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AXIOMATIC DESIGN AS A DESIGN METHOD FOR A HYBRID SERVICE ENGINEERING PRODUCT AS APPLIED IN AUTOMIZATION TECHNOLOGY

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ABSTRACT

The automobile industry is the largest innovator(-Engine) for the producers and providers of automization technology. New technology is frequently used in this field for the first time. A wide-ranging survey was made amongst the leading car builders in Germany. The aim of the interview was to analyse the functional requirements of the customers. Subsequently the requirements stated were classified with axiomatic design. The emphasis of the survey was placed on product properties in the service field. The aim was to determine to what extent axiomatic design is suited to plan a service around an already existing physical product.

Keywords: service engineering, automization technology, ROI Return on Investment

1 INTRODUCTION

The Institute of Machine Tools and Production Science of the University of Karlsruhe is a public research institute which researches and lectures in the field of production science. As part of the mechanical engineering faculty at the University of Karlsruhe the institute sees itself as the connecting link between the basic research institutes and the research and development fields in industry. The aim of the institute is to develop innovative solutions to improve production processes based on a balanced relationship between basic research and application oriented research. Due to the interaction between the groups of scientific researchers it is possible to cover many aspects of production science, from chip removal to factory organization.

The Robert Bosch *Automatisierungstechnik* GmbH is part of the Robert Bosch GmbH. The automization technology (AT) sector of the group with its 4722 employees achieved 1,650 billion DM of the groups annual turnover. The products made by *Bosch Automatisierungstechnik* are: industrial hydraulics, pneumatic systems, assembly technology, drive and control technology, screw and pressing systems as well as de-burring technology.

The automization product investigated at Robert Bosch GmbH – *Automatisierungstechnik* consists of a mixture of hardware and services. Hence it is a hybrid product.

Within the framework of a co-operative research project, the institute has developed and tested a three-phase product development method based on axiomatic design. The method has been especially developed for the development of hybrid products.

In the case of hybrid products the fact that during the development phase service and hardware are finely co-ordinated both in terms of schedule and content, must be taken into consideration. However, in most development departments the service aspects of the products to be developed are developed by the same person who is also developing the hardware aspect of the product. There is no such thing as an engineer who simultaneously and specifically develops the service aspect. This in turns means that only very occasionally a separate development department for services exists.

2 MOTIVATION

The manufacturers of products with short innovation cycles depend on very efficient and flexible production systems due to the very short write-off period. These types of producers include for example car manufacturers where the service life of a product hardly ever exceeds a period of five years.

The requirements of these special customers of automization technology have changed drastically over the past few years. Automization strategies and maintenance strategies are being subjected to big change. The construction of automized production lines for the automobile production has always been the task of an external general contractor. The manufacturers tend to increasingly contract out the planning and maintenance of production systems.

Added to this is the fact that products of automization technology are less frequently being sold as pure hardware, instead they are more frequently sold together with a maintenance and service contract (as a hybrid product).

3 AIM

Frequently the automobile industry is the first sector to use innovative products of automization technology. The result of this is that the primary aim of the provider of innovative automization technology is to place himself in a prime position in precisely this market.

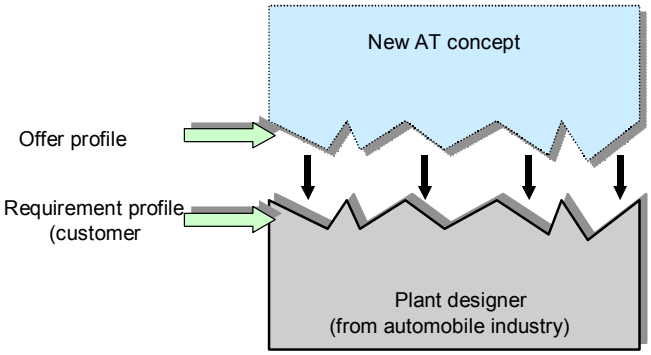

Figure 1. Adaptation of offer profile to requirement profile.

