

Using QFD and AHP Tools in the Case of Industrial Transmitters Manufacturing

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The analysis of a new product realization from the view of customer requirements and a relevant technical response of a company is presented in this paper. Two types of tools are used: QFD and AHP. HOQ within QFD is used for modeling technical requirements on the basis of defined customer demands. AHP serves as an addition in the process of technical requirements definition, it is used as a strategy for fast response to customer requirements. A comparison between leading foreign and domestic producers of transmitters has also been presented. HOQ realization on the example of intelligent pressure transmitter has shown that design parameters were defined. The implementation of AHP methodology has pointed at the significance of modular architecture for transmitter realization. Original contribution of this work is reflected in QFD analysis solutions – customer requirements were satisfied by giving technical characteristics with the aim of a new product realization.

Keywords: QFD, AHP, Designing of products, Transmitter, Modular design.

1. INTRODUCTION

The main objective of every manufacturing company is to launch a new product with better characteristics (quality) at acceptable prices on the market before the competitors. One of the mechanisms to achieve this objective is to implement QFD. Since the earliest studies [1-5], QFD has been treated as a method or a strategy for defining design attributes according to customers' expectations. Also, QFD can be considered as a system of engineering processes that transforms customers' wishes into a code understandable at all project levels, so they can be implemented in a product through its quality [6-10], or as a tool for planning a new product development or an improvement of the existing product [11-13].

In its initial form, QFD is a method which consists of four phases [11, 13-14]: 1) house of quality (HOQ), 2) parts deployment, 3) process planning, and 4) production planning.

According to aforementioned sources, HOQ consists of six elements (see Figure 1):

1. CNs - Customer needs or customer requirements (WHATs). This element is known as customer voice. The concept implies the transfer of customer needs in technical requirements (or characteristics) of a product (product technical requirements - PTRs), production planning and, finally, the production process.
2. PTRs - Product technical requirements (HOWs). This element represents the design conditions, product characteristics, engineering requirements, and it is an

- addition to the quality parameters. PTRs are accepted by teams of designers in the early phase of design according to the strategic objectives of a company.
3. VOC - This element is sometimes called "the voice of the company". PTRs are used to determine to what extent a company can satisfy customer needs. In other words, customer needs indicate "what to do", while PTRs indicate "how to do it. Term relative importance of the customer needs means: "The collected wishes may indicate that a customer has too many needs". If this happens, the company has to decide about certain conditions and priorities.
4. RM – The relation matrix. Relationships between WHATs and HOWs. RM shows how much PTRs affect every customer need. Generally, HOQ maps means how to develop a product that will satisfy the needs of a final user. The Mapping process of "What" to "How" is continued in a separate matrix. The matrix enables a detailed description of the future product development.
5. CM - Correlation matrix. The roof of HOQ is used to specify different PTRs which ought to be improved by providing the base for calculation of the number of the changes regarding the characteristics within one function that will affect other functions. The desired changes in one group of functions can cause negative effects in other functions. This interdependence makes a compromise between the needs of engineers and customers.
6. Total priorities of PTRs and additional objectives. A designer can always reconsider decisions made at every stage of a new product development, so this phase represents an important framework focused on giving the priority to the most important customer requirements. In addition, it is necessary to satisfy all requirements regarding product design, thus reducing unnecessary deviations from the targeted level of customer requirements.

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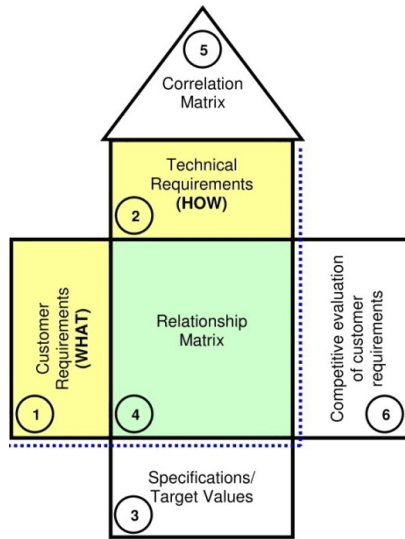


Figure 1. House of Quality

2. METHODOLOGY

In order to investigate customer wishes and according to them make appropriate technical requirements, two auxiliary tools have been used: Affinity diagram (AD) and Analytic hierarchy process (AHP). AD served as a technique for classifying customer wishes. Based on the meeting and customer survey some important information were collected on product characteristics. Customer wishes were written on pieces of paper and then sorted in certain groups [30, 31].

