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A Methodology for Variability Reduction in Manufacturing Cost Estimating in the Automotive Industry based on Design Features

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Abstract
Small to medium manufacturing companies are coming to realise the increasing importance of performing fast and accurate cost estimates at the early stages of projects to address customers' requests for quotation. However, they cannot afford the implementation of a knowledge-based cost estimating software. This paper explains the development and validation of a consistent methodology for the cost estimating of manufactured parts (focused on pistons) based on the design features. The research enabled the identification of the sources of variability in cost estimates, and the main one is the lack of formal procedures for the cost estimates in manufacturing SMEs. Finally, a software prototype was developed that reduces the variability in the cost estimates by defining a formal procedure, following the most appropriate cost estimating techniques.

Keywords:
Cost estimating, manufacturing SMEs, process improvement, variability.

1 INTRODUCTION

Currently, manufacturing companies are forced to invest more and more in innovation, in order to improve their products quality, flexibility, and variety, at the same time that they are trying to reduce their costs. This is necessary in order to survive, maintaining their competitive edge, and also satisfying the customers, who are demanding higher quality at lower prices. Therefore, it can be concluded that cost has become one of the main factors in product development.

Manufacturing companies are requested by the customers to provide a quote at the early stages of the project. Therefore, it is important for these companies to make use of accurate and well-defined methodologies to estimate the costs.

Many big companies have in place a cost estimating software that, combined with an Expert System, provides good estimates [1]. However, the Small and Medium Sized Enterprises (SMEs) cannot afford such an expensive system, but they still need a procedure that allows accurate estimates in order to be competitive.

There are several techniques for the cost estimating process. Most of the manufacturing SMEs are not aware of which of those techniques is most suitable in each situation. On top of that, most of them are not using a well-defined procedure, which leads them to a high fluctuation in the estimates.

Accordingly, the aim of this research paper is the identification of the sources of inaccuracy and the determination of the most suitable cost estimating procedure, in order to develop a framework to improve the cost estimating process within a manufacturing environment.

2 LITERATURE REVIEW

In a manufacturing environment, it is important to estimate the costs incurred when manufacturing products in order to issue a quote to the customers. In this way, the quote submitted is required to be lower than the competitors' one, but high enough to make a profit. Therefore, the requirements for a successful estimate are accuracy, speed and consistency [2].

Reduction of effort and time, increase in accuracy and higher consistency in estimates are additional advantages derived from the use of software programs for cost estimating. However, there are some disadvantages, for example, an up-to-date database is required and any competitor may use the same software, achieving similar results.

In order to improve the reliability and accuracy of cost estimates, many support tools have been developed for the early stages of the design [3]. Most of the authors agree that there is not a 'best' method. The most appropriate method depends on the context, that is, the company, the customers and the stage of production at which the cost estimating is being carried out [4].

In broad terms the qualitative methods are more suitable than the quantitative methods in the early stages, when the detailed information is not available. The main limitation of the qualitative methods is that are less accurate than the quantitative methods. Therefore, qualitative methods should be used as a decision-support tool that provides a rough cost estimate at the early stages of the project. On the other hand, quantitative methods should be used when detailed information is available and an accurate cost estimate is required [5].

Particularising for each technique, Traditional Detailed Cost Estimating is more accurate than Parametric Costing, Expert Judgement and Analogy-Based Reasoning. However, it has limitations in the allocation of indirect costs and overheads. Activity-Based Costing (ABC) overcomes this limitation but this technique is very costly [6]. Therefore ABC should be only implemented when accuracy in cost estimates is critical.

Parametric Costing, Expert Judgement and Analogy-Based Reasoning are quicker than Detailed Cost Estimating and Activity-Based Costing [7]. Expert Judgement can be considered as the quickest but the least accurate method, because it may be easily biased by subjectivity. Therefore it is suitable for calculating an initial rough estimate and also to contrast the result of any other method.

The transparency for the cost estimator is the main advantage of the Analogy-Based Reasoning over the Parametric Costing, which can be considered as a 'black-box'. Moreover, the Analogy-Based Reasoning has the ability of 'learning' from previous and new cases. However, the Analogy-Based Reasoning has a higher degree of subjectivity in the process than the Parametric Costing. Therefore, the suitability of this methods is based in the ease of identifying the 'cost drivers' and the availability of previous similar cases.

