

## Estimation of Manufacturing Costs in the Early Stages of Product Development Project

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**ABSTRACT :** *One of the crucial factors in increase of productivity of supply chains is the management of production costs. Since the number of methods and tools used to estimate the production costs in product development phase is limited, the designers often estimate the costs based on their experience. The designers can mainly affect the direct costs of a product, including material, labor and purchased parts. Direct costs vary greatly depending on the number of produced units. Indirect costs include for example the work in process, storage and internal transportations. The developed software prototype is based on the Lucas method. It will take a simple and ideal part, whose costs are known and then use factors to produce the final costs. The application calculates sophisticated estimates about how much it would cost to produce a single part. The developed software seems to work surprisingly well. It may not tell the final truth about the component costs but can be used to open the eyes of the designer when the costs of the component under design are growing too high. It can also be used to find the most suitable manufacturing method and when considering the make or buy decisions.*

**Keywords:** *Cost estimation, Manufacturing costs, Product Development*

### I. INTRODUCTION

The strength and basis of competitiveness of the technology industry in many European countries will be a flexible, rapid and cost effective mass customized small batch production. The effective performance of supply chains has also a strong connection with the competitiveness. The know-how of modern solutions and new innovations in products and production as well as the agility of production are important aspects in the future.

One of the most crucial factors in the productivity increase of supply chains is the management of production costs. Since the number of methods and tools used to estimate production costs in product development phase is very limited, the designers often estimate the costs based on their experience. They have tacit knowledge of manufacturing feedback, work community and general design rules. However, when manufacturing is more often performed in the supply chains, the information flow from manufacturing to design is limited.

It is well known fact that 70–80 % of the product life cycle costs are defined at the product development stage. An experienced designer can estimate the costs of different alternatives quite reliably. However, for example big assemblies or machining large welded constructions (tolerances, fixtures etc.) may cause difficulties. Experience may also be a negative factor. Designers are not often easily willing to give up traditional manufacturing methods and modern and more effective methods are not considered.

The only accurate way to define the manufacturing costs is to calculate them afterwards. In many cases, however, the calculation methods are used by the accountants, who use generalizations and don't have engineering education or experience. These calculations are also performed when the product is ready and nothing can be done to reduce the costs.

The vision of the research presented in this paper is to find a simple and easy tool to be used to estimate the life cycle costs of a component in the early stages of product development process. This paper presents a cost estimate model based on so called Lucas-method and evaluates it preliminary by comparing the cost results with some values of literature and other cost estimate tools.

### II. UNDERSTANDING THE MANUFACTURING COSTS

The ultimate goal of a company is to produce profit. Selling price is defined by markets so it is not easily changed by company actions. The only efficient way to increase profit is manufacturing cost reduction.

The costs can be lumped into two categories: direct and indirect costs. Direct costs can be traced to a specific component and are then potential target for cost reduction in product development phase. A major part of direct costs are based on material used to build the component. A good estimate for material costs of a large volume production would be about 50 % of total costs. For smaller lots it may be as low as 10 % of total costs. This includes the material of the final product but also the waste. The components that are purchased outside the company are also included in direct costs. Direct labor costs include the salaries and other expenses of the work force needed to manufacture and assemble the product. Also tooling costs can be seen to be direct costs. It is also good to remember the familiar 20/80 principle: 80% of costs are generated by 20 % of parts.

Indirect costs include for example work in process, storage and internal transportations. Work in process (WIP) inventory takes floor space and demands internal transportations. There may be thousands of work pieces in WIP inventories. Other types of inventories may be for raw materials and finished products. The common rule of thumb for estimating the costs of inventories is 25 % of the inventory value per year. If the value of inventories is for instant 1 million Euros, then the cost of it will be 250.000 Euros every year. Product development does not have much influence to these costs, but it is good to keep them in mind anyway.

Lot size has a significant meaning in production costs of a single component. The smaller the lot size, the higher are the costs per one piece of the product. This is mainly depending on the setup costs. Setup consists of those actions used to change the manufactured part, tools, programs, manufacturing instructions and fixtures and preparations for the part waiting to be manufactured. Fixed costs will also grow when the lot size is growing.

