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# CUSTOMER ORIENTED PRODUCT PLANNING PROCEDURE

**Abstract**

*One of the most important issues in product planning is to identify customer needs and combine them with product technical and trade characteristics. Identification of customer needs was discussed, and product decomposition method was presented in the paper. The Quality Function Deployment method was suggested to be applied as a product and production process data integration tool, where engineering characteristics of a product are combined with its trade characteristics.*

## 1. INTRODUCTION

One of the strategies adopted by several companies is to manufacture products according to individual customer requirements with low production costs.

Application of computer aided systems supporting decisions on customized pro-duct configuration requires identifying attributes which are important from both customer and producer perspective.

Researchers have developed methods which combine customer needs with product characteristics, taking into consideration the production process. Tseng et al. [22] combined virtual prototyping with manufacturing simulation techniques to allow individual customer requirements and production process capabilities of company to be balanced in the design stage. Yao et al. [24–26] proposed a system for a rapid design and simulation of manufacturing systems. In the proposed system, an information model based on part characteristics features was used.

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Cheng et al. presented a structure-based approach to evaluating product adaptability in adaptable design, where they noticed that modular product structure can be used to create a variety of products [2].

Knowledge based-systems, which support decision problems in enterprises, are widely developed, e.g. a knowledge-based system for assembly sequence planning was developed by Hsu et al. [6]. Neural networks NN in supporting decisions in manufacturing process were used by Kim et al. [11], Lai et al. [13] and Sukthomya [21]. Methods useful in product planning and manufacturing were analysed by Quiza et al. [17], Rafiei et al. [18], Sakamoto [20], Xu et al. [23].

The key issues of manufacturing products according to individual customer requirements are:

- Finding product characteristics suitable for a particular customer.
- Product planning procedure - finding or designing products which correspond to given product characteristics.
- Defining resources needed for the manufacturing process.

The proposed customer-oriented product planning procedure can be used as a method of data analysis in knowledge-based systems supporting product configuration.

## 2. FINDING PRODUCT CHARACTERISTICS SUITABLE FOR A PARTICULAR CUSTOMER

Product characteristics needed by a particular customer can be described on three levels: core part of the product, tangible product and augmented product. Core product refers to the product use and its function. The meaning of core product determines product assortment line. Tangible product characteristics include, among others, quality or style, and determine the type of product item in the assortment line. Augmented product includes warranties, installation, etc. and another services offered in relation with the product.

These tree levels of product can be used in the procedure of finding product characteristic suitable for a particular client. The main steps in the proposed product characteristics procedure include:

1. Core product characteristics – basic product function characteristics.
2. Tangible product characteristics – secondary product function characteristics.
3. Augmented product characteristics – services added to the product, trade characteristics.

Product function identification and improvement can be supported by value engineering. The basic questions which helps to identify the function are: What does the product do? What must it do? What should it do? What could it do? What must it not do? Value engineering was applied for instance by Cook et al. [4].

In product function identification, Kano's model (fig. 1) can be used. Kano's model divided product characteristics into the following categories [2]: must-be requirements, one-dimensional requirements, attractive requirements, indifferent requirements and reverse requirements. Must-be requirements are focused on customer buying decision. If the attributes are not offered, the product will not be bought at all. These attributes are necessary for a customer and create core product. One-dimensional requirements influence customer satisfaction. If this type of product attributes are offered on a high level, customer satisfaction will increase. Attractive requirements are not expected by customers. This kind of attributes cause customer satisfaction. If this kind of attribute is not offered, customer will not notice it. Indifference requirements – customer is not interested in these attributes. Reverse requirements – customer is dissatisfied if the attribute is offered, a lower level of this attribute causes customer satisfaction.