The technological advancement is stimulating the use of Artificial Intelligence (AI) in order to reduce time, handle uncertainty, increase accuracy and reliability of estimates. However, not many companies have implemented yet any kind of AI due to its high cost of implementation and maintenance. Another limitation of this technique is that it is like a 'black box'. Therefore, it is required to use it in collaboration with other technique in order to validate the estimate.

None of these techniques is more appropriate than any other for all the possible scenarios. Therefore, as Niazi [5] states, "recent research in the field focuses on getting quicker and more accurate results by developing integrated systems combining two or more approaches".

3 RESEARCH METHODOLOGY

3.1 The Case Study

The case study company, Cosworth UK Ltd., is a SME funded in London in 1958 and specialised on the manufacture of engine components for automobile racing (motorsport). Cosworth has had a long relationship with Ford, which began when Cosworth first started manufacturing racing engines in 1959. By the end of 2004 this relationship was broken off so Cosworth started to face a new scenario in which they have great expertise in the design, development and manufacture of automotive engines but the cost estimation for quotation was rising as a new challenge.

The main objective of this research is the reduction of the variability in cost estimating process within a manufacturing environment. It is necessary to identify the main causes of variability within a manufacturing environment [8].

In the case that the cost estimating process starts from scratch or is based on similar past cases, there is no predefined procedure to follow. Consequently, most of this process is based on the experience of the estimator and hence, the estimate is very fluctuating from one estimator to another. This is the key challenge identified in this study because the absence of a formal procedure may mislead the cost estimator. Unless this problem is addressed, the estimates are unreliable.

