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Estimating the Cost of the New Product in Development Process

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Abstract

Development of innovative products requires companies a lot of effort. The creation of an appropriate strategy development, climate, protection of resources and preparing a launch system is a major challenge. Uncertainties and risks that accompany innovation require use such methods and tools to design innovation is designed precisely and will guarantee of success. Achieving success is largely dependent on the effectiveness of the decisions in the implementation of the deployment process. Among relevant criteria which influence decisions making are costs. This paper shows an approach to estimate the cost in the new products development. In paper were presented examples for estimating the cost of future product at various stages of the implementation process. It was proposed methods that allow estimating the cost of the planning, development and operational activities at the NPD. This makes it possible to assess the cost-effectiveness of the process in terms of achieving the intended benefits and making effective decisions.

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Keywords: New product development; cost estimation; inovation; CAD; CAM

1. Introduction

The key to a rising enterprise in the 21st century is product quality, competition cost, fast delivery and flexibility. Fast implementation of the innovative solutions is key for the enterprises to obtain competitive advantage. Despite that the innovative approach to the development of an enterprise can enhance flexibility and product quality, it can be time consuming and unaffordable. The demanding client expects new products that will meet his needs. The intention for quick profit, which the fast implemented innovation will bring, may have negative impact on the innovation process. The situation can lead, for example, to neglecting the estimate of profitability of implementing

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the innovation process manifested in an underestimation of the costs resulting in implementing the operational goals or overestimating the costs which can lead to resigning from implementing the innovation from which the company may suffer and lose market. It highlights the importance of choosing the right methods in predicting the costs of the innovation process.

Important elements in the innovation field are skills which help to identify market opportunities, create conditions for developing innovative solutions and the ability to organize innovation processes. However, the most important element in the innovation field is decision-making in uncertain conditions. Uncertainty is connected with implementing actions of unique nature which have not been implemented before and can bring surprising results [1]. Therefore, in the field of innovation management one can speak of great risk which can have impact on the necessity of sustaining high costs or even failure of the implemented process.

Limiting the risk is connected with decision-making. Developing methods which will allow for limiting the uncertainty of information in the decision-making process is the key element in the management of the innovation processes. Decision-making in the innovation process in the traditional approach focuses on the economical estimate of the innovation. It indicates that implementing the innovation depends on its relative product value and profitability [2]. It is claimed that the decision of implementing the innovation depends on rational thinking, taking into consideration the profits which may result from implementing such innovation and costs associated with its adoption [3]. In this sense a rational thinking is used by managers in order to estimate costs and profits from implementing the innovation based on material measures [4].

The decision of implementing the innovation depends on the estimated profit, specifically its economic availability. Therefore, from the economic point of view, the decision-making process in innovation is reduced to the intended, conscious and rational processes which are mostly driven by the objective factors. Enterprises implement innovations when the acquired data allows to confirm that the potential profits exceed the risk [5]. Otherwise, they will need additional information before making the decision or they will not implement the innovations due to low estimated profits [6]. Gathering sufficient information to estimate profits is difficult due to high uncertainty accompanying innovation processes. Nevertheless, it is recommended to achieve the reliable cost estimate in the best way possible as an element of the main criterion in the decision-making process.

Decision-making in the innovation process does not only concern the economic aspect. One also has to consider the role of the innovation recipient (market acceptance) and the organization level of the enterprise implementing the innovation. The knowledge about the possibility of accepting the proposed innovative solutions by the client is important. In acquiring this knowledge the contact with the potential recipient is helpful as well as proper tactics in the field of market actions that lower the risk connected with the market acceptance [7]. From the point of view of the implementer of the innovation, the enterprise organization level is essential. It includes the level of resources and technological capabilities. Implementing innovations which are close to the current technology has greater chance of success than implementing completely new technologies. Apart from realizing one's capabilities of implementing innovations, it is also necessary to take into account the environment which is usually connected to the competitiveness estimate level on the market. High competition among enterprises increases the possibility of implementing the innovation [8].

