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ORIGINAL ARTICLE

The Technical Parameters of the Creation Process for Kayak Paddles as a Sport Product

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ABSTRACT

Background. Considering that a person's physical and psychological possibilities are not limitless, the technical means used by athletes are of great importance. In order to achieve high results in the kayak sprint competition, users-athletes orient to the highest quality products; therefore, a significant task falls to their manufacturers to analyze the competitors' products, evaluate users' needs at the maximum, and look for new technical solutions. Quality function deployment (QFD) is one of the methods, the use of which in the creation of high-quality paddles for the kayak sports competition is a relevant object of scientific research. **Objectives.** The purpose of this empirical study is to establish kayak paddle technical parameters for a sprint event deploying the extended quality function method. The article analyses the concept of quality function deployment, specifying opportunities for quality function deployment method applications when producing a new product. **Methods.** The research comprises three major phases: the first one is a verbal survey, applying the method of half structural interview, the second one is written survey on the respondents', prize holders', from nine European countries (Lithuania, Hungary, German, Russia, Byelorussia, England, Australia, Spain, and Romania) responses and the third one – quality house matrix producing backing on the results of calculations and experts opinions. **Results.** Based on the impact of technical requirements and impact comparative weight indexes, priorities of technical parameters for consumers' – rowers kayak paddle sprint events were established, which should be implemented first and foremost. Criteria such as the structure of the product material, rigidness, structure of carbon fiber, and the number of fabric layers were indicated. **Conclusion.** Based on the results of the study, it has been found that in order to create a kayak paddle for the sprint competition, which meets the users' needs, the greatest focus should be placed on the implementation of such needs as paddle blade parameters, paddle shaft parameters, durability, and grip between the arm and paddle, as the participants of the study confirmed that they are of paramount importance for users. This study extends the limits of applicability of the QFD method in developing new and improving the already existing products, including a specific field – the paddle for the kayak sprint competition, and also partially addresses the problem of the lack of research on using the scientific research method in the development of sports products. Therefore, in the future, it is recommended to develop research on the application of the QFD method in the creation of various sports products.

KEYWORDS: ***Kayak Paddles, Sport Product, Customers' Needs, Quality Function Deployment***

INTRODUCTION

Research Novelty. Tendencies evidence that relations in global markets are becoming more dynamic and challenges will force producers to react more flexibly to customers' desires looking for new solutions of quality and value. Search for innovative solutions has become the major issue for companies

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aiming long term growth and profitability. Specific markets, such as rowing sports, are not an exception. Bearing in mind that human's physical and psychological abilities are limited, technical equipment used by sportsmen becomes vitally important here. Runciman and Lyle (2013) recognized throughout the world, the paddle has remained largely unchanged since its inception thousands of years ago (1). Complex interactions occur between the oar blade and water, and over the last 30 years our understanding of the mechanisms that govern rowing propulsion has developed significantly (2). When seeking for the highest results in kayak sport sprint event, consumers-athletes seek highest quality products therefore their producers face with important task to analyse a competitive production, to assess to maximum consumers' needs and look for new technical solutions. Kammerlind et al. (2000) argues that today Quality Function Deployment (QFD) is a well-known method to understand customers' needs and to translate them into design attributes. This makes QFD very helpful in the product development process (3). QFD is a systematic means of ensuring that customer or market placed requirements are accurately translated into relevant technical descriptors throughout each stage of product development (4). Quality function deployment appears as one of the methods when producing high quality kayak paddles for sports events and occurs to be relevant object of scientific research.

Research Problem. Competing companies in the market seek to satisfy practical customers' needs within the minimum time span and with least input; however, they apply different strategies for achieving this goal. One of the strategies widely accepted in many countries is quality function deployment. Creative development of this strategy is approached as perspective field of scientific research and studies, which is popularised, however, not among all kayak paddles producers. Thus, the appliance of quality function deployment method in kayak paddle production occurs actual and up to the date. Research problem is formed in a question form - how applying QFD method to specify customers' needs, satisfy them and produce a more competitive product for the market.

The Level of Problem Research. Rowing sport is analysed in the works of the following authors: Sotiriadou et al. (2014) study explores the elite sport policy interrelationships of Sprint Canoe in order to explain the dynamic links between policies and how they may affect performance (5); Diafas et al. (2006) analyzed the weather conditions during August and September in the past 10-13 years in the Schinias area where the Olympic Rowing and Canoe-Kayak Regattas were held (6). According to Morgoch and Tullis (2011) the motion of a sprint canoe blade through the water is extrapolated from video analysis of the paddle handle motion and used to approximate the forces acting on the blade throughout a stroke (7). Authors frame analysis of the video provides the displacement of the blade, and consequently the water velocity and angle of attack at both the top and bottom of the blade. As it can be seen scientific works more often deal and discuss canoe sports issues than those of kayak.

Scientific articles do not analyse widely issues on paddles technical standards. In general the subject of paddles is presented in various analysis cuts, for instance Messinis et al. (2014) compares the swimming stroke technical characteristics and the physiological responses of swimming 100-m backstroke, with and without the use of paddles at maximum and sub-maximum intensities at the same swimming speed (8). Barbosa et al. (2013) study investigated the acute effects of different sizes of paddles on the force-time curve during tethered swimming and swimming velocity in front-crawl stroke (9). Runciman and Lyle (2013) compared resonance tendencies of two major types of recreational canoe paddles, the ottertail and voyageur styles, in stiff and flexible formats (1). Runciman et al. (2012) examined canoe paddle resonance in laboratory, open water, and computer modelling environments. The authors investigate the characteristics of this commonly occurring phenomenon and validate the techniques used in the modelling studies (10). M. Nakashima et al. (2014) developed a comprehensive dynamic model of the paddle, paddle and hull for a simulation analysis of the paddling motion in a single kayak (11).