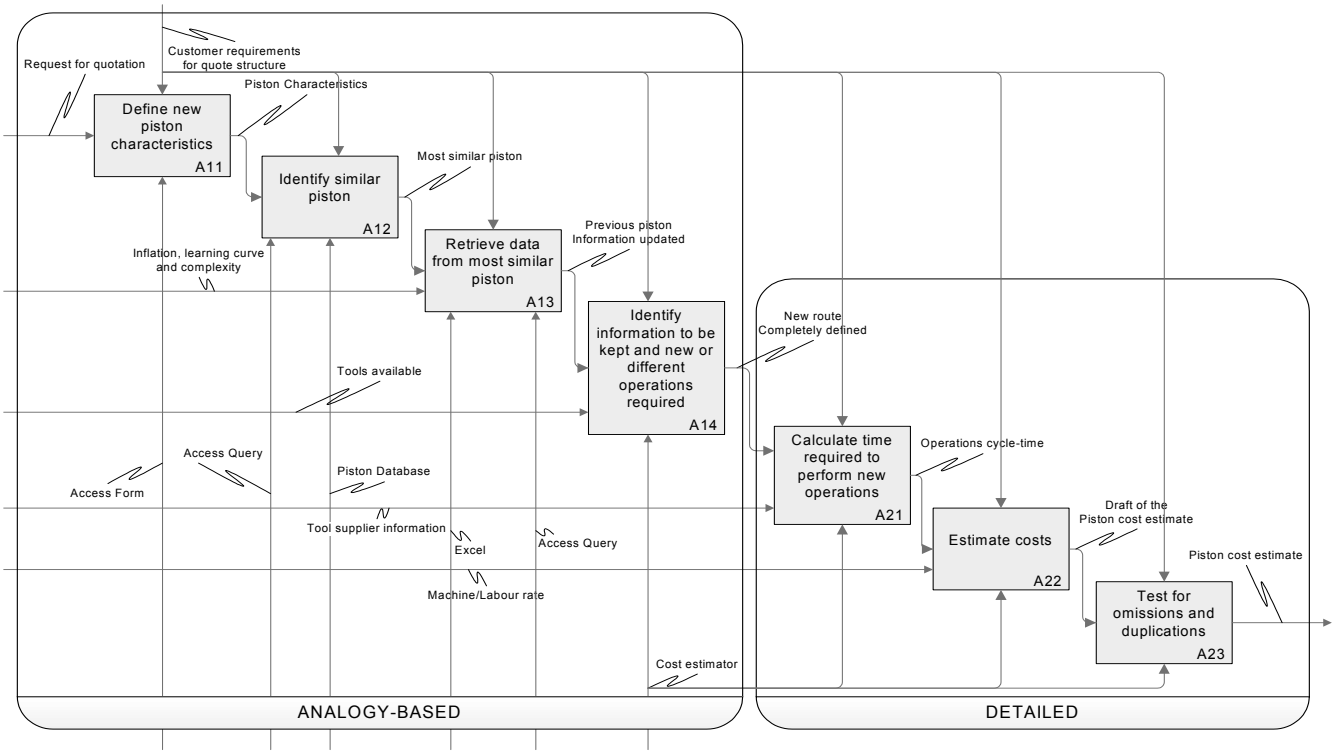

Figure 1. IDEF0 diagram of the Piston Quote Generator

Several sources of variability in the cost estimates have been identified during this study. Firstly, there is no formal procedure defined for the cost estimating. Therefore, the cost estimated by different employees for the same product may become very different.

Most of the employees are not properly trained for the performance of a cost estimate. Consequently, they will struggle to estimate costs and also the results obtained will be very fluctuant.

There is a lack of data available from previous cost estimates. Moreover, most of this data is stored arbitrarily, without following any logical criteria, making the retrieval process a very complex task. As a result, most of the cost estimating processes may start from scratch, increasing the range of fluctuation for the cost estimate.

3.2 The Approach Adopted

The first step is the capture of the current cost estimating practice within the case study company. Understanding of the current practice is very important because it is necessary to identify the areas that require further improvements [8].

Once it has been identified the sources of variability on the estimates and the necessity to reduce it in order to improve the results, the next step was the development of a solution. Taking into account that there are no formal procedures defined for the cost estimating process in SMEs, the development of it may reduce the variability to a great extent.

A framework based on the techniques reviewed in the literature survey was developed and validated. Subsequently, in order to develop the prototype that allows the implementation of this methodology in a manufacturing SME, a workshop was hold. It was attended by the main experts in pistons of the case study company, in order to determine the main characteristics of pistons that are considered for the measurement of the degree of similarity. From this point, the development of the prototype was based on MS Excel and MS Access.

4 DEVELOPMENT OF COST ESTIMATING FRAMEWORK

The most suitable methodology for those components that are similar to others that have been designed and manufactured in the past is the: Hybrid Analogy-Based / Detailed Cost Estimating [8].

This methodology combines the speediness of the Case Based Reasoning (CBR) and the accuracy of the Detailed Cost Estimating. Therefore, it is a suitable method for this scenario. It is based on the set of processes defined in the Virtual Cost Estimating Studio (V-CES) project [9], but it has been improved and adapted to the requirements of a manufacturing SME.

The methodology explained is focused on the pistons, but it can be equally adapted for the quotation of any other part comprised in this scenario. This Piston Quote generator is a tool that allows the cost estimate of any piston at the early stages of the design. This tool ensures the use of a well-defined procedure, which reduces the variability in the cost forecast.

