ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 2016
Seria: ORGANIZACJA I ZARZĄDZANIE z. 87 Nr kol. 1947

Krzysztof KNOP
Politechnika Częstochowska
Wydział Zarządzania
kknop@poczta.fm

USING A QFD METHOD AND CTQ TREE TO IDENTIFY THE AREAS NEEDING IMPROVEMENT IN THE PRODUCT – FARM TRUCK TRAILER

Summary. How to translate the subjective customers needs on engineers' technical language of product or process? The response is to develop QFD method. QFD method is used to design new product or improve the actual version of product and consists of analyzing the specific clients needs and determine the relationship between them and the technical characteristics of the products. The article presents the combined use the QFD method and CTQ tree (one's of Six Sigma tools) to improve the actual version of the farm truck trailer. The starting point was define the customers and their needs. The result of the analysis was to determine the necessary improvement action and key areas in terms of the analysed product.

Keywords: farm truck trailer, QFD method, CTQ tree, improvement.

WYKORZYSTANIE METODY QFD I DRZEWA CTQ DO IDENTYFIKACJI OBSZARÓW WYMAGAJĄCYCH DOSKONALENIA W PRODUKCIE – PRZYCZEPA CIĘŻAROWA ROLNICZA

Streszczenie. W jaki sposób przekładać subiektywne potrzeby klientów na techniczny język inżynierów produktu lub procesu? Odpowiedź to wykorzystanie metody QFD. Stosuje się ją do zaprojektowania lub udoskonalenia produktu, a polega ona na analizowaniu specyficznych potrzeb klientów i określaniu relacji pomiędzy nimi a technicznymi charakterystykami produktów. W artykule przedstawiono połączone wykorzystanie metody QFD oraz drzewa CTQ (jednego z narzędzi Six Sigma) do udoskonalenia przyczepy rolniczej. Punktem wyjścia była identyfikacja klientów i zdefiniowanie ich potrzeb. Efektem analizy było określenie obszarów kluczowych i koniecznych działań w zakresie badanego produktu.

Słowa kluczowe: przyczepa ciężarowa rolnicza, metoda QFD, drzewo CTQ, doskonalenie.

1. The essence of a QFD method and a CTQ tree

A QFD method is known as Quality Function Deployment, House of Quality or Customer-Oriented Design, it has been known and used in the industrial practice since the moment of its creation in 1972[1]. QFD is an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (i.e., marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production, sales)[2]. Its usefulness in design and improvement of industrial products quality has been often verified[3], which causes that QFD method is considered today as classic approach that can be useful for transformation of customer requirements into product functionality.

QFD concentrates on optimising customer satisfaction. QFD is a system that involves all the functions of the enterprise, used in order to ensure, through all the phases of product development (from the idea to supplies), that all the customer requirements are met[4]. QFD provides the answer to the following questions: who is the customer in the enterprise? what are customer needs and expectations? how to meet these requirements[5]? The answers to the above questions are written by means of the matrix termed the House of Quality (HoQ), which is the central tool of QFD[6]. The House of Quality contains 10 fields that illustrate the relationships between the needs and expectations of customers and the characteristics of the product or a process planned. This matrix, filled throughout individual stages in the method, represents the basis for comprehensive evaluation of the products in terms of meeting the user's requirements[7].

The primary functions of QFD are product development, quality management, and customer needs analysis, other functions are: design, planning, decision-making, engineering, management, teamwork, timing, and costing[8]. The essence of QFD was described by the QFD

---

[1] Por. Hamrol A.: Zarządzanie jakością z przykładami. PWN, Warszawa 2008, s. 364-376; Oke S.A.: Manufacturing Quality Function Deployment: Literature Review and Future Trends. „Engineering Journal", Vol. 17, issue 3, 2013, p. 82.

[2] Chan L.K., Wu M.L.: Quality function deployment: A literature review. „European Journal of Operational Research", 143(3), 2002, p. 463.

[3] Por. Borkowski S., Kaczorowski Ł.: Wykorzystanie metody QFD w zarządzaniu jakością mebli, [w:] Juchniewicz M. (red.): Zarządzanie przedsiębiorstwem w warunkach konkurencji. Determinanty konkurencyjności przedsiębiorstw. Cz. II. Wyd. UWarm-Mazur., Olsztyn 2006, s. 188-193; Prus A., Selejdak J.: Wykorzystanie metody QFD do zapewnienia jakości w przemyśle meblarskim. Prace Naukowe Instytutu Technologii Maszyn i Automatyzacji Politechniki Wrocławskiej, nr 78, 2000, s. 195-198.

[4] Por. Hamrol A.: Zarządzanie jakością z przykładami. PWN, Warszawa 2008, s. 364-376; Hamrol A.: Strategie i praktyki sprawnego działania. Lean, Six sigma i inne. PWN, Warszawa 2015, s. 188-193.

[5] Ibidem.

[6] http://www.webducate.net/qfd/qfd.html.

[7] Mazur M., Kaczorowski Ł., Borkowski S.: The QFD Method Application to Prognose the Quality. TRANSCOM 2007. 7th European Conference of Young Research and Scientific Workers. Proceedings. Section 2. Economics and Management. Part 2 (L-Z), Zilina 2007, p. 33-36.

[8] Chan L.K., Wu M.L.: Quality function deployment: A literature review. „European Journal of Operational Research", 143(3), 2002, p. 467.

Institute (an organization dedicated to dissemination and advancement of QFD). According to them QFD means:

- Understanding customer requirements.
- Quality systems thinking + psychology + knowledge/epistemology.
- Maximizing positive quality that adds value.
- Comprehensive quality system for customer satisfaction.
- Strategy to stay ahead of the game[9].

Application of the QFD in design and improvement of product quality yields measurable benefits in the form of time reduction during product implementation in the market, reduction of changes in the product design, reduction of costs of designing and manufacturing, enhanced quality, customer satisfaction and improved performance[10]. The benefits can be distinguished into three groups: organisational, economical and socio-psychological[11].

