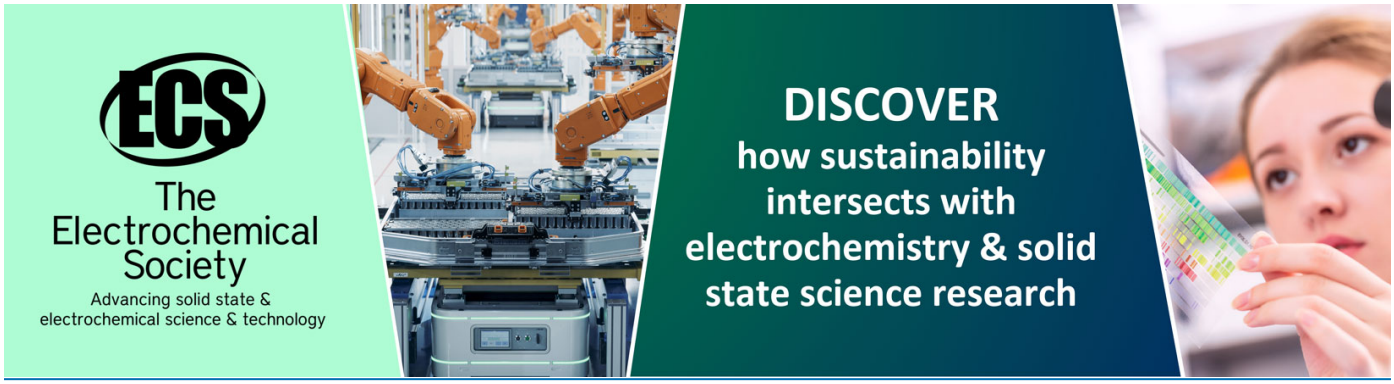
A customization-oriented framework for product development. Case study- energy-efficient windows



IOP Conf. Series: Materials Science and Engineering **399** (2018) 012041 doi:10.1088/1757-899X/399/1/012041

A customization-oriented framework for product development. Case study- energy-efficient windows

A L Parv[1*], B A Deaky[1], R Stasiak-Betlejewska[2] and J Stawicka[2]

[1] Department of Manufacturing Engineering, Faculty of Technological Engineering and Industrial Management, Transilvania University of Brasov, Romania
[2] Institute of Production Engineering, Faculty of Management, Czestochowa University of Technology, Poland

[*] E-mail: luminita.parv@unitbv.ro

Abstract. This paper presents the authors' approach to producing customised products. The authors address the support of information sharing and activity synchronization within and between teams. The paper discusses a methodology for modelling data and original software for product data management that includes customers' preferences and specifications. The developed system has the ability to select an activity, as well as machining processes and parameters based on a set of design and production parameters, and to estimate product cost throughout the entire product development cycle. The case study refers to a product type called "energy-efficient windows". Window panes must be delivered to customers in a variety of shapes, dimensions, and materials according to certain specifications. The Access database provides the geometrical data for the next module, the CAD module that is achieved using Solid Works.

1. Introduction

In order to create higher value for a variety of customer needs and wants [1, 2], manufacturers often customise their offerings [3] and integrate services more and more with their products [4]. Nowadays, product development is impossible without taking into account customers' requirements. When managers understand the jobs and outcomes their customers are trying to achieve and the constraints they are trying to overcome, they dramatically improve their chances for growth, as they know exactly where to create value – leaving less to chance.

It is important for managers to know just what types of information they obtain when capturing the voice-of-the-customer.

Development and marketing managers are responsible for identifying opportunities for growth, segmenting markets, conducting competitive analysis, generating and evaluating ideas, communicating value to customers, and measuring customer satisfaction. Interestingly, they are dependent on obtaining information from customers in order to successfully perform these activities, making the process of gathering "customer requirements" one of the most critical business processes [5, 6].

Product development might ever more take into account improved customers' tastes and requests in a shorter time-to-market [7].

This paper presents a methodology for modelling data that includes customers' preferences and specifications.

The case study refers to a product type called "thermo-insulating windowpanes". Windowpanes must be delivered to customers in a variety of shapes, dimensions, and materials according to certain specifications.

The system consists of four modules:

- the Customer requirement module;
- the CAD module;
- the CAM module;
- the ABC module.

The customer requirement module provides the geometrical data for the next module, the CAD module that was achieved using Solid Works. The CAD module provides the data for the CAM module. The CAD and CAM modules provide the data for the ABC module (Activity Based Costing).