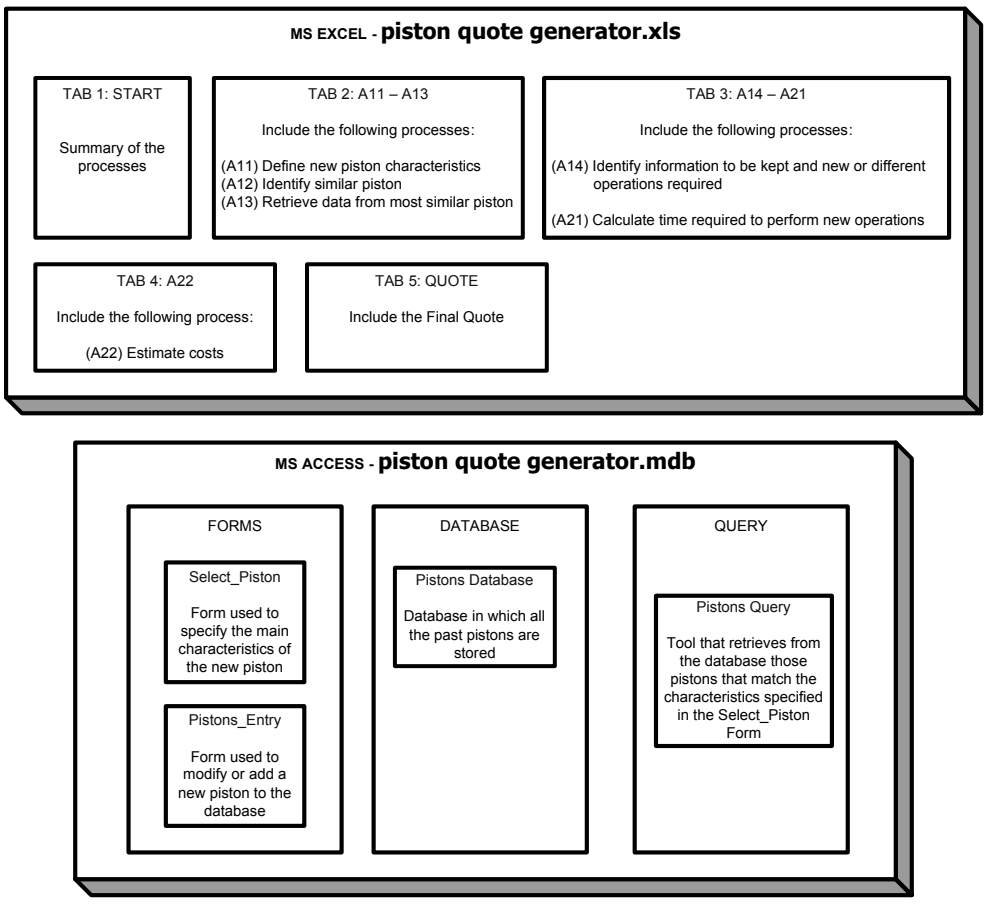

Figure 2. Piston Quote Generator Structure

4.1 Cost Estimating Scenario

In this section the rationale of the tool is described thoroughly. The overall process can be appreciated in the IDEF0 diagram (see Figure 1).

Each step of the process is explained as follows. The process starts when a 'Request for Quotation' is received from the customer, including the design specifications of the part that is intended to be quoted. This methodology commences applying the CBR technique, in terms of identifying the most similar past case. The first step is to define the main characteristics of the part that will be quoted. The cost estimator is required to assess them in order to be able to identify the most similar part stored in the database. The characteristics are entered in a form by the cost estimator. Then, the database is explored in order to identify the past cases that match those characteristics. At this stage, the cost estimator has the flexibility to undertake different searches, including the possibility of performing a partial match or exact match retrieval. That is, the cost estimator has the freedom to search just for those characteristics that are regarded as more important. Once the most similar past case has been identified, its quote is retrieved from the database. The data included in this quote should be updated and normalised by the cost estimator, regarding the inflation, learning curve and complexity. Subsequently, it is necessary to define the manufacturing route that the new part will follow. Then the cost estimator will be able to identify which operations of the past case can be maintained, which ones should be modified or removed and what operations should be added. The need for any new tool required to perform a new operation is also identified at this stage (Figure 1). This is the first step of the Detailed Cost Estimating phase of the overall process. Now that the manufacturing route has been completely defined for the new product; the cost estimator, based on the information provided by the tool supplier, is able to determine the cycle-time required for each operation. Once the cycle-time required for each operation has been determined, considering the machine and labour rates, the cost incurred during the manufacturing process can be easily estimated. The cost of materials, cosmetics, packaging, new tools and fixtures should be added to the manufacturing cost in order to calculate the final quote. (Note that the indirect cost, overheads, machinery depreciation and maintenance cost are already included in the machine rates). The objective of this last step is to assure that the quote is correct, avoiding omissions or duplications. The procedure defined for this purpose is: first, print and check a report of the cost estimate; second, correct any error found, an third, send the quote to the sales department, so it can be issued to the customer (Figure 1).

4.2 Overall Structure of the Developed Prototype

This methodology has been developed by combining MS Excel and MS Access. The structure of the prototype developed is represented in Figure 2.

In the "piston quote generator.xls" subsystem, all the necessary instructions for the performance of the cost estimating are expressed. Five tabs guide the cost estimator during the whole cost estimating process.