CTQ tree is a tool proposed within the Six Sigma concept[12], which decodes customer language (needs, expectations, requirements) into product/services specifications[13]. The goal of this transfer is transition from general concepts which are difficult to be measured towards specific elements that are subjected to particular measures[14]. CTQs are the internal critical quality parameters that relate to the wants and needs of the customer[15].

Stages in construction of CTQ tree include: 1) identification of customers, 2) identification of customer needs expressed with a general language typical of the customer, 3) identification of the set of requirements connected with a particular need (drivers), 4) definition of measurable and real (i.e. attainable) parameters/features so that they can be managed (measures)[16].

The study proposes the use of CTQ tree at the stage 3 of construction of the House of Quality matrix and idetifies technical parameters of the product.

[9] http://www.qfdi.org/what_is_qfd/what_is_qfd.html.
[10] Por. Wolniak R., Skotnicka B.: Metody i narzędzia zarządzania jakością. Teoria i praktyka. Wydawnictwo Politechniki Śląskiej, Gliwice 2008, s. 114-137; Wolniak R., Sędek A.: Wykorzystanie metody QFD do projektowania proekologicznych produktów i usług. „Problemy Ekologii", Vol. 12, nr 4, 2008, s. 179-180.
[11] Krzemień E., Wolniak R.: Zastosowanie komputerowego wspomagania w metodzie QFD. „Problemy jakości", nr 7, 2001, s. 31-34.
[12] http://sixsigmabasics.com/six-sigma/statistics/critical-to-quality.html.
[13] http://www.brighthubpm.com/six-sigma/86047-critical-to-quality-ctq-tree/.
[14] Por. http://www.4pm.pl/artykuly/dekoder-oczekiwan-klienta-na-parametry-produktu-czy-uslugi-czyli-narzedzie-ctq-critical-to-quality; https://www.mindtools.com/pages/article/ctq-trees.htm.
[15] http://www.isixsigma.com/dictionary/critical-to-quality-ctq/.
[16] Eckes G.: Rewolucja Six Sigma. MT Biznes, Warszawa 2010, s. 86-90.

2. Research subject characteristics - six tons' biaxial farm trailer

Agricultural double-axle trailers are designed to transport agricultural goods and other loose materials in the area of a farm or on public roads. These trailers are not adjusted and dedicated to transport people, animals and goods qualified as hazardous materials. The trailers are made of metal, with open design of loading surface and complete signalling and warning installation (electrical installations and reflective lights). The trailers are adapted to be coupled with agricultural tractors equipped in installation of an external hydraulic system, socket for signalling, warning and braking installations and a towing hook. Unloading the trailers is performed either manually or through tilting the cargo box to the rear and or to the side. Figure 1 illustrates the analysed product.

Fig. 1. View of the farm track trailer – the object of the research
Rys. 1. Widok przyczepy ciężarowej rolniczej – obiekt badań
Source: company's material.

3. Creation of *the House of Quality* for the QFD need

3.1. Customers' identification

The farm track trailer is offered by the company for farmers.

3.2. The customers' needs and requirements determination – 1st field

The first stage of construction of the House of Quality involved identification of customer requirements with respect to the product studied. The needs and requirements were evaluated and written by farmers using a dedicated questionnaire. The analysis and reduction of the answers obtained yielded 22 the most frequent needs and requirements. These include: *A. Easy unloading of loose materials, B. Easy loading of high-volume materials, C. Tightness after loading with loose material, D. Rigidity of walls after loading with loose material, E. Stabilization of high-volume materials during transport, F. Strength of trailer frames, G. Resistance of the floor to deformation and corrosion, H. Optional use of the trailer as*

a platform, I. Optional transport of the substantial quantity of loose and high-volume materials, J. Easier opening and closing the sideboard, K. Optional dosing of loose materials, L. Opportunity to develop high speeds, M. Optional attachment of the second two-axle trailer, N. Protection of the transported materials from variable weather conditions, O. Easier everyday use of the trailer, P. Safety of the operator during services, Q. Easier replacement of the punctured tire, R. Adaptation to transport on public roads, S. Independent braking system, T. Auxiliary equipment, U. Low weight, V. Low price. Furthermore, these requirements were used in individual rows of the House of Quality matrix.

Farmers who buy agricultural trailers are focused mainly on their reliability and high quality. For this reason the trailers should feature a firm design i.e. frames (upper and bottom) should be made of steel with particular grade so that they can last for many years of operation. Cargo compartment should show a particular strength, rigidity and tightness and the floor should have particular thickness and be covered with particular quality of varnish coat. Obviously, the whole structure should be also lightweight. In order to make it easier to load and unload high-volume materials (e.g. straw bales, pallets), the distance between the trailer floor and ground should be as low as possible while the walls and posts should be detachable. In order to make unloading of loose materials (e.g. corn, grains) easier, the trailer should allow for tilting towards three sides (to the left, to the right and to the rear), whereas, in order to dose the material, the rear wall should be equipped in an adjustable chute hole. Rich standard equipment and numerous options of auxiliary equipment and devices improve attractiveness and comprehensiveness of the trailer and keep it ready for any application and conditions.

3.3. Definition the customers' needs importance by using ABCD Suzuki method – 2nd field

ABCD Suzuki method was used for evaluation of the importance of individual customer needs and requirements with respect to the product studied. The ABCD Suzuki method is a very simple and popular method, which might determine the importance and ranking of individual factors (the most frequent causes of a problem)[17]. The most basic assumption for this method is active participation of a select team of employees. Furthermore, team members should be experts in their fields and experienced in the problem analysed, which ensures credibility of the analysis[18].

The fundamental condition was met in terms of the respective selection of people to the team of experts. These people were exclusively farmers who were the owners of double-axle

[17] Borkowski S.: Tradycyjne narzędzia zarządzania jakością. Teoria i praktyka. Oficyna Wydawnicza Stowarzyszenia Menedżerów Jakości i Produkcji, Częstochowa 2012, s. 99-101.
[18] Łuczak J., Matuszak-Flejszman A.: Metody i techniki zarządzania jakością. Kompendium wiedzy. Quality Progress, Poznań 2007, s. 123-126.

agricultural trailers, assigned the task of evaluation of the importance of individual requirements on a scale of 1 to 10.