AHP is increasingly used in making quality decisions on technical characteristics. The tool helps decision makers in companies to find the best decision for their goal and to understand the problem in the best way. In this way, a rational framework is offered for structuring a decision object (problem), presentation and quantification of its elements, linking the elements with overall aims and giving assessment of alternative solutions.

A combination of these tools enables better analysis in the HOQ. Regarding this, Bhattacharya et al. [15] suggested that first, technical requirements should be identified and then customer requirements. Disadvantages of QFD methodology, strategically speaking, should be completed by using AHP tool. In this regard, QFD tool is used for modeling technical requirements related to filling identified blanks in product quality while AHP tool is used for the assessment of initiatives regarding product quality improvement and it suggests the best solution [16].

Unfortunately, QFD methodology is insufficiently used in Serbia. The aim of this work is to explain the analysis and implementation of QFD methodology as well as its improvement by the implementation of AHP methodology during the course of making important strategic decisions on the example of industrial pressure transmitter's use.

2.1 QFD tool

Essential parameters determined at the level of validation in the analysis of QFD matrix are: RoI (Rate of Importance), OS (Overall Satisfaction), SP (Sales Point), and Wa (Weight attribute).

RoI – The calculation of the QFD matrix starts with defining the importance of every customer need [17]. During the examination process, the surveyed customers have defined the importance of every need. This value is the RoI and is marked on a scale from 1 to 5. By this a customer estimates the significance of every requirement and the number will be later used in correlation matrix. The OS is expressed as the relation of the targeted value and the product evaluation. Influence on purchase – The next step that implies an estimation of the influence of a certain customer need on product purchase, SP (Sales Point).

Wa – The last column of HOQ, related to customer needs, is the weight attribute of every need. The Wa represents a result of the importance, overall satisfaction and sales point.

$$W_a = RoI \cdot OS \cdot SP \quad (1)$$

According to many authors [15,18-19] QFD methodology is applied in several steps:

- Step 1: Identification of customer requirements;
- Step 2: Identification of technical requirements;
- Step 3: Making of CM along with professional consulting of the team that applies QFD tool;
- Step 4: Numerical calculation of the technical conditions significance degree by using the equation (2).

$$W_j = \sum_{i=1}^m R_{ij} w_i \quad (2)$$

W_j is significance degree for j technical requirement ($j=1,2,\dots,n$); R_{ij} is quantified relation between i customer requirement and j technical criterion in relation matrix; while W_i is weight coefficient for the requirements of i customers.

- Step 5: A significant degree of normalization is determined for technical requirements by using the equation (3):

$$\bar{W}_j = \frac{W_j \cdot 100}{\sum_{i=1}^n W_j} \quad (3)$$

- Step 6: Comparative matrix for every technical requirement is made by using numerical scale.
- Step 7: Overall weight coefficient is calculated for design parameter by the equation (4):

$$W_i = \sum_{j=1,n} W_{ai} \times W_{rj} \quad (4)$$

where j represents a number of customer needs covered by design parameter i . Design requirements are chosen on the basis of weight coefficient.

Design can positively affect one customer requirement, while it can affect negatively other requirements [8]. However, there are different scales and weight schemes which are used for measuring the relation between customer requirements and design requirements necessary for the description of the correlation, such as strong, weak and with no influence [20]. According to the described importance, the realized correlation can be expressed in numbers: 9 – strong correlation, 3 – medium correlation, 1 – weak correlation, and 0 – no correlation.

