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The maintenance Cost Allocation in Product Life Cycle

Rūta Lapašinskaitė, Vytautas Boguslauskas

Kauno technologijos universitetas
K. Donelaičio g. 73, LT-44029, Kaunas

This article describes the concept by the customer view of the consuming life cycle. Because the purchase price the customer pays is equal to the cost of the producer plus value added, the life cycle costs of the customer perspective will most often be complete. The article focuses on the customer's perspective to the lifecycle costs and not so much on the product life cycle.

There are developed four main different ways of performing LCC depending on the amount of resources available, the time available, the degree of accuracy and other aspects. This study utilizes a combination of product life cycle analysis, advanced modern costing methods and regression data analysis processing for the product maintenance costs calculations in its life cycle. The combination is necessary for solving the research task; life cycle costs analysis considers only product maintenance costs in this article. In this article we use life time as a cost driver helping us to allocate the maintenance costs between different trucks in their different life time.

This study presents the evaluation of the regression functions, describes its elements, illustrates the comparison and chooses the best. The elasticity analysis presenting the percent of the maintenance costs change if time has changed 1 %, is also used. The life cycle curve's estimation shows that the longer exploitation period is, the bigger maintenance costs are. This can help to make a decision about the further exploitation of the truck during its valuable life cycle and after it. It is the main purpose why life cycle costing system was created and developed, using non traditional life cycle costing curve estimation.

After the regression-correlation and elasticity analysis between trucks' maintenance costs and the time of its exploitation, it is clear that the exponential correlation exists between them because correlation and determination as well as elasticity rates are the biggest in this model. At the end of the article it is calculated at what point of time the direct regression curve breaks exponent regression curve. The break even means the point where companies should use exponential regression formula for allocating maintenance costs to different trucks in order to get the most exact result for cost management. The procedure is demonstrated according to one of the iteration methods – string method. The main aspect of this method is that the chosen interval should be isolating and it should meet all the requirements for isolating interval: 1. Function changes its sign in the interval; 2. The first derivative function does not change its sign in the interval; 3. The second derivative function does not change its sign in the interval. The calculation manifests that the break even exists and is equal 6.15568 periods for Mercedes Benz trucks in the real transport company.

Keywords: *Life cycle costing, product life cycle, regression analysis, iteration method, string method.*

Introduction

The earliest reference to S-shaped curve similar to product life cycle was detected in 1922-23 by Prescott, who proposed an equation that fits the growth of the automotive industry from 1900 to 1920 very well. The product life cycle concept is almost certainly one of the best-known if not most important concepts in marketing. Product life cycle is almost an inexhaustible concept because it touches on nearly every facet of marketing and drives many elements of corporate strategy, finance and production.

These statements are excerpts from Gardner's literature review of about 130 references. Gardner summarizes his findings by concluding that there is much agreement among the writers concerning the life cycle concept as a descriptive variable, but it does not fulfill the criteria of being a theory. At the end of his review, Gardner suggests that "future work should be tied, not only to increase our understanding of the phenomenon, but also increase our predictive ability." (Gardner, 1987).

Uusi-Rauva *et al.* define life cycle as "the period of a product in the market". This interpretation emphasizes the marketing point of view and revenue planning, but excludes the impacts of product creation and disposal for life cycle profitability. *Life cycle analysis* should consider the period between birth and decease. Even the definition of CAM-I excludes the period between withdrawal from the market and decease. "The period that starts with the initial product specification and ends with the withdrawal of the product from the marketplace. A product life cycle is characterized by certain defined stages, including research, development, introduction, maturity, decline and abandonment." (Lasse, 2001).

The interpretation of the term life cycle differs from decision maker to decision maker, as it is evident from the literature. A marketing executive will most likely think in terms of the marketing perspective, which consists of at least four stages (Adamany & Gonsalves, 1997):

1. Introduction
2. Growth
3. Maturity
4. Decline.

A manufacturer will think in terms of the production perspective, which can be described using five main stages or processes:

1. Product conception
2. Design

3. Product and process development
4. Production
5. Logistics.

When the product has reached the customer, user or consumer, a different perspective occurs: the customer perspective. This perspective often includes five stages or processes:

1. Purchase;
2. Operating;
3. Support;
4. Maintenance;
5. Disposal.

Burstein (1988) points out that life cycle costing becomes more and more crucial when the technology changes rapidly and the product life cycles become shorter. In addition, he enhances the concept by the customer view of the consuming life cycle. The idea presented in Figure 1 applies especially to durable goods, such as cars.