It was observed that the enterprises mainly implement innovations of incremental character, which are subtle changes in products. This method of innovation actions allows for implementing innovations with shorter time periods and which are less budget consuming. The innovation processes are easier to plan and execute. The raised frequency of the incremental innovations is well perceived by recipients due to high-frequency of implementing new products on the market. This approach was observed in Polish firms and reflects the global tendency [9]. Radical innovations are rare. They require long lead times, a complex and expensive process, and are characterized by high levels of risk and uncertainty which result in difficulties in decision-making. One of the advantages of such innovations is the opportunity to gain substantial competitive advantage and create immense value for an enterprise [10]. Such innovations require, however, substantial amounts of capital and well organized processes in the R&D field. Polish enterprises are usually relatively new and do not have such possibilities.

Regardless of the type of innovation introduced by enterprises the decisions concerning the implementation of the innovation process are usually made based on the cost estimates which will arise in the implementation process. Their accuracy translates into the quality of made decisions which is why it is necessary to estimate future costs in the right moment which will provide for reliable results with the required accuracy. On the basis of the research, analyzing the course of the innovation processes in Polish enterprises one can observe that the issue of estimating costs is usually limited to early stages of innovation process planning. Estimating costs at this stage, without full information on the innovation process, may only be conducted intuitively. The results in this case are inaccurate and the discrepancies between the estimated costs and the actual costs of the innovation process may amount to several dozen percent. Because managers are aware of these imprecisions, the estimated costs are frequently overvalued. It is safer to overvalue than undervalue the costs, which can result in terminating the implementation of the innovation process due to exceeding the planned budget. On the other hand, the innovation process with overvalued costs may not be accepted and thus not implemented. Because of the mentioned reasons estimating costs needs to be conducted using the methods which will limit the size of the mistakes.

It was also observed that the decisions in many cases were made intuitively. Such actions were a consequence of lack of information or unreliable information and excessive belief in knowledge and experience. Even though intuition is considered as an important feature and there are known intuitive methods in making decisions, still using it in decision-making is highly controversial due to the fact that intuition is perceived as the opposite to the analytical modes of thinking [11].

2. Cost estimating in new product development

The implementation of a new product requires a series of activities. The more innovative the product is, the more complicated is the process. It consists of several main phases: idea generation, idea screening, concept development and testing, marketing strategy, business analysis, product development, test marketing and commercialization. Each of them has a large uncertainty in the results. NPD process management requires the planning of each phase, taking into account the results of the previous phase. This requires continuous monitoring of the process and decision making. For this reason, management of NPD process is difficult. Robert Cooper, noted author on new-product development, uses “stages and gates” to convey the subsections and review steps of the NPD process [12].

The success of new products is usually measured in terms of their financial results [13]. Consequently, new product ideas can also be selected based on their expected financial results. Firms determine the upper limit of the budget for the NPD process and only consider new products that require a budget lower than this limit.

Therefore, companies must analyze the financial profitable for each new product ideas. It is necessary to have a number of financial information in order to conduct this analysis. For instance, they need to know the financial returns that they can generate from a new product. Similarly, they need to know the amount of financial resources needed to design, develop, manufacture and market it. Because there are uncertainties associated with all these information they also need to have the probabilities of achieving the financial results and of meeting the established budget goals. Finally, they also need to have benchmarks with regard to the acceptable amount of financial returns and new product budgets so as to be able to assess the financial viability of a new product idea.

Although financial analysis can be highly beneficial in idea selection, it also has certain limitations. First, relying on short-term financial results may pressure managers to focus on financially justifiable ideas and to reject more promising but uncertain ideas, just because they are uncertain and are not easily justifiable [14]. Second, many financial analysis methods cannot capture adequately the risks and uncertainties associated with new products [15]. Furthermore, these methodologies consider only a “snapshot” of the financial benefits and costs associated with a new product and may not reflect the changes in these factors [16]. Finally, this approach depends on a strong assumption that accurate financial information is readily available, which is not the case in many situations.