Quality function deployment (hereafter related as QFD) is the method supported by team work setting the major goal of customers' needs satisfaction alongside with the quality assurance on each stage of product production. QFD method in scientific works is rather widely applied and/or analysed in various areas (12-37). Scientific literature analysis performed proves the versatility and adaptability of this method in miscellaneous areas. Nevertheless the lack of scientific research implying QFD method application for improving kayak paddle is evident.

Theoretical Grounding. According to Trabal (2008), sport and science share the same ideal: to continually transcend the limits of the human being. Most research analyzing problems of kayak paddle appliance in rowing sport is concentrating to hydrodynamic, technical solutions, their modeling (1, 2, 7, 11) . Banks et al. (2013) empathized the significance of kayak paddle design in sprint event. Dealing with this problem of product design QFD method is widely applied (4, 33, 38, 39). The appliance of this method has proved itself in many sports when focusing on customer's satisfaction with the product (23, 39), and solving wide spectrum of problems - from design to technological, engineering issues. Webster and Roberts (2009) argues, that during the design of sports equipment, the main focus is usually on physical performance attributes, neglecting key subjective factors such as feel or comfort. However, we lack research dealing paddle related issues in the context of QFD (40). Despite this the versatility of the method provides an opportunity of extensive applicability.

In spite of the current research lack in sport products production field, the usefulness and recognition of the method is grounded by its history and broad geography. QFD is an important quality control theory proposed by the Japanese quality control master Yoji Akao (41). QFD has often been claimed to be the fundamental tool which helped the Japanese industry to achieve supremacy over the industries in the West QFD was introduced in the West in the mid 1980's and a decade has passed since its inception, varying degrees of success have been reported on its use (42); is applied in the early stages of the design phase so that the customer needs are incorporated into the final product (43), it leads to better product designs, lower product costs, and shorter development times (44). QFD method uses a two-phased approach for finding an optimum design strategy. During the first phase, the design team sets goals for customer perception for each customer attribute and relates them to those of its competitors (benchmarking); then, in the second phase, a goal-based model with a separated, mixed integer structure is used to minimize cost while respecting customer desires. The model defines fixed cost as a major improvement in design solutions such as changing parts, materials, or operational mechanisms (45).

According Shahin (2008), QFD is a structured process, a visual language, and a set of inter-linked engineering and management charts, which uses the seven management (new) tools. It establishes customer value using the voice of the customer and transforms that value to design, production, and manufacturing process characteristics (46). Also QFD is a planning tool based on user needs and expectations - quality functions - allowing the planning and design of the information products and representation processes (33), it is especially suited to the initial steps of the design process when the first concepts of a new pruning shears are being developed (38).

It is also worth bearing in mind that the method implies several drawbacks. It is basically a methodology which links the needs of the customer with design, development, engineering, manufacturing, and service functions by finding both spoken and unspoken needs, translating these into actions and designs, and focusing various business functions toward achieving this common goal. However, it still has some limitations and cannot guarantee satisfactory output in some scenarios (47). According Shahin (2008), QFD has been found to have some considerable problems, most of which seem to affect adversely its employment. Examples of some of the most important ones are: ambiguity in the voice of the customer, managing large HoQ and conflicts between Customers' requirements (46). In spite of the above problems, there exist a wide range of benefits and advantages associated with using such a customer satisfaction quality design technique, which make it beneficial to designing quality. QFD is a quality design and improvement technique and relatively is closer to the customers than other techniques. Furthermore, the results suggest that relative worth does not significantly change when a worth-calculation method is fixed. In contrast, if a worth-calculation method is changed, large changes may occur. These large changes are more likely in QFD relationship matrices with small numbers of rows and columns less than or equal to six. These results may imply that designers need to commit to a worth-calculation method when they use information from QFD to make their design decisions (36). The authors only pay attention to the possibilities of application but do not deny that the method is efficient and up to date.

All things considered it could be assured that though QFD method is not widely researched in the context of sports products production, it provides an opportunity to maximally assess customers' needs, including the development of technical-qualitative product parameters, innovation search and water sports equipment production processes.

MATERIALS AND METHODS

Aiming to create a new product - kayak paddle for sprint event, to assess customers' needs and establish technical parameters for their implementation, quality function deployment method was used with the purpose of maximum customers' needs satisfaction with the least input, better quality, shorter time of product getting to the market and significant market advantages in Lithuanian-Hungarian organisation "Brača-sport", producing high quality paddles. This is an effective product creation, customer-oriented method. QFD method provides organization with an opportunity to collect information on the major customers' needs and model them to product technical specifications (48).

Participants and Measurement Procedures. The research was performed in three-phase approach. The first phase implied research of verbal questionnaire. The research material was chosen on the basis of Lithuanian Canoe and Kayak Federation data for the year 2011, twelve people (kayak rowers) were randomly chosen and purposeful group was formed, which was interviewed in semi structural interview. The data obtained from the interview was used for questionnaire compiling. Interview with purposeful group is such a mode of questioning when a group of 8 to 12 people are invited to the agreed in advance place and they discuss or analyse a certain issue or problem (49). Obligatory questions are formulated in advance for a semi-structural interview; other questions are made up to the situation and discussion. This interview method is reliable as it creates more relaxed atmosphere for communication, people can share their thoughts and ideas (50). The second phase implied research on written questionnaire. The researched were rowers (kayak) - professionals from six countries from European and World Championships and 2008 Olympic Games prize winners from these countries: Lithuania, Hungary, Germany, Russia, Byelorussia, England, Australia, Spain and Romania. Sportsmen were questioned from a special questionnaire. Research data was used for the first phase of QFD method, the so-called quality house filling. The third stage implied of quality house matrix producing.

