Chapter 4

Configuration of a Customized Product

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Additional information is available at the end of the chapter

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Abstract

The chapter discusses problems of the product configuration process and application of chosen methods to represent the knowledge related to this process. One of the most important issues in product life-cycle management is to identify customer needs and combine them with product's technical and trade characteristics. The main tasks related to product configuration are focused on identifying the most suitable product to a particular customer, product decomposition, and estimating product characteristics. In the presented approach, identification of customer needs was discussed, and a product decomposition method was presented. The quality function deployment (QFD) 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.

Keywords: QFD, product structure, product customization, product decomposition, knowledge base

1. Introduction: product customization

In recent years, in order to enhance ability of an enterprise to quickly respond to dynamic changes in the market, the concept of product customization has been introduced into industry [1, 2]. Customer requirements cause increased product complexity and shortened product life cycle [3–5]. In made-to-order (MTO) manufacturing enterprises (ME), product architecture is usually modularized, and components are standardized. Product configuration is focused on selecting product modules or components and assembling them according to customer requirements [6]. Reusing certain modules can simplify a new product design and improves ability of an organization to offer greater product variety to the market [2, 7, 8]. The customization level is usually defined during the product design phase, in order to specify which components, parts or modules, known also as a configuration item, can be customized and selected according to customers' expectations [9, 10]. The concept of open-architecture product (OAP) can balance product economy and user requirements and can be applied to functional modules and adaptable interfaces for users to replace or add personalized modules into an original product in order to meet a personalized need [11, 12]. Any customized product is designed based on customer's requirements [13] and has to meet diversified requirements of product users. Product structures and design methods, such as a product configured from modules, are required to meet the need in developing personalized products with a cost-effective solution [12, 14, 15]. Product variant management has the goal to offer as many product variants as possible to the customer but keep the internal variety as low as possible at the same time [16]. Product design requirements should include the characteristics of modularity and reliability, as well as the cycle time and the implementation of production process reconfiguration [15, 17]. The three main goals of each manufacturing systems are cost, product quality, and responsiveness to markets [18].

Reconfigurable manufacturing system (RMS) is a recently proposed, new class of manufacturing systems [19]. RMS has the ability to update itself, in order to answer dynamic requirements or unpredictable failures [20], and is characterized, among others, by modularity: all major components are modular, and modules are designed with interfaces for component integration [21].

2. Quality function deployment

Quality function deployment (QFD) is one of the methods useful in product customization, taking into consideration customer requirements and product and production process characteristics. QFD is developed as a "method to transform qualitative user demands into quantitative parameters, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process" [22]. Quality function deployment (QFD) was developed as a product-oriented quality technique, which formulates customer expectations and then translates them into measurable product and manufacturing characteristics (**Figure 1**). For this purpose, a basic QFD matrix is extended to a series of matrices (**Figure 2**) [23, 24].

QFD provides:

- Product development, which takes into consideration customer requirements
- Integrating thinking in all stages of product development
- Identification of inconsistency between requirements analyzed from different points of view

The development of new products requires performing an analysis of alternative products and recognizing the desired product attributes. The QFD matrix determines the relations between customer needs (denoted as "what's") and product characteristics (denoted as "how's"). QFD joins customer requirements and product characteristics in a matrix, with a list of customer requirements on the left. The first column is related to the first row of the matrix

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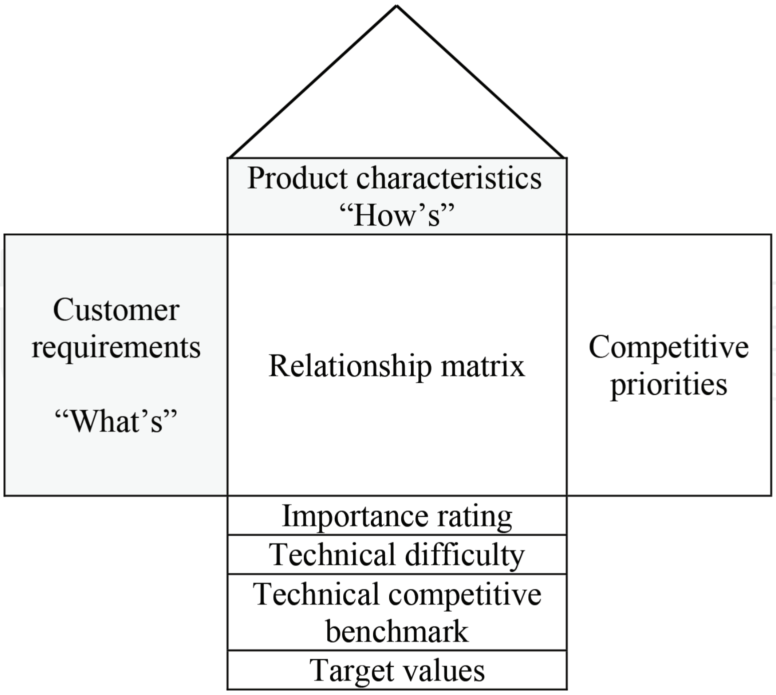

Figure 1. QFD matrix structure.