2.2 AHP tool

AHP represents a tool for determining priority in relation to customer requirements [21]. After the determination of first customer requirements, technical requirements are identified and quantified. AHP tool determines customer priorities by setting a relative level of significance to every customer requirement [22-23]. According to aforementioned sources, AHP represents a method which serves as a support to decision – making process and is performed in three basic steps:

1. Description of a decision regarding a complex problem on hierarchy level,
2. Comparison of priorities in order to estimate a relative priority through comparison matrix,
3. Integration of the priorities in order to make overall assessment of alternative decisions.

At using numerical values, a numerical scale of nine numbers is used for comparison of pair elements. The relevant scale, given in Table 1, shows the significance of the element which serves as the element for comparison with other elements [15,24].

Table 1. Scale for APH

Importance value	Value name	Value Definitions
1	Equally important	Both factors are equally significant
3	Moderately preferred	Factor 1 is little bit more significant than Factor 2
5	Essentially preferred	Factor 1 is more significant than Factor 2
7	Very strongly preferred	Factor 1 is strongly significant than Factor 2
9	Extremely preferred	Factor 1 is extremely preferred to Factor 2
2,4,6,8	Intermediate importance	Intermediate value of significance between two adjacent decisions

AHP method uses the pairs of data in order to quantify and rank them according to their value. The following steps are used in the realization of AHP method [22-25]:

Step 1: If criteria and problems are known, a comparison matrix is made $[K_{ij}]$. Comparison matrix for n elements contains $n \times n$ elements, while the values of diagonal matrix elements ($i=j$) are equal to 1. Also, in comparison matrix there is a relation between the elements above the diagonal and the elements under the diagonal that is given by the relation (5):

$$k_{ji} = \frac{1}{k_{ij}} \quad (5)$$

Step 2: In the comparison matrix an overall weight for every criterion is not visible so a column vector is formed for the overall weight. Each element is divided by the sum of values in their column, see the equation (6):

$$S_{ij} = \frac{k_{ij}}{\sum_{i=1}^n k_{ij}} \quad (6)$$

Table 2. Average values of random consistency – RI

Importance value	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

For making the column matrix, n are column vectors which are formed in the matrix S .

Step 3: By means of $[S_{ij}]$ matrix, a weight vector is obtained through the percentage of the elements by calculating arithmetic mean of the elements in the rows of the column matrix and it is marked as A . The sum of weight vector elements is 1 (equation 7).

$$A_i = \frac{\sum_{j=1}^n S_{ij}}{n} \quad (7)$$

Consistency measurement is performed after the weight results are obtained. This analysis shows if there is an error in work or the result is consistent by itself. Regarding this, the following steps are taken [26].

1. For calculating consistency a comparison matrix and weight matrix are multiplied and the result is T column vector, see the equation (8):

$$T = [K]x[A] \quad (8)$$

2. After obtaining T column vector the values of the basic elements are obtained by dividing each element of T vector with the elements of weight vector A , see the equation (9):

$$E_i = \frac{t_i}{a_i}, \quad i = 1, 2, \dots, n \quad (9)$$

3. Arithmetic mean of basic elements gives a basic value of comparative comparison of the defined problem with a pair marked by λ , see the equation (10):

$$\lambda = \frac{\sum_{i=1}^n E_i}{n} \quad (10)$$

4. Depending on λ , a consistency indicator (CI) is obtained according to the following formula (11).

$$CI = \frac{\lambda - n}{n - 1} \quad (11)$$

5. Finally, a consistency relation (CR) is obtained, see the equation (12):

$$CR = \frac{CI}{RI} \quad (12)$$

The result is consistent if consistency relation (CR) is smaller than 0.1. If it is over 0.1, there is an error at implementing AHP, otherwise the operation is inconsistent. Average values of random consistency (RI) are given in the Table 2 [21].