In order to guarantee this good placement and therefore also a wide acceptance, the offer of innovative automization technology must fulfil the customer's requirements precisely. This presupposes that the provider of automization technology adapts the form of his offer to exactly suit the requirements of his customer. (compare Fig. 1). To do this it is necessary to open up new potential in the form of enthusiasm requirements and enthusiasm features (compare fig. 2).

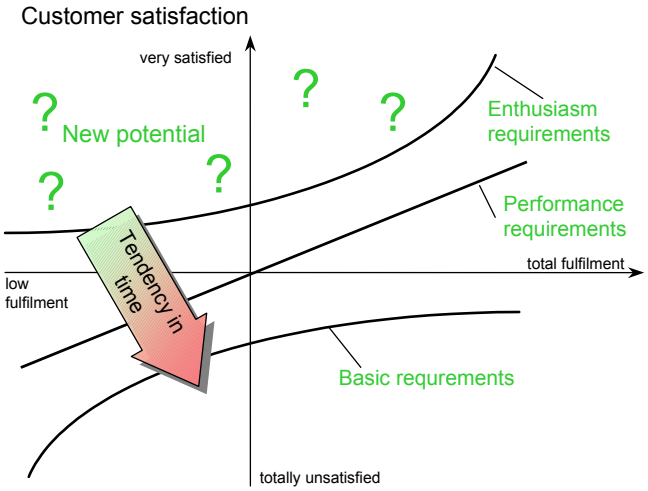

Figure 2. KANO-Model

Enthusiasm features are new latent, existent customer requirements of which the customer is frequently not aware himself. Therefore these are frequently thought of and developed by the manufacturer of a new product. Specific fulfilment and realization of latent customer requirements which have not yet been voiced by the customer are especially suited to stand out from the remaining existing competing products.

4 PROCEDURE

The planning phase of the innovative product package was divided into three stages:

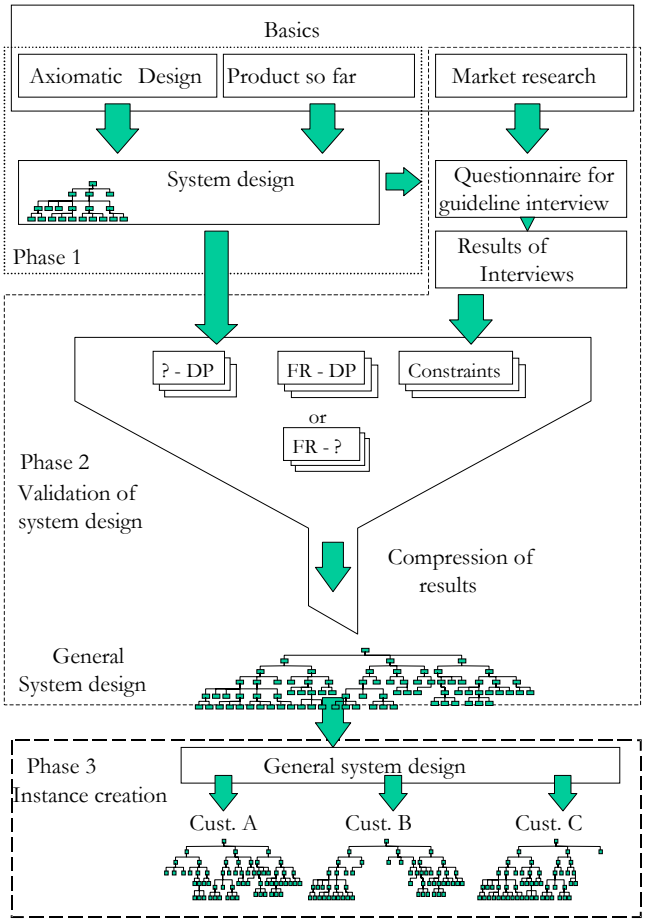

Figure 3. Three phases

1. In the system design phase, the central question of the appearance of the general automization module is to be clarified.
2. Phase two consists of validating the product package from the customer point of view. In doing so, the individual details make up a general axiomatic design structure into which all the customer's requirements (functional requirements) have been included.
3. In the final phase, special customer orientated product packages are derived from the general axiomatic design structure.