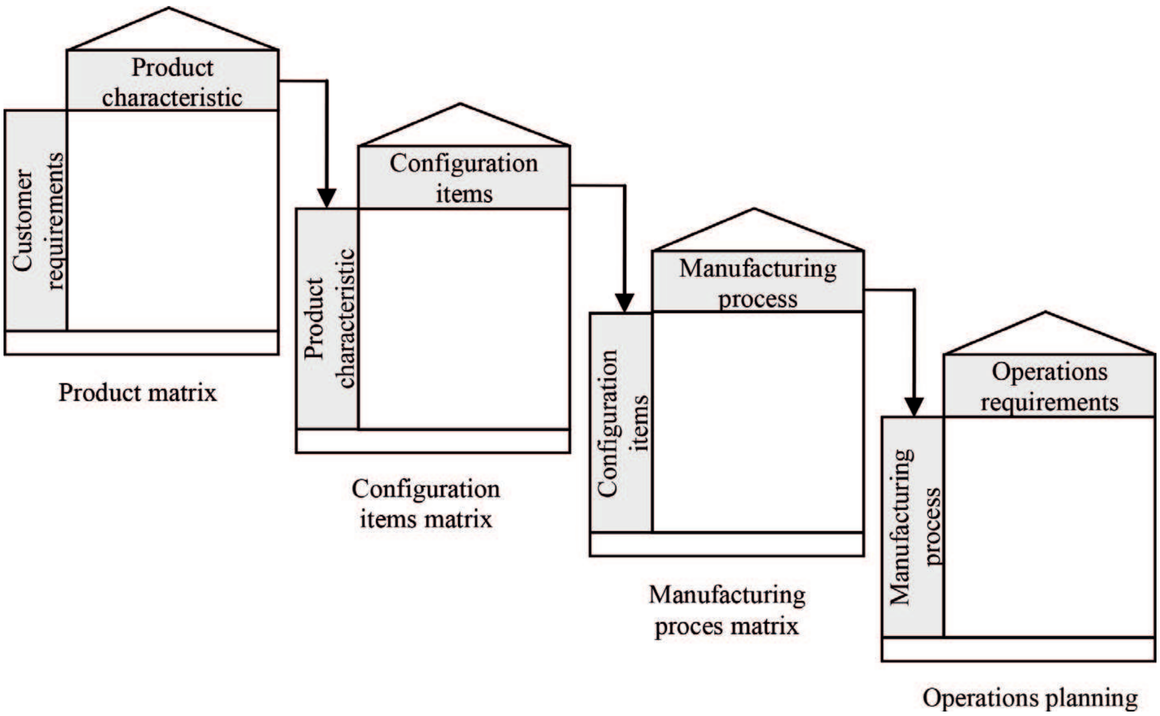

Figure 2. QFD sequence of matrices.

which specifies engineering characteristics of the product. The top part of the matrix, called a "roof," indicates how product characteristics interact. The right part of the matrix includes an assessment of the products. The target level of each product characteristic is presented at the bottom of the matrix.

QFD consists of a series of matrices, in which the first row of one matrix becomes the first column of another one [25–27]. The matrices sequence (**Figure 2**) regarding product characteristic, configuration items, manufacturing planning and operation planning matrix.

The main steps in QFD include [28]:

- Identification and prioritization of customer requirements. Several information sources can be used for this purpose, such as [29] potential customers, the firm for which the product is being made, similar products and any authorities that can impose restrictions on the product (standards, safety, etc.) The customers' requirements are prioritized based on its relative importance, using a 1–5 rating scale, with 1 having the minimum priority and 5 having the maximum priority. The requirements are placed on the left side on the QFD matrix. Analyzing customer requirements needs a certain product function and a certain definition of dimension parameters [30].
- Technical requirements related to a product should be specified, and product features should be identified. Each product has its own attributes, and these attributes should be described [30] in the first row of a QFD matrix.
- A relationship matrix between "what's" and "how's" should be established. Relations between customer expectations and product characteristics constitute the core part of the matrix. Typical relations between "what's" and "how's" are no relation, weak, strong and very strong [23]. Symbols or numbers can be used as correlation marks.
- A trade-off matrix should be established, which is often named a roof matrix and shows the relationship between various technical requirements. A trade-off is positive when an increase of a feature value causes an increase of another one, and a trade-off is negative when an increase of a feature value causes a decrease of another one.
- Customer competitive assessment is focused on comparing competitive products and product being developed, taking into consideration customer requirements. The right part of the matrix should include an importance coefficient of customer requirements. Customer expectations are rated, and product features importance for the customer is established. The next task in this step is product competitive comparison, which should be made with the use of a scale from 1 to 5, where 1 means the least satisfying and 5 stands for excellent performance [29].
- The next step is technical competitive assessment of products. Each product feature pointed in the first row of the QFD matrix should be rated taking into consideration product comparison situated in the bottom part of the QFD matrix. Product technical feature analysis includes assessment of the degree of technical difficulty which represents the capability of an organization to make a given feature of the product. Technical competitive benchmark is a study that compares specification of different products, so, in this stage product alternatives are characterized and compared. Finally, target values of product parameters are set in the bottom part of the matrix.

3. Customized product configuration with a QFD-based knowledge base

3.1. Knowledge representation

Product adaptation needs knowledge in the field of product and production process redesign. Product adaptations consist in changing technical documentation of products from the enterprise product portfolio. To support the redesign of product configuration, it is necessary to know the answers to the following questions [31]:

- What are the main product features noticed by the customer?
- What are the main product features noticed by the producer? Is it necessary to select the most important product engineering and trade characteristics and specify target product characteristics?
- What is the product structure?
- What kinds of changes are necessary to introduce to the product?
- What product or product part from the product portfolio is close to customer requirements?
- Which product parts have to be redesigned?
- What is the risk regarding product failure?
- What product engineering and trade characteristics can be offered to the client?

QFD-based knowledge base (QFD-KB) for product configuration needs proper methods of knowledge representation. There is plenty of research work focused on gap analysis between knowledge area, knowledge type, and methods of data analysis [32, 33].

Knowledge comes from different sources and could have a different form. Knowledge could be tacit, which means preverbal—understood as unvoiced—unspoken, intuitive and emotional. On the other hand, explicit knowledge is expressed clearly, verbally or in mathematical models [34].