The relation between QFD and AHP tools is established in the third Step of QFD method during correlation matrix formation, ie an assessment of alternatives is performed, which are most suitable to technical requirements obtained from the second Step of QFD methodology [16]. By using AHP tool inconsistency elimination of producer's decision making is performed.

3. A CASE STUDY

For measuring the physical quantities in industrial plants, a specific kind of electronic measurement instruments has been developed, commonly known as industrial (or process) transmitter. These transmitters are widely used in power generation plants, oil and gas industry, chemical, pharmaceutical, and food industry, shipping, metallurgy, water processing, heating and ventilation systems, and other industrial and technological processes. In industrial environment they are typically exposed to atmospheric, mechanical, chemical, and temperature influences, so it is necessary for their construction to be rugged.

This is particularly important for their enclosures, whose ingress protection level must be at least IP65. Following the rapid advancement of industrial electronics, especially digital acquisition and control systems, a need has arisen for two-way digital communication with industrial transmitters, leading to the development of industrial communication interfaces.

Today a number of industrial interfaces exists, with different capabilities and incompatible with each other. The most common of them are: HART, ProfiBus and Foundation Fieldbus. Industrial transmitters with digital signal processing and communication using an industrial interface are called "smart" transmitters. [27]

Many of the foreign transmitter manufacturers are present on the Serbian market, while, as far as the authors know, the only currently active Serbian manufacturer is ICTM-CMT.

Until recently, ICTM produced only analog transmitters, while the offering from foreign manufacturers has been expanded to include transmitters that belong to the new technological generation (so-called smart/intelligent transmitters), with digital signal processing and two-way digital communication.

The foreign manufacturers had a significant advantage in terms of functionality, performance, and design, due to the use of new technologies.

In general, every transmitter consists of three main parts: 1. measurement cell (containing the sensing element), 2. mechanical coupling fixture, and 3. enclosure, containing the electronics and the terminal block.

Transmitters belonging to the new technological generation typically have a local user interface intended for readout of the measured value (by means of a digital display), and for setting and adjustment of the device.

Table 3 shows some important features of industrial pressure transmitters produced by several foreign manufacturers, compared to the analog transmitter made by the mentioned Serbian manufacturer.

It can be concluded from the Table 3 that the transmitters made by the foreign competitors are superior in many aspects, when compared to the product of the domestic manufacturer. It has been observed that:

- The measurement cell usually has a cylindrical shape, compared to the square shape in transmitters produced by ICTM-CMT. This implies that for the production of a measurement cell the foreign manufacturers use cylindrical semi-products, which yields savings in technological operations, and reduction of waste.
- Considering the electronics enclosure, the competitors use die casting instead of milling. There is again a considerable saving in terms of the used material, the waste is minimized, and the technological operations are simplified.
- Microprocessor-based electronics used in intelligent transmitters enables digital signal processing, digital communication and realization of the local user interface. Apart from achieving better measurement performance, it provides significant additional functionality, including the measurement of several physical quantities and calculating the results as a function of more than one measured value.
- The supply voltage of the competitors' transmitters has a greater range (typically from 10.5-30 VDC), compared to the analog transmitter made by ICTM. This is rarely a decisive feature, but can be significant for some customers.

The measurement accuracy of intelligent transmitters is typically 0.1% of the full scale. Such a low value can only be achieved through the use of digital signal processing. Achieving technological prerequisites for such value has become the main goal for the domestic manufacturer.