In order to reduce the manufacturing costs both the manufacturing and design must be developed. Fig. 1 is an example of how design and manufacturing affect the cost of a manufactured component [1]. Average part cost is considered as 100 % (or for example 100 Euros). If it is possible to improve both production and design, the cost can be lowered to 61 % of average. If both of them are instead worsen to poor level then the cost is increased to 175 %. It is worth realizing that improving only manufacturing efficiency, the cost is almost the same as average.

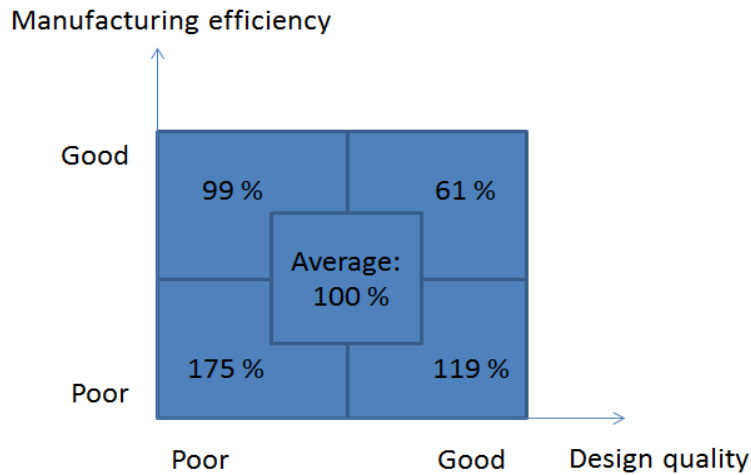


Figure 1. The effect of design and manufacturing quality on costs. Modified from [1].

### III. ESTIMATING THE MANUFACTURING COSTS

Many of the DFMA-based solution are going hand in hand with manufacturing costs [2] [3]. It is important that the designer understands the meaning of manufacturability in the determination of product's cost structure. However there is still need for a simple and easy tool to estimate the costs. Examples of such research can be found from [4], [5] and [6].

The Lucas- method [7] [8] is developed to estimate production costs in concept phase of product development process. It will take a simple and ideal part, whose costs are known and then use factors to produce the final cost estimate. The method was developed at the early 80's and it includes estimate models for both the single parts and assemblies. This paper concentrates on the cost calculations of single parts only.

The cost is calculated by using the equation

$$M_i = VC_{mt} + R_c P_c$$

Where,

$M_i$  = manufacturing cost

$V$  = volume of the manufactured piece

$C_{mt}$  = material cost including waste

$R_c$  = factor based on the complexity of the piece

$P_c$  = processing cost of ideal piece

Lucas calculation model requires the use of multipliers based on for example the material, manufacturing method, tolerances and roughness. The material cost is calculated using the volume ( $V$ ) of a part multiplied with the cost of the specific material and the waste cost factor of the part. Another factor related to the material illustrates how well certain material is suited for a used work method. The Lucas method is explained in more detail in [7] and [8].

### IV. COMPUTER APPLICATION

A prototype application that uses the Lucas method to calculate sophisticated estimates on how much it would cost to produce a single part was developed. It was created using the SolidWorks software and its VBA (Visual Basic for Applications) system. The screenshot of the software is presented in Fig. 2. The user simply needs to find suitable selections and the software will give the cost estimate. The user can also easily compare for example different materials, manufacturing methods and lot sizes in order to find an optimal solution.

Some modifications had to be done to make the method suitable for the used manufacturing machines and work force. Also the material prices vary depending on time and place.