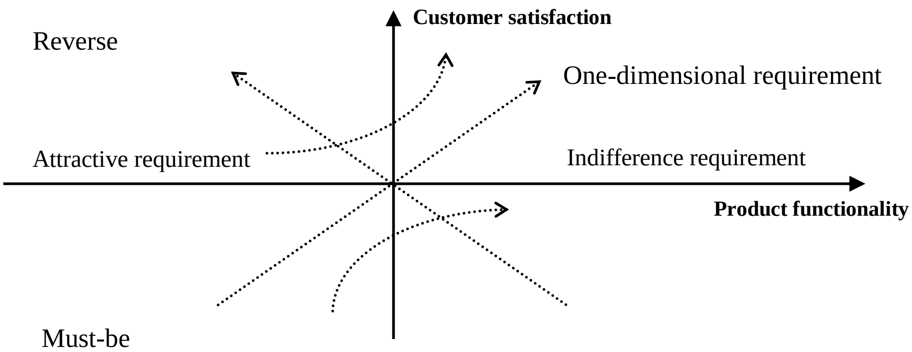



**Fig. 1. Kano's model of customer satisfaction [source: on the basis of [2]]**

## 3. PRODUCT PLANNING PROCEDURE

The concept of made-to-order (MTO) product assumes that customers influence product design. In many cases product changes bring about production process changes. Some product changes require tools which have not been used until now in the production process. The question is how product changes influence production cost and product delivery time, and how that calculation should be performed. MTO product planning requires: establishing the type of product changes, limit of acceptable changes (e.g. product dimensions, materials, functions), product reliability assessment and production process capability assessment. The procedure of product planning was presented in fig. 2.

In the proposed procedure, the concept of three level product characteristics was applied.

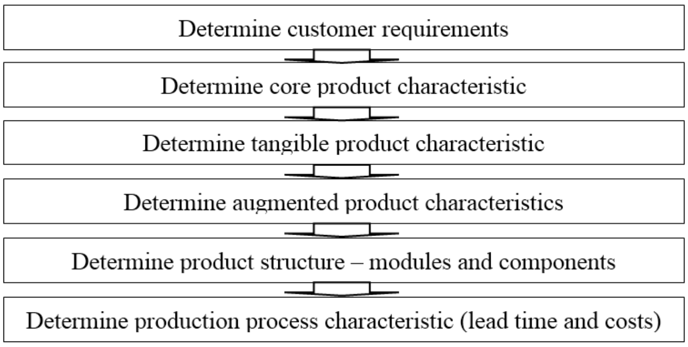
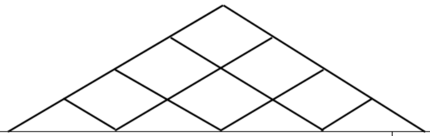



**Fig. 2. Product planning procedure [source: own study]**

Customer requirements determination can be carried out with the use of the QFD method. QFD is used as a method which helps increase customer satisfaction. Jariri et al. [8] applied QFD for optimizing customer satisfaction focused on target costs. Many authors link QFD with other methods, Baier et al. [1] links Quality Function Deployment and Conjoint Analysis for new product design, Chou [3] joins NN with QFD in conceptual design. Poel [16] has also discussed some methodological problems in QFD.

QFD has been applied in many industrial branches in a wide range of use. QFD helps to specify product features which are important for the customer and designers, as well as for production engineers.

The relation between main features important for the customer, designer and production engineers can be presented in QFD series of matrices. The first one represents the relation between customer requirements and product characteristics (fig. 3). The second one describes the relation between product characteristics and product parts. The third QFD matrix provides information related to the production process. The fourth one provides information related to the production process parameters [7, 19].



| What? / How? | | | Product characteristic | | | | Importance |
|---|---|---|---|---|---|---|---|
| Customer requirements | **Attributes** | **Value** | $p_{mk1}$ | $p_{mk2}$ | ... | $p_{mkz}$ | |
| | $f_1$ | $f_{11}^{w}$ | $c_{11}$ | $c_{12}$ | | $c_{1k}$ | |
| | $f_2$ | $f_{22}^{w}$ | $c_{21}$ | $c_{22}$ | | $c_{2k}$ | |
| | | | | | | | |
| | $f_n$ | $f_{n2}^{w}$ | $c_{z1}$ | $c_{z2}$ | | $c_{zk}$ | |
| | **Target level of product characteristic** | | $p_{mk1t}^{woz}$ | $p_{mk2t}^{woz}$ | | $p_{mkzt}^{woz}$ | |