Table 3. Comparative view of industrial transmitters' characteristics on the market

Transmitter		No.	1.	2.	3.	4.	5.
		Producer	SIEMENS	ENDRESS +HAUSER	ROSEMOUNT	YOKOGAWA	ICTM-CMT
Module	Name	Weight [kg]	~ 1.5	~ 2.5	~ 2	~ 1.3	~ 2
I	Measuring chamber	Material			AISI 316		W-Nr 1.4571
		Shape			cylindrical		square
		Process connector			standard		
		Material			silumin		AlCu4MgMn
III	Enclosure	Production			drip molding		Semi-finished product
		Surface protection			plastification		anodizing
		SMART module			yes		no
		Accuracy [% FS]			0.1		0.6
		Power supply [VDC]	10.5-30	10.5-30	10.5-36	10.5-36	14-26
		Current output [mA]			4-20		
		Mechanical protection	IP 65	IP 65	IP 65, IP 67	IP 67	IP 65
Operation temperature [°C]	-10...+60	-30...+80	-20...+80	-30...+80	-20...+70		

4. TARGET GROUP

In this work, it is obvious that customers represent a demanding and technically and technologically literate group. The work presents opinions of 40 experts who work in supply and maintenance sector in hydroelectrical and termoelectrical plants (Powerplants Nikola Tesla - TPPNT), as well as in oil refinery (NIS). Although the sample is small customer requirements are in most cases identical regarding a new product realization.

In this regard, customers/buyers stressed the following crucial criteria and requirements in relation to a new product realization through the implementation of new technologies: protection from overloading, resistance to mechanical stress of transmitters, easy usage of local user interface, display visibility, resistance to electromagnetic interference, chemical resistance of parts exposed to external influence, protection from overvoltage, easy assembly and disassembly, economical servicing, fast servicing, availability of spare parts, possibility of additional upgrade, change of measuring scope or interface, possibility of recycling and exchange of the old product for a new one.

Customers/buyers asked the following questions: 1) Does a device have protection from overloading?; 2) Is a device resistant to mechanical stress?; 3) Is the use of a local user interface easy for the user?; 4) Is a display visible?; 5) Is a device resistant to electromagnetic interference?; 6) Is a device resistant to chemical influence from external environment?; 7) Does a device have protection from overvoltage?; 8) Is a device easy to assembly and disassembly?; 9) Is it possible to service a device in short term?; 10) Is it possible to change certain elements on the device?; 11) Are spare parts available?; 12) Is there a possibility of recycling or exchanging the old product for a new one?

5. RESEARCH RESULTS

5.1 Voice of Customers

AD was used as auxiliary tool for grouping customer wishes [28]. On the basis of the set questions, the ideas were first written on pieces of paper followed by discussion, see Figure 2.

Fast assembly and disassembly	Fast servicing	Overvoltage protection
Availability of spare parts	Mechanical stability	Display presentation
Simple user interface	Easy exchange of parts	Chemical stability
Recycling possibility	Protection from overloading	Resistance to electromagnetic interference

Figure 2. Presentation of ideas on pieces of paper

Robustness	Usage	Maintenance
Protection from overloading	Fast assembly and disassembly	Easy exchange of parts
Overvoltage protection	Simple user interface	Fast servicing
Mechanical stability	Clear display presentation	Availability of spare parts
Chemical stability		Recycling possibility
Resistance to electromagnetic interference		

Figure 3. Presentation of the grouped customer ideas

This is followed by ideas grouping in certain categories: 1) robustness of the device; 2) usage of the device; and 3) maintenance of the device, see Figure 3.

Hence, by using Affinity Diagram the customers set the following requirements: robustness, usage and finally, maintenance of the device. In this regard, each group is defined by the wishes imposed to producers.

5.2 HOQ Realization

By the implementation of AD customer wishes are grouped in three categories which are later divided into elements:

- 1) Robustness of the device includes: protection from overloading, protection from overvoltage, mechanical stability (resistance to mechanical stress of the device parts), chemical stability (chemical resistance of parts exposed to external influences), resistance to electromagnetic interference;
- 2) Usage of the device includes: simple assembly and disassembly, easy usage of the local user interface (training is compulsory), display visibility; and
- 3) Maintenance of the device includes: economical servicing which assumes that it is possible to exchange some parts, fast servicing, spare parts availability, recycling possibility or exchange of the old product for the new one.