Knowledge should be codified and stored in a way that enables other people to understand and reuse it easily [34].

Formal description of knowledge is called knowledge representation. According to the level of formalism used for knowledge representation, we can distinguish procedural knowledge, which defines algorithms that help to achieve given goals, and declarative knowledge, which gives the solution without analyzing the problem structure.

There are different methods and tools which could be used for knowledge representation. Knowledge representation methods include, among others [34]:

- Decision rules—which contain expressions such as IF *x1* is *F1* **and/or** *x2* is *F2* **and/or** … *xn* is *Fn*, THEN *y* is *P* where *x1, x2, ….. xn, y* denotes objects or attributes and *F1, F2, …….* *Fn*, *P* denote values. Decision rules describe both information elements (expressions) and relations between them, and therefore, a set of such rules (*r*) defines a knowledge base: *KB* = {*r*1, *r*2,…}.
- Decision trees—which are graph representations of the decision process. The inspection of the condition in the decision path starts from the beginning node called the root and ends in the leaves which give the decision.
- Frames are used when information units are characterized by many important features. The structure of a simple frame contains three different lines: a heading with the frame name, a pointer to another frame with appropriate relation, and slots defining attribute names and values.
- Semantic networks capture knowledge as a graph, in which nodes represent pieces of information (objects, concepts, or situations in the problem domain), and the arcs represent relations or associations between them.
- Artificial neural networks (ANNs) are inspired by neurons in the brain and have become a popular knowledge representation useful for learning [35]. Among many kinds of ANNs, feed-forward ones are widely used by researchers who apply them as a tool for data classification or as a predicator. The idea of ANN usage is to create a learning set, which includes data characterized by input and output features. During training, ANNs create a model which is able to transform input features into output features of a data set. If the predicted or classified data depends on many variables (features), ANNs are a convenient tool for analyses.
- Case-based reasoning (CBR), in which the problem-solving method is focused on finding the solution in the base of examples (cases). The case which has been found will be adapted to the new usage. This method is applied when knowledge is presented as a description of cases.

Knowledge can take many forms, and it is necessary to identify the kind of knowledge representation method which is the most suitable for solving a particular problem.

In the presented customized product configuration QFD-KB, the following methods of knowledge representation were used [32]:

- Procedural knowledge used for identifying the product features recognized by the customer and identifying the product features recognized by the producer.
- Declarative knowledge applied to define the evaluation rules.
- Artificial neural network (ANN), used for assessing the missing manufacturing process parameters.
- Case-based reasoning (CBR), applied for identifying product alternatives.

The data and knowledge generated and used during manufacturing may be related to products, machines, processes, materials, inventories, maintenance, planning and control, assembly, logistics, performances, etc. [33].

3.2. Algorithm of QFD-based knowledge base for product configuration

Enterprises develop data bases to store different types of data, e.g., data orders, codes of products, technical documentation related to products and the manufacturing processes, and product and process failure data.

Taking into consideration categories mentioned above, product configuration needs information related to customer requirements, product use circumstances, needed product characteristic analyzed from the functional point of view, product portfolio, parts characteristics, and manufacturing process characteristics.

The problem of determining product configuration can be structured according to the decision method presented in **Figure 3**. The presented approach developing web-based selection system was described by Gibson et al. [36].

Product configuration is divided into three levels including product-level configuration, component-level configuration, and manufacturing parameter-level configuration [37]. These three levels can be developed with the use of QFD series of matrices.

In the algorithm of QFD-KB for product configuration presented in **Figure 4** [32], the methods of knowledge representation such as rules from an expert, case-based reasoning and neural networks were applied.

Product offer preparation requires information regarding product portfolio offered by the enterprise and an evaluation of differences between customer requirements and the offered

Given: a set of products (configuration items) and processes.
Identify: a set of evaluation attributes, create scales, determine the importance and estimate missing product parameters.
Rate: Each alternative relative to each attribute.
Rank: Products (configuration items) from the most to the least promising.

Figure 3. A decision model for product configuration.

1. Identification of product characteristic.
2. Specification of target product characteristics, product decomposition, variants identification.
3. Variants evaluation, choosing the product to be redesigned.
4. Range of change identification, assessment of work time related to technical documentation preparation and the manufacturing process of the configured product.
5. Scheduling tasks related to product configuration, confirmation of product configuration.

Figure 4. Algorithm of QFD-KB for product configuration.

products. Customer service department staff should know how the product characteristics needed by the customer are different from the product characteristics offered by the enterprise and what kind of changes it is possible to implement in the product.

Product offer preparation needs a product requirement analysis, which includes analyzing product functions, reliability, safety, environment, packaging, transportation, storage, etc.

The decision problem solved with the use of QFD-KB for product configuration is how to choose and evaluate the right product from the product portfolio and adopt it to particular customer needs. The knowledge needed to solve this problem could origin from, e.g., experienced staff, databases, and documentation.

Possible data sources used in product configuration are presented in **Figure 5**.

3.2.1. Identification of product characteristics

Identification of customer requirements, product characteristics, their correlations and variant comparison were denoted with symbols presented in **Figure 6**, where a QFD scheme uses a square roof instead of a triangular roof matrix, as it is easier to use in a spreadsheet.

Configuration items should be determined according to the given criterion included in, e.g., [38]:

- Influence on functional and physical product characteristics determined by the client
- Innovatory character of product and process structure
- Safety of product usage
- Product reliability
- Logistic aspects

Identification of product characteristics from the customer point of view could be made in three stages.

The first stage regarding the category of requirements is related to product functions, which, in the case of toothed gear configuration, include, among others, torque transmission, weight of material handling and velocity of material handling.

The second stage regarding the category of requirements includes product environment conditions, e.g., environment temperature, dustiness, humidity, etc.

