycle of analysed tools by applying innovative materials. The article was developed as part of a project „Increasing the life of tools and components of the mechanisms used in forestry technology".

2 REASONS AND USES OF LIFE CYCLE COSTING CONCEPT AND REQUIRED INPUTS

Life cycle costing is increasingly being used in the industry to make various types of decisions. Some of the reasons for this upward trend could be increasing maintenance cost, competition, increasing cost effectiveness awareness among product users, budget limitations, costly products (e.g., aircrafts, military systems), and greater ownership costs in comparison to procurement costs. The life cycle costing concept can be used for various different purposes including selecting among options, determining cost drivers, formulating contractor incentives, choosing the most beneficial procurement strategy, assessing new technology application, forecasting future budget needs, making strategic decisions and design trade-offs, providing objectives for program control, deciding the replacement of aging equipment, improving comprehension of basic design associated parameter sin product design and development, optimizing training needs, and comparing logistics concepts. A life cycle costing project can only be accomplished effectively if the required information is available. Nonetheless, the professionals involved in conducting lifecycle cost studies should seek information on general items such as those listed below prior to the start of the project under consideration [Venkannavar 1999]:

- Estimate goal
- Time schedule
- Required data
- Involved individuals
- Required analysis format
- Required analysis detail
- Treatment of uncertainties
- Ground rules and assumptions
- Analysis constraints
- Analysis users
- Limitations of funds
- Required accuracy of the analysis

Nonetheless, the specific data required to conduct life cycle cost studies for an item include useful life, acquisition cost, periodic maintenance cost, transportation and installation costs, discount and escalation rates, salvage value/cost, taxes (i.e., investment tax credit, tax benefits from depreciation, etc.), periodic operating costs (e.g. energy cost, labour cost, insurance, cost of materials, and cost of supplies) [Venkannavar, 1999].

2.1 LIFE CYCLE COSTING STEPS AND ACTIVITIES

A life cycle costing study can be conducted in seven steps as shown in Fig. 1. There are many activities associated with life cycle costing.

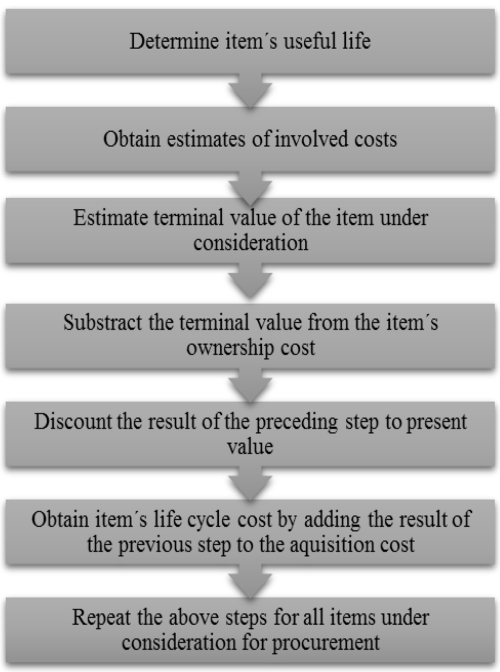

Figure 1. A life cycle costing study [Venkannavar 1999]

Some of those activities are as follows:

- Develop an accounting breakdown structure.
- Define activities that generate ownership costs of products.
- Establish cause-and-effect relationships.
- Identify cost drivers.
- Determine or define the life cycle of items/products.
- Develop cost estimate relationships for every element in the life cycle cost breakdown structure.
- Conduct sensitivity analysis.
- Develop escalated and discounted life cycle costs.

2.2 COSTS INVOLVED AT DIFFERENT STAGES OF PRODUCT LIFE-CYCLE

For each of the business functions at each stage of life-cycle of each product, costs keep on being incurred. Let us try to identify the possible costs at each stage of the life-cycle:

1. At the planning and design stage: Research and Development cost, Costs of product design, etc.
2. At the manufacturing stage: This stage witnesses both growth and maturity in sales. All the manufacturing, marketing, selling and distribution costs are incurred at this stage.
3. At the service and abandonment stage: This last stage of the product life-cycle is signified by a decline in sales volume. The demand for the product declines at this stage. The producers may be required to provide after sales service for the already sold products. Costs that are incurred in this stage include all costs relating to after sales service including provision of spares and expert services and costs of abandonment and disposal of the product.

