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Effective data usage for the proper and beneficial automotive production cost improvement

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ABSTRACT

Purpose: The article aims to present a proposal and discuss the investment cost calculation procedures based on data collected during the manufacturing process, according to standard SPC control chart evaluation and standard PDCA. It is applied as a tool to support the process of continuous improvement of the manufacturing process and improve profitability by proper allocation the cost of investment and resources.

Design/methodology/approach: The study uses the results of a literature review on the issue of cost analysis and their modelling. Key elements are the main cost components, but also those that are considered less important and maybe overall decisive. Application cost to benefit relations – as a method of data evaluation for cost modelling to improve overall cost structure is proposed.

Findings: The relationship between return on investment and amortisation time allows to easily visualise which of the proposed changes are the most cost-effective over time. Based on the analysis conducted the results, the change is proposed below, in order from the most cost-effective.

Research limitations/implications: Further research should focus on the impact if a decision were based on the findings and proposals defined.

Practical implications: Each production process is based on the use of resources. This applies to both production plants and other activities. A resource can be anything that will be used in the manufacturing process. Of key importance for the success of the project is their proper use and not only effective but most of all efficient.

Originality/value: The considerations presented in the study may be the basis for determining the key factors of the cost of production and investment. The proposed simulation model allows for determining the efficient direction for investment. This, in turn, should enable us to define the main directions of searching for the optimisation of the product cost to achieve the expected cost and quality level.

Keywords: Cost calculation, Cost modelling, Manufacturing costs, Control chart, Quality costs, Statistical Process Control (SPC)

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INDUSTRIAL MANAGEMENT AND ORGANISATION

1. Introduction

Mass production of automotive products has characteristics that must be controlled. They are often called key or critical characteristics. They are of key importance for the correct operation of the mechanisms to which they will be mounted or for the safety of usage. These can be measurements of distance, diameter, roughness, etc. It is carried out by control during production and by using control cards used to record the measurement results, and we record them. There are multiple control charts to keep track of the results, and with real-time analytics, the operator can make process adjustments to ensure the processes meet expectations. If it is possible to introduce the Industry 4.0 approach, it is also possible to follow them in real-time, and if we apply a feedback mechanism, we could adjust process parameters based on characteristics read in real-time [1,2]. Their practical usage is presented in many publications where the method of data collection based on Statistical Process Control "SPC" cards is discussed in detail. However, several methods will be presented on effectively processing and using the collected data to transparently present the results of the analyses performed [3-5].

As shown, the cost modelling process is crucial at every stage of the product's production life. The first analysis should be made at the very beginning when the company assesses whether joining a tender for a specific production segment can be profitable for it. Further verifications are made when the production of the product is underway, and we are looking for areas to reduce costs. Efficient cost modelling can be supported by data collected during production processes. Example of data possible to collect efficient usage [6-8]:

- analysis of waste sources,
- changeover analysis,
- failure analysis,
- verification of downtime in the production process,
- any other analysis that allows to figure out the indicator or factor affecting the cost of the product.

This allows a proper selection of cost factors and an indication of those that can be most effectively improved to achieve the expected state. That is, depending on the needs: unit cost reduction, production process efficiency or quality change. Most often, it is dictated by customer orders. Depending on the needs and expectations of the market, to keep up with the requirements, companies must adapt to the requirements and expectations of the customer.

Another tool used effectively is the Deming cycle PDCA (Fig. 1):

- Plan – plan each activity,
- Do – do, conduct, do the planned action,
- Check – analyse the impact of the implemented, previously planned change,
- Act – if you see the benefits of the planned change – try to implement it as a new standard.

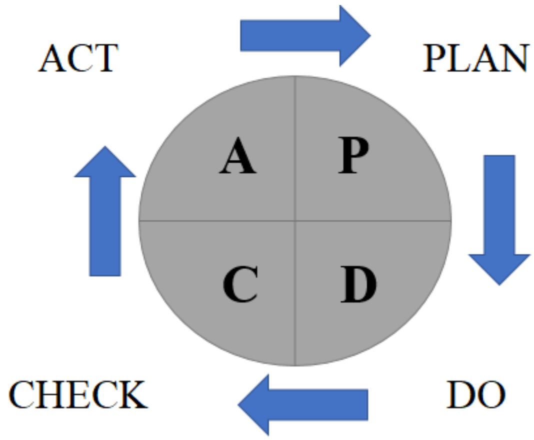

Fig. 1. Cycle PDCA [9]

The Deming cycle process is extremely helpful in all kinds of activities related to the search for room for improvement. Also recommended to use in cost analysis is particularly useful and effective. The first step in PDCA analysis is the data collection process. Properly processed, they allow you to present potential action directions and plan their implementation. Collecting data from the initial state and analysing them allows the selection of the most desirable and those that will bring the most expected improvements, regardless of whether we are dealing with a new product or a process of continuous improvement of an existing process [9,10].