The third stage regarding category of requirements includes product trade characteristics, e.g., price, delivery time, warranty, etc.

3.2.2. Specification of target product characteristics, product decomposition and variant identification

To create a product, it is necessary to identify product features, quality level, packaging, etc. [37]. Accuracy and efficiency of product configuration depend on product structure used in product configuration.

Procedural knowledge helps to indicate the target value of configuration baseline which is needed for variant identification.

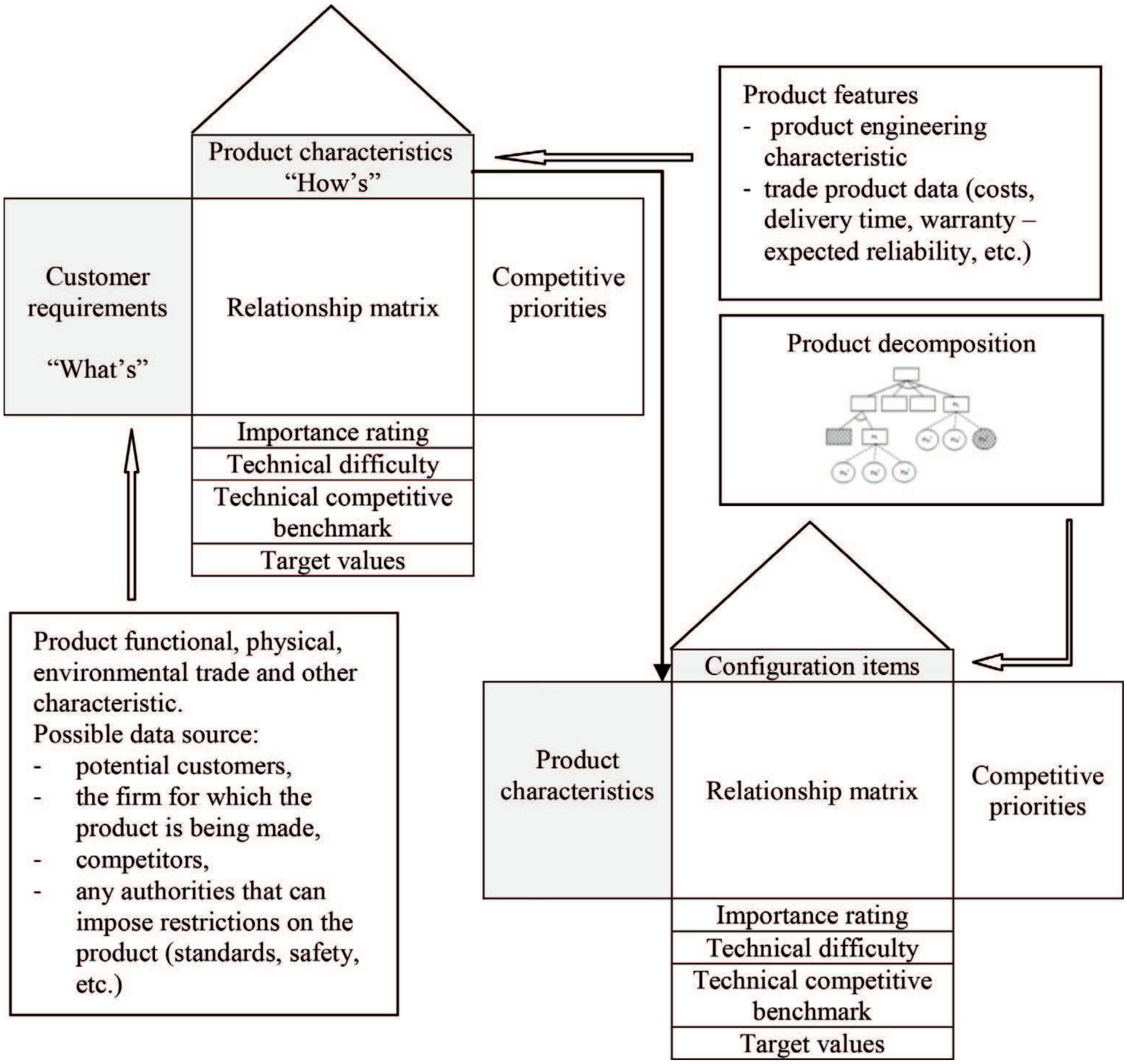

Figure 5. Product configuration data.

In the presented approach, decision rules were used to identify product alternatives. The premises in the proposed rules contain variation intervals of product features, where the conclusions include the proposed products (m_{zl}^{*}).

A general form of the rules is the following:

if $(p_{mk1t}^{wo1} - x_1) \leq p_{mk1} \leq (p_{mk1t}^{wo1} + x_1)$

and $(p_{mk2t}^{wo2} - x_2) \leq p_{mk2} \leq (p_{mk2t}^{wo2} + x_2)$

and ….

and $(p_{mkzt}^{woz} - x_z) \leq p_{mkz} \leq (p_{mkzt}^{woz} + x_z)$

then $m_k = m_{zl}^{*}$

where:

x_z—range of change, z∈Z,

p_{mkzt}^{woz}—target value of product characteristics, z∈Z,

p_{mkz}—product characteristics, z∈Z,

m_k—a configuration item, k∈K,

Z—a set of product characteristics,

K—a set of configuration items.

One of the important issues in product configuration is product decomposition, which provides the combination of components which gives a product suitable for a particular client. Product decomposition and functional requirements will help to answer the following question: which physical element(s) is responsible for the fulfillment of a specific functional requirement?

In literature we can find different approaches to product decomposition [39]. The presented method applies decomposition tree (**Figure 7**) [40], in which "and" nodes means that all components go together into product structure and "or" nodes mean that one of component alternatives should be put into product structure were used.