Life-cycle costing refers to the system that tracks and accumulates every individual cost which is incurred during the whole life cycle of a product starting from its initial planning stage to the post sales service and abandonment stage. At the Figure 2 is shown time frame of typical Product Life-Cycle Cost [Munawar 2009].

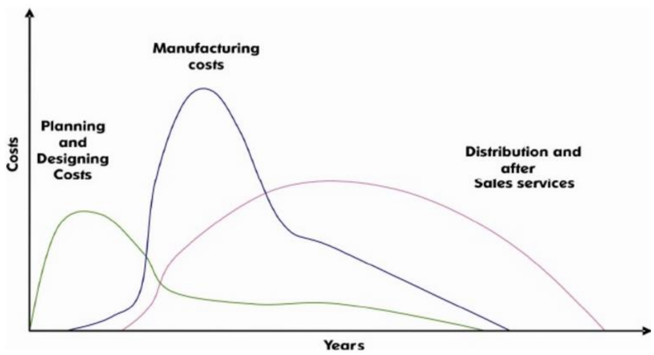

Figure 2. Time frame of typical Product Life-Cycle Cost [Munawar 2009]

2.3 DESIGN AND CALCULATION OF LIFE-CYCLE COSTS

Costs for development of a primary system represent user's total one-time investment. The main portion of this cost could consist of accruing costs. System maintenance costs in use can be divided into one-time and running yearly costs. The first subgroup can include: costs for user documentation, initial training, cost of minimal inventory of supporting materials and spare parts, purchase of maintenance tools, if necessary, and more. Running costs spent during operation include: gas and energy, salaries of operators and maintenance staff, other costs for repair and maintenance, selected parts of other expense, and other. Third group of user's costs includes loses caused by system failure, including costs of finding replacement technology, loss of production and more [Nenadal 2002].

Cost items include all costs that arise from conception until the end of a life-cycle. These cost items should be structured so that they make it easier to identify potential connections between them with the goal to set the correct amount for a product's life-cycle. This should be possible by performing a product life-cycle analysis. The final stage of the calculation is to define calculation of life-cycle costs [Freiberg 2011].

The final stage comprises of eight steps:

- Establish a production profile: regimes of operation for the product's entire life-cycle are defined as part of this step.
- Determine used factors: while the production profile monitors a time frame during which the machine will be used or will not be in use, used factors show how will the machine react in different operational regimes (continuous, intermittent, etc.).
- Identify all cost items.
- Set all critical cost parameters: to set parameters that influence costs of the product's life-cycle. For example, the period between breakdowns, repair, general repair, scheduled maintenance, etc.
- Calculate all costs in current prices.
- Decrease common costs to adjust for inflation.
- Recalculate all costs.
- Summary of all recalculated costs.

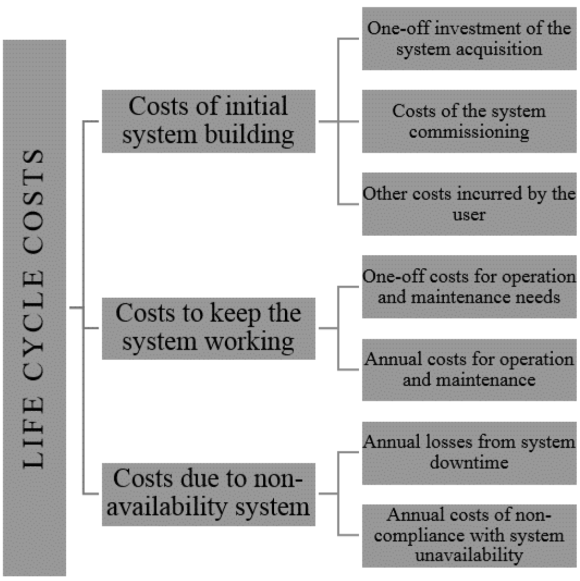

Figure 3. Basic life-cycle cost structure [Nenadal 2002]

We realize that it is important to perform a product life-cycle analysis in the design and product development phases. Since it is hard to predict how various construction and development alternatives will affect the costs, which arose as part of the production and pre-productions phases of the product's life-cycle, the room to influence costs in the design phase of the product's life-cycle diminishes. In the design phase and during production, it is not possible to determine production or operational characteristics of the product, maintenance needs, volume of production, logistics or other factors [Freiberg 2011].