Information about the cost of future implementation of the new product is important. For this reason, it is urgent to indicate the appropriate cost estimating techniques [17]. The hardest part is to assess the future costs at the planning stage. A large number of uncertain information makes the cost can be evaluated only subjectively. The intuitive or analogical technique can be used. Intuitive techniques require adequate knowledge and experience. It is possible also to use the knowledge of experts, but in this case you should use the appropriate tool for analyzing expert judgment. This makes the method becomes laborious and expensive. Analogical methods require historical data. Cost estimation is possible on the basis of similarity to the previously executed process. They usually use regression analysis. The more features are compared the more accurate the results, but the calculations are more complicated. Design stage is the next place where the cost estimates may be important. In this stage the characteristics of the future utility of the product are determined. These features can be a cost drivers and can be used for estimating the costs using the parametric method. The most accurate cost analysis results are obtained at the stage planning of the manufacturing process. Detailed description of the manufacturing process let to use the analitical method of estimation, because operational task and resources assigned to them are known. Activity Based Costing (ABC) and Features Based Costing (FBC) methods are often used as an analogical estimation techniques. The idea of costs estimating in NPD process and proposed estimation techniques are shown in Fig. 1.

Estimated costs are the basis for planning the next task in the process of NPD. Their level is also the basis of assessment of the correctness of the process and any deviation must be corrected immediately by the decisions taken. Monitoring and control of costs must be carried out during the production process. Therefore, an important role is played by cost accounting. In the next parts of this article are examples of estimating the costs at the planning, product design and process design stages .

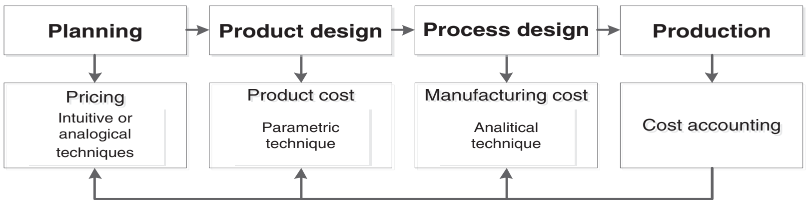

Fig. 1. Costs estimating in New Product Development.

3. Example of use of cluster analysis in the planning stage

Cluster analysis is an approach to grouping objects by analyzing the similarity of their characteristics. For this purpose, the data set about products manufactured in the past must be used. An example is the company which manufactures industrial valves. This company has a strong position in the Polish market. Many years of experience and the knowledge allows for the production of valves for a wide range of parameters. Stable market position and the need for adherence to standards makes the company introduces mainly incremental innovation. They are based on modifications of existing products for example by means of changes in the design to improve the flow of the fluid, or make changes to the ongoing technological processes. This example relates to the next innovative solution, which is related to the change of the channel shape for reducing of the flow resistance. For the analysis of clusters was chosen the group of previously manufactured products that have introduced innovative solutions. The characteristic variables describing the products are in this case the diameter of the valve, pressure valve, valve type and the cost of the innovation process. The data along with the values of the variables are presented in Tab. 1.

Table. 1. Data for cluster analysis and results of data standardization .

	Before standardization				After standardization			
No	Diameter [mm]	Pressure [bar]	Type	Cost [PLN]	Diameter	Pressure	Type	Cost
1	40	40	1	333,33	-0,70	-1,10	-1,03	-1,11
2	65	40	1	433,33	0,11	-1,10	-1,03	-0,40
3	65	63	1	466,67	0,11	-0,17	-1,03	-0,16
4	100	40	2	600,00	1,24	-1,10	0,11	0,79
5	25	63	3	283,33	-1,19	-0,17	1,26	-1,46
6	40	63	3	340,00	-0,70	-0,17	1,26	-1,06
7	120	63	2	700,00	1,89	-0,17	0,11	1,50
8	32	100	2	533,33	-0,96	1,32	0,11	0,32
9	50	100	1	566,67	-0,38	1,32	-1,03	0,55
10	80	100	3	633,33	0,59	1,32	1,26	1,03
$\bar{x}_j$	61,70	67,20	1,90	489,00	0,00	0,00	0,00	0,00
S_j	30,79	24,76	0,88	140,63	1,00	1,00	1,00	1,00

Valve type: 1- simple valve, 2- angular valve, 3- skew valve

Due to the difference in units of the variables used to make the comparison, it is necessary to standardize. Tab. 1 shows also the result of data standardization. Now all the characteristics are comparable. They have the same average and standard deviation.