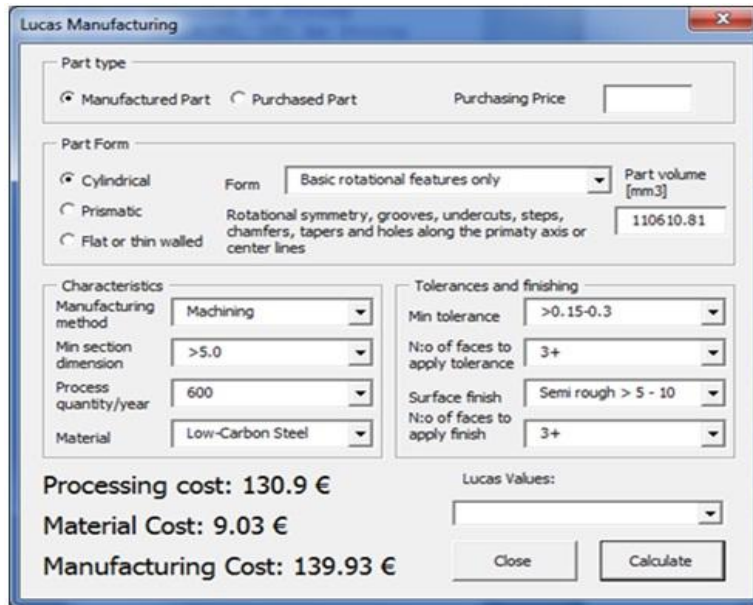


Figure 2. The software user interface.

### V. THE RESULTS ACHIEVED

Two machined parts (materials low carbon steel AISI 1020 and aluminum alloy 6061) represented in figures 3 and 4 were taken as test examples. Their costs were calculated for a lot of one by using the developed software. Reference cost information was taken from literature, asked from an expert (only in part number one) and by using the Solid Works costing solution included in the software version 2013. The results are presented in tables 1 and 2.

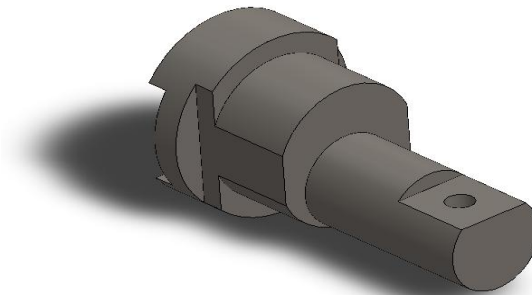


Figure 3. A test piece number one [1].

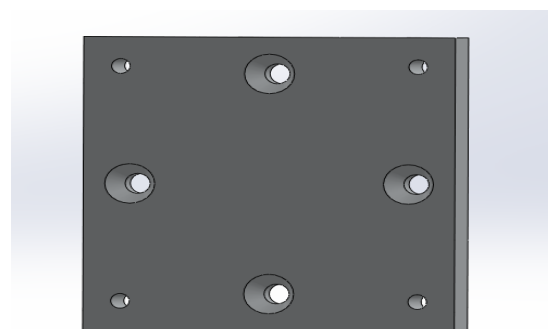


Figure 4. A test piece number two [9].

**Table 1. Cost comparison for piece one.**

Method	Material cost [€]	Processing cost [€]	Manufacturing cost [€]
SolidWorks macro	9	171	180
Litterature	N/A	N/A	130
Expert estimate	11	173	184
SolidWorks Costing	5	140	146

**Table 2. Cost comparison for piece two.**

Method	Material cost [€]	Processing cost [€]	Manufacturing cost [€]
SolidWorks macro	17	51	68
Litterature	7	52	59
SolidWorks Costing	12	39	51

## VI. CONCLUSION

The developed software seems to work surprisingly well. It may not tell the final truth about the component costs but can be used to open the eyes of the designer when costs of the component under design are growing too high. It can also be used to find the most suitable manufacturing method and when considering the make or buy decisions.

The software is very simple and easy to use. The Solid Works costing application uses the feature structure of the part before it can be used. The Lucas-based solution works also without it and it has wider range of manufacturing methods. So the conclusion might be that the Lucas-based solution is useful in the early stages where the shape and manufacturing methods are unclear. Solid Works costing can be used to evaluate the piece whose shape and manufacturing methods are fixed.

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