Also, design parameters are defined in order to satisfy customer requirements. These design parameters are: blockade installment, accuracy, power supply voltage, software, sensor type, selection of material, surface protection, design and fast disassembly.

According to the results of the HOQ analysis (see figure 4), designers should be focused on the following parameters in order to satisfy customer wishes: research and development of new solutions (34.9%), realization of new transmitter through modular architecture (18.19%), selection of material according to the specification of a purchaser/customer (13.74%) and software realization (12.5%). The choice of such a product is in direct relation with the intelligent transmitter electronics, as it implies the local user interface (readout). Therefore, the key prerequisite to improve the production of transmitters in ICTM-CMT is to develop an intelligent transmitter.

Within the roof of quality (see figure 5), there is an additional matrix that indicates conflicting objectives.

The symbols that denote the link between objectives are: "++" for a strong positive link, "+" for a positive link, "-" for a negative link, and "--" for a strong negative link.

On the grounds of the analysis of elements in the roof of quality, we came to the conclusion that it is necessary to improve the following parameters:

- 1) Software;
- 2) Selection of materials - the use of materials according to customers' technical specifications;
- 3) Fast disassembling for modularity – a concept of modular architecture of products should be mastered, which assumes a division of product design into several independent entities (i.e. modules); and
- 4) Research and Development (R&D).

		1	2	3	4	5	6	7	8	9	
		DESIGN REQUIREMENTS									
		IMPORTANCE	Install blockade	Accuracy	Power supply voltage	Software	Sensor type	Selection of material	Surface protection	Fast disassembly	R&D
CUSTOMER REQUIREMENTS	Robustness	Protection from overloading	5	9							3
		Overvoltage protection	5		9						3
		Mechanical stability	4				9	3			9
		Chemical stability	4				9	9			9
		Res. to electromagnetic interference	3				3				9
	Usage	Fast assembly and disassembly	5				1			9	3
		Simple user interface	5			9				1	3
		Clear display presentation	4			9				1	3
	Maintenance	Easy exchange of parts	5			3				9	9
		Fast servicing	5			1	3			9	9
		Availability of spare parts	4					3			3
		Recycling possibility	3					9		1	3
IMPORTANCE		5	4	4	5	4	4	3	4	5	
TARGETS			up to 400 bar	0.1%FS	10.5...36 V DC	Compatible with standards	Measurement cell	316L HSS /AlCu4MgMn	Surface coating	More parts and assemblies	New pallet of products
<ul style="list-style-type: none"> ● - SIEMENS ■ - ICTM-CMT 			5 - excellent	4 - very good	3 - good	2 - satisfactory	1 - unsatisfactory				
ABSOLUTE IMPORTANCE			45	0	45	101	29	111	48	147	282
RELATIVE SIGNIFICANCE (%)			5.57	0	5.57	12.50	3.59	13.74	5.94	19.19	34.90
											100

Figure 4. Table of HOQ during the production of intelligent transmitter

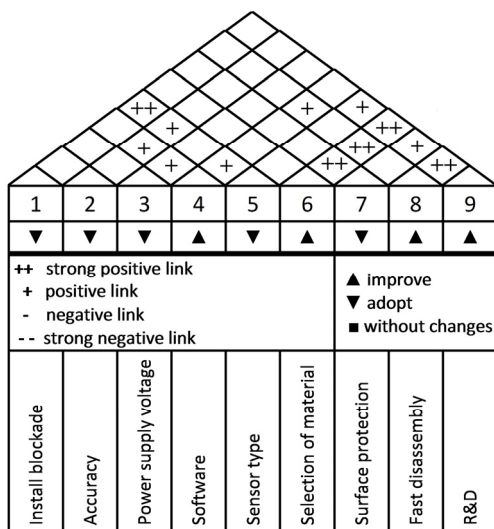


Figure 5. Roof of the HOQ for intelligent transmitter production

5.3 AHP Application

The obtained quality matrix represents the basis for the use of AHP tool. The tool determines a strategy for satisfying customer requirements.