The next step is to calculate the distances that will be the basis to define the next clusters. A natural measure of the distance is Euclidean distance calculated by the formula (1). On the basis of the calculated distance was formed the distance matrix $D=[d_{ik}]$ (Tab.2).

$$d(x_i, x_k) = d_{ik} = \sqrt{\sum_{j=1}^{p}(x_{ij} - x_{kj})^2} \tag{1}$$

where: x_{ij} – value of object x_i for characteristic j
p – numer of characteristics

Table 2. First distance matrix.

Distance matrix - step 1										
Clusters	1	2	3	4	5	6	7	8	9	10
1	0,00	1,08	1,56	2,95	2,54	2,47	3,96	3,04	2,95	4,16
2	1,08	0,00	0,96	2,00	2,98	2,68	2,99	2,97	2,65	3,65
3	1,56	0,96	0,00	2,09	2,93	2,59	2,69	2,22	1,73	3,02
4	2,95	2,00	2,09	0,00	3,63	3,06	1,34	3,31	3,14	2,77
5	2,54	2,98	2,93	3,63	0,00	0,63	4,43	2,60	3,49	3,41
6	2,47	2,68	2,59	3,06	0,63	0,00	3,82	2,34	3,19	2,88
7	3,96	2,99	2,69	1,34	4,43	3,82	0,00	3,44	3,10	2,33
8	3,04	2,97	2,22	3,31	2,60	2,34	3,44	0,00	1,30	2,06
9	2,95	2,65	1,73	3,14	3,49	3,19	3,10	1,30	0,00	2,53
10	4,16	3,65	3,02	2,77	3,41	2,88	2,33	2,06	2,53	0,00

The order further proceedings to determine clusters of similar objects is realized through:

1. Finding the most similar pairs of objects and merge them into a single cluster- in the sense of the shortest distance. These objects will be connected and from now will be exist as a one object described by coordinates of the center according to the formula (Tab. 3):

$$\bar{x} = \left|\bar{x}_1, \bar{x}_2, \ldots \bar{x}_p\right| \text{ , } \bar{x}_j = \frac{1}{r}\sum_{i=1}^{r} x_{ij} \tag{2}$$

where: r – number of objects in cluster
p – number of characteristics describing objects

2. Reducing the dimension of the matrix D by one (two objects have been replaced by one) and calculated the distance between the new cluster and other objects (Tab. 3).

Table 3. List of clusters after first step and new distance matrix.

Clusters – step 1					Distance matrix – step 2										
No	Diameter	Pressure	Type	Cost	Clusters	1	2	3	4	5,6	7	8	9	10
1	-0,70	-1,10	-1,03	-1,11	1	0,00	1,08	1,56	2,95	2,48	3,96	3,04	2,95	4,16
2	0,11	-1,10	-1,03	-0,40	2	1,08	0,00	0,96	2,00	2,82	2,99	2,97	2,65	3,65
3	0,11	-0,17	-1,03	-0,16	3	1,56	0,96	0,00	2,09	2,75	2,69	2,22	1,73	3,02
4	1,24	-1,10	0,11	0,79	4	2,95	2,00	2,09	0,00	3,34	1,34	3,31	3,14	2,77
5,6	-0,95	-0,17	1,26	-1,26	5,6	2,48	2,82	2,75	3,34	0,00	4,12	2,45	3,33	3,14
7	1,89	-0,17	0,11	1,50	7	3,96	2,99	2,69	1,34	4,12	0,00	3,44	3,10	2,33
8	-0,96	1,32	0,11	0,32	8	3,04	2,97	2,22	3,31	2,45	3,44	0,00	1,30	2,06
9	-0,38	1,32	-1,03	0,55	9	2,95	2,65	1,73	3,14	3,33	3,10	1,30	0,00	2,53
10	0,59	1,32	1,26	1,03	10	4,16	3,65	3,02	2,77	3,14	2,33	2,06	2,53	0,00

These steps repeat until will created a single cluster that contains all objects. If we manage to get one cluster containing all objects should look carefully at the following distances, which were used to link objects in the group. The aim is to determine the optimal number of clusters and capture the likeness of objects due to the analyzed traits. In this case, the dendrogram will be useful (Fig. 2).