During analysis and reduction of the answers, we eliminated extreme answers (in order to reject the ineffective opinions) in order to determine the number of non-crossed answers (18) and the value of the corrected sum of markings (as a sum of products of rank values and the number of answers to a particular rank), rank index (by dividing the corrected sum of markings by the number of non-crossed answers) and indicated the final rank for individual requirements (through organization of rank indices from the lowest to the highest value and assigning them consecutive integers, starting from 1). The most important requirement is represented by the lowest value on the evaluation scale i.e. "1" (accroding to ABCD method). At the next stage of ABCD analysis, the ranking was reversed in order to use it at the next stages of construction of the QFD House of Quality (the scale was reversed – the least requirement was marked by "1"). Results of the ABCD Suzuki analysis were presented in table 1.

Table 1

ABCD Suzuki matrix

SYM-BOL	CRITERIA OF RANK										∑	SSZ	LON	WR	R	R for QFD
	1	2	3	4	5	6	7	8	9	10						
A	*7*	*7*	*4*		*0*						***18***	***33***	***18***	***1.833***	***1***	***22***
B	*7*	*4*	*3*	*4*							***18***	***40***	***18***	***2.222***	***3***	***20***
C	*6*	*6*	*3*	*3*							***18***	***39***	***18***	***2.167***	***2***	***21***
D		*5*	*4*	*3*	*3*	*1*	*2*				***18***	***69***	***18***	***3.833***	***10***	***13***
E		*2*	*3*	*3*	*4*	*2*	*2*	*1*	*1*		***18***	***88***	***18***	***4.889***	***14***	***9***
F	*1*	*6*	*6*	*4*	*1*						***18***	***52***	***18***	***2.889***	***5***	***18***
G	*2*	*6*	*5*	*2*	*2*	*1*					***18***	***53***	***18***	***2.944***	***6***	***17***
H	*1*	*5*	*6*	*3*	*2*	*1*					***18***	***57***	***18***	***3.167***	***8***	***15***
I				*5*	*5*	*2*	*1*				***13***	***64***	***18***	***3.556***	***9***	***14***
J				*2*	*1*	*3*	*2*	*2*	*1*		***11***	***70***	***18***	***3.889***	***11***	***12***
K				*5*	*6*	*3*	*3*	*1*			***18***	***97***	***18***	***5.389***	***16***	***7***
L				*5*	*3*	*2*	*3*	*2*	*1*	*2*	***18***	***113***	***18***	***6.278***	***18***	***5***
M				*7*	*4*	*3*	*4*				***18***	***94***	***18***	***5.222***	***15***	***8***
N						*4*	*5*	*4*	*3*	*2*	***18***	***138***	***18***	***7.667***	***21***	***2***
O						*5*	*5*	*4*	*2*	*2*	***18***	***135***	***18***	***7.500***	***20***	***3***
P				*6*	*5*	*3*	*2*	*1*	*1*		***18***	***98***	***18***	***5.444***	***17***	***6***
Q					*2*	*5*	*3*	*4*	*3*	*1*	***18***	***130***	***18***	***7.222***	***19***	***4***
R	*1*	*6*	*5*	*3*	*3*						***18***	***55***	***18***	***3.056***	***7***	***16***
S			*3*	*6*	*4*	*5*					***18***	***83***	***18***	***4.611***	***13***	***10***
T	*3*	*6*	*7*	*2*							***18***	***44***	***18***	***2.444***	***4***	***19***
U							*6*	*4*	*5*	*3*	***18***	***149***	***18***	***8.278***	***22***	***1***
V			*7*	*4*	*5*	*1*	*1*				***18***	***75***	***18***	***4.167***	***12***	***11***

Legend: SSZ - corrected importance sum, LON - number of answers which were not struck off in a list, WR - index ranks, R - rank according to ABCD analysis, R for QFD - rank for QFD analysis.

Source: own study.

Analysis of the results obtained using the ABCD Suzuki method helped identify the most essential customer requirements with respect to agricultural double-axle trailers, such as: *easier unloading of loose materials, easier loading of high-volume materials, tightness after loading with loose material*. The least important requirements were: *protection of the goods transported from variable weather conditions, easier everyday operation of the trailer and its lightweight*.

3.4. Identification of technical parameters of the product based on CTQ tree – 3rd field

It was used the tree for the requirements which are critical to quality (CTQ) in order to transform the customer needs and requirements into technical specifications of the double-axle agricultural trailer.

The results of the use of the CTQ tree are presented in Table 2.

Table 2

Result of CTQ tree usage

Sym-bol	Needs	Drivers	CTQs – Measures	Unit
A	Easy unloading of loose materials	Opening and folding side	**Construction of the walls and pillars of the load box**	*type*
		Multilateral system of tilting	**System of tilting**	*sy-stem*
		High angle tilting sideways of load box	**Tilting angle of the load box to the sides**	*de-grees*
		Shape of the load box platform for quick unloading	**Shape of the load box platform**	*shape*
		Quick way to open the walls of load box	**Opening and closing system of the walls of the load box**	*sy-stem*
		Small number of levers to open the walls of load platforms	**Number of levers to open the walls of load platforms**	*nu-mber*
B	Easy loading of high-volume materials	Short distance of load box platform from the ground	**Height of load box platform from the ground (land)**	*mm*
C	Tightness after loading with loose material	High tightness of load box	**Manufacturer of profiles trailers**	*name*
D	Rigidity of walls after loading with loose material	Option of stabilizing the sides of the walls	**Way of walls stabilizing**	*type*
		Thick sheet on the wall	**Sheet thickness of walls/floor**	*mm*
E	Stabilization of high-volume materials during transport	Equipped with a large number of cargo handles in the floor	**Number of cargo handles in the floor**	*nu-mber*

