INTERNATIONAL DESIGN CONFERENCE - DESIGN 2010
Dubrovnik - Croatia, May 17 - 20, 2010.

AN INFORMATION FRAMEWORK FOR ESTIMATION OF INSTRUMENT TRANSFORMER COST

D. Pavlić and M. Vanhatalo

Keywords: cost, PDM, ERP, PM system, eBOM, mBOM

1. Introduction

In today's business world, corporations must be able to react to the changing market needs rapidly, effectively and responsively. Market needs, such as shrinking product life cycles, increased competition, rapidly changing technologies and variety in customers' demands represent driving forces in the manufacturing companies.

Instrument transformer companies are regarded as manufacturing companies whose competition on the market depends on the manufacturing phase of a product life cycle. Each transformer is produced for known customer and they are categorized as tailor made products. Delivery time for instrument transformer has been reduced down to six months from the contract agreement and delivery time for purchased components is measured in months. Therefore is important to meet customer requirements, even before the contract is made. But the most important for companies is that cost of production is always less than the selling price. For this reason managing the cost of production from the early beginning till the end of production has crucial role in competitive ability on the today's market. The first step in managing of production cost is to estimate the cost. The cost estimation can be done manually or automatically. Manually cost estimation is done when a bill of material (BOM) is defined. But BOM is defined always after the contract agreement is done and therefore the sales people don't have right information at right time. Hence the challenge is to automatically estimate the cost of production in order to have right information before the contract agreement is done.

Companies in their business use several IT systems to manage the information needed for business. Almost all of them use Enterprise Resource Planning (ERP) system to manage information in sales, purchasing and financial department. Instrument transformer companies produced tailor made products and each transformer is project for itself. Each project has individual: delivery time, engineering bill of material, manufacturing bill of material, quotes for manufacturing operations, purchasing components etc. Such information is managed by the IT system called Project Management system (PM). In design departments a product data management system (PDM) is used to manage information related with the design. Those three systems cover all the information necessary for cost estimation but neither IT system can estimate the cost by itself.

It is assumed that a method for estimation of instrument transformer costs can be implemented in addition to above mentioned IT systems in the companies. The objective of this research is the mutual integration between ERP, PM and PDM information systems enable the estimation of instrument transformer costs in the offering phases of a product life cycle.

2. Cost estimation

Comprehensive literature review of product cost estimation is presented by Niazi et al. (2006), and Wang et al. (2007). Many authors in the reviews describe the methods from the theoretical point of view, focused on the estimation of an overall product cost. Such efforts are praiseworthy but industrial companies are looking for different methods. Project oriented companies such as instrument transformer companies are looking for a method for easy and accurate estimation of the costs relevant for a project. Such estimation calls for an automatic calculation based on the information stored in existing IT systems within the company. All other costs which are irrelevant for a project but belong to the companies' business are not included in the estimation.

Automatic cost estimation could have significant impact on decisions made in several departments within the company. Some of them are:

- In most cases, the cost of design is small fraction of the product total costs, but the decisions made by designers have huge influence on the costs in the later phases of the product's life cycle. Therefore, it is crucial for a designer to be able to compare different variants and their manufacturing costs in advance.
- The manufacturing costs are also used for the make-or-buy analyses, especially in smaller companies where the resources of searching for alternative solutions are limited. Knowing the manufacturing costs early makes great difference for the designers. They are more likely to manufacture a component than to outsource/buy it if they do not have enough information about the costs of their manufacturing. If the cost of making a component is higher than another company's selling price, it is logical to outsource the component [Fill and Visser 2000].
- If a designer is able to get information about manufacturing costs the designer is more likely to make correct decisions about the structure of a product, as well as, manufacturing operations needed for production.
- Also, over tight tolerances increase the manufacturing costs and this is an area generally forgotten in the product design.
- In cases where the company purchases large amounts of raw material at the time, the market value can increase or decrease dramatically. If the original price is used in estimation, the costs cover more truthfully the actual cost for the company. When product cost is estimated the consequence of wrong decisions because of lack of cost information is eliminated.

Those are examples of how automatic cost estimation has influence on the decisions within the company.