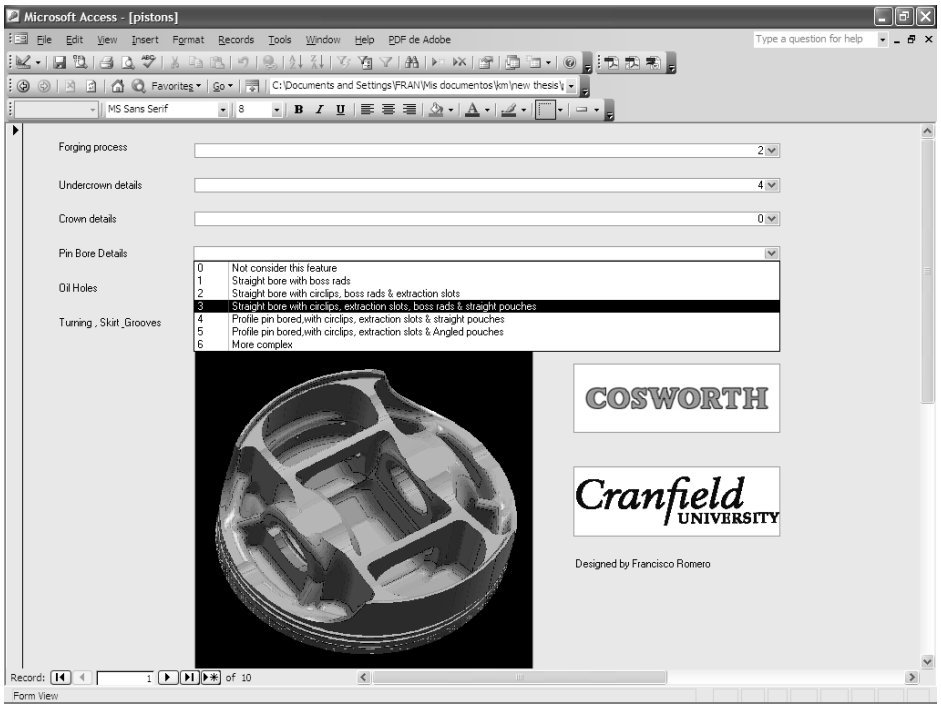

Figure 3. Selection Form of the System

The "piston quote generator.mdb" subsystem includes two forms, a database and a query. In the database it is stored all the information related to past pistons, their characteristics and their quote. As it is shown in Figure 3, the "Select_Piston" form has six lists of options. Each list is associated with a different characteristic that defines the piston. For each characteristic there are six possible values for the assessment of the new piston. There is an extra value "0" that can be selected if the cost estimator decides not to include that characteristic in the search query. Every time the user selects any option, an image representative of that option is displayed. This feature, added to the form by means of Visual Basic for Applications (VBA), ease the selection process for the cost estimator.

The ‘Pistons_Entry’ form allows the user to make additions of new pistons to the database. It also gives the user the possibility of making any modification in the information about the pistons already stored in the database. By means of this form, the user is able to populate the database, adding every piston that has been quoted.

The Pistons Query has been developed using VBA, in order to allow the user the retrieval of the pistons stored in the database that matches the characteristics specified by the user.

5 VALIDATION

In order to validate this procedure defined for the piston quote generator, the detailed IDEF0 diagram (summarised in Figure 1) was explained to the 3 main experts in pistons and cost estimation from the Engineering/Manufacturing department of the case study company. After checking it, all of them gave their approval.

Another validation process was performed, in order to make sure that the prototype is working properly and fulfils all the requirements for which it was designed. The validation of this tool was performed by the Production Engineering Manager of the manufacturing SME. He is the most appropriate one for this purpose, because he combines expertise in pistons and also in cost estimating. Therefore, he is capable to determine whether this programme meets his expectation. After running the program and testing it with several hypothetic cases, it was verified that it works properly and fulfils the requirements.

6 CONCLUSIONS

The methodology defined for the rationale of the tool developed is a hybrid between detailed cost estimating and analogy-based costing. This decision is based on the literature review carried out. The reason behind this decision is the combination of level of effort required and accuracy provided by this methodology.

The literature review and the study about the current cost estimating practice within manufacturing companies have revealed a lack of formal procedures for the cost estimating in manufacturing SMEs.

The fluctuation of the cost estimates is a concern in manufacturing SMEs. The variability of the estimates has been reduced defining a structured procedure. The customer-expectation study has identified the time expected by the customer to receive the quote for each scenario since the Request for Quotation (RFQ) is sent. The study has identified the need to reduce cost estimate development time.

Considering the previous statements and the validation results, it is observed that the Piston Quote Generator developed has improved the cost estimating process within a manufacturing SME. Therefore, the aim of the research has been accomplished, reducing the variability in the cost estimates.

7 ACKNOWLEDGMENTS

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