In product decomposition tree, there were distinguished standard components, and this one needs to be redesigned.

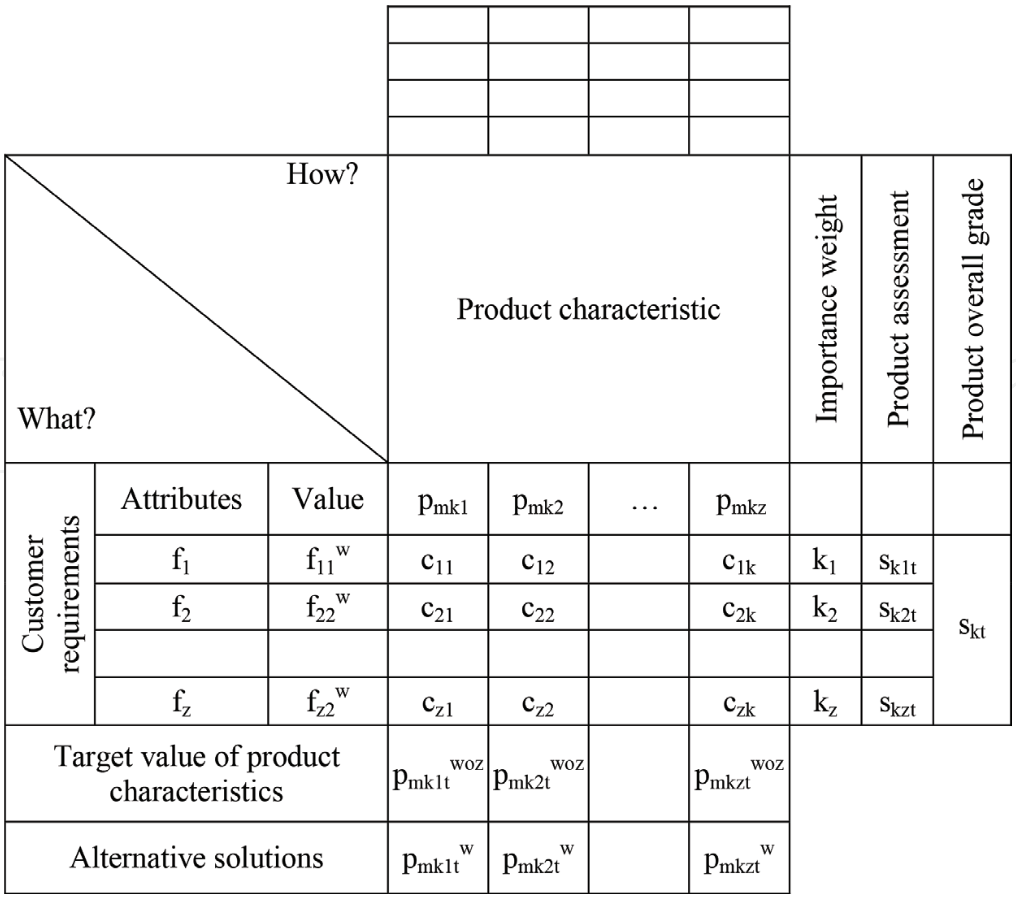

Figure 6. Product planning QFD matrix.