If introduced to the action phase, a well-planned implementation gives a chance to achieve the expected result. In the implementation phase, the result will only confirm that the desirability of the planned activities is correctly defined. If what we have planned brings benefits, we have no choice but to implement the change as a new standard and look for further elements to improve.

After collecting all the key information about the production process, we must initiate an analysed data process. Before we start such an analysis, there is a task, question or need, i.e., a goal. Depending on the direction of the analysis, we can freely choose the right tools as well as measurement and assessment units. Regarding costs, it is possible to carry out a cost-to-benefit analysis. We could use

Olsen's approach, described in “The Lean product playbook: how to innovate with minimum viable products and rapid customer feedback”. But we must adjust the chart – “the importance versus satisfaction framework” to our needs, which means saving to cost relation (Fig. 2) [11].

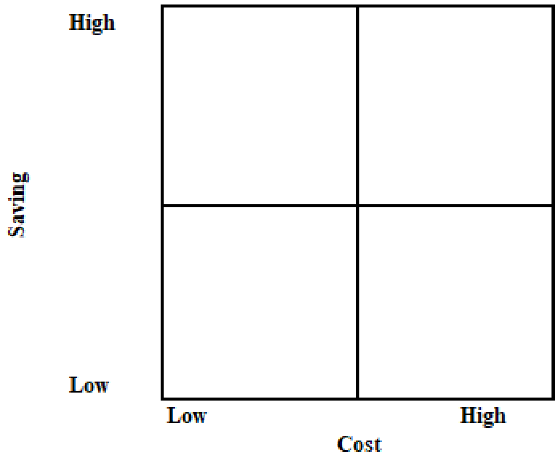

Fig. 2. Cost to benefit relations [11]

Or the second proposal adopt payback evaluation, which means: Annual Return on Investment to Amortization Time (Fig. 3).

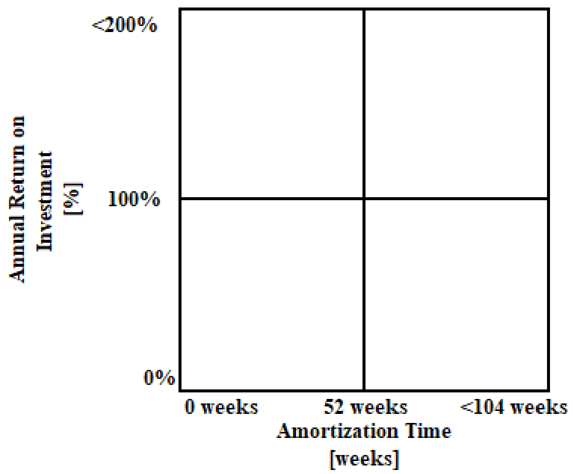

Fig. 3. Annual Return on Investment to Amortization Time [11]

Referring to the cost-to-benefit relationship gives an exceptionally good and simple method of showing the relationship between these two values. But it also allows you to show these relationships for different solutions under the same conditions. This is immensely helpful in convincing the management board to the direction of development or directions to achieve improvement.

The graphical presentation does not have to be just about costs, but it will be very useful for commissioned analysis. For example, in evaluating process efficiency development: capital expenditure in relation to maximum production capacity is most often given in relation to a unit of time, e.g. number of parts per hour. Improving the throughput of production processes, automation, inter-operational transport, etc.

