PLM ANALYSIS APPROACH FOR FORMWORK CONSTRUCTION EQUIPMENTS

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ABSTRACT: The paper analyses, by using the PLM (Product Lifecycle Management) approach, the demands a new equipment in the formwork construction domain requires. The aim is to design a new intelligent product that responds to the market’s needs. By using primary and secondary information data we first determined the main components of such formwork equipments followed by the definition of the proposed requirements. Following the steps of other investigation methods we determined the functions of the new product, evaluated and established their priority.

Hence, by validating the needs we obtained the product specifications and by using this input data we can proceed with a next step in the creation process: the design of the equipment.

KEY WORDS: PLM, formwork, equipment, functions, market research.

1 INTRODUCTION

The market is defined by a resource economy directed towards the consumer. Also, another important aspect in this technological era is the increase of the computer science industry.

Because there are various ways of fulfilling the client’s needs and desires, all the products are customized ones, with low production costs and short manufacturing periods of time.

Hence, the construction domain is no exception. The path is to design new efficient and even intelligent technological equipment.

The paper presents a new approach regarding the design of concrete pouring formworks - mainly the function identification stage for the product - a base element for the execution of customised constructions at low costs.

In the construction domain having an equipment that has a much higher productivity rate than the present existing ones and to design an intelligent formwork that responds to the market’s request is a necessity not only in order to survive in this area but also to assure a high quality element.

2 PLM APPROACH OF THE PRODUCT IN THE CONSTRUCTION DOMAIN

In order to obtain a product that satisfies all the demands and to embed all the data collected in an optimum manner we used the Product life management cycle concept.

As the diagram shows (Figure 1), the life cycle management contains all the activities from the acknowledgment of needs until the withdrawal and recycling of the product, following five important steps: need review, design, production stage, usage and withdrawal from the market.

Figure 1. Product life cycle management

Hence, by using the product life cycle management concept we can determine all the demands, the resulting solutions, the optimum model and the model itself. The centre point in this paper is the demand management and the predesign of the product by identifying the needs.

This first part is also divided in three other steps as shown in Figure 2:

- The identification of needs, where the input data are all the quality and quantity analysis methods that lead us to the consumer’s needs;
- The enunciation of needs;
- The validation of the needs.

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3 THE PRODUCT

Our starting point for this research is an existing simple wall formwork. Formworks are construction elements used as a mould in order to pour concrete.

Specialists in the construction domain study the possibility to design a formwork based on the market’s needs, with the possibility to use it at various constructive solutions for different elements, having maximum efficiency.

Their shape depend on the type of element we will pour, it can have different types of material and of course assembling elements (Figure 4).
elements that assure the smoothness and strength requirements. The main components can have different shapes and may differ depending on the manufacturer. The principle components of such a formwork are noted in the figure below with an affinity diagram referring to the final shape and position on the field.

Analysing the following affinity diagrams we can see the shapes, components and we can understand their role as a formwork component.

In the first part of the diagram (Figure 6) we studied the basic part of the formwork’s main components: the panel and the fixing elements.

In case of wall formworks the panels have large dimensions and can differ function of the type of vertical poured diaphragm.

The second diagram we analysed the stiffeners. As principle reinforcing element in a formwork, the number of walers are determined function of the element’s lateral surface and the pressure acting upon the panel. Its role is to factorize the forces acting upon the formwork.

The secondary stiffeners (studs) are also used in order to shrunken the bay. The walers and the studs form the resistance element of the formwork.

One of the fixing elements is the linings – in this case the tie rod. Its main purpose is to assure the verticality of the formwork and to confer in both

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**Figure 5. Formwork – main components**

3.1.1 Formwork components

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**Figure 6. Formwork affinity diagram - part 1**
stability. It can be made out of timber or metal, and cases it has the possibility of adjusting the length of the tie with purlins (for the wooden type) and by a screw thread (for the metallic tie rod).

The assembling elements are also part of the fixing components of the formwork. By using them one can assure the connection between different parts and the continuity of the panels.

The diagrams are a result of the data obtained through research and gathering of information.

It represents a support in identifying the starting point for designing the product and a skeleton for the constructive solution.

By using the PLM method, analysing the market’s demands and having the right information we established the working algorithm.

3.1.2 Formwork analysis

Theoretical aspects
The first step in market analysis is the research. By documentation, focus groups and brainstorming methods we determine what are the leaks concerning an existing product and the needs for a new one.

In our case we used (as previously explained) an affinity diagram in order to group all the known data referring to the actual product. The starting point was the idea that by knowing its components and working manner one can determine where we can improve/enhance the product.

By knowing these aspects we analysed the markets’ needs.

We started by determining what people consider to be a weak point of the existing formwork. After obtaining this information we analysed the causes. A second approach in our research was the analyse from a different point of view the needs. We carried out a questionary to determine what people consider a new formwork must contain in terms of functions.