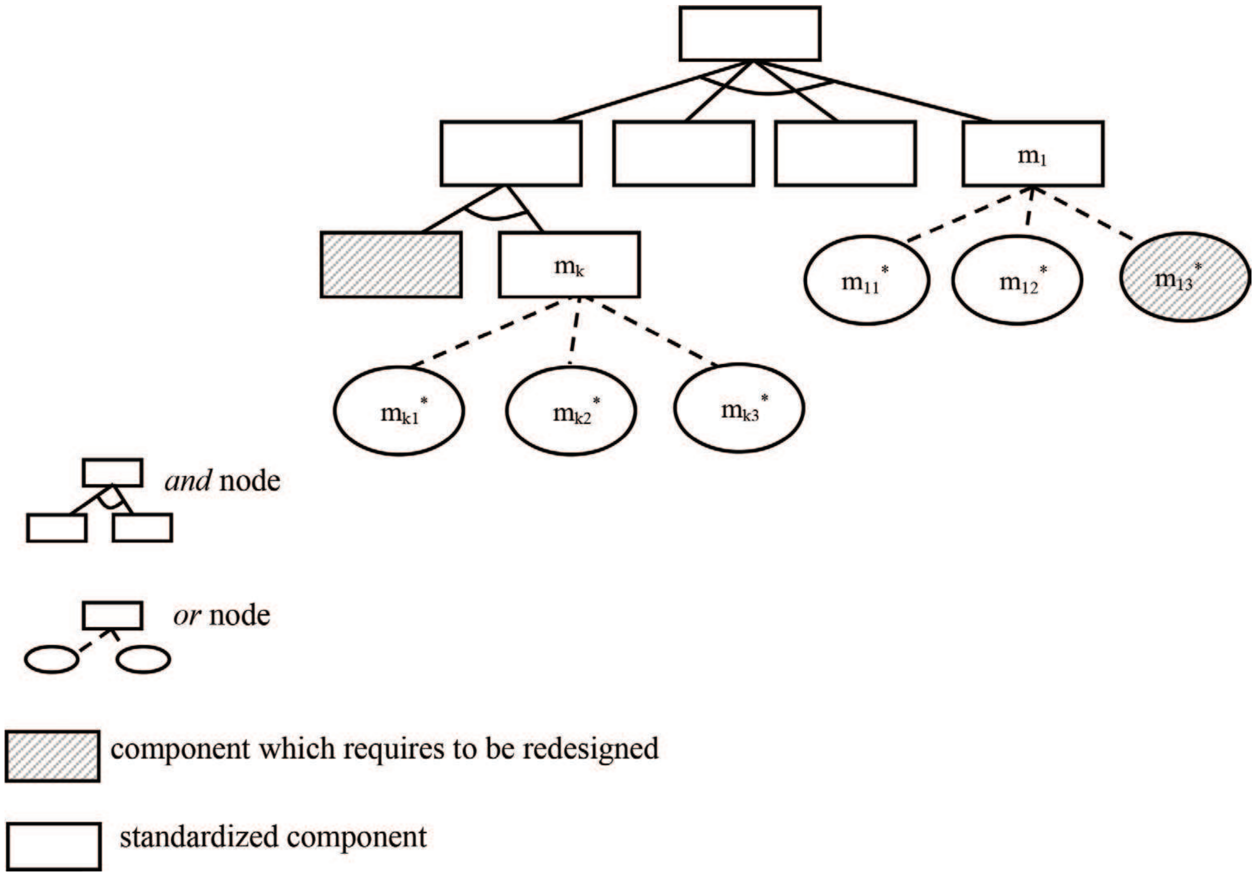

Figure 7. Product decomposition.

The identified configuration items, like product parts, components or modules should be described with the use of attributes and their values as appropriate specification with functional and physical characteristics (**Figure 8**).

Product decomposition in the product configuration process determines how detailed the product structure is. The presented product structures include alternative configuration items, which were characterized in **Table 1**.

3.2.3. Variant evaluation: choosing the product to be redesigned

Comparing product variants identifies the range of product change. The presented rank method applies an evaluation indicator calculated according to the formula (1):

$$w_{kzt} = \frac{\left|p_{mkzt}^{woz} - p_{mkzt}^{w}\right|}{p_{mkzt}^{woz}} \cdot 100 \qquad (1)$$

where:

w_{kzt}—assessment indicator for product k, attribute z and variant t;

p_{mkzt}^{woz}—target level of product characteristic;

p_{mkzt}^{w}—offered attribute value.

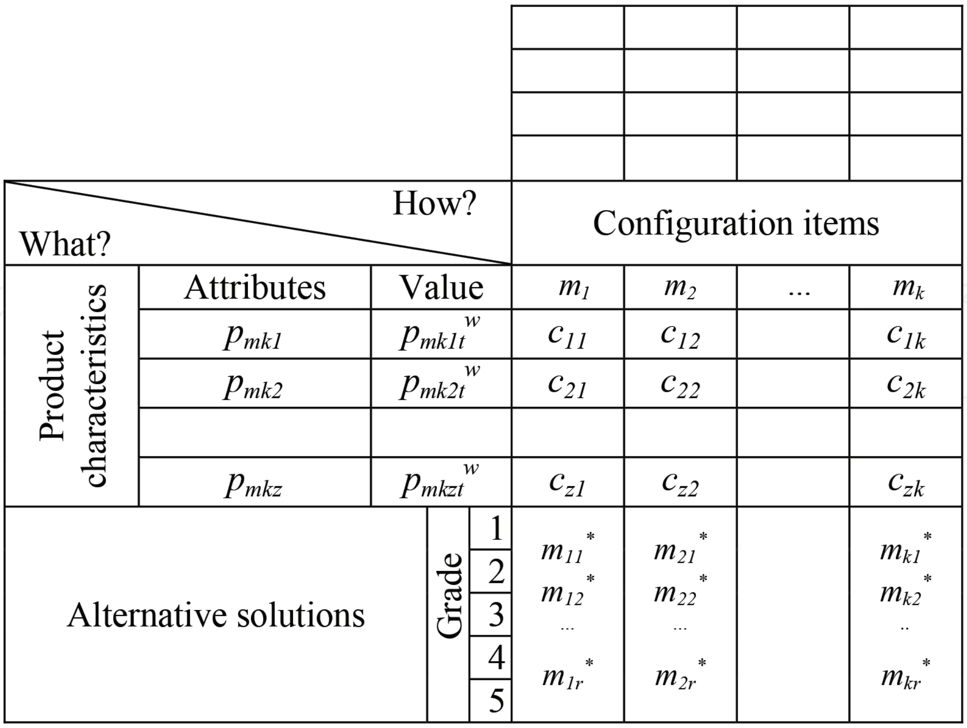

Figure 8. Configuration item planning QFD matrix.

Configuration items	Alternatives	Attributes			
		p_{mk1}	p_{mk2}	….	p_{mkz}
m_1	m_{11}^*	p_{m111}^w	p_{m121}^w	….	p_{mkz1}^w
	m_{12}^*	p_{m112}^w	p_{m122}^w	….	p_{mkz2}^w
	…	…	…	….	…
	m_{1l}^*	p_{m11t}^w	p_{m12t}^w	….	p_{mkzt}^w
m_2	m_{21}^*	p_{m2121}^w	p_{m221}^w	….	p_{mkz1}^w
	m_{22}^*	p_{m212}^w	p_{m222}^w	….	p_{mkz2}^w
	…	…	…	….	…
	m_{2l}^*	p_{m21t}^w	p_{m22t}^w	….	p_{mkzt}^w
….	….	….	….	….	….
m_k	m_{k1}^*	p_{mk11}^w	p_{m221}^w	….	p_{mkz1}^w
	m_{k2}^*	p_{mk12}^w	p_{m222}^w	….	p_{mkz2}^w
	…	…	…	….	…
	m_{kl}^*	p_{mk1t}^w	p_{m22t}^w	….	p_{mkzt}^w

Table 1. Configuration item variants.