Research Instrument. Firstly, the qualitative research was performed that is a semi structural interview with purposeful group, aiming to analyse the significant rowers' needs for a paddle. The interview was recorded into electronic device. The central question was asked at the very beginning: "What are the essential specifications for a paddle?"; in addition, some supplementary questions followed for more detailed analysis of customers' standing points.

A questionnaire consisting of 18 questions was compiled. The questions were divided into four units: instruction, demography issues, respondent's characteristics, diagnostic questions. Respondents were briefly introduced with the research goal, research ethics, anonymity was guaranteed.

The following diagnostic variables for paddle customers' needs were pointed out; the principal customers' needs, customers' satisfaction with the current product comparison with similar products of competitors; impact of customers' needs satisfaction to products sales. Response versions were presented in several formats: choosing of a single version; a line for text; a matrix. A single version choosing: respondents had to choose the best version to their minds and mark it. The scale consists of three parts, namely - no impact - 1, average impact - 1.25, strong impact - 1.5. A line for text: respondents had to access and put on the line the significance of each need when choosing a paddle in the significance scale 1 to 100. Matrix: produced on the basis of 5 points in Likert scale, assessing each need separately, comparing with competitors. Respondents had to choose one version from 5 possible.

Quality house filing implies: customers' needs and wants matrix, planning matrix, technique reaction matrix, relations matrix, technical correlation matrix, technical matrix.

Matrix of Customer's Wants and Needs. The questionnaire served to establish customers priority needs, which were classified up to Clein (16) customers' needs net where the significance is established (really significant: expected needs and needs of great impact; insignificant: needs of little impact and hidden needs), significance is revealed (weak correlation: expected and little impact needs; strong correlation: needs of great impact and hidden needs) (more details in picture 1). Seeking to classify customers' needs to the named categories, in the first place we have to clear up established and disclosed significance. Established significance is the significance of product characteristics which is established after direct questioning of users and finding out how significant a definite product characteristic is for them. Here we have the formula (51):

$$NS = \frac{\sum PRi}{R_{sk}} \qquad (1)$$

Where:

NS - established significance

PRi - needs assessment

R_{sk} - number of respondents

If:

NS > 50, high significance is established

NS ≤ 50, low significance is established

Disclosed significance - significance of product specification, which is established when calculating the index of significance (strong and weak correlation), when measuring how satisfaction with the product specification level is related to satisfaction with the whole total product. Here we have formula:

$$R = \frac{RR_{sk}}{R_{sk}} \qquad (2)$$

Where:

R - correlation (significance index)

RP_{sk} - number of respondents who have chosen correlation

R_{sk} - number of respondents

R_{st} - strong impact

R_{sl} - weak impact

If:

$R_{st} > R_{sl}$, high significance is disclosed

$R_{st} < R_{sl}$, little significance is disclosed

Backing up Clein's customers' needs net when the high level of established significance occurs and disclosed significance is low, customer's needs are called "expected". When both established and disclosed significance is low, such wants are called of "little impact". When high significance is disclosed, but low significance is established, such needs are called "hidden". Needs established as of little impact were eliminated from the further analysis. Only significant needs were included into quality house first matrix.

Planning Matrix. Here seven data types are distinguished, which have to be assessed before filling this matrix: significance for a customer, achievement of customers satisfaction, seeking of competitive advantages, aims and degree of improvement, sales, total value, comparative value.

Significance to a customer. Aiming to calculate it, we have to choose relative significance which was assessed by respondents in a questionnaire survey, applying 100 points scale. Where - 1 is least significant wants and 100 - the most significant needs. Planning matrix table column significance to a customer includes an average of all obtained data.

$$SV = NS \quad (3)$$

Where:
SV - significance to a customer
NS - established significance

Achievement of customers' satisfaction. It is customers perception how existing products in an organization satisfy their needs. It was established applying 5 points scale: 1 - insufficient, 2 - sufficient, 3 - no opinion, 4 - well enough, 5 - excellent.

The following formula was applied for further calculations of customers satisfaction achievement:

$$VPP = \frac{\sum R_{sk} PV}{R_{sk}} \quad (4)$$

Where:
VPP - customers satisfaction achievement
$R_{sk}PV$ - number of respondents to achievement value
R_{sk} - number of respondents

Seeking for competitive advantages. This column implies information on strong and weak sides of organization's product comparing them with competitive product characteristics. Planning matrix table contained average of competitive advantage for each need taken separately applying customers satisfaction achievement formula (4).

Goals and the level of improvement. Being aware of current customers satisfaction level, we have to be clear what level has to be achieved, i.e. to clear up the goals. Goals are usually measured with the same measurement units as current satisfaction and competitive satisfaction levels i.e. in 5 points scale. Hence, assessing the current situation in an organization and in competitors' organizations, the goal was formulated for each need. Comparing these goals with the current level of satisfaction, the degrees of improvement were:

$$GL = \frac{T}{VPP} \quad (5)$$

Where:
GL - improvement degree
T - goal
VPP - current level of satisfaction

Sales. In accordance to QFD model this column implies the information on opportunities for product sales, which depend on the factors how well customers' needs are satisfied. The impact to sales could be assessed in three levels: weak impact, with established value of 1, moderate impact - 1.25; strong impact - 1.5.