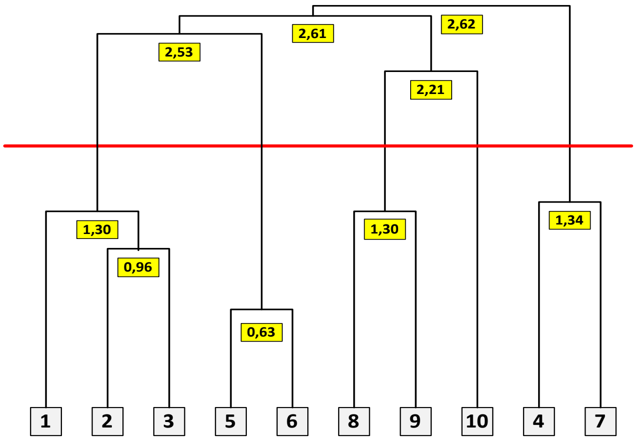

Fig. 2. Dendrogram with the arrangement of the clusters.

Choosing the best number of clusters is often undertaken subjectively on the basis of distance analysis. If the values begin to significantly increase, this means that the similarity between the objects is less and it is a signal to the end of the agglomeration procedure objects. In the present case was selected the five clusters. Defining clusters make it possible to determine the similarity of the proposed new product with similar characteristics to the products manufactured in the past. The objective is to determine the estimated cost of the product based on the greatest similarity to one of the clusters. The newly designed product has known characteristics: diameter 50 mm, working pressure 65 bar and type 3, because it will be the skew valve. After the standardization of these characteristics are calculated the distance to the each cluster (Tab. 4). Closest distance designates the highest degree of similarity. The estimated cost of the innovation process for this new product will be the cost of appropriate cluster.

Table 4. Characteristics of new object and distances to defined clusters.

Characteristics of new object			
	Diameter	Pressure	Type
	50,00	63,00	3
After standardization	-0,38	-0,17	1,26

Distances to clusters		
I	1,2,3	2,39
II	5,6	0,57
III	8,9	2,29
IV	10	1,78
V	4,7	2,31

The biggest similarity is the cluster No. II. Coordinates of the center of this cluster are -0.95, -0.17, 1.26, -1.26. Cost is described by last coordinate. Taking into account that they were subjected to standardization it is necessary to determine its true value. In this case the estimated cost of newly designed valve is 311,67 PLN.

4. Use of parametric method to estimate the cost of a new product – example

Parametric models use statistical methods and express cost as a function of values that reflect the level of costs. Parametric techniques are effective in situations where it can be clearly and simply extract these variables. They belong to a fast method of estimating costs, but the costs of dependence on a single factor in a simple regression model may not provide a satisfactory accuracy of the results. When using more of the factors determining the cost, the results are more accurate, but in this case the regression models are more complex and require more labor [18]. Parametric methods due to its advantages are readily used to estimate costs in the early stages of design [19].

For presenting the parametric method will be used the product for which the costs were estimated by using cluster analysis at the planning stage. In the referred case, it was decided that the valve is skew valve - type 3. In this case, the parametric method will take into account only the valves of this type. To develop a parametric model taken 14 representatives of the product. The nominal diameter will used as a parameter describing cost level (Tab. 7). The method consists in describing the relationship between the cost and the parameter. It is necessary in this case to find the values of the constants *a* and *b*.

$$K = ad_n + b \tag{3}$$

where: K – cost of product
d_n – valve diameter
a, b – constants

To calculate the constants a and b will be used the method of normal least squares. It involves finding the values of the parameter for structural model estimates that the sum of squared deviations of the empirical values of the explanatory variable from its theoretical value determined from the model as small as possible. This condition can be described as follows:

$$\sum_{t=1}^{n} e_t^2 \to \min \tag{4}$$

where: $e_t = K_t - b - ad_{nt}$ – deviation of actual values from the theoretical values, ie. the rest of the model.