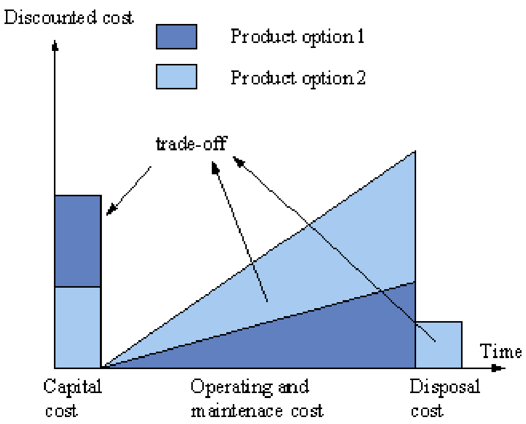

Figure 1. The customer's perspective to life cycle costs (Burstein 1988)

Because the purchase price the customer pays is equal to the cost of the producer plus value added, the life cycle costs of the customer perspective will most often be complete (Day, 1981).

Finally, we have the most comprehensive perspective, namely that of the product itself. The product life cycle is essentially all the activities that the product, or parts of the product, undergo regardless of which decision makers are involved. It may involve the proceeding perspectives except one: the marketing perspective (Bian, 1974). The reason is that the product life cycle is on the individual level of each product unit, whereas the marketing perspective is on the type level of the product (Levitt, 1965).

This article focuses on the customer's perspective to the lifecycle costs. In any case two genuinely unique life cycles exist: one on the individual product level (the product life cycle) and one on the product type level (the market life cycle).

The literature also makes an important distinction between product's *life cycle costs* and its *whole life costs*. Life cycle costs refer to all the costs that the producer will incur and whole life cycle costs also include the costs that consumers incur, i.e. installation, operation, maintenance, revitalization and disposal. (Shields & Young 1991).

What is life cycle cost? Some of the better definitions are (Emblemsvag, 1999):

- The sum total of the direct, indirect, recurring, non-recurring, and other related cost incurred, or estimated to be insured, in the design, development, production, operation, maintenance, and support of a major system over its anticipated useful life span.
- The amortized annual cost of a product, including capital costs, installation costs, operating costs, maintenance costs, and disposal costs discounted over the lifetime of a product.
- The total cost throughout its (an asset's) life, including planning, design, acquisition and support costs, and any other costs, directly attributable to owing or using the asset.

In this article the life cycle cost of a product is defined as "maintenance costs".

The life cycle concept is also recommended by Barksdale & Harris to optimize the allocation of resources and guide strategic decisions of business units in multi product companies. They consider this important while the concept recognizes the life span of products and emphasizes the changes of opportunities associated with different stages of growth (Barksdale & Harris 1982).

The purpose of this article is to find the break even where the direct regression curve breaks the regression curve describing relations between maintenance costs and time, as cost driver, the most exactly.

The object is maintenance costs in the truck's life cycle.

The method used in this article is one of the iteration methods – string method.

Four ways of LCC

As most concepts, LCC has evolved over time, and today LCC serves three main purposes (Barringer & Weber, 1996):

1. LCC can be an effective engineering tool for providing decision support in the design and procurement of major open systems, infrastructure, and so on. This way it is the original intent for which it was developed. It was soon realized that it is better to eliminate costs before they are incurred instead of trying to cut costs after they are incurred.
2. LCC overcomes many of the shortcomings of traditional cost accounting and can therefore give useful cost insights in cost accounting and management.
3. LCC has remerged as a design and engineering tool for environmental purposes.

Depending on the amount of resources available, the time available, the degree of accuracy, and other factors such as data availability, four main different ways of performing LCC exist: analogy, parametric, engineering cost methods, and cost accounting (Fuller & Petersen, 1996). The different ways suspect to different advantages and disadvantages (Emblemsvag, 2004).

✓ Analogy Models

An LCC estimate made by an analogy identifies a similar product or component and adjusts its costs for differences between it and the target product. This way of conducting LCC is common in shipbuilding, for example, where mass is the factor they relate costs to.