Sales column of planning matrix table column implies established numbers for each need. The values are calculated taking into account the number of respondents who have chosen this impact.

Total value indicates the significance of needs, achieved satisfaction with it, implemented efforts to satisfy customers' needs and sales opportunities. It was calculated with this formula:

$$BV = \frac{SV \cdot T \cdot P}{VPP} \quad (6)$$

Where:
BV - total value
SV - significance to a customer
T - goal
P - sales
VPP - customers satisfaction achievement

Single customers' needs have different impact on total value; thus, it is essential to calculate comparative weight of value and gradually growing comparative weight of value to get the indexes for the priorities of customers' needs. The sum of all needs total values has to be worked out with the following formulas:

$$BVS = \sum_{8}^{1} BV \quad (7)$$

Where:
BVS - the sum of all needs total values
BV - total value

$$VLS = \frac{BV_X}{BVS} \quad (8)$$

Where:
VLS - comparative weight of value
BV_x - x need total value
BVS - sum of all needs total values

$$\begin{aligned} TVLS_1 &= VLS_1 \\ TVLS_2 &= TVLS_1 + VLS_2 \\ &\vdots \\ TVLS_8 &= TVLS_7 + VLS_8 \end{aligned} \quad (9)$$

Where:
$TVLS_x$ - x need gradually growing comparative weight of value
VLS_x - x need comparative weight of value

Value comparative weight indexes were used for technical matrix.

Technical Reaction Matrix. "Customers voice" in this matrix was translated into "organization voice", i.e. every single customer' need was deployed establishing one or several technical requirements, named on the top of quality house. The further step was to choose unit of measurement for each technical requirement and establish the direction of worth: more is better ↑; less is better ↓; precision X.

Relationship Matrix. This matrix compares customers' needs with technical requirements. Impact symbols put in each intersection box have appropriate values. No correlation - was established when customers satisfaction that reflects the need is not related to technical requirements (marked 0). Weak correlation - when the correlation between customer's needs and technical requirements is weak (marked Δ and 1). Moderate correlation - when the correlation between customer's satisfaction and technical requirements is moderate (marked □ and 3). Strong correlation - when correlation between customers' satisfaction and technical requirements is strong (marked ○ and 9).

Having calculated relationship between customers' needs and technical requirements, impact of technical requirements to customers' needs satisfaction achievement was obtained.

$$PV_x = SSV \cdot VLS_x \qquad (10)$$

Where:

PV_x - x need impact

SSV - digital value of impact

VLS_x - x need value comparative weight

$$BPV_y = \Sigma_8^1 PV \qquad (11)$$

Where:

BPV_y - total y technical requirement impact

PV - need impact

$$BPVS = \Sigma_{14}^1 BPV \qquad (12)$$

Where:

BPVS - total impact of all technical requirements

BPV - total impact of a single technical requirement

$$PLS_y = \frac{BPV_y}{BPVS} \qquad (13)$$

Where:

PLS_y - y technical requirement comparative weight impact

BPV_y - y technical requirement total impact

BPVS - all technical requirements total impact

Matrix of Technical Correlation. It is the roof of the quality house, reflecting inter correlation between technical requirements. Technical impact degrees and trends: Strong positive impact from the left to the right is marked as: → VV; moderate positive impact from the right to the left is marked: ← V; an empty box indicates that there is no impact; moderate negative impact from the right to the left is marked ← X; strong negative impact from the left to the right is marked: → XX.

Technical Matrix. The data obtained from relationship matrix evidence what technical requirements are priority, in other words we defined those requirements which are vital for final product producing. Priorities were established considering each impact value of technical requirement and values of their impact comparative weights - the greater the value is, the more significant the technical requirement becomes.

Planning matrix presents customers' needs competitiveness assessment and this matrix estimates the competitiveness of researched organization technical requirements. In this case the research was performed by the Executor of Lithuanian-Hungarian organization "Brača-sport". Five points Likert scale was applied for assessing and comparison (1 - very bad, 2 - bad, 3 - sufficient, 4 - good, 5 - excellent).

Having assessed impact of technical requirements to customers' satisfaction and competitiveness, goals for each technical requirement were set; again with Likert scale. These goals could be transferred to another - second phase of QFD method, affecting all further steps of product creation.

Data Analysis. Interview Data Analysis was used to systemise the data obtained from the interview with purposeful group. The data was analysed, grouped and finally ten needs for paddle were chosen and used for the questionnaire compiling.

Statistic data analysis was used for questionnaire data analysis. They were processed with SPSS program and the results prioritising technical literature analysis were used for quality matrix filling.

Expert Assessment. Aiming to purposefully fill in the third quality house matrix for technical reactions, the fourth for relationships, the fifth - technical correlation, experts' assessments were taken into consideration, backing up on specialists - experts groups opinion, knowledge, experience and intuition. The expert group consisted of honourable Olympic team coachers; the chief canoe and kayak rowing coach, canoe rowing coach, kayak rowing coach.

Quality House Matrixes Filling. The first matrix of customers' needs and benefits contains systemised data from interview with purposeful groups. The second planning matrix contains statistic data analysis obtained from the questionnaire. Seven different data types were obtained with the help of appropriate formulas. Experts group was invoked to provide assistance for the third, the fourth and the fifth matrixes filling and producing. The group discussed our chosen technical requirements, established correlations between customers' needs and technical requirements, inter correlation between technical requirements and submitted proposals which were evaluated and discussed before final filling of matrixes of the technical reaction, relationship and technical correlation. The final technical matrix was produced after estimating results of all matrixes and setting on goals, which could be moved to the second phase, the so-called product projecting. The Executive of Lithuanian-Hungarian organization "Brača-sport" performed the assessment of competitiveness for this matrix.