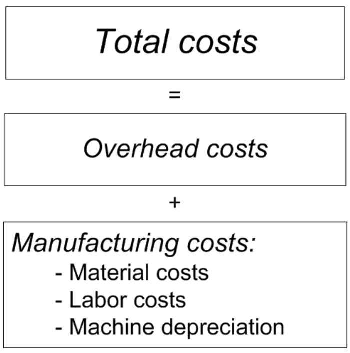

Figure 1. Division of Costs

Automatic cost estimation seeks for boundaries. Total costs comprise the overhead costs and the manufacturing costs. The manufacturing costs consist of machine, labor and material costs (figure 1) [Ehrlenspiel 2007]. Evaluation of the overhead costs is a complex and non accurate task, and, therefore, it is not enclosed in automatic cost estimation. Overhead costs are divided during the calculation of actual costs and proportionally added to a project cost. Manufacturing costs from the industrial point of view give enough information to the person in the sales, design or any other department for making decisions. Therefore, further cost estimation is based on the manufacturing cost.

3. Proposed information framework for cost estimation

Automatic estimation of instrument transformer costs is based on information exchange between several IT systems in the companies: PDM (Product Data Management), ERP (Enterprise Resource Planning) and PM (Project Managements) (figure 2). These IT systems need to be fully integrated for automatic estimation of instrument transformer cost because each system separately covers only one part of information needed for automatic estimation of instrument transformer costs.

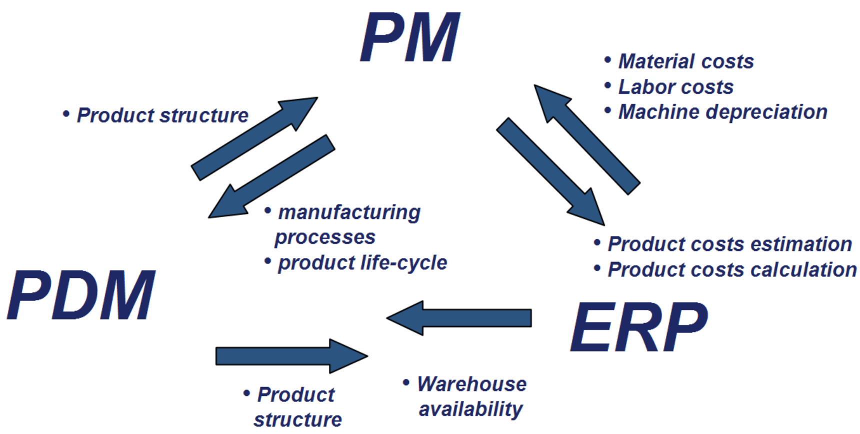

Figure 2. Information exchange between IT systems in the company

Information about instrument transformer design is stored in Product Data Management system. The PDM system is used for a creation of engineering bill of material (eBOM). eBOM defines the complete set of physical components (product structure) required to manufacture a product. But eBOM does not contain information about the manufacturing processes used for manufacture a product. Therefore, the first phase in automatic estimation of instrument transformer costs is creation of an extended bill of material. Extended bill of material should ensure that the information from eBOM is possible to map with information from manufacturing bill of material (mBOM). A manufacturing bill of material contains all the manufacturing tasks performed during the manufacturing process of the whole product. The mapping of these two BOMs combines the information about the materials and how a final product is produced.

3.1 Extended bill of material

One component may be produced by only one manufacturing process or by several manufacturing processes. If a component is produced by one manufacturing process, the estimation of the product cost is simple. But most of the components are produced by several manufacturing processes as shown on figure 3, and therefore the estimation of product costs is complex.
From the cost estimation viewpoint, material cost of the component should be calculated only in the first manufacturing task where the raw material is used. The following tasks of the manufacturing process only add value to the component by changing its shape for example. Therefore in the following tasks there is no need to recalculate the material costs, again.
The complete product consists of the components manufactured within the company and from the components manufactured and delivered by company suppliers. Components manufactured within the company are produced from raw materials and readymade components delivered by suppliers. For these two different types of components the quantity value has different meaning from the cost viewpoint. Quantity of component produced from raw material represents the amount of the used material, and it is used in the determination of material costs. Quantity of component delivered from suppliers represents the number of used components in assembly and it is used in the determination of

component cost (material cost for that type of component is already added in a component price by the suppliers).