**Fig. 3. QFD matrix [12]**

In the QFD matrix presented in fig. 3 above, “$c_{zk}$” denotes a correlation between customer requirements and product characteristics and takes value 1, 3 or 9, where 1 means a weak correlation, 3 means a medium correlation and 9 means a strong correlation. The correlation between product characteristic on the matrix roof can be positive, denoted by “+” or negative, denoted by “–“.

The next step in the proposed product planning procedure is focused on product structure determination. Fan et al. [5] proposed a product structure which includes: basic module (an indispensable module for forming a product), must – selected module chosen to create a customised product, may – selected module – a special supplementary and customized module.

Researchers have focused on different aspects and methods supporting product configuration. Ming et al. [15] presented gaps analysis in the existing concepts supporting product configuration:

- collaborative design portal – lack of design of user friendly interfaces to enable real time collaboration,
- configurable design – lack of systematic ontology and processes on product configuration design,
- modular design – lack of systematic technology to represent, identify, reuse modules in new product development,
- platform-based design – lack of systematic technology to represent platform design,
- product knowledge management – lack of systematic way to represent, capture, organize, share, apply, create the design knowledge,
- lifecycle evaluation and optimization – lack of systematic way to evaluate life cycle efficiency at an early design stage.

Customer needs identification is the first step of product configuration. Customer needs can include engineering characteristics, as well as trade characteristics. Engineering characteristics include product attributes determining product usefulness, which include technical product attributes, e.g. power, speed. In turn, trade characteristics can include e.g. product price, warranty and delivery time. Customer product characteristics should be transformed to the product characteristics made by producers and product structure comes from these characteristics. One of the concepts useful in creating product structure is modular design.

In MTO product modularity is a useful concept in modelling customized product configuration. The concept of modularity is focused on designing products that can respond rapidly to market needs and allow the changes in product design in a cost-effective manner. Modularity can be applied to the design process to build a modular product and a modular manufacturing process [10].

Modular products may shorten product-development time and help to introduce new product variants at reduced costs [14].

Modularity in product and process design is focused on reducing the range of product parts and manufacturing processes variation. According to this concept, product variants use common units (fig. 4).

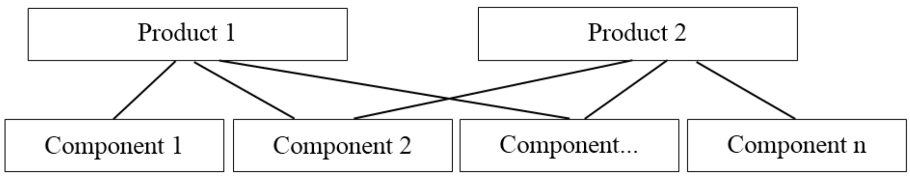
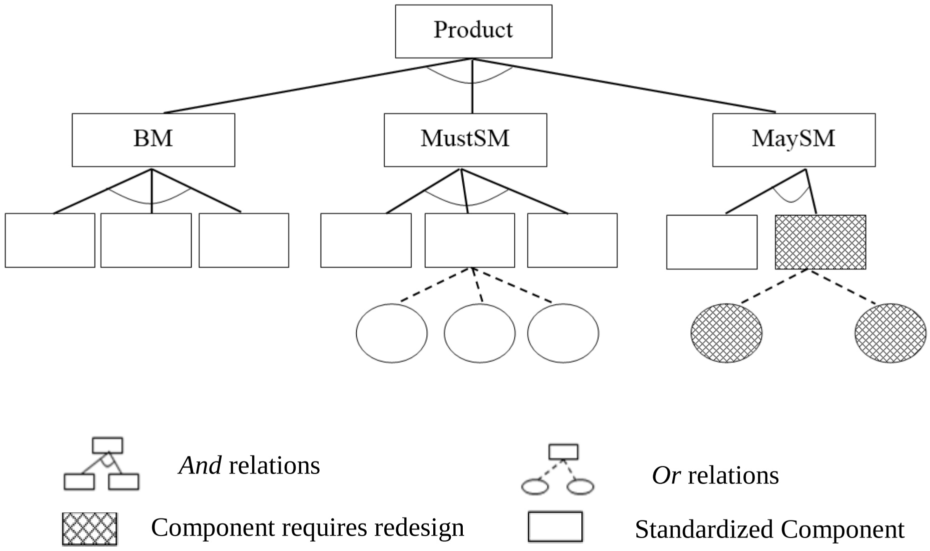