Determination of the partial derivatives with respect to *a* and *b* and aligning them to zero, allows to obtain the following formulas:

$$a = \frac{\sum_{t=1}^{n}(K_t - \overline{K})(d_{nt} - \overline{d}_n)}{\sum_{t=1}^{n}(d_{nt} - \overline{d}_n)^2}, \quad b = \overline{K} - a\overline{d}_n \tag{5}$$

where: $\overline{K}, \overline{m}$ - arithmetic averages of variables K i m

On the basis of these formulas were calculated both constants and the parametric model is described function:

$$K = 4{,}0139\ dn + 187{,}0357 \tag{6}$$

To determine whether the constructed model is correct a number of tests to be carried out:

- Specified levels of significance for the parameters *a* i *b*
- Calculated values of relative errors
- The coefficient of determination
- Symmetry test was performed
- Checked the condition of stationarity
- Performed autocorrelation using the Durbin-Watson test

All tests gave positive results indicating the validity of the model. To calculate the cost of the new product is therefore possible using the function (7). The cost is: K = 4,0139 ·50 + 187,0357= 387,7301≈ 387,73 PLN. Fit of the model to empirical data is shown in Fig. 3.

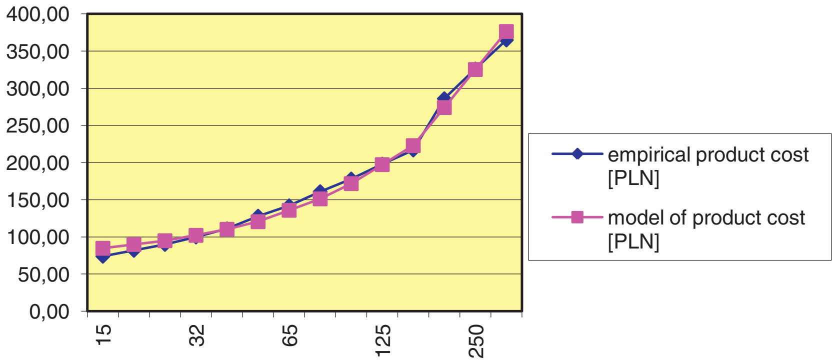

Fig. 3. Fit of the model to empirical data.

5. Features Based Costing method for estimating the cost of the manufacturing process

The assumption of the FBC method [20, 21, 22, 23] is to describe tasks as group of elementary objects, which are fragments of these tasks, associated with each other in different ways. These objects contain cost information. Defining the cost features is dependent on the organizational level of companies and are built based on historical data of past tasks. Cost features may relate to simple activity, group of activities, or even entire tasks. They support the planning process by creating the appropriate configuration to give different values of the cost. It is possible also to build various solutions that can be analyzed and optimized. In designing, cost features are defined as pairs of design features and manufacturing features. This determines the manufacturing process and describes a cost of process.

Fig. 4. Alternative processes depends of features connection.

Cost features can exist as:

- Simple - built with only one pair of objects: design and manufacturing
- Composite - including a larger number of pairs of design and manufacturing objects. Composite cost features might describe the machining processes for composite shapes . They can be described by the equation:

$$KOE = \sum_{i=1}^{n} \{KPE, TOE\} \tag{7}$$

where: *KOE* – cost elementary object
KPE – design features
TOE – manufacturing features
n – number of pairs of design and manufacturing features belonging to cost feature

Defined cost features are stored in the database and used to develop machining plans for new products. For this purpose, a computer program was developed to integrate CAD/CAM systems. Its purpose is to identify the design features in CAD model, fit them the manufacturing features and to estimate the cost of the manufacturing process (Fig. 5). For calculate indirect costs this program uses data from database of financial division.