Figure 4 shows how interaction with the customer increases throughout the three phases.

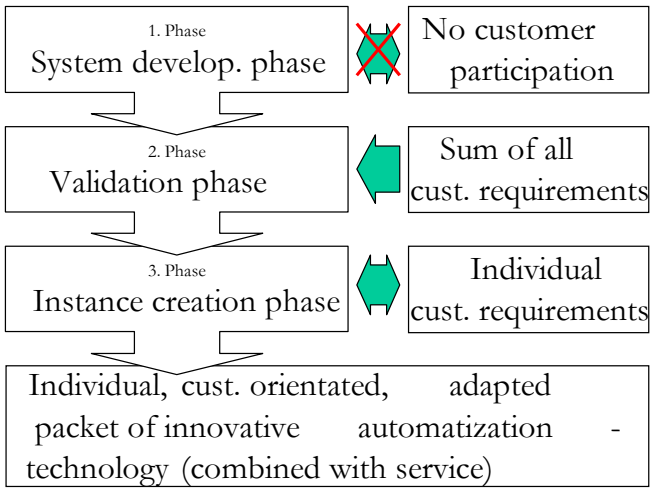

Figure 4. Influence of customer on the three phases of product development

4.1 System design phase (Structurization of the planned Product)

An intensive analysis of the customer requirements by the customer is always preceded by the structurization of the planned product package made of hardware and service with the help of the axiomatic design method.

The basis of axiomatic design structure always assumes an economic factor of the customer for automization technology: the „Return on Investment“ (ROI). The customer's aim in automization technology is to maximize the ROI. The ROI is generally defined (Equ. 1).

$$\mathrm{ROI} = \frac{\text{turnover - costs}}{\text{Investment}} \qquad (1)$$

In terms of automization technology, for the customer of automization technology the ROI is defined as in (Equ. 2).

$$\mathrm{ROI} = \frac{\text{Time saved by AT - Current costs to maintain the AT}}{\text{Investment to use the AT}} \qquad (2)$$

The three most important requirements to specify the aim in detail are a result of the assumed functional requirements of the customer: „Maximize the ROI“.

1. Maximize turnover (using automization technology)
2. Minimize running costs
3. Minimize investment when using automization technology

On the first two levels, the realization of the aims in axiomatic design takes place as follows:

Table 1. Realization of aims in AD.

FR1: Maximize the Return on Invest-ment	**DP1: Automization module of Robert Bosch GmbH**
FR11: Parallelize and integrate and minimize primary and secondary processes	DP11: Speed up and optimize processes through automization
FR12: Reduce the costs to ensure process and plant functions during operating periods.	DP12: Target cost orientated operating using suitable business processes and tools.
FR13: Optimize costs for planning and forecasting AT components	DP13: System orientated investment

The following design matrix is a result of these functional requirements and design parameters (compare Equ. 3):

$$\begin{Bmatrix} FR11 \\ FR12 \\ FR13 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} \cdot \begin{Bmatrix} DP11 \\ DP12 \\ DP13 \end{Bmatrix} \qquad (3)$$

After defining the first two levels, it was divided into additional, more detailed levels in accordance with the zigzagging principle.:

The greater detail provided an initial system design for an innovative product package of automization technology.

4.2 Validation phase

The validation phase consisted of the analysis of customer requirements in general and the comparison with the system designed in Phase 1. The aim is to validate whether or not the structure found in phase 1 leads to a “good” product from the customer's point of view.

As has been already discussed in Chapter 3 (Aim), the automobile manufacturer is the main customer of innovative automization technology. The circle of customers is made of four different sectors/ departments: users, factory planning, maintenance and purchasing. All four sectors / departments make joint decisions in terms of purchasing automization technology. For this reason, this decision-making committee should have equal say during the interviews.

To ensure that the interviews are comparable, every interview was held in accordance with some guidelines which were generated along the lines of the system design arrived at during Phase 1.

The result of the validation phase was that the customer for automization technology does not really think in terms of economic factors (e.g. ROI). The customer's foremost concern is to ensure that the plant runs without any problems. Therefore the system design arrived at in Phase 1 had to be adapted to incorporate the results from Phase 2.