**Fig. 4. A structure of product family [source: on the basis of [5]]**

Product structure should help to increase external diversity of products – diversity of configured products, and reduce internal diversity of product.

Modular product structure can be presented with the use of a decomposition tree. Jiao et al. [9] proposed product decomposition tree which applies two types of nodes and two types of edges. A squared node means a product component, an oval node means an attribute characterising a product component. Edges link nodes in two manners, as and/or relations.

The general structure of a modular product was presented in fig. 5. In the presented product structure, some components are basic, which means they are indispensable module for forming the product; some of them are selected to create a customised product, and some are special supplementary and customized modules which need to be redesigned.




BM – basic module, MustSM – must selected module, MaySM – may selected module.

**Fig. 5. Modular product structure [source: on the basis of [9]]**

## 5. AN EXAMPLE OF PRODUCT PLANNING

Product planning is focused on finding the right moto reducer components. A customer defined main product requirements which were divided into categories according to Kano's model. Each customer requirement was assessed in the right part of the QFD matrix (fig. 6) according to following scale:

1 – must – be requirements,
2 – one – dimensional requirements,
3 – attractive requirements,
4 – indifferent requirements,
5 – reverse requirements.

| What? / How? | | | Product characteristic | | | | | |
|---|---|---|---|---|---|---|---|---|
| Customer requirements | **Attribute** | **Value** | Weight | Size | Stage_no | Costs | Lead time | **Import.** |
| Core product | Type of use | feeder device | 3 | 3 | 3 | | | 1 |
| Tangible product | Power | 3 kW | 3 | 3 | 3 | 3 | | 2 |
| Tangible product | Speed | 3 m/s | 3 | 3 | 3 | 3 | | 2 |
| Augmented product | Price | low | 3 | 3 | 3 | 9 | | 5 |
| Augmented product | Delivery time | 2 weeks | 3 | 3 | 3 | 9 | 9 | 5 |
| | **Target level of product characteristic** | | 120 | 230 | 1 | 250 | 50 | |