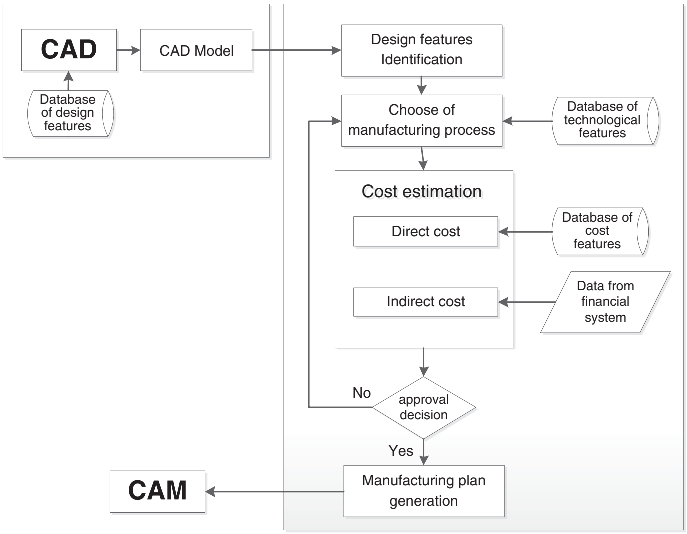

Fig. 5. Functional diagram of the program for integrating CAD/CAM with cost estimation module.

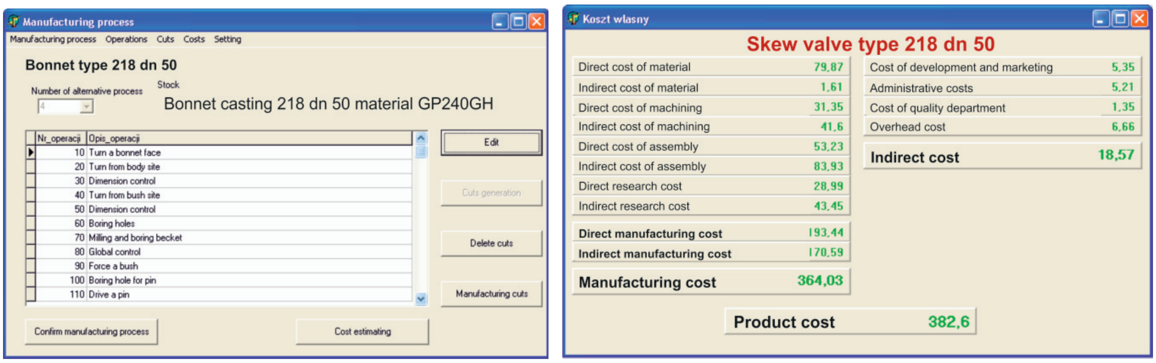

Fig. 6. Manufacturing plan for the element belonging to the skew valve type 218 dn 50 and cost estimated.

The program was used to estimate the cost of the same valve presented in the previous examples.

The CAD models of all valve components was imported. Design features were recognized by program and the manufacturing process was proposed by fitting the manufacturing features. The sum of all cost features and added indirect costs based on data from the finance department have estimated the cost of manufacturing and the product cost (Fig. 6).

6. Conclusion

Examples presented in this paper show that it is possible to estimate the costs at every stage of product development. But it should be noted that the accuracy of the estimation depends on the accuracy of the information. The level of knowledge and the number and quality of information increases with the progress of the work. This allows for using a more accurate cost estimation techniques and provides accurate results. This can be seen in performed calculations. FBC and parametric technique gave similar results, but the estimated cost of the beginning of the process by a method analogous varies significantly. For this reason, we can not plan for the future costs of relying solely on qualitative techniques. It is necessary to verify the results of repeating the estimation of costs when more information about the process occur. The most accurate results provide analytical techniques and should seek to apply these techniques. Therefore, it is important to constantly monitor the process to gather enough information for their application. This ensures the reliability of the results and allows better control of the product development process and more effective decision-making.

Estimating costs is an important task at every stage of product development. In the planning phase allows to evaluate the cost-effectiveness of the process and funding opportunities. In the design stage allows you to adjust the parameters of the future product and in the manufacturing stage decide on the selection of resources. Costs are primarily important element in the decision-making and therefore their estimation plays an important role in management. Further researches will be conducted to verify the proposed method for estimating the costs for product development representing other industries. It is also interesting that the presented techniques for estimating the cost can be used in the processes of development services.

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