Evaluation of product variant could be determined with the use of the rules presented in **Table 2** and the Eq. (2) [45]:

$$s_{kt} = \frac{\sum_z s_{kzt} \cdot k_z}{z} \tag{2}$$

$$s_{kt} \in \{1, 2, 3, 4, 5\}$$

$$k_z \in N$$

where:

s_{kt}—overall grade assessment of fulfilling requirements for variant t and configuration item k.

s_{kzt}—assessment grade of fulfilling requirements for variant t and configuration item k.

k_z—importance weight of attribute *z*.

Product alternative evaluation uses assumptions of the CBR method and decision rules which help to evaluate the presented solutions.

It could happen that the selected product is not suitable for a particular client. In such a case, it is necessary to assess the range of change in the product and the manufacturing process, which helps to determine the trade data related to the configured product.

The presented approach helps to identify the importance of product attribute and compares product components. The assessment of product components helps to choose the proper component variant or the variant which needs to be redesigned.

The presented approach is useful in supporting decisions during product configuration. The results of overall product assessment are given in the bottom part of a QFD matrix (**Figure 8**) [41].

3.2.4. Range of change identification, assessment of work time related to technical documentation preparation and the manufacturing process of the configured product

Changes in a redesigned product are focused on product structure and adapting the manufacturing process to allow to, e.g., fulfill a new function, reduce delivery time and reduce costs.

Assessment indicator		Assessment grade	
if	$w_{kzt} \le o_{1z}$	then	$s_{kzt}=5$
	$o_{1z} < w_{kzt} \le o_{2z}$		$s_{kzt}=4$
	$o_{2z} < w_{kzt} \le o_{3z}$		$s_{kzt}=3$
	$o_{3z} < w_{kzt} \le o_{4z}$		$s_{kzt}=2$
	$o_{4z} < w_{kzt}$		$s_{kzt}=1$
Where o_{1z}, o_{2z}, …, o_{4z} – bottom and upper values of parameter w_{kzt}			

Table 2. Assessment rules.

Product customization takes time needed to product redesign and manufacturing. Work time of specified tasks related to product development and manufacturing is one of the most important criteria which contribute to offer attractiveness. Delivery time could be assessed based on work time of product technical documentation and the manufacturing standard preparation.

Work time can be estimated with the use of work measurement methods which determine the length of time to complete a given task.

Work measurement methods include:

- Synthesis and analytical estimation (in this method it is necessary to break down the tasks into elements).
- Analytical estimation (the time required to complete a task is build up from synthetic data).
- Time study (the time of manufacturing tasks is measured).
- A method based on artificial intelligence [42–44]. In case of product redesign, missing data can be estimated with the use of ANN [46, 47].

Work time estimation of the manufacturing process needs the process structure and planning parameters.

3.2.5. Scheduling tasks related to product configuration: confirmation of product configuration

Scheduling the tasks to redesign product is focused on fixing the project deadline. For that purpose methods such as Gantt chart, PERT, CPM and GERT can be used.

Gantt chart is a type of bare chart which illustrates project task order in function of time; duration of each activity is shown.

Another approach presented network-based methods such as PERT, CPM and GERT.

Project evaluation and review technique (PERT) is focused on analyzing tasks involved in the project and enabled fixing the minimum time needed to complete the project. This method uses probabilistic duration of project tasks.

Critical path method (CPM) is a method which calculates the longest path in the project task network, fixing the shortest time to complete the project with the use of deterministic duration of project tasks.

Graphical evaluation and review technique (GERT) use both probabilistic network and probabilistic estimation of project task duration.

3.3. QFD-KB supporting configuration of a motoreducer

An example presents a configuration of a motoreducer used as a feeder device driving gear. Based on the algorithm presented in **Figure 4**, the evaluation of product configuration items was developed.

The first stage of the algorithm was focused on definition of feeder device driving gear characteristic which was placed on the left part of QFD matrix (**Figure 9**).

In the second stage of the algorithm, target motoreducer characteristics were specified and entered to the bottom row in the QFD matrix.

The next stage of product configuration is concerned with identifying the product structure and product decomposition and selecting the configuration items (**Figure 10**). A too detailed product decomposition causes costs, but rough product decomposition causes risk related to product characteristic failure.

Characteristics of configuration item (components, modules, parts) alternatives of feeder device driving gear are presented in **Table 3**.

An example of w_{kzt} coefficient calculation and s_{kzt} grade determination for configuration items of feeder device driving gear was presented in **Tables 4** and **5**. Assessment of configuration items alternatives used the rules presented in **Table 6**.

A comparison of configuration item alternatives is presented in **Figure 11**.

The range of change in product structure depends on, among others, the type of function introduced to the product. In the case of a motoreducer, product function can include, e.g., enabling assembly in a particular workplace, transmitting torque, etc. Changes on functions related to product assembly in a particular workplace can, for example, be focused on changing output shaft diameter.

	4				
	3	+	+		
	2			+	
	1			+	
What? / How?		Nominal power	Output speed	Ratio	…..
Attribute	Value	1	2	3	
Belt with	1200				
Belt speed	3		9	9	
Power	30	9			
….					
Needed delivery time	5				
Target value		30	108	14	

Figure 9. Attribute target value of feeder device driving gear.