This way of handling costs may sound crude. It says nothing about direct labor or overhead costs. It simply looks at what the costs have been historically and scales them according to the most important cost driver, which in shipbuilding is mass. Such methods can serve well when extensive historical material is available, the products are produced unit by unit, one dominant cost driver is used, and the products do not differ much (such as in size, technology, use patterns, and operational characteristics). To ensure the relevance of historical data, it is vital that the products do not change much. Thus, such method has limited usage.

✓ Parametric Models

Parametric models are in many ways more advanced analogy models. A parametric LCC model is based on predicting a product's or a component's cost either in total or for various activities by using several models describing the relationships between costs and some product- or process-related parameters. The predicting variables typically include:

- Manufacturing complexity
- Design familiarity
- Mass
- Performance
- Schedule compression.

Compared to the analogy models, three main differences exist. First, an analogy model depends on one single, dominant cost driver, whereas a parametric model can use several parameters. Second, an analogy model is based in linear relationships between costs and cost drivers, while parametric models rely only on one or more nonlinear regression models. Third, whereas analogy model uses an analogy (such as mass) as a driver, parametric models are essentially regressions, or response surface. Model can be linear, quadratic, multidimensional and so on.

Like the analogy models, parametric models do not handle overhead costs in a credible fashion, nor do they go beyond simply presenting an assessment number without any further insight, except what is a direct consequence of their parameters. It is clear that parametric models are easy to use in optimization algorithms.

Since parametric models can offer more insight and higher accuracy than analogy models, they are often found in the engineering literature. A parametric model can also perform well as models within accost accounting system, preferably one that can handle overhead costs well, such as Activity Based Costing.

✓ Engineering Cost Models

According to the New South Wales Government Asset Management Committee in Australia, The engineering Cost method is used where there is detailed and accurate capital and operational cost data for the asset. It involves the direct estimation of a particular cost element by examining the asset component-by component. It uses standard established cost factors to develop the cost for each element and its relationships to other elements.

Numerous methods in literature probably mix three before mentioned methods. None of these approaches handles overhead costs correctly because none captures the complexity of modern organizations, and many of them include only simple mathematical manipulations of already identified costs. These costs estimates that are taken as input are probably generated by traditional cost accounting systems and are therefore likely to be distorted.

Engineering cost models although offering much more insight than analogy and parametric models are therefore also limited in usage. But they are useful in engineering and development situations to give an early cost estimate.

As information becomes more and more available, the next type of models is preferable: cost accounting models.

✓ Cost Accounting Models

The literature contains numerous cost accounting models and system. Here these systems are grouped into three groups for simplicity:

- Volume-based costing systems
- Unconventional costing methods
- Modern cost management systems.

Some of the most important cost accounting approaches are briefly discussed below.

Volume base costing systems are often referred to both as conventional costing systems and traditional costing systems; an example is standard costing. These costing systems have the well known limitations of using only direct labor as an allocation base. So volume based costing systems are not attractive under any circumstances for Life cycle costing purposes because they perform too poorly.

Unconventional Costing Methods are quite different from most cost management approaches or not popular. The first is called Attribute-Based-Costing, which is a development of ABC and hence is simply denoted ABCII. The purpose is to provide a detailed cost-benefit analysis of customer needs aimed at providing effectiveness. ABCII appears to be hybrid between ABC, Target costing and Quality Function Deployment (QFD) (Walker, 1992). QFD brings in a lot of subjectivity and caution is advised, which probably explains why such an interesting idea has received so little attention in the literature.

The second unconventional costing method is Feature Costing (FC). In FC the product features are the focal point. FC can be an improvement over ABC in that it leads to a more direct reduction of costs and an improvement of performance. Nonetheless, how FC is an improvement over ABC in general cases is unclear.

Modern cost management systems will not be discussed in this article. One of the few management inventions that actually have its roots in industry and that is interesting itself is Activity Based Costing (ABC). Although ABC has great potential for use in all companies, it is important to implement it step by step to ensure efficient organizational learning (Kaplan, 1998). Using ABC for LCC purposes does not raise the risk of integrated ABM systems because LCC is ad hoc in nature, at least for the time being (Shank & Dudy, 1997). Activity-Based LCC is a sound next step up from traditional LCC and the hindsight of cost management in general (Maccarone, 1998).

Life cycle analysis together with modern cost accounting systems can help to correct lots of problems of the traditional cost accounting systems, and that's why it can be useful for cost accounting and management.

In this article we use life time as a cost driver what can help us to allocate the maintenance costs between different trucks in their different life time.