RESULTS

Seeking to define major customers' needs for a paddle, an interview with a purposeful kayak rowers' group, consisting of 12 sportsmen, was carried on. Some fragments from the interview are presented in Table 1.

Table 1. Fragments from the Interview with a Purposeful Kayak Rowers Group

Category	Response Fragments
Kayak paddle	
Paddle shaft specifications	<...> comfortable base. <...> protection from sliding paddle non slip. <...> not too short, not too long. <...> light. <...> foldable. <...> slight and strong. <...> with adjustable length. <...> hand grip mark <...> adjustable length. <...> durability and weight. <...> conformity of blade and shaft. <...> joinable from two parts <...> non slip hand adhesion. <...> good value for money.
Paddle blade specifications	<...> adjustable angle. <...> adjustable blades. <...> nice colour. <...> aerodynamic shape. <...> easy adjustable blade angle. <...> nice. <...> size at the end of distance somehow would reduce. <...> blade with maximum strong stroke. <...> not jumping out from water. <...> good value for money.

Having analyzed the results obtained from the interview, they were systemized and ten major customers' needs for a paddle were established: paddle shaft parameters; paddle blade parameters; adjustability of paddle parts function; functional transportation; adherence of hand and shaft; technological innovations; lightness; attractiveness; durability; price. Respondents evaluated how each of the ten presented needs is essential for them when choosing a paddle. An average was taken from the results of each need. For assessments from 0 to 50, the need is considered insignificant (low significance is established), and from 50 to 100, including the later, the need is considered as very significant (high significance is established), when establishing the significance disclosed, respondents assessed how implementation of each need impacts satisfaction with the whole product - strong correlation (high significance established) or weak correlation (low significance established):

Paddle shaft parameters: established high significance (NS = 96), disclosed significance - high (1 > 0).

Paddle blade parameters: established high significance (NS = 97), disclosed significance - high (1 > 0).

Adjustability of paddle parts function: established high significance (NS = 57), disclosed significance - low (0.3 < 0.7).

Functional transportation: established high significance (NS = 65), disclosed significance - low (0.4 < 0.6).

Good adhesion of hand and paddle (non slip paddle grip): established high significance (NS = 76), disclosed significance - high (0.8 > 0.2).

Technological innovations: established high significance (NS = 65), disclosed significance - low (0.05 < 0.95).

Lightness: established high significance (NS = 58), disclosed significance - low (0.25 < 0.78).

Attractiveness: established low significance (NS = 32), disclosed significance - low (0 < 1).

Durability: established high significance (NS = 95), disclosed significance - high (1 > 0).

Price: established low significance (NS = 46), disclosed significance - low (0.15 < 0.85).

Hence, having established disclosed significance and established significance, customers' needs were classified as follows (Figure 1).

"Hidden" needs were not established in this classification and "low impact" (price, attractiveness) were eliminated from further analysis, as they usually do not have great impact on customers' satisfaction (13). Needs established as "expected" and of "great impact" were analyzed in other matrixes. Kayak paddle planning matrix distinguishes eight data types, which had to be assessed when filling the matrix. Significance to customers were calculated in needs and wants matrix: paddle shaft parameters - significance to a customer 96; paddle blade parameters - 97; adhesion between hand and paddle (non slip) - 76; durability - 95; adjustability of paddle parts function - 57; functional transportation - 65; technological innovations - 65; lightness - 58. Customers satisfaction indexes were calculated using the mentioned before customers satisfaction formula. The results are concluded in Table 2.

Customer's satisfaction achievement formula was applied for competitive advantage index establishment (4), results presented in Table 3. "Brača" produced paddles were compared with other producers ("Jantex", "Plastex", "Vajda") paddles for kayak sprint event.

Having established customers satisfaction degrees to each need, the goal was set - what level of customers' satisfaction has to be achieved. Comparing "Brača-sport" paddles with competitors an obvious superiority of the product was observed with an exception of functional transportation function which is also equally satisfied by the competitor. The goal was set to achieve maximum 100 % of customers satisfaction for the needs which currently reach 80 % of satisfaction level and the goal for needs do not reaching 80 % of customers satisfaction - to increase customers' satisfaction by 20 %. Hence, the satisfaction degree of such parameters as paddle shaft, paddle blade, durability and technological innovation should be increased up to 100 %. Customers' satisfaction degree should be increased up to 20 % for such demands as adhesion of hand and paddle, adjustability function and lightness. When the goals were set, the degree of customers' satisfaction improvement was calculated applying the formula GL (5) (Table 4).