This paper describes the module regarding customers' requirements management. The implementation of the above presented model was carried out using Microsoft Access.

2. Considerations regarding the systemic designing approach

Systemic methods allow visualizing and understanding data organization. These methods are abstractions that present the real world as a collection of entities and associations established between those entities [5, 8]. Figure 1 shows the system architecture.

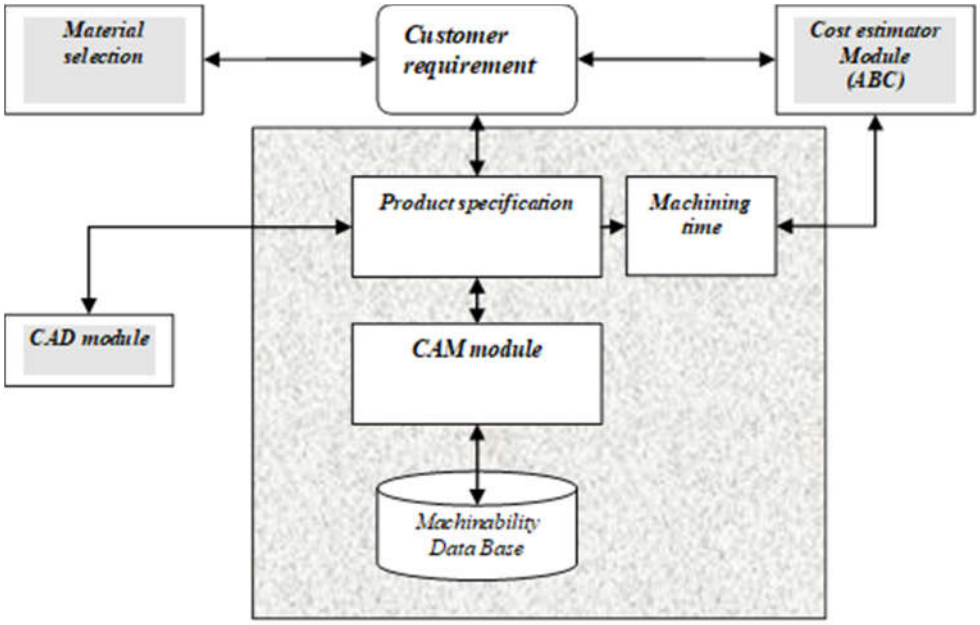


Figure 1. The system architecture.

Most systemic methods allow defining restrictions that describe static aspects, dynamic aspects or even temporal characteristics of entities.

They are legible formalisms of required specifications. Two methods are usually references for semantic representation: the individual method that will be integrated Merise and the entity-association method. Combining basic concepts of entity-association model (entity, attribute, association, cardinality, integrity restrictions) with Codd's normalizing rules was defined as a dictionary of data, entities, associations, cardinalities, structural, and semantic integrity restrictions.

The matrix of functional dependencies between attributes, as an additional element for validating the models of the studied system from a conceptual, relational (logical), and physical point of view was also defined.

These Codd´s rules provide the theoretical (although sometimes not practical) underpinnings for modern database design [8]. The rules may be summarized as follows:

- all database management must take place using the relational innate functionality of the database;
- all information in the database must be stored as values in a table;
- all database information must be accessible through the combination of a table name, a primary key, and a column name;
- the database must use null values to indicate missing or unknown information;
- the database schema must be described using the relational database syntax;
- the system must be able to update all updatable views;
- the database must provide single-operation insert, update, and delete functionality;
- changes of the physical structure of the database must be transparent for applications and users.

These are the rules used for the proposed database model.

3. Defining the thermo-insulating windowpane product

Specialized studies show that heat in a building is lost in many ways: 41% through the windows, 9% through the floor, 24% through the roof, 26% through the walls [9].

The thermo-insulating windowpane is an assembly of two window sheets that seal between them an air cushion with zero humidity or an inert-gas, usually argon for perfect thermo-insulating. If phonic insulation is wanted the argon is replaced by sulphur hexafluoride.

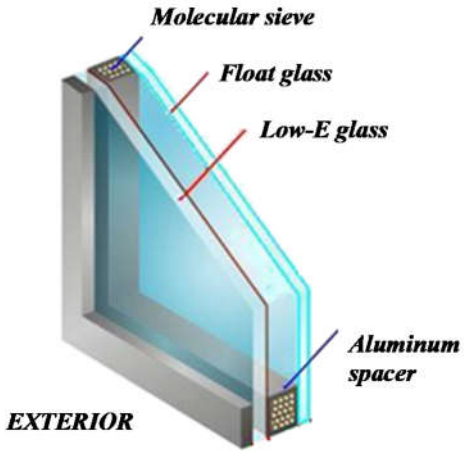


Figure 2. Studied product – Windowpane.