The comparison of regression models

After we have defined the activities with the most resources and attributed the cost drivers for them we still do not know how to allocate the costs for different trucks in the different trucks' groups because the exploitation time of the trucks' is not the same. During the exploitation of the truck the costs are growing all the time. That's why we can not divide the maintenance costs to trucks in the same group in equal parts. We are going to solve this problem with the help of life cycle concept.

The calculated life cycle cost curve should show how the maintenance costs are growing when the exploitation period is increasing. This dependence should help to make a decision about the usage of the trucks during the exploitation time and after it.

The calculation of the maintenance cost curve in the truck's life cycle, the determination of the functions was made with computer program "Statistica".

The regression and correlation analysis is used for research of random dependence upon expressions having no strict functional character. The regression and correlation theory, as one of the main mathematical-statistical science areas, gives opportunities:

- To express the connection and the form of the economic expression quantitatively
- To determine the influence over the factors operating the same index at the same time.

The elasticity analysis shows the percent at which the maintenance costs change if time has changed 1 %,.

The result is given in the Table.

Table

The regression models analysis

	Direct regression model		Gradual regression model		Index regression model		Exponential regression model	
Formula	costs=335.771+ +212.9882x time		costs=304.1361x $xtime^{0.9803}$		costs=595.1204x $x1.17978^{time}$		costs=595.1206x $xe^{0.165358 \times time}$	
	D	ε=bx/y	D	ε=b	D	ε=lnbxX	D	ε=EXP(bxX)
ranges	0.2236	0.89946	0,.81297	0.9803	0.8368	2.5167	0,8368	5.6761

After the regression-correlation and elasticity analysis between trucks' maintenance costs and the time of its exploitation, it is clear that the exponential correlation exists between them because correlation and determination and elasticity rates are the biggest of this model. So we can come to the conclusion that the life cycle curve differs from the traditional curve, and we can draw it as in Figure2.

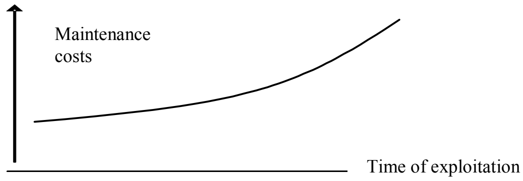

Figure 2. The truck's maintenance costs curve in product's life cycle

The life cycle curve's estimation shows that the longer exploitation period is, the bigger maintenance costs are. This can help us to make a decision about the further exploitation of the truck during its valuable life cycle and after it. It is the main purpose why life cycle costing system was created and developed, using non traditional life cycle costing curve estimation.

The break even analysis

Because the exponential dependence discover maintenance costs state in product's life cycle the most exactly, and companies use linear dependence usually, this article describes the analytical calculation of break even where linear regression curve breaks the exponential regression curve :

$$a + bx - c\mathrm{e}^{\mathrm{dx}} = \Delta \qquad (1)$$

In Figure 3 you can see the graphical view of maintenance costs of trucks Mercedes Benz break even in real transport company.

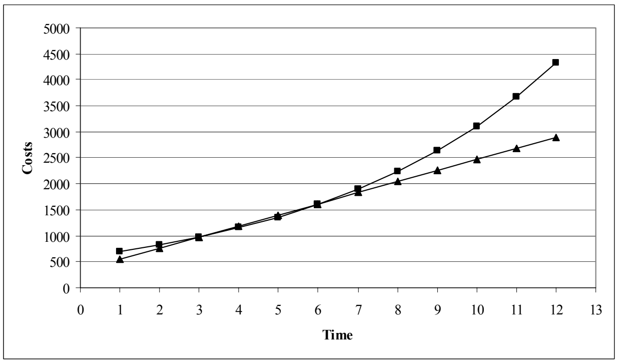

Figure 3. Maintenance costs break even for Mercedes Benz trucks

The break even means the point where companies should use exponential regression formula for allocating maintenance costs to different trucks in order to get the most exactly result for cost management.

We will find the break point where the line $y = a + bx$ breaks curve $y = ce^{dx}$, with the help of one iteration solution method for nonlinear equation – string method. We will find roots with accurate ε=0, 000001.

We have the equation $a + bx - c\mathrm{e}^{\mathrm{dx}}$ =Δ, where a, b, c, d, Δ are the real figures.