In theory, the most desirable proposals will be those where the input cost is low and the benefit increase is high. Presenting these relationships in the form of a graph allows you to determine the relationship between cost and benefit quickly. After making all possible dependencies, you can proceed to the selection of the most effective one. In addition, a meeting is most often organised to figure out the method of meeting the need. Using analyses and visualisations of the actual state and confronting them with development proposals, we can indicate the possible scenarios of meeting them are and what costs must be incurred to meet them. How the analysed change will affect other processes, what threats may occur, and what are new opportunities for improvement? It is most important that at the end of this analysis, there is information about the cost needed, what is incurred to introduce the change/need and what benefits it can bring. Ideally, this benefit can be expressed as a sum, regardless of whether the result is a reduction in the cost of the product, reduction of capital used for production, reduction of employment, reduction of product weight, shortening of cycle time, reduction of product quality, reduction of production capacity or process change. Any arbitrary change should be presented in the form of a difference in the cost of production. Most often, such a numerical value with a currency symbol is reported as saving [11-13].

2. Methodology, materials and experiments

Using the relationship between the return on investment and the depreciation time allows for a highly effective and quick visualisation of the investment-to-cost ratio. Below are three exemplary and at the same time, effective indicators to determine the profitability of a given project:

1) Amortization Time – usually calculated in terms of one accounting year. it can be given as a percentage, but presenting the result in weeks is more transparent. It is an investment in relation to the expected profit in a year, divided by 52. Of course, after exceeding 52 weeks, the payback time of the investment will be longer than one year (1).

$$AT = \frac{I}{\left(\frac{AS}{52}\right)} \tag{1}$$

AT – amortisation time
AS – annual savings,
52 – weeks in one year.

2) Annual Return on Investment – often given as a percentage, also in terms of one accounting year. It is defined as the ratio of the expected profit in one year to the total investment made for its implementation in one year of operation of the proposed change (2).

$$ARoI = \frac{AS}{I} * 100\% \tag{2}$$

ARoI – annual return on investment,
I – investment,
AS – annual saving.

3) Lifetime Return on Investment – most often given as a percentage, the second method for calculating the return on investment, but in terms of the entire duration of the project, i.e., several months or several years. It is defined as the ratio of the expected profit over the entire product life cycle to the total investment made for its introduction. Most often used for very costly changes, for projects whose life cycle is at least several months or even several years. And those that give great possibilities of implementation for other applications, while the duplication of the application should be associated with lower costs of implementing the copied change (3).

$$LRoI = \frac{PLS}{I} * 100\% \tag{3}$$

LRoI – lifetime return on investment,
I – investment,
PLS – project lifetime saving.

Referring to the pipe-forming process and the previously mentioned publication [14,15], an analysis of the calculation of potential savings will be presented. Referring to the Pareto-Lorenzo chart, it was proposed to address the five most common problems according to the chart, accounting for 73% of all registered rejects from production [3]. These are characteristics: Op 010 (Elbow Overall Dimension); Op 002 (Upsetting length); Op 003 (Upsetting Overall dimension); Op 011 (Elbow angle); Op 016 (Visual Defects) (Tab. 1). All these operations are performed on the technological line, the so-called „one piece flow" system. This means that all operations are performed with the same cycle time and no buffers between operations, additionally for quality reasons and technological requirements, without the possibility of repairing damaged products. This means that failure to complete the first operation, i.e., scrapping the product, will have the same value from the point of view of the entire production process as if the last operation had not been completed. This translates into the unit cost of the product, i.e., regardless of where the defect occurs, it can be assumed that the cost of the scrapped product will be the same. So, to be more precise: the cost of the material, the cost of the operation and other added costs will be the same regardless of the location of the defect and the need to scrap the product.

Table 1.
Most problematic processes based on Pareto-Lorenz, part 1

Characteristic name	What must be changed	Process #No
Elbow Overall Dimension	New forming tooling	Op010
Upsetting length	New forming module	Op002
Upsetting Overall dimension	New forming module	Op003
Elbow angle	New forming tooling	Op011
Visual Defects	Cross check Visual Standard	Op016

The selected five highest characteristics in terms of generating losses were subjected to a thorough analysis. The main goal was to propose corrective actions to eliminate or reduce the source of the problem, which is waste. A source analysis was carried out, supported by the cost modelling process. Thanks to these activities, it was possible to generate proposals for corrective actions and determine the cost of their implementation. They are presented in the table form; each operation is assigned a cost that arises because of product scrapping, at the same time, a corrective action supported by cost and adequate capital expenditure is proposed for each operation (Tab. 2).