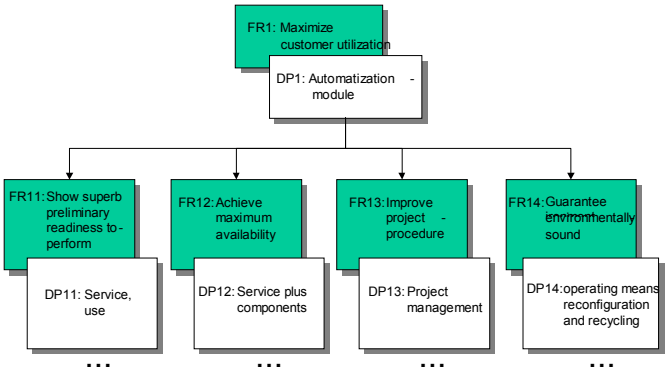

Figure 5. Customer's influence on the three phases of product development

This figure shows which constraints have been able to be decided by all users. The constraints are divided into two categories: hardware and service.

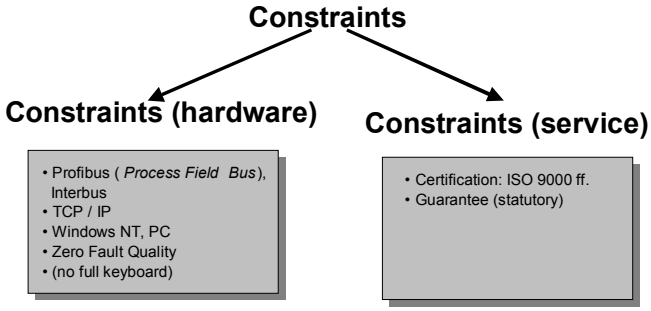

Figure 6. Constraints arising from he interviews

The overall planning of the product package and the further development is a result of the axiomatic design structure arrived at in the validation phase and the associated constraints.

4.3 INSTANCE CREATION PHASE

The general structure of the product designed in Chapter 4.2 can now be adapted to suit the individual customers. This process can be called instance creation as there are parallels with object orientated programming.

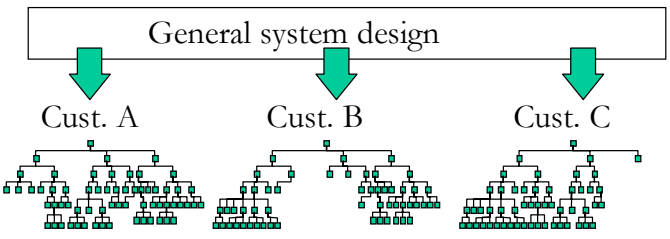

Figure 7. Instance creation

5 SUMMARY

In the first phase a product was planned with AD, this product was then validated during the second phase in accordance with the customer's requirements using aids from the sector of market research. The result was a product package which covered the most important requirements of ALL customers. During the third phase the general product package was adapted to suit the requirements of individual customers.

The general axiomatic design structure created during the second phase serves the manufacturer of the product as a guideline for further research and development.

6 CONCLUSION

The structurization of the given products in accordance with an economic factor and axiomatic design resulted in a very clear structure. However, the validation showed that the customer never sees a factor , instead he only sees the direct use he derives from automization. This means that on principle different functional requirements result in the first and second level of an axiomatic design structure. However, subordinated structure areas from the structure found in Phase 1 can be used at a later stage.

7 FORECAST

The instance creating phase has already been concluded for a number of key customers of the automization manufacturer. Instances of the general structure developed during Phase 2 have been created. Now the effect of the structures derived especially for the individual customers must be evaluated critically. In addition, the flow on the market must be reviewed regularly and be integrated into the general system design from Phase 2 as otherwise there is the danger of the structure becoming outdated too quickly.

Furthermore, the extent to which a pure service product can be planned using the support of axiomatic design must also be investigated. The question whether service planning methods such as "BluePrinting" can be supported by axiomatic design, is currently being investigated at the Institute.

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