The degree of thermo insulation is determined according to the type of glass. For better results, treated glass is recommended, for example, LowE glass (low emission glass).

Emissivity is the property of a material to release the absorbed heat [9]. Normal glass surfaces allow significant heat loss caused by conduction and convection phenomena. Low emission glass allows improving the insulation property of double sheet windows by reducing heat convection.

This kind of window works like a mirror, reflecting back the heat in the environment where it was produced (figure 2).

4. Modelling and implementing technical and non-technical data

Data Dictionary

Database modelling is an important part of the database design process. It provides a structured, systematic approach that supports the development of well-structured and high-performance databases.

If databases are well designed, potential problems associated with data redundancy and poor performance due to ill-structured links between tables can be avoided or minimized.

A data dictionary will be developed according to the modelling methodology presented before and based on the enumerated data administration rules.

The matrix of the functional dependencies is used for the determination of the relationships between the attributes.

Conceptual model

The conceptual model defines the entities and relationships in the system being modelled.

Logical model

Having as starting-point the data dictionary and the conceptual data model, the logical or relational model is created.

For this purpose, the well-known rules regarding the normal forms of Codd (FN1, FN2, FN3) and the rules for passing from the conceptual data model to the relational (logical) data model were used.

Software implementation

Microsoft Access is widely used by small businesses and hobby programmers to create ad hoc customized systems for handling small tasks. Its ease of use and powerful design tools give non-professional programmers a lot of power for little effort.

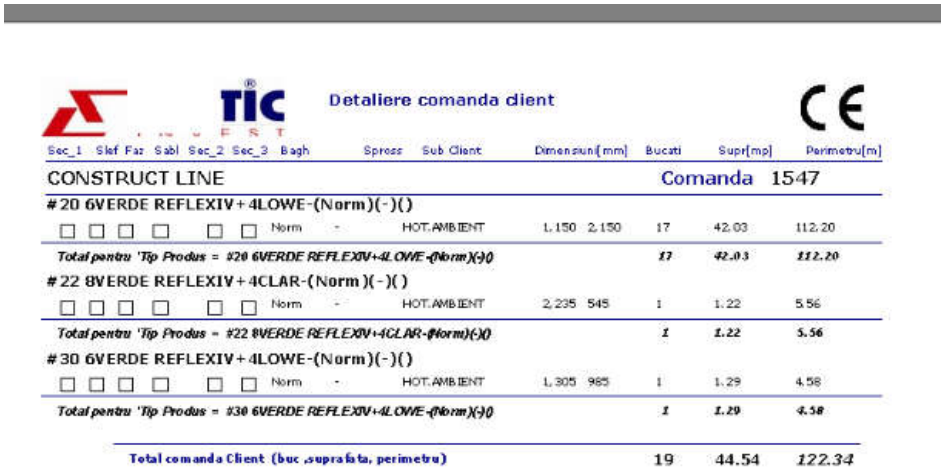


Figure 3. Customer requirements.

However, this ease of use can be misleading. This sort of power user is often an office worker with little or no training in application or data design.

Because of Access, it is possible even for such developers to create usable systems and many are misled into thinking that the tool itself is limited to such applications.

Creating a module for data administration in Access (figure 3) allows data transfer in Excel tables, which facilitates the integration of the two modules (this module and the CAD module which contain the parametric design of the windowpane).

The main menu contains five sub-menus. These sub-menus manage:

- customers with principal data;
- requirements;
- types of glass;
- types of baguette;
- types of window bar.

5. The CAD module

As each CAD system has its own method of describing geometry, both mathematically and structurally, there is always some loss of information when translating data from CAD data format to CAM.

The intermediate file formats are also limited in what they can describe, and they can be interpreted differently by both the sending and the receiving system [10].

It is therefore important when transferring data between systems to identify what needs to be translated.

A model of the component is constructed in Solid Works by the designer via the CAD system. The component dimensions and its volume are retrieved from the database of CAD.

The designer must specify all the features of the component and their attributes.

The system then prompts the user to select the material of the product.