**Fig. 6. A QFD matrix for moto reducer [source: on the basis of [12]]**

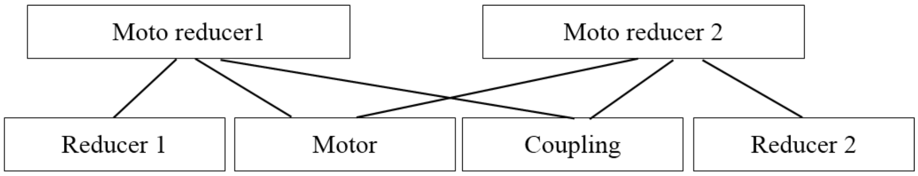



**Fig. 7. Structure of product family [source: own study]**

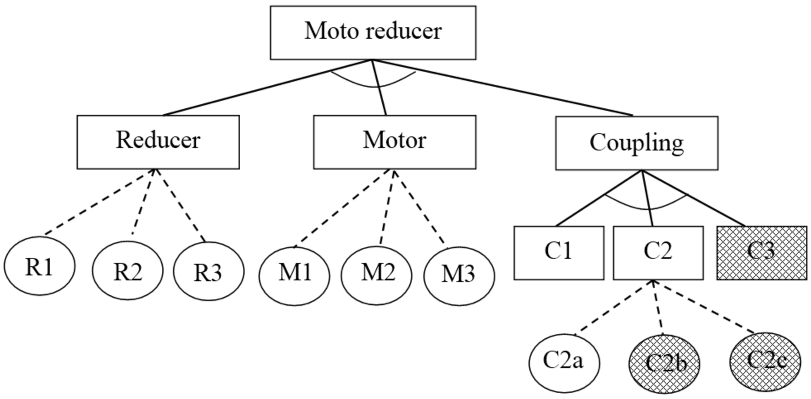
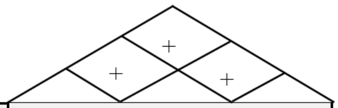



**Fig. 8. Modular product structure [source: on the basis of [12]]**




| What? \ How? | | | Product structure | | |
|---|---|---|---|---|---|
| | **Attribute** | **Value** | reducer | motor | coupling |
| **Product characteristic** | Weight | 120 | 9 | 9 | 9 |
| | Size | 230 | 9 | 3 | 3 |
| | Stage_no | 1 | 9 | | |
| | Costs | 250 | 9 | 9 | 3 |
| | Lead time | 50 | 9 | 9 | 9 |
| | **Part type** | | R1 | M2 | C3 |

**Fig. 9. A QFD matrix for toothed gear [source: on the basis of [12]]**

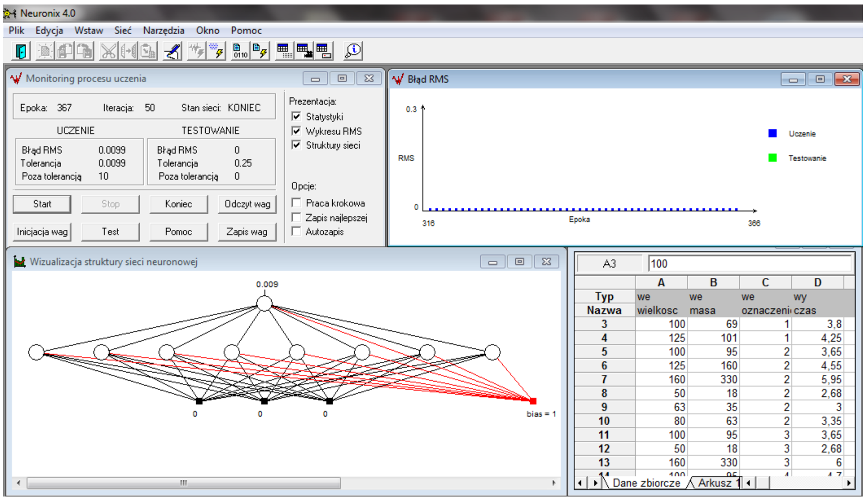



**Fig. 10. NN learning process [12]**

Structure of the product was presented in figs. 7 and 8. The QFD matrix presented in fig. 9 helps to find the right product components.

The data related to time consumption estimation regarding product structure change was made with the use of NN. The learning process of NN and result of data modelling were presented in fig. 10 [12].

## 6. CONCLUSION

The presented Kano's model of customer requirements can be used as a base of customer requirements evaluation in the QFD method. Application of graphs in product structure analysis helps in product configuration and reusing product components. The proposed product planning procedure is useful in product attributes identification needed by customer as well as attributes identification which characterise product and manufacturing process. The presented approach can be useful in applying computer technology in systems supporting product configuration decisions. Data analysis and attribute definition which emerge from the presented methodology can be applied in training set development, which is useful in data mining technique, like neural network.

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