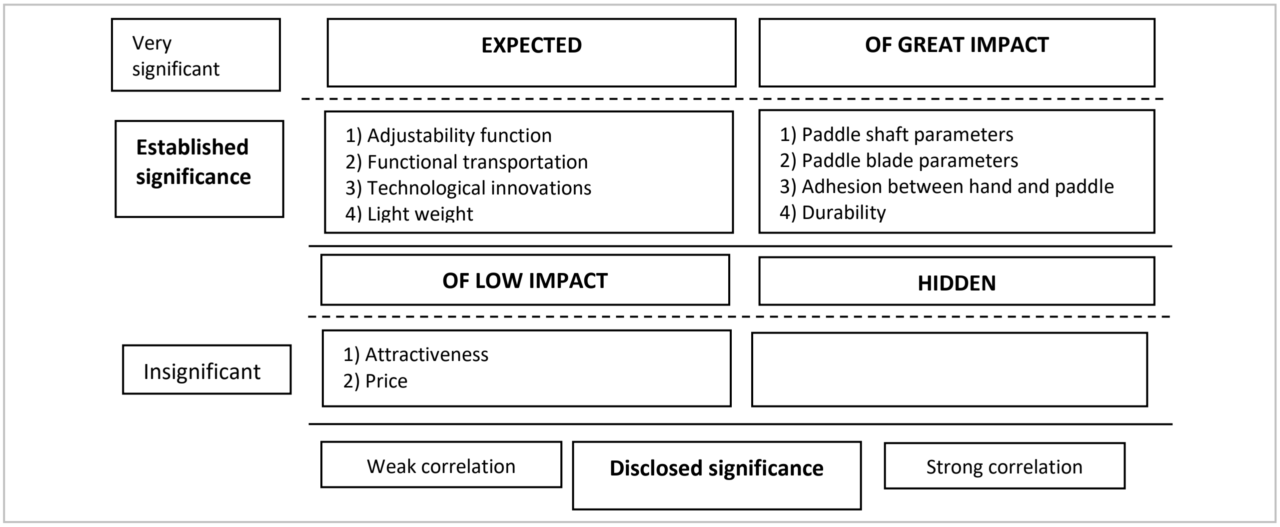

Figure 1. Classification of Customers' Needs for Kayak Paddle in Accordance to Clein Customers' Needs Net

Table 2. Customers Satisfaction Achievement Indexes

Sum or Average	Assessment in Points	Number of Respondents	Value of Achievements (Achievements* Number of Respondents)	Customers Satisfaction Achievement VPP
Up to kayak paddle shaft parameters				4.4
Total (sum)	–	20	88	
Total (average)	3			
Up to kayak paddle blade parameters				4.35
Total (sum)	–	20	87	
Total (average)	3			
Up to adhesion of hand and paddle				3.6
Total (sum)	–	20	72	
Total (average)	3			
Up to kayak paddle durability parameters				4.6
Total (sum)	–	20	92	
Total (average)	3			
Up to kayak paddle parts adjustability				3.6
Total (sum)	–	20	72	
Total (average)	3			
Up to kayak paddle functional transportation				3.85
Total (sum)	–	20	78	
Total (average)	3			
Up to kayak paddle technical innovations				4.2
Total (sum)	–	20	84	
Total (average)	3			
Up to kayak paddle lightness				3.8
Total (sum)	–	20	76	
Total (average)	3			

Table 3. Customers' Satisfaction Achievement for Kayak Paddle Comparison with Competitors

Needs	Brača	Jantex	Plastex	Vajda
Paddle shaft parameters	4.4	3.85	2.95	2.6
Paddle blade parameters	4.35	3.85	2.75	2.65
Adhesion of hand and paddle (non slip paddle shaft)	3.6	3.55	2.35	2.1
Durability	4.6	3.6	2.25	2.1
Adjustability function	3.6	3.15	2.7	2.65
Functional transportation	3.85	3.85	3.25	3
Technological innovations	4.2	3.85	2.2	2.05
Lightness	3.8	3.75	3.6	3.45

The goal of the next research stage is to establish what needs implementations have the greatest impact on product sales. Respondents established impact for each need: low impact with its value of 1, moderate impact with its value of 1.5. Total value was given by the 6th formula and the results were rounded and divided into eight specifications presented in Table 5.

Aiming to calculate needs value comparative weight and value of gradually growing comparative weights, the total sum of values was obtained applying formulas 7, 8 and 9. BVS index is 989 and results are presented in Table 6.

All the indexes indicated above were put in the table and planning matrix was produced (Table 7), the column “significance to a customer” in quality house remains attributed to customers’ needs and the other indexes are transferred to the right side of quality house (and correlation matrix between them).

Customers’ needs in technical reaction matrix were converted into technical need comprising the essence of KFI product creation. With the experts help each need was deployed establishing one or several technical requirements for their implementation, which were put into technical reaction Table 8.

Table 4. Achievement of Customers’ Satisfaction, Goals for Kayak Paddle and Customers’ Satisfaction Achievement

Needs	Current Satisfaction		Goal		Degree of Improvement (GL)
	Degree	%	Degree	%	
Paddle shaft parameters	4.4	88	5	100	1.114
Paddle blade parameters	4.35	87	5	100	1.115
Non slip paddle shaft	3.6	72	4.6	92	1.28
Durability	4.6	92	5	100	1.09
Adjustability function for paddle parts	3.6	72	4.6	92	1.28
Functional transportation	3.85	77	4.85	97	1.26
Technological innovations	4.2	84	5	100	1.19
Lightness	3.8	76	4.8	96	1.26

Table 5. Establishment of Kayak Paddle Impact to Sales and Total Value of Kayak Paddle

Needs	Number of Respondents	Established Impact on Sales	Impact Index	Total Value (BV)
Paddle shaft parameters		Strong	1.5	164
Strong	19			
Moderate	1			
Low	0			
Paddle blade parameters		Strong	1.5	167
Strong	20			
Moderate	0			
Low	0			
Adhesion of hand and paddle (non slip paddle shaft)		Moderate	1.25	121
Strong	8			
Moderate	12			
Low	0			
Durability		Strong	1.5	155
Strong	20			
Moderate	0			
Low	0			
Adjustability function of paddle parts		Moderate	1.25	91
Strong	6			
Moderate	14			
Low	0			
Functional transportation		Moderate	1.25	102
Strong	6			
Moderate	13			
Low	1			
Technological innovations		Moderate	1.25	97
Strong	3			
Moderate	16			
Low	1			
Lightness		Moderate	1.25	92
Strong	2			
Moderate	16			
Low	2			