3 METHODS AND MATERIAL

3.1 LIFE CYCLE COST MODEL

Remer [Remer 2010] developed a mathematical model for calculating the life cycle costs for a project where the operating costs increase or decrease in a linear manner with time. The life cycle cos tis shown to be a function of the investment costs, initial operating costs, operating cost gradient, project life time, interest rate for capital, and salvage value.

Life cycle costs are defined as the initial costs, P, plus the sum of the operating costs, U, over the project life, n. Thus,

$$LCC = P + \sum_{j=1}^{n} U_j \quad (1)$$

Let´s assume the operating cost function, U, is a uniformly increasing function of time. For the purposes of their development [Remer 2010] they considered discrete step increases in costs rather than a continuous function because the discrete approach more closely matches their actual budgeting and forecasting system. The initial operating cost in year number 1 was designed by U_j^0 and the operating cost increases an amount R each year. It is needed to introduce the time value of money for these future operating cost cash flows. There is some discussion at the present time as to whether DSN should discount future cash flows, use a negative discount rate, or ignore discounting and use no time value of money.

The present value, P, of a future amount of money, F, is

$$P = F(1+i)^{-n} \quad (2)$$

where I is the value of money (interest rate) per year and n is the number of years between P and F. The factor $(1+i)^{-n}$ is referred to as the discounting factor and accounts for the time value of capital. For the no discounting case i is zero.

3.2 EQUIPMENT CHARACTERISTICS

The research project VEGA 1/0531/15 is focused on undesirable growths´ mulcher used in forestry. These are machines with numerous systems with exchangeable cutting parts. Due to a specific impact load and unfavourable conditions of operation in a heterogeneous environment – wood, soil and stones, these machines are made with exchangeable parts of different shapes and structure. The goal of this project is innovation of materials and technology to increase the life-cycle of machines used by the forestry industry. Another partial aim of this project is economic evaluation of contribution of application to increase life-cycle of tools what is also goal of the paper. As part of the indicated paper aim, we decided to evaluate life-cycle costs of these machines, since this is a more complex evaluation that includes a time factor and all users' costs, not only purchasing costs of tools and machines.

The analysed technical equipment is used to dispose of unwanted wood or plant growth on restocked areas, or other areas that need to be reforested.

A mulcher for unwanted growth consists of a bearing and a working part. The bearing part is a robust frame, which also serves as a protective shield ensuring that wood, plant materials or rocks are not thrown in the air in the surrounding area. The working part is a horizontally placed rotor and cutting of unwanted growth is achieved by movement and quick rotation of the rotor. On the rotor are tightly fastened working tools (teeth), which can, if needed, (in case of wear or loss of tooth) be quickly changed. A rotor is connected to the frame by bearings. The rotor runs with the help of a shaft from the tractor through a jointed shaft into the transmission. Energy is moved from the transmission through belts into the rotor of the mulcher [Hnilica 2015].

4 RESULTS AND DISCUSSION

4.1 COLLECTION OF RELEVANT DATA

Data collection was performed at mulchers´ user during the period February – March 2016. We have selected two types of mulchers for our research – AHWI FM 600 profi and Seppi m_ Midifrost dt 250. Mulcher type AHWI has 56 teeth where price per tooth is 70 Euros. Mulcher type Seppi has 46 teeth and each tooth costs 82 Euros.

Wearing of elements during operation is high and frequent. End of life-cycle for teeth is maximum 1,200 hours (200 days at 6 hours per day). The level of wearing depends on placement of a tooth on the rotor. Teeth on on the outside of the rotor get more wear down then teeth placed in the middle of the rotor [Kalincova 2016].