Table 2.
Most problematic processes based on Pareto-Lorenz, part 2

Process #No	Op010	Op002	Op003	Op011	Op016
Scrap, pcs	87	73	53	43	30
Scrap annual, pcs	20 097	16 863	12 243	9 933	6 930
Scrap annual, %	0.40%	0.34%	0.24%	0.20%	0.14%
Cost one pce, EUR	0.80	0.80	0.80	0.80	0.80
Average scrap cost/day, EUR	69.60	58.40	42.40	34.40	24.00
Annual (231 days) lost, EUR	16 077.60	13 490.40	9 794.40	7 946.40	5 544.00
Scrap reduction, %	80%	75%	75%	80%	68%
Volume annual, 1000pcs	5 000 000	5 000 000	5 000 000	5 000 000	5 000 000
12 moths cost, EUR	2 500	250	250	2 500	-
12 months saving, EUR	12 862.08	10 117.80	7 345.80	6 357.12	3 769.92
Lifetime, years	6	6	6	6	6
Capex, EUR	1 500	15 000	15 000	1 500	1 000
Total Investment, EUR	4 000	15 250	15 250	4 000	1 000
Amortization Time, weeks	16	78	108	33	14
Annual Return on Investment, %	322%	66%	48%	159%	377%
Lifetime Return on Investment, %	468%	368%	267%	231%	2262%

Table 3.
Most problematic processes based on Pareto-Lorenz – consolidated

Process #No	Scrap, pcs	Scrap annual, pcs	Annual Return on Investment, %	Lifetime Return on Investment, %
Op010; Op011	130	30030	240%	3,4944
Op002; Op003	126	29106	57%	3,1752
Op016	30	6930	377%	22,61952

A deeper analysis (Fig. 4), of proposed solutions allowed to figure out that the characteristics Op 010 and Op 011 are produced during the same operation. This approach made it possible to narrow down the methods of analysis and simultaneously combine corrective actions to reduce the costs of implementing process improvement. Similar observations apply to characteristics Op002 and Op 003; This meant that the same solutions as to the characteristics were used in Op 010 and Op 011. Characteristic Op016, as a visual inspection was aimed at searching for defects on the surface of the finished product.

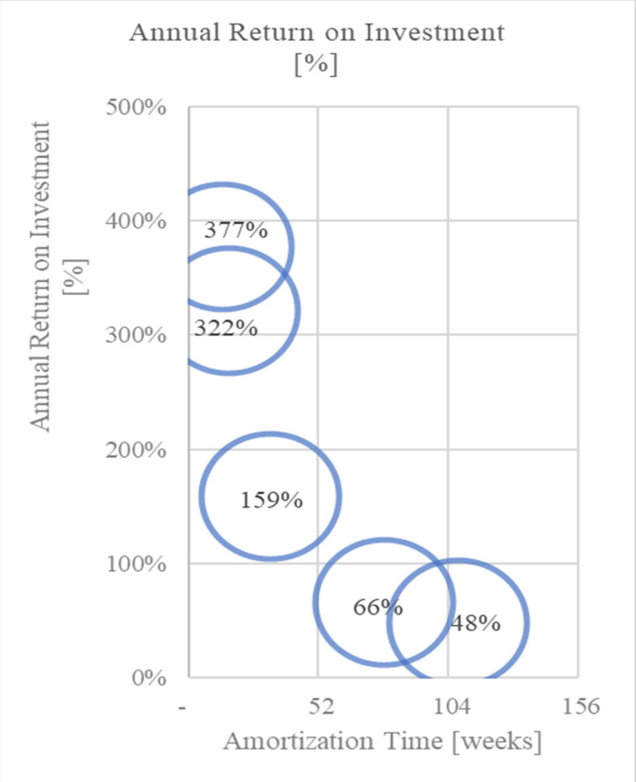

Fig. 4. Visual presentation – Annual Return on Investment vs Amortization time

Consolidation of corrective actions made it possible to group actions; therefore, instead of a list of 5 actions shown in Figure 4, a list of 3 is shown in Table 3. According to the consolidation process, actions were created and presented in Figure 5.

3. Results of research

The graphical representation of the relationship between return on investment and amortisation time allows you to easily visualise which of the proposed changes are the most cost-effective over time. Based on the analysis carried out and the graphical summary of the results, the change is proposed below, in order from the most cost-effective.