We change the equation in a comfortable forma:

$a + bx - \Delta = c\mathrm{e}^{\mathrm{dx}}$, divided by c≠0 (if c is never equal zero).

Here $a - \Delta = u$;

$$\frac{bx}{c} + \frac{u}{c} = e^{dx}$$

We mark $\frac{b}{c} = a1$; $\frac{u}{c} = b1$;

Then $a1x + b1 = e^{dx}$

Let's say, the parameters a, b, c, d and Δ are equal:

$a := 335.771$
$b := 212.9882$
$c := 595.1206$

$d := 0.165358$
$\Delta := 0.000001$

Then $u := a - \Delta = 335.771$

$$\text{a1} := \frac{b}{c} = \frac{212.9882}{595.1206} = 0.3579$$

$$b1 := \frac{u}{c} = \frac{335.771}{595.1206} = 0.56421$$

We divide the given equation into two functions:

$$f(x) := a1x + b1 \quad (2)$$
$$f(x) \to 0.3579x + 0.56421$$
$$g(x) := e^{dx} \quad (3)$$
$$g(x) \to \exp(0.165358x)$$
$$F(x) := a + bx - ce^{dx} - \Delta \quad (4)$$

Then we draw the graph of the given functions:

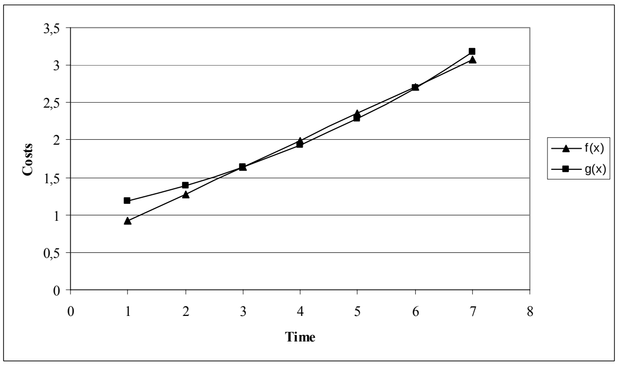

Figure 4. Maintenance costs graph in the product's life cycle

We choose the interval [3; 7], where one function breaks the over function.

f(3)	-2.657799668
f(4)	34.58898933
f(5)	40.23476323
f(6)	8.597172302
f(7)	-67.02790724

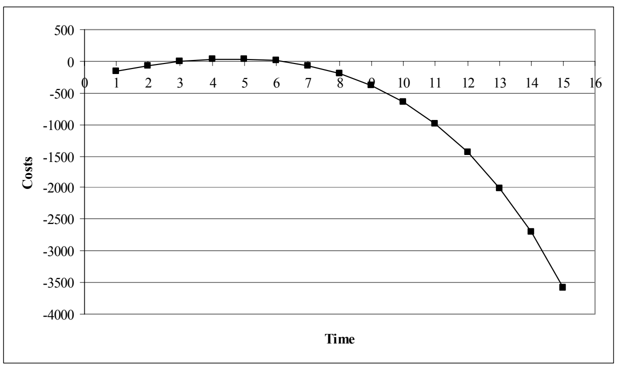

Figure 5. Function (4) graph in the chosen interval

We can see from Figure 5 that the given function changes its sign in it.

We check if our chosen interval [3; 7] is isolation. That's why we analyze the first (5) and the second (6) derivatives.

$$f1(x) := \frac{d}{dx} f(x) \quad (5)$$

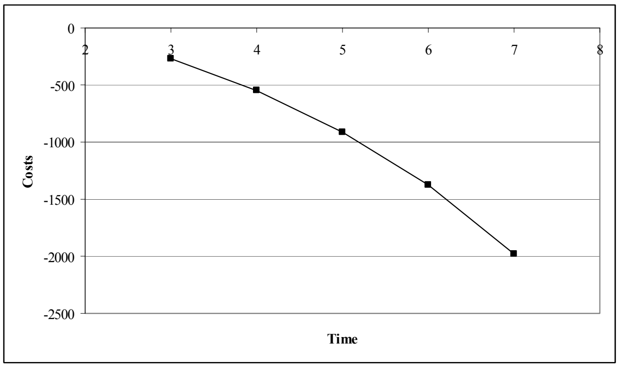

Figure 6. The first derivative graph

From the Figure 6 we can see that our function does not change its sign.