In the previous article [Sujová 2015], we developed a methodology for rating LCC of the analyzed device. In the above methodology we created view of suggested specific cost items of a life-cycle of rotary tillers accrued by the user via Ishikawa diagram. The methodology has been used for the items identification for relevant data collection.

We have evaluated the following on analyzed equipment in terms of life-cycle cost for users:

General Information:

- Characteristics of equipment, type and description of use.
- List of changed parts/components/equipment.
- List and frequency of regular maintenance activities.

Identification of Costs:

- Purchasing cost.
- Yearly cost for equipment maintenance.
- Yearly operational cost.
- Yearly cost for energy/gas.
- Cost of disposal of equipment.

Other Costs:

- Required testing (frequency, price per one test).
- Environmental aspects (disposal of oil, etc.).
- Reconditioning of equipment.

The following information is a result of collected data from users:

- Components to be changed: teeth – frequency – as needed.
- Regular maintenance: balancing of equipment - frequency 1x per year, or when changing a tooth.
- Regular equipment maintenance activities: change of 10 belts - frequency 3x per year, change of bearings – as needed, greasing of moving parts – 4 x per month, check of moving parts – daily.
- General repairs - 3x per year.
- Diesel oil consumption for use of tractor: 130 l per day, which will provide approx. 1 hectare of activity.

4.2 INITIAL ANALYSIS

In our initial analysis, we focused on determining purchasing cost of equipment (Tab. 1) and on determining available annual operating cost (Tab. 2).

Table 1. Purchase Cost of Equipment

Type of Mulcher	AHWI FM 600 profi	Seppi m_Midifrost dt 250
Purchase Cost of Equipment	eur	eur
Purchase Price of Equipment	46 000	34 000
Price of equipment - teeth	3 920	3 772
Total Purchase Cost	**49 920**	**37 772**

Table 2. Annual Operating Costs

Type of Mulcher	AHWI FM 600 profi	Seppi m_Midifrost dt 250
Annual Operating Costs	eur	eur
1x change of components	3 920	3 772
Change of Belts	900	900
Change of Bearings	600	600
Cost of Diesel Oil (for 200 days of operating)	27 534	27 534
Cost of Lubricant	550	480
Renovation of Tools	500	500
Annual Depreciation of Equipment	9 200	6 800
Total Yearly Operating Expenses	**43 204**	**40 586**

An initial analysis shows that the annual operating costs of the equipment AHWI are 43 204 euros, they are hence higher than the annual operating costs Seppi equipment (40 586 euros). However, the data are incomplete and will be updated. Identification of other costs required for calculation of LCC will be subject of another research. It is primarily the cost of employee's work who performs specific maintenance and repair activities. The aim of the research is to implement methods for increasing the life-cycle of working components of mulchers, to implement these tools, and monitor their life-span. After determining the life-cycle of updated equipment and after determining the cost of the update (hardening and drawing, teeth from sintered carbide), we will be able to compare costs of their use with costs of LCC of the original equipment.

5 CONCLUSION

The article highlighted importance of product life-cycle cost analysis in general and concrete terms specified LCC for mechanisms used in forestry, exactly mulchers of undesirable growth. Our goal was to collect relevant data and to perform initial analysis for economic evaluation of life-cycle costs of a process to increase a life-cycle of analysed machines by applying innovative materials.

Based on information presented in Chapter 3 a 4 we complete following recommendations for users as regards the LCC processing:

1. Analysis of the organization in terms of financial flows.
2. Collection of relevant data.
3. Cost specification of analyzed items.
4. Comparison of the data for several kinds of analyzed devices.
5. Presentation of findings and conclusions for users.

In our following research, we would like to continue in our analysis of life-cycle costs by identification of other costs required for calculation (f. e. else operating costs).

Success of cost analysis of a product life-cycle depends on access to appropriate data related to a wide range of areas and activities that affect a product's life-cycle. These are for example data related to product design, product development, pre-production activities, product's use, maintenance, recycling and liquidation. Companies usually possess vast amounts of data about product costs; however their use for LCC analysis can be problematic. Majority of cases, companies do not possess necessary volume of information, information is not relevant or appropriate for solving a specific problem, and it does not encompass enough areas of phases.

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