Paddle shaft parameters were deployed into two technical requirements; length and rigidity. Paddle shaft is measured in centimeters, depending on a rower’s height. Rigidity depends on the number of carbon fiber layers, used for paddle production and is measured in units. Paddle blade parameters were deployed into width and bend. Paddle blade width and bend are measured in centimeters, which depend on sportsman rowing techniques. Adhesion of hand and paddle (non slip paddle shaft) was deployed into: non slip fabric and wax. Every single paddle has precise established weight, so there is no opportunity to put even a little more of non-slip fabric, which could increase adhesion of hand and paddle, however, changing the structure of carbon fiber, an opportunity of putting some additional non slip fiber appears and paddle balance is maintained. Another solution is special wax, improving adhesion of hand and paddle. Durability was deployed into: carbon fiber structure, fabric structure and number of fabric layers. Durability of produced paddle depends on the fabric it is produced of. Firstly, durability is impacted by the structure of carbon fiber, which using different waving techniques is used for carbon fabric production, the number of layers which define the final product durability. Adjustability function of paddle parts was deployed into: paddle shaft adjustability and adjustability of angle between blade and shaft. Functional transportation was deployed into paddle protection. Sportsmen constantly travel and it is essential for them that a paddle would be protected from unexpected bangs which could cause paddle break. Seeking to avoid this, paddle protection bags could be created, protecting a paddle during transportation. Technological innovations were deployed into equipment renovations serving to better results achievement or improving products. Lightness was deployed into fabric structure. Paddle weight depends on number of fabric layers and is measured in grams. The greater number of fabric layers is used for paddle production, the heavier it becomes. Seeking to reduce the number of fabric layers, fabric structure has to be alternated, the more rigid it appears, the less layers are needed for paddle production and a paddle is lighter.

Trends of worth were established converting customers' needs into technical requirements (Table 9).

Technical requirements such as: length, width, bend, trend of worth require definite rates without any deviations, precision is the best. As it was mentioned above, paddle shaft depends on a sportsman height that means the best solution is when the length of shaft is as precise to a sportsman height as possible. In case a shaft is too long or too short, a sportsman will face difficulties in achieving the maximum results. The same could be said about paddle blade width and bend. Both width and bend have to be as price as possible and match with a sportsman rowing technique.

Table 6. Needs Value Comparative Weight and Value of Gradually Growing Comparative Weights

Customers' Needs	Value of Comparative Weight (VLS)	TVLS
Paddle shaft parameters	$VLS = \frac{164}{989} = 0.17$	TVLS = 0.17
Paddle blade parameters	$VLS = \frac{167}{989} = 0.17$	TVLS = 0.17 + 0.17 = 0.34
Non slip shaft	$VLS = \frac{121}{989} = 0.12$	TVLS = 0.34 + 0.12 = 0.46
Durability	$VLS = \frac{155}{989} = 0.16$	TVLS = 0.46 + 0.16 = 0.62
Adjustability function of paddle parts	$VLS = \frac{91}{989} = 0.09$	TVLS = 0.62 + 0.09 = 0.71
Functional transportation	$VLS = \frac{102}{989} = 0.1$	TVLS = 0.71 + 0.1 = 0.81
Technological innovations	$VLS = \frac{97}{989} = 0.1$	TVLS = 0.81 + 0.1 = 0.91
Lightness	$VLS = \frac{92}{989} = 0.09$	TVLS = 0.91 + 0.9 = 1.00

Table 7. Planning Matrix for Kayak Paddle

Customers Needs	Significance to a Customer	Achievement of Customer Needs	Achievement of Competitive Satisfaction			Goal	Degree of Improvement	Sales	Total Value	Value of Comparative Weight	Value of Gradually Growing Comparative Weights
			1	2	3						
Paddle shaft parameters	96	4.4	3.85	2.95	2.6	5	1.14	1.5	164	0.17	0.17
Paddle blade parameters	97	4.35	3.85	2.75	2.65	5	1.15	1.5	167	0.17	0.34
Adhesion of hand and paddle and (non slip paddle shaft)	76	3.6	3.55	2.35	2.1	4.6	1.28	1.25	121	0.12	0.46
Durability	95	4.6	3.6	2.25	2.1	5	1.09	1.5	155	1.16	0.62
Adjustability function of paddle parts	57	3.6	3.15	2.7	2.65	4.6	1.28	1.25	91	0.09	0.71
Functional transportation	65	3.85	3.85	3.25	3	4.85	1.26	1.25	102	0.1	0.81
Technological innovations	65	4.2	3.85	2.2	2.05	5	1.19	1.25	97	0.1	0.91
Lightness	58	3.8	3.75	3.6	3.45	4.8	1.26	1.25	92	0.09	1
Total									989	1.00	

Note: competitive satisfaction column implies different competitors: 1 - Jantex; 2 - Plastex; 3 - Vajda.

Technical requirements such as: rigidity, non-slip fabric, wax, structure of carbon tissue, fabric structure, number of fabric layers, paddle shaft length adjustability function, paddle blade adjustability (on shaft), paddle protection and equipment renovation, trends of worth were established as "the more is better". Paddle durability depends on paddle shaft rigidity, structure of carbon fiber, structure of fabric, number of fabric layers, thus, the more we have here, the better the results are, as the durability increases. Requirements for non-slip fabric and wax increasing adhesion of hand and paddle are the same - the more wax and non-slip fabric, paddle shaft adhesion function becomes tighter. Trend of worth "the more is better" also implies the requirements for shaft length adjustability and shaft blade adjustability (on shaft), this could be explained that the more functions to adjust individual paddle parts are applied to paddle production, the higher quality and perfection are achieved. As no guarantees could be given that a paddle could bear severe bang, its needs protection, the higher level of protection, the better - results. Trend of worth "the less is better" for the number of fabric layers (2) means that the smaller number of fabrics, the lighter is a paddle.