cont. table 2

F	Strength of trailer frames	The shape of the frame provides increased strength	**Shape of the frame**	*shape*
		Durable frame profiles	**Type of profiles on the frame**	*type*
		Durable steel used for the frame	**Grade of steel used on the frame**	*class*
G	Resistance of the floor to deformation and corrosion	Durable steel used on the floor	**Type of steel used on the floor**	*type*
		High-quality paintwork used on the floor	**Quality of the paint coating**	*type*
H	Optional use of the trailer as a platform	Removable walls and pillars of load box	**Construction of the walls and pillars of load box**	*type*
I	Optional transport of the substantial quantity of loose and high -volume materials	A large load area	**Loading surface**	m^2
		A large cargo capacity	**Load capacity**	m^3
		The high walls of the box	**Height of walls of the load box**	*mm*
		Long loading box inside	**Length of the load box inside**	*mm*
		Wide load box inside	**Width of the load box inside**	*mm*
		Optimal overall dimensions	**Overall dimensions**	*mm x mm x mm*
J	Easier opening and closing the sideboard	Quick opening and closing system of load box walls	**Opening and closing system of walls load box**	*type*
K	Optional dosing of loose materials	The rear wall load box equipped with a chute and latch enable streaming discharging bulk material	**Type of equipment of the rear wall of the load box**	*type*
		Large angle tilting load box to back	**Tipping angle of the load box to back**	*de-grees*
L	Opportunity to develop high speeds	High maximum speed	**Maximum design speed**	*km/h*
M	Optional attachment of the second two-axle trailer	Equipped with a rear hitch	**Type of additional equipment**	*type*
		Equipped with pneumatic, electric and hydraulic socket for the second trailer	**Type of additional equipment**	*type*
N	Protection of the transported materials from variable weather conditions	Equipped with a rack and tarpaulin	**Type of additional equipment**	*type*
		Loading box fitted with mountings for tarpaulin	**Construction of the walls and pillars of the load box**	*type*

cont. table 2

O	Easier everyday use of the trailer	Equipped with supporting wedges	**Type of additional equipment**	*type*
		Equipped with ladder	**Type of additional equipment**	*type*
		Equipped with side steps	**Type of additional equipment**	*type*
P	Safety of the operator during services	Suitable mechanical protection on load box against falling	**Type of protection against load box falling**	*type*
Q	Easier replacement of the punctured tire	Equipped with a tool box	**Type of additional equipment**	*type*
		Equipped with a spare wheel	**Type of additional equipment**	*type*
R	Adaptation to transport on public roads	Equipped with a lighting system	**Type of additional equipment**	*type*
		Equipped with a warning triangle	**Type of additional equipment**	*type*
		Having homologations	**Type of document regarding approval to the public road traffic**	*type*
S	Independent braking system	Equipped with a brake systems	**Way of stopping the trailer**	*type*
		Equipped with a hand brake	**Way of stopping the trailer**	*type*
		Equipped with a supporting wedges	**Type of additional equipment**	*type*
T	Auxiliary equipment	A large number of items of standard equipment	**Number of items of standard equipment**	*kg*
U	Low weight	Low overall weight	**Overall weight**	*kg*
V	Low price	Low price	**Price**	*euro*

Source: own study.

The above technical parameters characterize the product from the standpoint of a designer. They were selected so that they are measurable and realistic with respect to the manufacturing process. It was determined the direction of optimization of technical specifications that might have the nature of: *minimant* („↓”; the higher the parameter the more satisfied the customer), *maximant* („↑”; the lower the parameter the more satisfied the customer), *nominant* („●”; there is a target value for a particular parameter or a value from a narrow range that should be approached or achieved).

The most (73%) of technical specifications in the analysis performed were of nominant nature. The examples of these parameters are: *type of frame, system of opening and closing the walls of cargo compartment, type of equipment in rear wall of the cargo compartment box etc.* Medium-frequent technical specifications were of maximant nature, e.g. *thickness of wall sheet metal, thickness of varnish coat, loading surface, loading capacity, height of walls of the cargo compartment box.* Technical specification which are of minimant nature include the

height of cargo compartment platform from the ground (lower distances of the loading surface from the ground make it easier to load and unload materials), *trailer weight* (the lower, the better, e.g. lower fuel consumption), *price* (the lower price, the more satisfied the customer).

3.5. Identification of the relationship between customers' needs and technical characteristics of the product – 4th field

In order to determine the relationship between the specific technical characteristics of the analysed product and satisfying the specific needs of customers it was used a three-stage scale: 1, 3, 9, where 1 means weak (barely noticeable) relationship, 3 medium (indirect impact), 9 - strong (direct impact). If between the particular technical characteristic and the particular customer's requirement is not occurred any relationship, such a field in the matrix was left empty.

3.6. Evaluation of the importance of technical parameters – 5th field

At another stage we carried out the evaluation of importance of individual technical specifications by calculation of the absolute coefficients of importance (sum of products of coefficients of importance for individual requirements and coefficients of their correlation with a particular technical parameter) and relative coefficients (quotients of the level of a particular coefficient of absolute importance and total of all coefficients of relative importance). The values of the coefficients obtained helped unequivocally determine the most important technical parameters for the product, termed critical characteristics.

The critical characteristics (5) were: *design of the walls and posts of the cargo compartment box, system of opening and closing the walls of the box, price, manufacturer of sideboard profiles, type of auxiliary equipment*. Achievement of target values for these parameters determines whether the concept of the product studied is successful in the market and whether there are customers interested in the purchase of the product. The particular focus in the manufacturing process should be on the achievement of these parameters.

3.7. Identification the relationships between technical specifications – 6th field

Technical parameters have mutual effect on each other, which might also affect the opportunities for meeting customer requirements. This effect might be *positive* („+"; if improvement of one technical parameter leads to improvement of the other), *negative* („-"; if improvement of one technical parameter leads to deterioration of the other), or *neutral* (empty

field; lack of effect between technical parameters). This analysis is based on information of the nature of individual characteristics and tendencies of forming them in the product (field 3). These correlations were marked in the "roof" of the House of Quality in the crossing of the rows connecting selected two technical parameters[19].