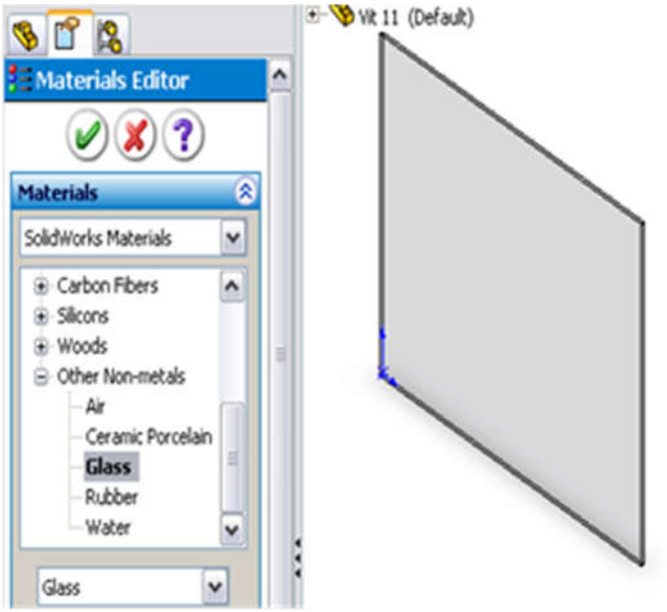


Figure 4. Material selection.

There are many constraints for material selection (figure 4), such as product functionality, material cost, and the type of manufacturing process.

6. The CAM module

The compatibility of the modularly designed system components is assured while facilitating a continuous production process – from storage to cutting solutions, to automatic breaking and sorting systems.

The extensive product variety ranges from manual plants up to fully automatic complete solutions [11, 12].

Figure 5 shows the CAM software (X-cut) would output code for the Bystronic CNC machine.

Bystronic glass cutting systems (figure 6) guarantee efficiency at the highest level.

Figure 5. Optimization window.

Figure 6. Bystronic CNC window.

7. The cost estimation module

The cost estimation according to the ABC method assumes covering the main following stages [13]:

- sharing the costs in direct and indirect costs;
- indirect costs separation on activities connected to survey centers;
- the identification of cost determinants for each type of activity;
- activities realignment based on cost determinants in realignment centers and the unitary cost estimation/determinant;
- the total cost estimation of the product through totalizing the direct cost with that of the cost determinants deriving from the realignment centers necessary for the achievement of the product.

In conformity with the carried-out survey upon the costs situation on activities, authors made the cost model shown in the relation (1).

$$C = F + \sum_i b_i * x_i + \sum_{ij} D_i * B_{ij} \quad (1)$$

where:

C - product cost;
b_i - direct costs of the product unit (including human resource costs, direct costs with materials, etc);
x_i - number of type i of cost drivers;
D_i - cost driver rate of i activity;
B_{ij} - number of cost drivers on i activity used by j resource.
The relation (1) will become:

$$C = F + VD + AD \tag{2}$$

where:
VD- total direct variable cost;
AD - total indirect activity cost.

The previous model can be shown as a matrix in relation (2), so:

$$VD = \begin{bmatrix} b_1x_1 & b_2x_2 & b_3x_3 \dots & \dots & b_mx_m \end{bmatrix}^{\mathrm{T}} \tag{3}$$

where:
b_i - direct costs of the product unit (including human resource costs, direct costs with materials, etc.) ;
x_i – number of type i of cost drivers.

The total indirect cost of activities will be presented in relation (4):

$$AD = \left[\frac{A_{ij}}{\sum_{i=1}^{m} A_{ij}}\right]_{m*n} * \left[\frac{R_{jk}}{\sum_{j=1}^{n} R_{jk}}\right]_{n*s} * p_k \tag{4}$$

where:
A_{ij} -number of activity j consumed of product;
R_{jk}- resources consumed by j activity;
p_k - price of type k .

Adding the parameter time t to this formula leads to the determination of the cost drivers.

8. Conclusion

Over the past few years, two issues have become mantras for corporations all around the world: ″mass customization″ and ″meeting or exceeding the customer's needs″.

The original software presents a way of implementing a customer module with a CAD module, a CAM module, and a Cost management module (ABC).

The integration of the module referring to customer requirements is absolutely necessary in the context of the presented product typology.

The module may be generalized and its use extended to other products.

Customer requirement management has been well recognized as one of the principal factors in product development for achieving success in the marketplace.

The developed system has the ability to select a material, as well as machining processes and parameters based on a set of design and production parameters, and to estimate the product cost throughout the entire product development cycle, including the assembly cost.

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