Engineering decisions and design parameters are tested as well. In the realization of intelligent pressure transmitter the following three criteria were considered: modular design, fast servicing and material usage. Strategically speaking, these criteria assume the realization of a new concept of transmitter. Comparison of alternatives according to criterion "modular design"; "user interface" and "fast servicing" are given in Table 4 and Table 5.

Finally, consistency relation is calculated (CR), see Table 6. The value for the first criterion is smaller than 0,1 which means that it will represent a consistent operation or strategy that the company should use. These criteria are most suitable to technical requirements in the framework of the HOQ.

Table 4. Criterion "modular design"; "user interface" and "fastservicing"

	Modular design					User interface					Fast servicing				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Blockade (1)	1	5	7	5	9	1	3	9	5	7	1	3	3	3	7
PSV (2)	1/5	1	5	4	5	1/3	1	7	3	5	1/3	1	2	2	3
Software (3)	1/7	1/5	1	2	3	1/9	1/7	1	2	2	1/3	1/2	1	2	5
Material (4)	1/5	1/4	1/2	1	3	1/5	1/3	1/2	1	3	1/3	1/2		1	9
R&D (5)	1/9	1/5	1/3	1/3	1	1/7	1/5	1/2	1/3	1	1/7	1/3	1/5	1/9	1
$\sum K_{ij}$	1,65	6,65	13,83	12,33	21	1,78	4,67	18	11,33	18	2,13	7,33	6,7	8,11	25

Table 5. Main parameters for criteria

Modular design									
S_{ij}	1	2	3	4	5	A_i	T	E_i	
1	0,606	0,752	0,506	0,406	0,429	0,540	3,194	5,916	
2	0,121	0,150	0,362	0,324	0,238	0,239	1,369	5,729	
3	0,085	0,030	0,072	0,162	0,143	0,098	0,506	5,146	
4	0,121	0,038	0,036	0,081	0,143	0,084	0,418	4,985	
5	0,067	0,030	0,024	0,027	0,047	0,039	0,206	5,290	
User interface									
1	0,562	0,642	0,500	0,441	0,389	0,507	2,771	5,467	
2	0,185	0,030	0,389	0,265	0,278	0,229	1,519	6,622	
3	0,062	0,030	0,056	0,177	0,111	0,087	0,455	5,227	
4	0,112	0,071	0,028	0,088	0,167	0,093	0,454	4,875	
5	0,079	0,043	0,028	0,029	0,056	0,047	0,238	5,084	
Fast servicing									
1	0,469	0,682	0,448	0,370	0,280	0,450	2,638	5,865	
2	0,155	0,136	0,299	0,247	0,120	0,191	1,096	5,731	
3	0,155	0,068	0,149	0,247	0,200	0,164	0,914	5,583	
4	0,155	0,068	0,075	0,123	0,360	0,156	0,832	5,324	
5	0,066	0,045	0,030	0,014	0,040	0,039	0,215	5,534	

Table 6. Consistency relation (CR) in future strategy of the company definition

Strategy	λ	CI	CR
Modular design	5,413	0,103	0,092
User interface	5,455	0,114	0,102
Fast servicing	5,820	0,205	0,183

5.4 Realization of the industrial pressure transmitter

On the basis of HOQ and AHP tool, it can be concluded that modular architecture is very important for sustainable development of ICTM – CMT in the realization of a new product.

Modular architecture is an engineering methodology that takes into consideration both physical and functional relations between the components within a product life cycle [29]. According to Kimura et al. [30] it is necessary that all modules of the product are designed to be reused and recycled.

Because of the requested chemical stability during the device functioning, the choice of material is specific which results in higher cost on the market. The most frequently used materials are: 1) stainless steel alloy (AISI 316), 2) aluminum alloy (AlCu4MgMn), 3) plastics, 4) brass, and 5) glass and rubber.