Plus signs (+) and neutral signs dominate in the roof of the House of Quality, which means that the concept of product analysed offers opportunities for further facilitation in order to adapt to actual and future needs of the customer and, importantly, it will not negatively affect other technical parameters. Negative relationships occur mainly between *the price* and *other technical parameters* i.e. improvement in these parameters will negatively affect the price (this will cause an increase in the price, which will make customer dissatisfied).

3.8. Comparison analysed product with competitive products in terms of meeting customer requirements – 7th field

We evaluated the product studied with products manufactured by four biggest competitors in Poland who manufacture similar trailers due to the degree to which a product meets the requirements contained in the rows of the House of Quality. The evaluation of meeting these requirement was based on a scale of 1 to 5 points, where: 1 - *failure to meet the requirement*, 2 - *the requirement met at an insignificant level (far insufficient)*, 3 - *the requirement met at a poor level*, 4 - *the requirement met at a good level*, 5 - *the requirement met entirely*. The scores were written in the table marked as the image profile. The next step involved determination of the overall number of points for individual products by multiplication of individual levels of meeting the requirements (numbers 1 to 5) for the products compared by the importance of customer requirements. The obtained values revealed the products that best suited the customer expectations and those which were next in the ranking[20].

The results of comparative analysis of the product with competition from the standpoint of meeting the customer requirements show that the product studied is the best in terms of meeting these requirements. The agricultural trailer analysed has a very competitive position in the market of Polish agricultural machines. It does not meet all the requirements entirely, but it meets entirely the requirements which are particularly important to the customer. The difference in the level of meeting the requirements by the manufacturer and competitors is relatively insignificant.

[19] Por. http://www.zarz.agh.edu.pl/bsolinsk/QFD.html; Sikorski M.: Zastosowanie metody QFD do doskonalenia jakości użytkowej serwisów WWW. Zeszyty Naukowe Politechniki Poznańskiej, s. Organizacja i Zarządzania, nr 35, Poznań 2002, s. 119-131; Hamrol A.: Zarządzanie jakością z przykładami. PWN, Warszawa 2008, s. 371.

[20] Por. http://www.zarz.agh.edu.pl/bsolinsk/QFD.html; Sikorski M.: Zastosowanie metody QFD do doskonalenia jakości użytkowej serwisów WWW. Zeszyty Naukowe Politechniki Poznańskiej, s. Organizacja i Zarządzanie, nr 35, Poznań 2002, s. 119-131; Hamrol A.: Zarządzanie jakością z przykładami. PWN, Warszawa 2008, s. 371-372.

3.9. Determination of target levels of technical parameters – 8th field

Performing all the activities connected with creation of QFD diagram allowed for obtaining a good picture of the product improved, including customer expectations, competitive products and the way technical parameters impact on meeting specific requirements. Having this information helped determine target values to be reached by measurable technical parameters in order to meet customer requirements and improve competitiveness of the product studied.

Full list of target value is contained in the lower part of the House of Quality.

3.10. Determination of the indices of technical difficulty of performance – 9th field

The indices that provided the measure of technical and organizational difficulties that can be expected at reaching target levels of technical parameters were also determined. The focus was on the following aspects of the company studied: maturity of technology, staff competencies, availability of resources, manufacturing capability, availability of suppliers, technical risk. Feasibility of assumptions made was evaluated on the scale of 1 to 5, with 5 being very high difficulty in meeting the target value for a particular parameter in the manufacturing process.

The biggest difficulty in the production process is to obtain the appropriate *height of the trailer floor* with respect to the ground as this parameter results from many other parameters of the trailer, which have to be taken into consideration in order to reach the target value for this parameter. Ensuring *the three-directional chuting system*, which requires specific constructional assumptions, was also evaluated at the same level of difficulty. Feasibility of other design assumptions was evaluated as medium or easy.

3.11. Comparison of the product with other competitive products in terms of technical characteristics – 10th field

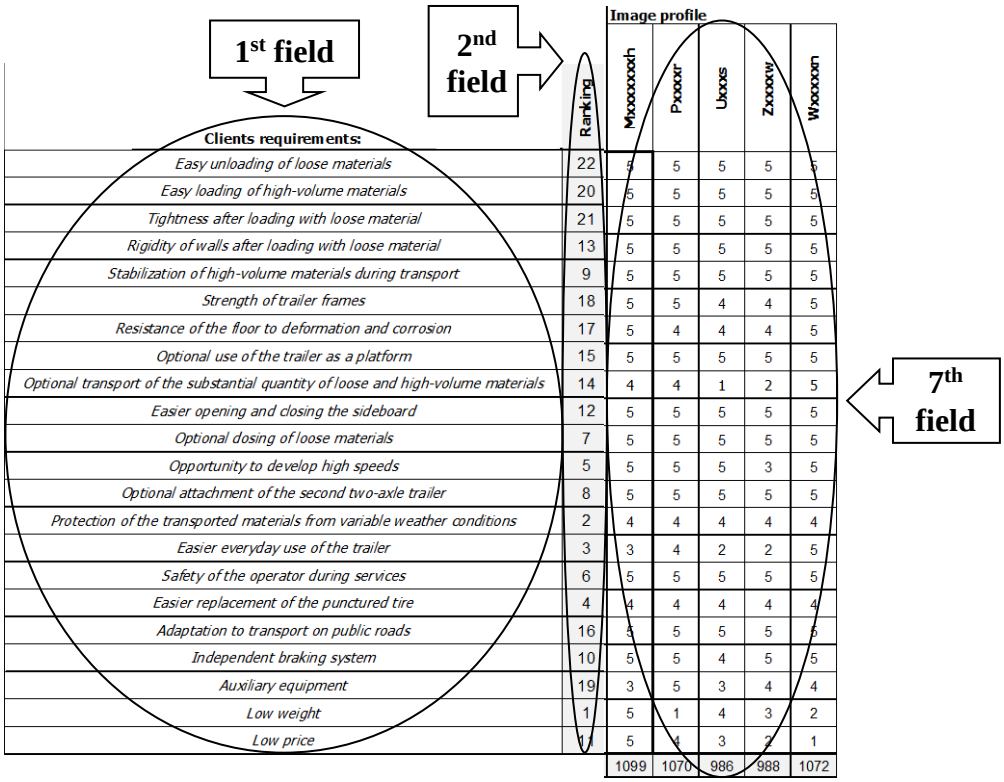
Analogically to the customer benchmarking, we also carried out a comparative analysis of the product studied compared to four products manufactured by competitive companies in order to evaluate technical levels of the solutions offered (target values) in terms of all the technical parameters (evaluation whether technical requirements are met to the best possible degree and in the most professional manner). The evaluation of meeting technical parameters was based on a scale of 1 to 5 points[21].