By reviewing all the data obtained in the questionary we then continued the need analysis with the ranking of the functions. By comparison we determined which is the most important function that a vertical formwork must have.

After this step, by using creative methods we can determine what are the practical solutions for these functions and how can we satisfy a specific demand. In this way (through the need assay) we will have an answer for the question: What is the product’s purpose?

Formwork analysis

An important aspect in identifying the needs is the input data. These can be obtained by accessing the primary and secondary information sources.

As mentioned in the previous sub-chapter, we started the formwork analysis data by analysing the known data from the existing formwork.

In order to determine what are the causes for the low productivity and the lack of output data information in using a now-a-days usual wall formwork we used the Ishikawa diagram (also known as the fishbone diagram).

The diagram allows us to highlight and rank the causes that generate a certain effect.

The main step in creating such a diagram is to note the problem. After this was achieved, brainstorming sessions were made in order to determine the causes for our mentioned effects but also to have as much details as possible for each branch. Figure 9 presents the most important parameters that led to this effect. The selection of these causes was made by using a Pareto plot (Figure 9).

Also known as the 80/20 rule, the diagram follows the principle stating that most of the problems (80% of them) have only few key causes (20%). As one can notice, the causes obtained in the Pareto diagram as being important were also used as principle causes for the low productivity effect and lack of output information from the existing equipment of the formwork.
Another method used for analysing the market’s demands was the questionary. Analysing the previous obtained data, we created a questionary in order to determine what people consider necessary to improve at the existing vertical formwork (the product), to suggest a solution for each idea and also to state what other aspects can be changed by adding new functions to the equipment. In creating a new product, the market is one of the most important aspects in the need analysis because it represents the meeting point of the demand and request. The market can provide valuable information that can help the design process. For example: a product can theoretically respond to all the demands, but in practice, the market can be saturated. These data can only be discovered by analysing the market pulse.

Hence, besides the secondary information sources (internet, manuals, journals, articles) where all the formwork’s general characteristics can be determined, by using such a questionary we can establish the actual functions of the product. The objective of the pole is to determine the unsatisfied demands and to find and opinion concerning an implementing solution.

In order to gather all the necessary data, we first defined the sampling of interest. For the present questionary a number of subjects having different jobs in the same company or in a different company but with the same area of interest (civil engineering) were selected. All of them have direct contact with the formwork industry or use the technical formwork data (e.g. for planning activities). They were asked about what they consider necessary to improve at the existing formwork.

Hence, the questionary was a confirmation of the data obtained through the secondary information sources but also a capital of new functions (Figure 10).

The next step in the market analysis was the identification of the functions for the new equipment.

For this, a focus group was formed in order to see which of the functions obtained so far are most important.

The persons for the group were the ones who also done the questionary: civil engineering designers (specialists), mechanical engineers, architects, members from beneficiary/ employer, workers and engineers that have contact with this type of vertical formwork and economists.

Based on the information obtained from the gathered data, we transformed all the demands into functions and ranked them taking into account the importance and the workability aspect of each of them (named the raking criteria).

The used method is the TRIPLE CROSS method. The identified functions are the ones noted in the table below.

**Table 1. Function definition**

<table>
<thead>
<tr>
<th>Function no.</th>
<th>Notation</th>
<th>Type/ Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F1</td>
<td>Quick assembling / dismantling</td>
</tr>
<tr>
<td>2</td>
<td>F2</td>
<td>Concrete pressure resistance</td>
</tr>
<tr>
<td>3</td>
<td>F3</td>
<td>Formwork plane surface</td>
</tr>
</tbody>
</table>
Another step in the PLM diagram of activities is to validate the functions. By achieving this step we establish if these functions have any chance of evolution and if so, we need to determine the risk of a negative development.

In order to rank the stated functions, we compared them one by one giving notes taking into account their superiority in regard to a specified criterion.

The formula defining the hierarchy is the following: $R_i = \frac{\sum n_i}{\sum n_i}$

Knowing the ranking score obtained, one can easily calculate the percentage of each function.

From here we extract the most important ones and for them, using creative methods, we will determine the new solutions. When analysing the charts one can see that three functions are constantly present (although in different percentage - the value depending on the ranking factor): F1 – quick assembling/dismantling, F8 – formwork monitoring devices and F11 – durability (referring to the number of uses of the formwork).

![Figure 12. Function percentage – importance criterion](image12)

![Figure 13. Function ranking workability criterion](image13)

Also by analysing the data obtained from the questionnaire, we can summarise that the functions needed for the new equipment products are the ones listed in Figure 15.
4 CONCLUDING REMARKS

Starting from the Product life cycle management principles, by achieving the first step: preconception (demand management) we obtained the specifications concerning the functions of the new product.

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7 NOTATION

The following symbols are used in this paper:

- $R_i$: the rank of function „i”;
- $n_i$: the point obtained by function „i” in comparison with all the other functions;
- $n_i$: the points obtained by comparing each function with all the others (the total sum of the points obtained by every function „i”).

Figure 15. Formwork functions