The measurement system capability for transmitters is fully utilized by using the software program. With enhancing productivity, special calibration system has brought in repeatability and consistency [31].

The new intelligent transmitter was made according to the defined parameters (see Figure 6).

A range of new intelligent transmitters has been realized based on the QFD analysis and using the modular

architecture: a pressure transmitter, a temperature difference transmitter, and a liquid level transmitter (see Figure 7).

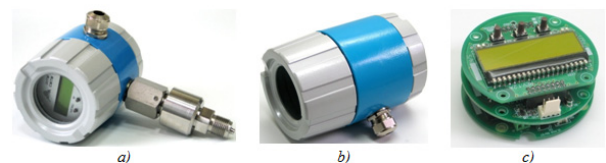


Figure 6. The new electronics enclosure: a) photograph of the finished intelligent transmitter, b) enclosure, c) intelligent electronics

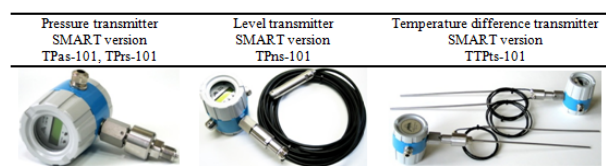


Figure 7. Modular architecture in intelligent transmitter

6. CONCLUSION

The main aim of this work is to point at the significance of QFD tool using the example of intelligent pressure transmitter's realization, the improvement of its quality, as well as to show the possibilities of expanding product range by modular architecture application.

Well created design of transmitters prevents the appearance of unnecessary and unstable sub-assemblies and also simplifies assembly/disassembly and fast servicing.

By the implementation of AHP tools and on the basis of consistency factor it was pointed at the strategy that a company should use in order to satisfy customer requirements.

The paper also distinguishes that modular architecture has a great importance in the realization of intelligent transmitter IHTM-CMT. Strategically observed, a product realization based on module palette exists for the sake of customer individual desires and requirements. By combining several modules a company tries to bridge the gap between customers and designers.

Finally, the use of QFD tools in the case of the intelligent transmitter enables sustainable development of the manufacturer through the efficient assessment of customer requirements, better design and manufacture integration, provision of improvement and support for products, and consideration of consequences related to the return, recycling and storage of products.

In our future work the described approach will be used both for further improvement of the transmitter design and for expanding the product range in order to respond to the requirements of the existing and new customers optimally.

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NOMENCLATURE

<i>QFD</i>	Quality Function Deployment
<i>AHP</i>	Analytic Hierarchy Process
<i>HOQ</i>	House of Quality
<i>CN</i>	Customer Need
<i>PTR</i>	Product Technical Requirements
<i>VOC</i>	Voice of the Company
<i>RM</i>	Relation Matrix
<i>CM</i>	Correlation Matrix
<i>RoI</i>	Rate of Importance
<i>OS</i>	Overall Satisfaction
<i>SP</i>	Sales Point
<i>Wa</i>	Weight attribute

КОРИШЋЕЊЕ QFD И АНР АЛАТА У СЛУЧАЈУ ПРОИЗВОДЊЕ ИНДУСТРИЈСКИХ ТРАНСМИТЕРА

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У овом раду представљена је анализа реализације новог производа са аспекта потреба купаца и релевантног техничког одговора компаније. Користе се две врсте алата: QFD и АНР. HOQ у оквиру QFD се користи за моделирање техничких захтева на основу дефинисаних потреба клијената. АНР служи као додаток у процесу дефинисања техничких захтева, употребљава се као стратегија за брзо реаговање на захтеве купаца. Такође је приказано поређење водећих страних и домаћих произвођача трансмитера. Реализација HOQ-а на примеру интелигентног трансмитера притиска показала је да су параметри дизајна дефинисани. Примена АНР методологије указала је на значај модуларне архитектуре за реализацију трансмитера. Оригинални допринос овог рада огледа се у QFD анализама - захтеви купаца су удовољени давањем техничких карактеристика са циљем реализације новог производа.