[21] Por. http://www.zarz.agh.edu.pl/bsolinsk/QFD.html; Sikorski M.: Zastosowanie metody QFD do doskonalenia jakości użytkowej serwisów WWW. Zeszyty Naukowe Politechniki Poznańskiej, s. Organizacja i Zarządzanie, nr 35, Poznań 2002, s. 119-131; Hamrol A.: Zarządzanie jakością z przykładami. PWN, Warszawa 2008, s. 372.

The study revealed that, in terms of the most of the technical parameters, the product studied met the requirements entirely. Only in a few parameters (*height of cargo compartment box platform with respect to the ground, loading surface, loading capacity, number of components of standard equipment, type of additional equipment, number of load holders*) the product was worse than the competitor's. These technical parameters need improvements to better reflect customer requirements.

4. House of Quality

Finished the QFD's House of Quality for the product - biaxial farm trailer is shown on Fig. 2. The QFD matrix was elaborated based on program QFD (ver. 2.23) developed by Bartosz Solinski[22]. Denotation of particular filelds in elaborated QFD's House of Quality for analysed product was presented in the Fig. 2.



[22] http://www.zarz.agh.edu.pl/bsolinsk/download.html.

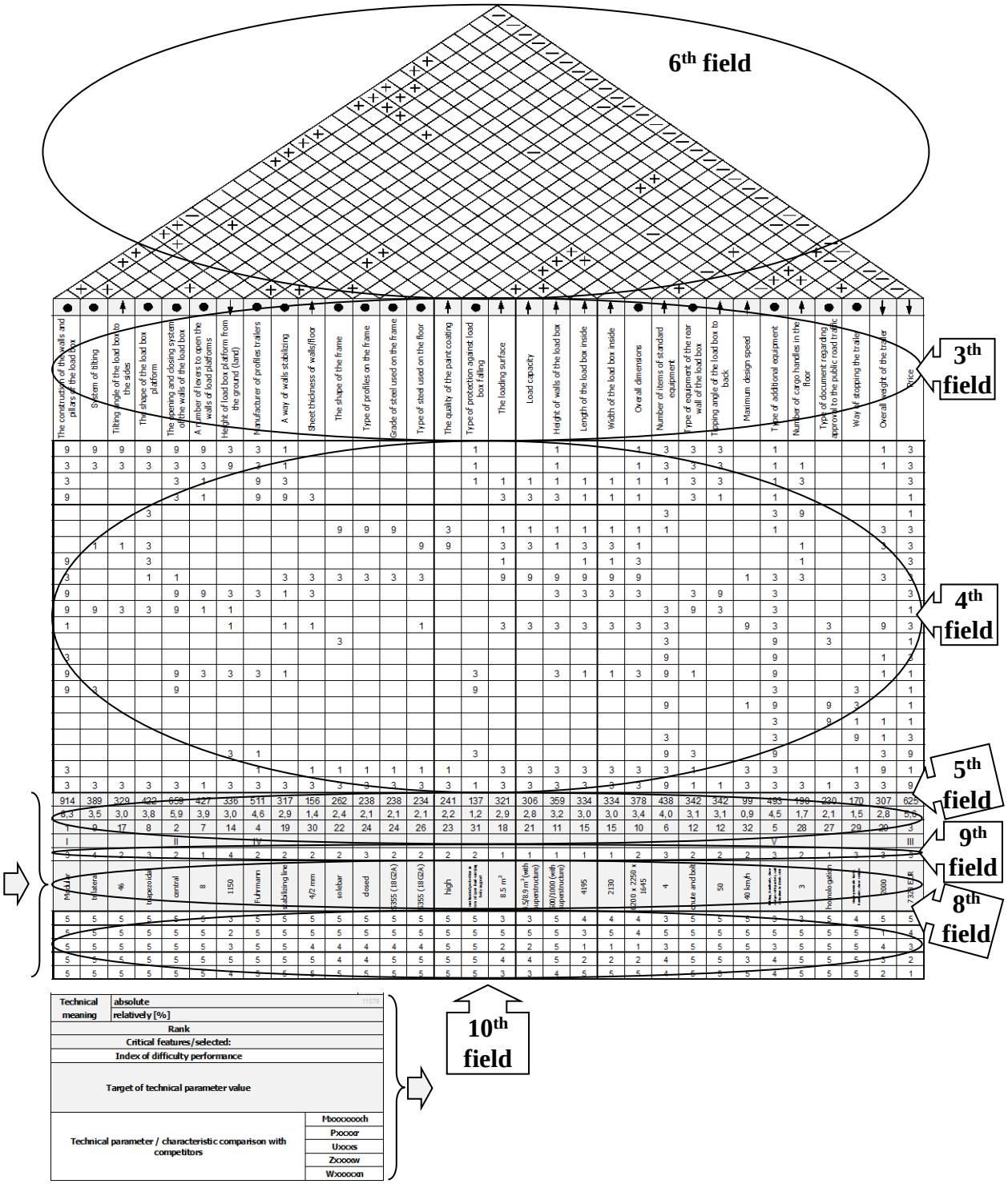


Fig. 2. Denotation of particular fields in elaborated QFD's House of Quality for analysed product
Rys. 2. Oznaczenie poszczególnych pól w opracowanym Domie Jakości QFD dla badanego produktu
Source: own study.