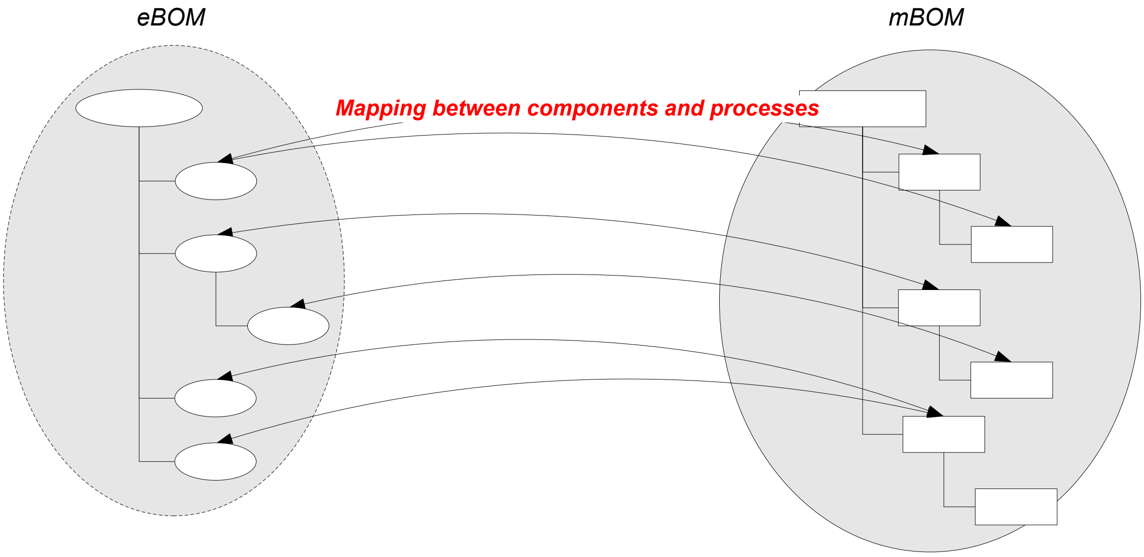

Figure 3. Mapping between two BOMs

To achieve mapping between engineering and manufacturing bill of material, the mapping parameters has to be defined. Mapping parameters are part of the components information and belong to the engineering bill of material. These parameters are:

- Activity_id – represents the identification number (id) of the first manufacturing process in which the components are used;
- Resource_id – depends on whether the part represents the material used in manufacturing process or a physical component. If the part is made from raw material then the resource_id receives the id from a material catalogue. If the part is purchased component then the resource_id receives the id from a component catalogue;
- Quantity – depends on the value of resource_id parameter. If the resource_id parameter represents the material, quantity parameter determinates the amount of the used material. If the resource_id parameter represents a physical component, the quantity parameter determinates the number of used components in the assembly.

The eBOM together with the mapping parameters form the extended bill of material. Parameters of manufacturing process are stored in the Project Management system and therefore, the next phase is to link PDM with the PM system.

3.2 Integration between PDM and PM system

The extended bill of material is the basis of the cost estimation. Stored in the PDM it includes the data about all the components, both from own manufacturing and purchased components. The manufacturing and production tasks are defined by the manufacturing bill of material and stored in the PM system. The interaction between PDM and PM determines exactly the process from raw materials to the final product. Mapping between PDM and PM systems is based on the manufacturing processes defined in the extended bill of material by activity_id parameter and manufacturing processes defined in mBOM. When PDM and PM systems are linked together, information about the manufacturing processes is available within the extended bill of material as well as component information is available within the structure of manufacturing process.