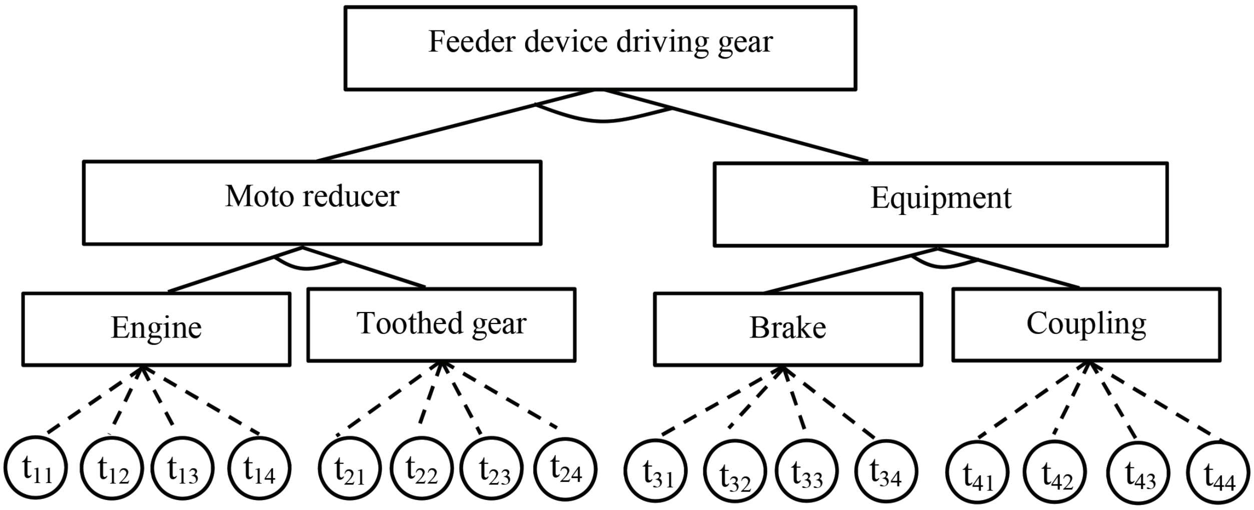

Figure 10. Feeder device driving gear structure.

Configuration items	Alternatives	Attributes		
		Power	**Speed**	**Ratio**
Toothed gear	t_{11}	33	83	18
	t_{12}	32	50	20
	t_{13}	33	94	16
	t_{14}	35	56	18
Engine	t_{21}	30		
	t_{22}	35		
	t_{23}	40		
	t_{24}	35		

Table 3. Feeder device driving gear—Configuration item alternative characteristics.

Configuration items	Alternatives	Attributes w_{kzt} coefficient calculation					
		Power	w_{k1}	**Speed**	w_{k2}	**Ratio**	w_{k3}
Toothed gear	t_{11}	33	10,00	83	23,15	18	28,57
	t_{12}	32	6,67	50	53,70	20	42,86
	t_{13}	33	10,00	94	12,96	16	14,29
	t_{14}	35	16,67	56	48,15	18	28,57
Engine	t_{21}	30	0,00				
	t_{22}	35	16,67				
	t_{23}	40	33,33				
	t_{24}	35	16,67				

Table 4. Configuration items—Indicator of w_{kzt} calculation.

Configuration items	Alternatives	Attributes grade						
		Power	Grade	Output speed	Grade	Ratio	Grade	Overall grade
Toothed gear	t_{11}	33	4	83	2	18	2	2,67
	t_{12}	32	4	50	1	20	2	2,33
	t_{13}	33	4	94	3	16	3	3,33
	t_{14}	35	3	56	2	18	2	2,33
Engine	t_{21}	30	5					5
	t_{22}	35	3					3
	t_{23}	40	2					2
	t_{24}	35	3					3

Table 5. Configuration item variants, partial assessment s_{kzt}.

	Assessment indicator		Assessment grade
If	$w_{kzt} \leq 5$	Then	$s_{kzt} = 5$
	$5 < w_{kzt} \leq 10$		$s_{kzt} = 4$
	$10 < w_{kzt} \leq 20$		$s_{kzt} = 3$
	$20 < w_{kzt} \leq 50$		$s_{kzt} = 2$
	$50 < w_{kzt}$		$s_{kzt} = 1$

Table 6. An example of assessment rules.

What? / How?			Toothed gear	Engine
Attribute	Value		1	2
Power	30		9	3
Output speed	108		9	
Ratio	14		9	
….				
Delivery time	5 week			
	Grade	1		
		2		t_{23}
		3	$t_{11}, t_{12}, t_{13}, t_{14}$	t_{22}, t_{24}
		4		
		5		t_{21}

Figure 11. Configuration item assessment in QFD matrix.

The presented product configuration algorithm helps to identify product attributes and compare and select product components. It is based on the following assumptions [32]:

- The product can be divided into configuration items which are components, modules or parts with a modular structure.
- There exist some alternatives of the configuration items.
- Enterprise staff is experienced in product adaptation according to individual customer requirements.

4. Conclusions

In basic applications QFD uses human knowledge. The presented approach is focused on developing a QFD-KB knowledge base, which is able to support human decisions related to product configuration. The presented algorithm joins methods of knowledge representation and supports decisions related to identifying and assessing product configuration items, such as components, modules and parts. In the presented QFD-KB, attributes analyzed by customer and producer are related to one another with the QFD matrix.

Methods of knowledge representation, such as procedures, rules, ANN and CBR are useful in the presented QFD-KB. The presented approach uses advantages and avoids disadvantages of different methods of knowledge representation. Selection of the proper knowledge representation method determines the effectiveness of QFD-KB.

Integration of the knowledge related to customer requirements, product structure and the manufacturing process helps to assess product characteristics in make-to-order product offer preparation.

The proposed algorithm of product configuration uses the QFD method and performs comparison and evaluation of configuration item variants, as well as missing data estimation related to the production process of product redesign.

Product configuration requires knowledge related to, among others, product structure, manufacturing process and potential failure problems.

Product configuration efforts are focused on the following categories:

- Collection of rules related to product selection and redesign
- Collection of facts about products functions and their structure
- Collection of facts and rules regarding product manufacturing variants, possible failures, timing and costing

The decision process regarding product configuration, which is focused on compatibility between customer requirements and functional and physical product features, can be supported with the use of QFD-KB for product configuration.

Conflict of interest

There is no conflict of interest.

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