Finished, full elaborated the QFD's House of Quality for the product – farm truck trailer was presented in the Fig. 3.

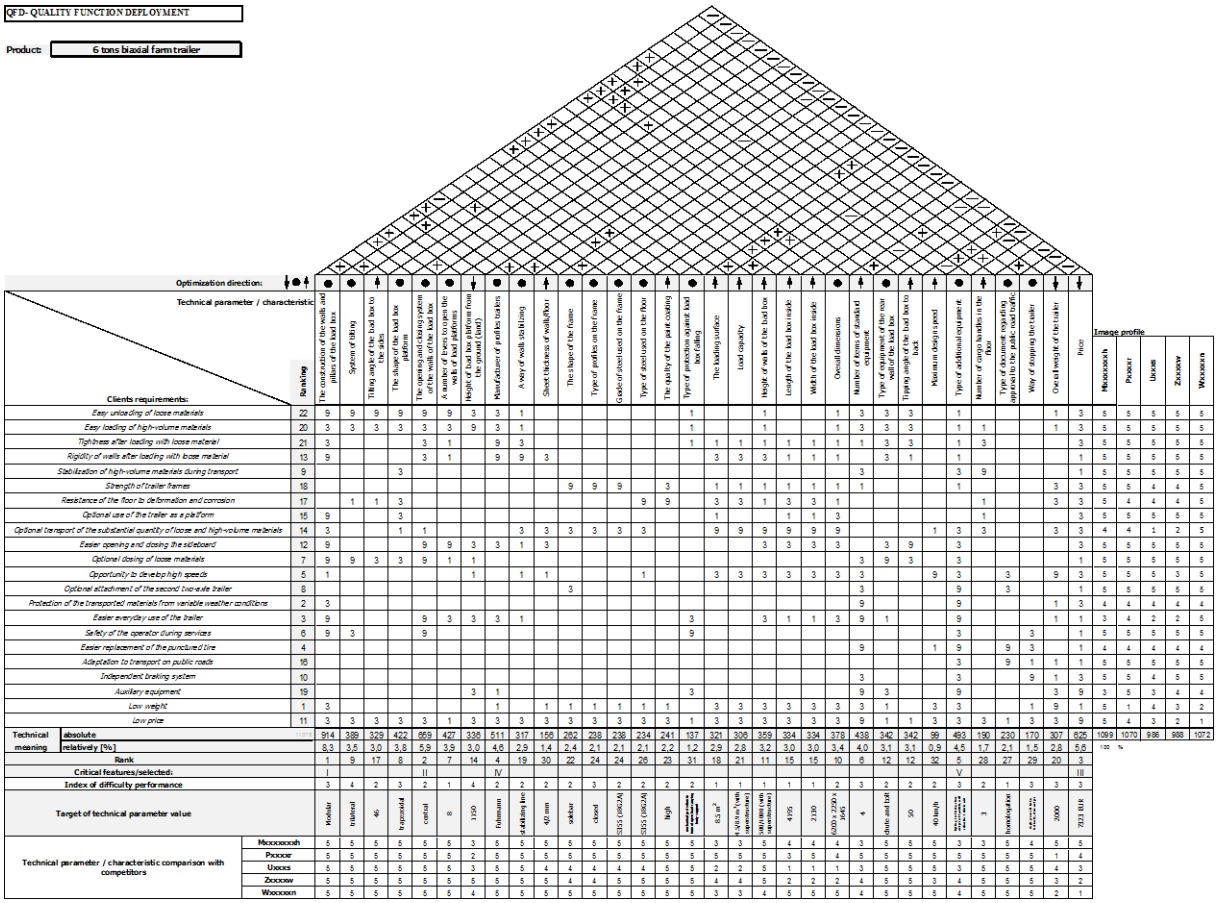


Fig. 3. Finished QFD matrix for the product – farm truck trailer
Rys. 3. Gotowa macierz QFD dla produktu – przyczepa ciężarowa rolnicza
Source: own study.

5. Summary and conclusions

QFD analysis is a labour-intensive yet profitable procedure. The analysis helped obtain a concrete picture of the product that met best the customer requirements. It is important that the conclusions drawn from QFD analysis should be immediately implemented. Identification of the position of the product compared to competitive products revealed the areas that should be first improved in order to adapt to current customer needs.

In order to carry out QFD analysis, we identified the following critical characteristics of an agricultural trailer: *design of the walls and posts of the cargo compartment box, system of opening and closing the walls of the box, price, manufacturer of sideboard profiles, type of auxiliary equipment*. These parameters are critical to the product because controlling them will help the company meet the particularly important customer require-ments.The conclusions from the analysis were used to designing the improved version of the trailer. The new product is expected to feature three-directional chuting system through supporting the

cargo compartment box with a system of articulated joints that offer such functionality. Furthermore, the rear wall will also be equipped with a damper with a chute for unloading loose materials. It is expected that this parameter will have the effect on customer decisions on purchasing the product since the purchasers need the loose materials to be unloaded efficiently. In order to make loading of high-volume materials easier, the trailer will feature a relatively low level of floor with respect to the ground (this is the area of further improvements since competitors are better in this field). Opportunities of disassembly of posts and walls will help using the trailer as a platform to transport small quantities of straw bales, boxes or pallets. The walls of cargo compartment box will be made of Fuhrmann side-board profiles which ensure perfect rigidity and tightness of the design. The light and firm design will be ensured by using closed profiles. The bottom and upper frame will be made of steel [S355 (18G2A) grade], which will guarantee its strength for many years of trailer's operation. The floor will be made of S355 steel with thickness 4 mm, covered with high-quality varnish coating, which will guarantee its resistance to deformations and corro-sion. The trailer will be consistent with EU directives and EC certificate and appropriate official approvals. Single-cable pneumatic brake will be included in the standard equipment. In order to make everyday use easy, the trailer will be equipped in the central system of locking walls at the floor's edge. Standard ladder will also facilitate using the machine. In order to ensure the appropriate rigidity of the design, a stabilizing line will be used after loading, released with a lever on the side wall. The operator will be protected from falling the cargo compartment box during maintenance works with the mechanical safety device in the form of a support under the box. The standard equipment will also include braking wedges for wheels. At the customer request, the tipper will be equipped in a spare wheel with mounting system under the bottom frame, rear coupling and the frame with tarpaulin canvas. This technical solution offers advantage over competitors.