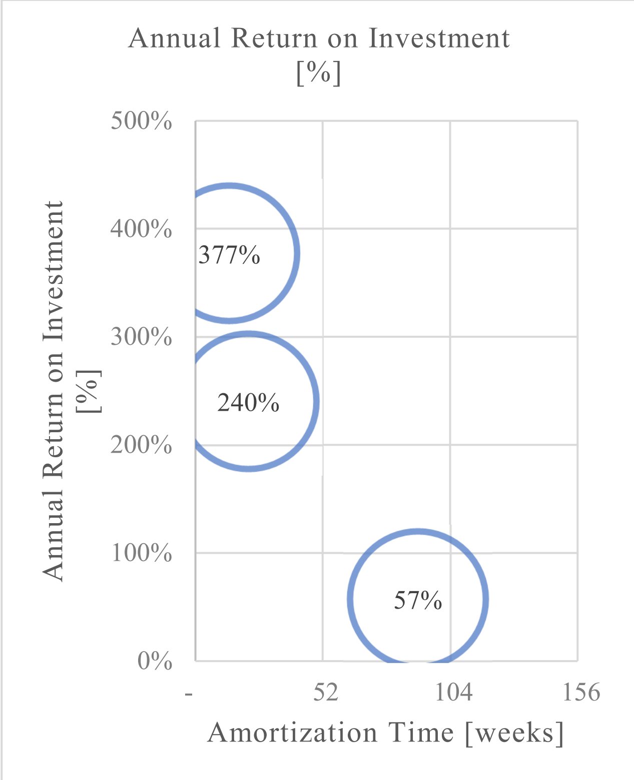

Fig. 5. Visual presentation – Annual Return on Investment vs Amortization time – consolidated

The first will be the modification of the process and characteristics of Op016, the amortisation time is only 14 weeks, and the return on investment is almost fourfold during the year. Nevertheless, there is a claimed saving of EUR 3,768 at approximately EUR 1,000. Conscious lowering of the quality of the product, and this is how we can define the Op016 modification, is one of the riskiest processes launched to reduce production costs. The choice of characteristics to be subject to relaxation must be carefully planned. The first stage is the analysis of the impact of a given characteristic on the functionality of the finished product. Determining them is of fundamental importance and should be carried out on many levels. Lowering the quality requirements and their impact is discussed in the publication [14].

The second most effective change will be modifying the forming tools, i.e., the characteristics of Op010 and Op011, amortisation time of 22 weeks, and a two-and-a-half-fold return on investment within a year. Claimed savings of 19,219 EUR for a total cost of 8,000 EUR.

As the third item, the modification of the forming module, i.e., the Op002 and Op003 characteristics, is the least effective due to the high level of investment, and the amortisation time is almost two years. Claimed annual savings of 17,463 EUR, with a modification cost of €30,500. When fully assessing the third change, we can use the Lifetime Return on Investment rating indicator. Considering that the entire project will last at least six more years, the proposed change in the manufacturing process may be effective, but only in the perspective of the full life cycle of the product. The board must decide on this change of directors, whether it is worth investing in or whether it is safer to refrain from this change.

4. Conclusions

During the manufacturing process, we can collect many data, some of which are beneficial for cost reduction approaches. But for sure, before already collected data to be benefiting for development cost reduction ideas, it must be correctly selected and evaluated. In theory, the most desirable proposals will be those where the cost of inputs is low, and the increase in benefits is high. So, if evaluations are already done, all costs and all benefits are defined, we can recommend the most effective cost savings proposals. Usually, in the next steps for selected proposals, before recommended ideas become cost-saving projects, each of which has to be presented for approval. After completing all the official feedback, from different functions, for the most effective and transparent project, there will be a recommended cross-function meeting which will be the best level to determine the direction and savings projects worth investing in. Getting analysis and visualisation of the actual state and comparing modelling results with development results can help; what are the maximum costs of savings scenarios and what costs must be incurred to achieve them. We will find out how the analysed change impacted other processes that may cause a threat and what are the new opportunities for improvement. It is very important at the end of this analysis to refer to the information about the costs that need to be incurred to implement the improvement and what benefits can be introduced. For sure, self-transparent way, savings should be presented as an amount; whether the result is a reduction in product cost, an analysis of the data involved in production, an analysis of employment, a calculation of product mass, a reduction in cycle time, a reduction in product quality, consideration of production capacity or a process change.

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