$$f2(x) = \frac{d^2}{dx^2} f(x) \quad (6)$$

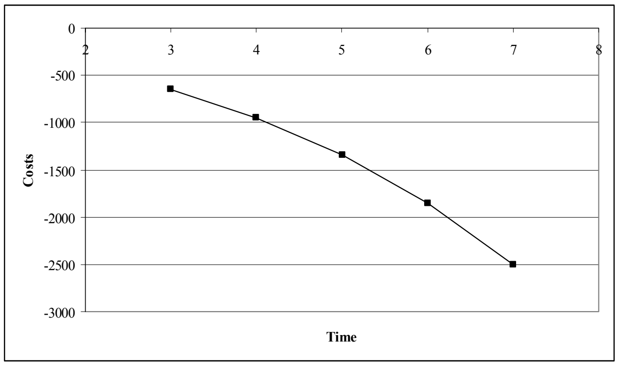

Figure 7. The second derivative graph

From Figure 7 we can also see that our function does not change its sign.

We can see that our chosen interval [3; 7] is not isolative because it does not meet all the requirements for isolative interval (Kvedaras & Sapagovas, 1974):

1. Function changes its sign in the interval
2. The first derivative function does not change its sign in the interval
3. The second derivative function does not change its sign in the interval.

The interval [6; 7] meets all the conditions for isolative interval and we will further analyze this interval.

We will find the constant end of the interval [6; 7]: it is where the second derivative sign is equal to the function sign in the end of interval.

The second derivative of the function is negative in the whole interval, the function is negative in the point x=6, so the constant point is x=6.

$x\_const := a\_pr$
$x0 := b\_gl$
$a\_pr := 6$
$b\_gl := 7$

We calculate proximities according to the formula:

$$x(n+1) = x(n) - \frac{f(x,n)}{f(x\_const) - f(x,n)}(x\_const - x(n)) \quad (7)$$

$$f(x) \to 335.771 + 212.9882x - 595.1206e^{0.165358} - \Delta \quad (8)$$

We need to know the module minimum of the first derivative function for error of calculations:

$$m := \left| f1(x0) \right| \quad (9)$$

$$m = 1379.461951$$

We use the formula of the string method till we get the wanted error of calculation ε=0.000001

$$\left| \text{xn} \leftarrow \text{x0} \right. \quad (10)$$

$$\text{xx:} = \left| \text{while } \frac{|f(xn)|}{m} > \varepsilon \right.$$

$$\left| \text{xn} \leftarrow x(n) - \frac{f(x,n)}{f(x\_const) - f(x,n)}(x\_const - x(n)) \right.$$

$$\text{xx:} = 6{,}15568$$

We have got the answer: x= 6.15568±0.000001

We check the answer with the help of MathCAD functions:

$$f(x)solve, x \to 6.1556857531937244159$$

$$k := 1 \quad root(f(k), k) = 6.15568$$

From this we can say that the break even exists and is equal 6.15568 periods for Mercedes Benz trucks in the real transport company.

Conclusions

The following conclusions may be drawn:

1. After the regression-correlation and elasticity analysis between trucks' maintenance costs and the time of its exploitation, it is clear that the exponential correlation exists between them.
2. The life cycle curve's estimation shows that the longer exploitation period is, the bigger maintenance costs are. This can help us to make a decision about the further exploitation of the truck during its valuable life cycle and after it.
3. The break even between exponential and usually used linear dependence means the usage time when companies should use exponential regression formula for allocating maintenance costs to different trucks in order to get the most exactly result for cost management.
4. The break point can be found with the help of one iteration solution method for nonlinear equation – string method. It means that function has one answer in the given interval if it meets 3 requirements for isolative interval.

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Rūta Lapašinskaitė, Vytautas Boguslauskas

Remonto išlaidų paskirstymas produkto gyvavimo cikle

Santrauka

Literatūroje susiduriama su skirtingais termino „gyvavimo ciklas“ apibrėžimais. Prekybininkai gyvavimo ciklo stadijas vertina prekybiniu požiūriu, gamybininkams svarbesni produkcijos gamybos aspektai, produktui pasiekus vartotoją, toliau žvelgiama į gyvavimo ciklą vartotojų požiūriu. Tiksliausias ir išsamiausias požiūris į gyvavimo ciklą vadinamas produkto gyvavimo ciklu. Jis apima esminius visų veiklų, kurias produktas ar jo dalys pereina gamyboje ar eksploatacijos laikotarpiu, kaštus. Gyvavimo ciklo vertinimas yra metodas, padedantis numatyti būsimus kaštus bei skaičiuoti gyvavimo ciklo kaštus specifiniams produktams.