In further phases of manufacturing, the company plans to take measures to increase the number of cargo holders, increase the length and width of the cargo compartment box, increase the number of standard components of equipment (adding a platform for easier everyday operation, tarpaulin canvas for protection of materials during transport), and ensure more opportunities for ordering optional equipment. These activities will be aimed at better adaptation of the product to customer expectations and improving the competitiveness of the product in the market.

Bibliography

1. Borkowski S.: Tradycyjne narzędzia zarządzania jakością. Teoria i praktyka. Oficyna Wydawnicza Stowarzyszenia Menedżerów Jakości i Produkcji, Częstochowa 2012.

2. Borkowski S., Kaczorowski Ł.: Wykorzystanie metody QFD w zarządzaniu jakością mebli, Juchniewicz M. (red.): Zarządzanie przedsiębiorstwem w warunkach konkurencji. Determinanty konkurencyjności przedsiębiorstw. Cz. II. Wyd. Uniwersytetu Warmińsko-Mazurskiego, Olsztyn 2006.
3. Chan L.K., Wu M.L.: Quality function deployment: A literature review. „European Journal of Operational Research". 143(3), 2002.
4. Eckes G.: Rewolucja Six Sigma. MT Biznes, Warszawa 2010.
5. Hamrol A.: Zarządzanie jakością z przykładami. PWN, Warszawa 2008.
6. Hamrol A.: Strategie i praktyki sprawnego działania. Lean, Six sigma i inne. PWN, Warszawa 2015.
7. Krzemień E., Wolniak R.: Zastosowanie komputerowego wspomagania w metodzie QFD. „Problemy jakości", nr 7, 2001.
8. Łuczak J., Matuszak-Flejszman A.: Metody i techniki zarządzania jakością. Kompendium wiedzy. „Quality Progress", Poznań 2007.
9. Mazur M., Kaczorowski Ł., Borkowski S.: The QFD Method Application to Prognose the Quality. TRANSCOM 2007. 7th European Conference of Young Research and Scientific Workers. Proceedings. Section 2. Economics and Management. Part 2 (L-Z), Žilina 2007.
10. Oke S.A.: Manufacturing Quality Function Deployment: Literature Review and Future Trends. „Engineering Journal", Vol. 17, Issue 3, 2013.
11. Prus A., Selejdak J.: Wykorzystanie metody QFD do zapewnienia jakości w przemyśle meblarskim. Prace Naukowe Instytutu Technologii Maszyn i Automatyzacji Politechniki Wrocławskiej nr 78, Wrocław 2000.
12. Sikorski M.: Zastosowanie metody QFD do doskonalenia jakości użytkowej serwisów WWW. Zeszyty Naukowe Politechniki Poznańskiej, s. Organizacja i Zarządzanie, nr 35, Wydawnictwo Politechniki Poznańskiej, Poznań 2002.
13. Wolniak R., Skotnicka B.: Metody i narzędzia zarządzania jakocią. Teoria i praktyka. Wydawnictwo Politechniki Śląskiej, Gliwice 2008.
14. Wolniak R., Sędek A.: Wykorzystanie metody QFD do projektowania proekologicznych produktów i usług. „Problemy Ekologii", Vol. 12, nr 4, 2008.
15. http://www.brighthubpm.com/six-sigma/86047-critical-to-quality-ctq-tree/.
16. http://www.isixsigma.com/dictionary/critical-to-quality-ctq/.
17. https://www.mindtools.com/pages/article/ctq-trees.htm.
18. http://sixsigmabasics.com/six-sigma/statistics/critical-to-quality.html.
19. http://www.qfdi.org/what_is_qfd/what_is_qfd.html.
20. http://www.webducate.net/qfd/qfd.html.
21. http://www.zarz.agh.edu.pl/bsolinsk/QFD.html.
22. http://www.zarz.agh.edu.pl/bsolinsk/download.html.
23. http://www.4pm.pl/artykuly/dekoder-oczekiwan-klienta-na-parametry-produktu-czy-uslugi-czyli-narzedzie-ctq-critical-to-quality.

Omówienie

Aby wprowadzić produkt na rynek, który będzie spełniał oczekiwania klientów, a nawet je przekraczał, należy bardzo dobrze poznać potrzeby i wymagania klientów, a następnie umiejętnie je przełożyć na konkretne cechy jakościowe dla produktu oraz parametry dla procesu, w ramach którego taki produkt jest wytwarzany, zwracając uwagę na to, żeby zrobić to możliwie szybko (bo, jak wiadomo, jakość jest pojęciem dynamicznym – zmienia się w czasie). W tym celu można wykorzystać analizę QFD, która prawidłowo przeprowadzona, zwiększa szansę na to, że „nowy" produkt będzie odpowiadał aktualnym wymaganiom klientów. Metodę QFD razem z narzędziem koncepcji Six Sigma, tj. drzewem CTQ wykorzystano do udoskonalenia przyczepy ciężarowej rolniczej jednego z polskich producentów. Analiza QFD i CTQ pozwoliła wskazać na mocne strony badanego produktu oraz zidentyfikować „obszary", tj. charakterystyki, cechy tego produktu, wymagające doskonalenia, celem jeszcze lepszego spełnienia wymagań klientów.