3.3 Integration between ERP and PM system

The estimation of instrument transformer cost includes the calculation of material and labor costs and machine depreciation. A PM system contains information about data related to the costs, while input/output costs within the company are stored in ERP system. Accordingly, the last phase in automatic estimation of instrument transformer costs is to link ERP system to the PM system. The link between ERP and PM system is established in both directions. The link from ERP to PM system is established to transfer material and labor costs and machine depreciation. When PM system contains the information about data related to the costs and costs information, the estimation process is performed within the PM system. Cost estimation process is based on the mBOM. Each manufacture process within the mBOM contains information about the:

- Components and materials necessary to accomplish the manufacturing process,
- Quantities for each components or material,
- Labor quotes for manufacturing process,
- Machine depreciation used in the manufacturing process.

Cost estimation process counts the costs based on the data from the manufacturing processes. The link from PM to ERP system is established to transfer the estimated cost. When cost information is available in ERP system, it is automatically available for any other use within a company.

As the cost information is based on the actual costs of present situation, the designer gets valid information supporting the decisions that has to be made at the very early phase of designing. Naturally this is not the whole truth, but manufacturing cost is one major criterion in the industry.

4. Cost estimation example

Estimation of a manufacturing cost will be shown here by an example of a product which consists of two plates including two holes, and which is assembled using two bolts and nuts. The holes are not similar in dimension so they need to be made in separate tasks by two different machines.

The product structure is shown on table 1, and it is extended by the additional parameters needed for integration with process structure. The component "plate" is a part which is produced from a raw material, and, therefore, the quantity represents the amount of used material (weight of plate is 100 kg). Bolt and nut are standard parts and, therefore, the quantity represents the number of times the component is used in the assembly. Material information is stored in the ERP systems and is shown on table 3.

Table 1. Product structure

Product structure	*Activity_id*	*Resource_id*	*Quantity*
Product P1			
- Plate	*D1*	*PartNumber 1*	*100*
- Plate	*D1*	*PartNumber 1*	*100*
- Bolt	*ASM1*	*PartNumber 2*	*2*
- Nut	*ASM1*	*PartNumber 3*	*2*

As in most of the cases the product goes through a number of different tasks during the manufacturing process. The example case includes the two drilling and an assembly tasks.

Table 2. Process structure

Process structure	Activity_id
Product P1	
- Drilling	*D1*
- Drilling	*D2*
- Assembling	*ASM1*

The manufacturing process tasks of the example product are listed in the process structure table (table 2).

The information from the ERP system needed for the manufacturing cost calculations is shown on table 3. The material database content is the costs of the raw materials and costs of the purchased components. Labor database shows the direct labor costs for each operation. In the depreciation database there are the costs originating from the use of manufacturing machines.

Table 3. Material, labor and machine depreciation databases

Material database (ERP)	
Name	Costs
PartNumber 1	10
PartNumber 2	2
PartNumber 3	1

Labor database (ERP)	
Labor Number	Costs
Drilling	6
Assembling	3

Depreciation database (ERP)	
Machine depreciation	Costs/Operation
Drilling machine 1	7
Drilling machine 2	16

After the integration of eBOM and mBOM the manufacturing bill of material consists of the manufacturing processes and components used in those processes (figure 4).