Kaip ir dauguma koncepcijų, gyvavimo ciklo vertinimas ilgainiui vystėsi ir dabar apima tris pagrindinius tikslus:

1. Gyvavimo ciklo vertinimas gali būti efektyvus projektavimo įrankis sprendimams priimti, produkcijai kurti, tiekimui organizuoti, infrastruktūrai plėtoti ir pan. Tai pagrindinis tikslas, dėl kurio gyvavimo ciklo vertinimo sistema buvo sukurta.
2. Gyvavimo ciklo vertinimas ištaiso daugybę tradicinių kaštų apskaitos sistemų trūkumų ir dėl to gali suteikti naudos kaštų apskaitai ir valdymui.
3. Gyvavimo kaštų vertinimas iškilo kaip tikslų siekimo produkto projektavime ir plėtojime įrankis.

Straipsnio tikslas yra surasti tašką, kuriame tiesinės regresijos kreivė kerta eksponentinės regresijos kreivę, tiksliausiai įvertinančią remonto kaštų ir laiko kaip išlaidų paskirstymo vieneto, santykį.

Tyrimo objektas yra vilkiko remonto kaštai jo gyvavimo cikle.

Straipsnyje naudotas tyrimo **metodas** yra vienas iš iteracinių metodų – stygų metodas.

Priklausomai nuo turimų išteklių, turimo laiko ir kitų veiksnių, tokių kaip duomenų prieinamumas, apimtis, išskiriami keturi skirtingi būdai atlikti gyvavimo ciklo vertinimą:

- ✓ analoginis,
- ✓ parametrinis,
- ✓ kaštų inžinerijos metodas,
- ✓ kaštų apskaita.

Visi šie modeliai turi savų privalumų ir trūkumų.

Gyvavimo ciklo kaštų įvertinimas pagal analogijos modelį pritaiko panašaus produkto ar komponentų kaštus atsižvelgiant į šių produktų skirtumus. Tačiau, norint užtikrinti pasirinktų praeities duomenų tinkamumą, produktai bėgant laikui neturėtų labai keistis. Taigi tokių modelių taikymas yra labai ribotas.

Parametrinis modelis gali naudoti keletą parametrų, be to, remiasi vienu ar daugiau kreivinės regresijos modelių ir naudoja analogiją kaip kaštų veiksnį, Kadangi parametriniai modeliai gali pasiūlyti didesnį tikslumą už analoginius modelius, jų dažnai pasitaiko techninėje literatūroje.

Kaštų inžinerijos metodas pasirenkamas ten, kur yra išsamūs ir tikslūs kapitalo ir valdymo kaštų duomenys turtui analizuoti. Čia tiesiogiai apskaičiuojami kaštai, tikrinant kiekvieną turto detalę, taip pat pasitelkiami kaštų faktorių standartai, padedantys nustatyti kiekvieno elemento kaštus ir jų ryšį su kitais elementais.

Gamybos apimties vertinimo sistemos dėl savo silpnybių nėra tinkamos gyvavimo ciklui vertinti, o netradiciniai vertinimo metodai yra nepopuliarūs.

Iš moderniųjų žinomiausia ir plačiausiai taikoma ABC kaštų apskaitos sistema. Nors ji viena ir negali įgyvendinti visų sistemos pokyčių, tačiau, ją integravus į gyvavimo ciklo sistemą, būtų galima tiksliausiai įvertinti gyvavimo ciklo kaštus.

Nustatę daugiausia išteklių reikalaujančias veiklas bei priskyrę joms išlaidų paskirstymo vienetus, vis dar nežinome, kaip išlaidos pasidalija vilkikų grupėse atskiriems vilkikams, nes jų eksploatacijos laikas nevienodas. Eksploatuojamo vilkiko reikalingų išteklių skaičius nuolatos auga. Taigi negalime vilkikų grupėse sugeneruotų sąnaudų išdalyti vienodomis dalimis atskiriems vilkikams. Iškilusią problemą apibūdina gyvavimo ciklo sąvoka. Produkto gyvavimo ciklas apima esmines visų veiklų, kurias produktas patiria eksploatacijos laikotarpiu, išlaidas.

Apskaičiuota gyvavimo ciklo kaštų kreivė parodo, kaip didėjant eksploatacijos laikotarpiui auga eksploatacijos sąnaudos vilkiko gyvavimo cikle. Ši priklausomybė gali padėti priimti sprendimą dėl tolimesnio vilkikų naudojimo per jų eksploatacijos laikotarpį ir jam pasibaigus. Tai pagrindinis tikslas, dėl kurio gyvavimo ciklo vertinimo sistema buvo sukurta ir toliau vertinama, pasitelkus netradicinį gyvavimo ciklo kaštų kreivės vertinimą.

Remonto sąnaudų kreivės vilkikų gyvavimo cikle skaičiavimai, funkcijų nustatymas ir grafikų braižymas buvo atliekama su kompiuterine programa „Statistika“.

Remiantis atliktos vilkikų remonto sąnaudų priklausomybės nuo vilkikų eksploatacijos laiko koreliacinės-regresinės analizės rezultatais, sąnaudų daliai, tenkančiai kiekvienam vilkikui, nustatyti buvo panaudota eksponentinė priklausomybė, nes šio modelio koreliacijos ir determinacijos koeficientai bei elastingumo koeficientas yra didžiausi. Tai rodo, kad pasirinktas regresinis modelis tinka eksperimentiniams duomenims, ir yra reikšmingas koreliacinis ryšys tarp vilkikų eksploatacijos laiko ir remonto išlaidų.

Norėdami nustatyti sąnaudų dalį, tenkančią kiekvienam vilkikui, naudosime eksponentinio regresijos modelio eksploatacijos laiko ir išlaidų priklausomybės lygtį:

$$Išlaidos = 595{,}1206 \cdot e^{0{,}165358 \, laikas}$$

Taigi galima padaryti išvadą, kad gyvavimo ciklo kaštų kreivė skiriasi nuo tradicinių.

Kaštų kreivės gyvavimo cikle vertinimas parodo, kad didėjant eksploatacijos laikotarpiui gyvavimo ciklo kaštai auga, ir tai gali padėti priimti sprendimą dėl tolimesnio vilkikų naudojimo per jų eksploatacijos laikotarpį ir jam pasibaigus. Gyvavimo ciklo vertinimas kartu su moderniosiomis kaštų apskaitos sistemomis gali padėti ištaisyti daugybę tradicinių sistemų trūkumų ir dėl to gali suteikti naudos kaštų apskaitai ir valdymui.

Kadangi eksponentinės regresijos kreivė remonto kaštus produkto gyvavimo cikle įvertina tiksliausiai, o kompanijos dažniausiai naudoja tiesinės regresijos kreivę, šiame straipsnyje aprašomas analitinis lūžio taško, kuriame eksponentinė kreivė kerta tiesinės regresijos kreivę, apskaičiavimas:

$$a + bx - c\mathrm{e}^{\mathrm{d}x} = \Delta$$

Lūžio taškas reiškia tašką, kuriame kompanijos turėtų rinktis eksponentinės regresijos formulę kaštams paskirstyti tarp skirtingų vilkikų, kad galėtų gauti kuo tikslesnį rezultatą kaštų valdymui.

Lūžio taškas buvo apskaičiuojamas vienu iš iteracinių sprendimo metodu – stygų metodu. Šio metodo esmė ta, kad lygčių sistema turi sprendinį pasirinktame intervale, jeigu tenkina visas tris izoliacinio intervalo sąlygas:

1. Funkcija keičia ženklą šiame intervale;
2. Pirmoji funkcijos išvestinė nekeičia ženklo šiame intervale;
3. Antroji funkcijos išvestinė taip pat nekeičia ženklo šiame intervale.

Apskaičiavimai buvo atliekami ε=0, 000001 tikslumu. Apskaičiavus intervalą, kuris tenkina visas tris izoliacinio intervalo sąlygas, apskaičiavus artinius ir nustačius išvestinės modulio minimumą, buvo gautas lūžio taškas. Šis taškas buvo patikrintas, pasitelkus MathCAD funkcijas.

Iš šio rezultato galima teigti, kad lūžio taškas egzistuoja ir yra lygus 6,15568 periodams Mercedes Benz markės vilkikams realioje transporto kompanijoje.

Raktažodžiai: *gyvavimo ciklo kaštai, produkto gyvavimo ciklas, regresinė analizė, iteracijos metodai, stygų metodas.*

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