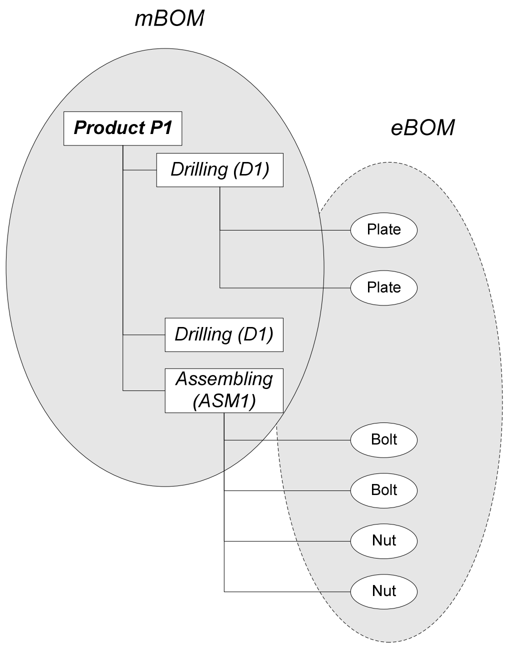

Figure 4. Integrated mBOM and eBOM

Calculation of the costs begins with the first process defined in mBOM (figure 4) and it is shown in the costs calculation table (table 4). During the calculation of the first process (D1) the following items are counted: material costs of two plates (based on the mapping between eBOM and mBOM) and costs of labor and drilling machine for each plate. The next manufacturing process is also drilling process for the second hole but as the mapping between product and process structure doesn't exists, the material costs of the plates are not included in the calculation. Items included in the calculation of the second process costs are the costs of labor and drilling machine 2. Second drilling process is performed on the plates which are already used in the first manufacturing process and therefore the material costs are not included in the second process. The cost of the second process is calculated from the labor cost and machine depreciation. Last manufacturing process is an assembly process and the cost calculation is calculated from the purchasing costs of bolts and nuts (based on the mapping between eBOM and mBOM) and labor costs.

Table 4. Cost calculation table for summing up the costs

Costs calculation			
Process steps:	*Items*	*Costs*	*Total*
- Drilling (D1)	PartNumber 1	10	
	Labor for drilling	6	
	Drilling machine 1	7	
	PartNumber 1	10	

	Labor for drilling	6	
	Drilling machine 1	7	46
- Drilling D2	Labor for drilling	6	
	Drilling machine 2	16	22
- Assembling (ASM 1)	PartNumber 2	2	
	PartNumber 2	2	
	PartNumber 3	1	
	PartNumber 3	1	
	Labor for assembling	4	10
		Total	**78**

The costs calculation table sums up the direct costs of the example product. As the tool gets the actual data from the company IT systems, the estimation presents the best possible information in hand for the designer.

5. Results

An information model for estimation of product cost consists of eBOM and mBOM which are mapped together. Each BOM separately holds information about the product and until the link between the BOMs is not established the full information about the product cost is not possible to estimate. The study conducted on the integration during this research showed the following results:

- An information model which integrates eBOM and mBOM enables the automatic calculation of manufacturing cost,
- Cost calculation is made using existing IT systems in the company (ERP, PDM, PM)
- Cost calculation enables designers and employees in other departments of the company to estimate the cost in a design phase
- Estimated product cost calculation enables the comparison with real product cost.

6. Conclusions

This research is focused on the production companies which expect benefits from the manufacturing processes. Instrument transformer companies are regarded as manufacturing companies whose competition on the market depends on manufacturing phase of product life cycle. Instrument transformers are always designed for a particular customer and its production is tailor made. From a design viewpoint, instrument transformers are not a complex product and their design time is measured in days. The above characteristics of instrument transformer make them an adequate example for costs estimation in an early phase of the products life cycle.

Mutual integration of the PDM, PM and ERP systems enables the estimation of instrument transformer costs. An engineering bill of material which contains structure of physical elements is extended by the elements necessary for mapping with the manufacturing bill of material. Those elements are Activity_id, Resource_id and Quantity_id. Such extension enables the ability of estimation of instrument transformer cost. Therefore, extended bill of material and manufacturing bill of material, together with the integration between the BOMs, constitute the information model for determination of instrument transformer costs. Automatic estimation of costs based on accurate information from different IT systems results in fewer deviations between estimate cost and real cost.

References

Ehrlenspiel, K., Kiewert, A., Lindeman, U., „Cost-Efficient Design", 978-3-540-34647-0, Springer Berlin Heidelberg New York, 2007.

Fill, C. and Visser, E., "The outsourcing dilemma: a composite approach to the make or buy decision", Management Decision, 38/1, 2000, p. 43-50

Niazi, A., Dail, J.S., Balabani, S. and Senevirante, L., "Product Cose Estimation: Technique Classification and Methodology Review", Journal of Manufactruing Science and Engineering, May 2006, Vol. 128, pp563.575.

Wang, L., Song, B., Li, X. and Ng,W.K., „A Product Family Based Life Cycle Cost Model for Part Variety and Change Analysis“, ICED 07, Paris, August 28-31, 2007.

Davor Pavlić, PhD
Chief of Product Family Development and IT Integration
KONČAR – Instrument transformers
Josipa Mokrovića 10
10090 Zagreb, Croatia
Telephone: +385 99 3177 620
Email: davor.pavlic@koncar-mjt.hr