Relationship matrix, compiled with the experts' assistance, reflects correlation between customers' needs and technical requirements, applying related rates implying symbols (Table 10).

Table 8. Customers' Needs for Kayak Paddle Deployment to Technical Requirements

Customers' needs	1. Length	2. Rigidity	3. Width	4. Bend	5. Non Slip Fabric	6. Wax	7. Carbon Fiber Structure	8. Fabric Structure	9. Number of Fabric Layers (1)	10. Adjustability of Paddle Length	11. Adjustability of Blade (on Shaft)	12. Paddle Protection	13. Equipment Renovation	14. Number of Fabric Layers (2)
Paddle shaft parameters														
Paddle blade parameters														
Non slip paddle shaft														
Durability														
Adjust ion function of paddle parts														
Functional transportation														
Technological innovations														
Lightness														

Table 9. Technical Reaction Matrix for Kayak Paddle

Technical Requirement	1. Length	2. Rigidity	3. Width	4. Bend	5. Non Slip Fabric	6. Wax	7. Carbon Fiber Structure	8. Fabric Structure	9. Number of Fabric Layers (1)	10. Adjustability of Paddle Length	11. Adjustability of Blade (on Shaft)	12. Paddle Protection	13. Equipment Renovation	14. Number of Fabric Layers (2)
Trend of worth	X	↑	X	X	↑	↑	↑	↑	↑	↑	↑	↑	↑	↓

Table 10. Kayak Paddle Relationship Matrix

Technical Requirement	1. Length	2. Rigidity	3. Width	4. Bend	5. Non Slip Fabric	6. Wax	7. Carbon Fiber Structure	8. Fabric Structure	9. Number of Fabric Layers (1)	10. Adjustability of Paddle Length	11. Adjustability of Blade (on Shaft)	12. Paddle Protection	13. Equipment Renovation	14. Number of Fabric Layers (2)
Customers' Needs														
1.	○	○	○		□		○	○	○	○	Δ		□	○
2.	○	○	○	○			○	○	○		○		□	○
3.		□			○	○	Δ	○	○		Δ		○	○
4.		○					○	○	○	Δ	Δ	Δ	□	○
5.	○			○			Δ	Δ	Δ	○	○		○	Δ
6.	○	Δ	□	Δ			□	□	□	○	Δ	○	□	□
7.	Δ	□	Δ	Δ	○	○	Δ	○	Δ	○	○	□	○	Δ
8.	○	○	○		□		○	○	○	□	□		○	○

Having calculated correlation between customers' needs and technical requirements, the impact of technical requirements to customers' needs satisfaction achievement was calculated. Results were given by formula 10th and presented in Table 11.

Having calculated (11th formula) impact of single technical requirements to customers' needs satisfaction and summing up the results obtained, total impact value of every single technical requirement (PPV) was established. Aiming to establish what technical requirements are more significant for customers' needs satisfaction, what are of less importance, and what should be reviewed once more, the total impact was given by formula 12th (BPVS = 114.86) and impact of comparative weights by (13th formula) (Table 12).

These data obtained (impact and impact comparative weight) will be used for the final - technical matrix producing. Experts assisted in producing technical correlation matrix, presenting the relationship and dependence between technical requirements (Figure 2).

Table 11. Results of Kayak Paddle Technical Requirements Impact on Customers' Satisfaction Achievement

Technical Requirement	1. Length	2. Rigidity	3. Width	4. Bend	5. Non Slip Fabric	6. Wax	7. Carbon Fiber Structure	8. Fabric Structure	9. Number of Fabric Layers (1)	10. Adjustability of Paddle Length	11. Adjustability of Blade (on Shaft)	12. Paddle Protection	13. Equipment Renovation	14. Number of Fabric Layers (2)
Customers' Needs														
1.	1.53	1.53	1.53	0	1.51	0	1.53	1.53	1.53	1.53	0.17	0	0.51	1.53
2.	1.53	1.53	1.53	1.53	0	0	1.53	1.53	1.53	0	1.53	0	1.51	1.53
3.	0	0.36	0	0	1.08	0.12	0.12	0.12	0.12	0	0.12	0	0.12	0.12
4.	0	10.44	0	0	0	0	10.44	10.44	10.44	1.16	1.16	1.16	3.48	10.44
5.	0.81	0	0.81	0.81	0	0	0.09	0.09	0.09	0.81	0.81	0	0.81	0.09
6.	0.9	0.1	0.1	0.1	0	0	0.3	0.3	0.3	0.9	0.1	0.9	0.3	0.3
7.	0.1	0.3	0.1	0.1	0.9	0.9	0.1	0.9	0.1	0.9	0.9	0.3	0.9	0.1
8.	0.81	0.81	0.81	0	0.27	0	0.81	0.81	0.81	0.27	0.27	0	0.81	0.81

Table 12. Technical Requirements: Total Impact Value of Each Technical Requirement and Impact Comparative Weight

Technical Requirements	PPV	PLS
Length	$PPV_1 = 5.68$	$PLS_1 = 0.05$
Rigidity	$PPV_2 = 15.07$	$PLS_2 = 0.13$
Width	$PPV_3 = 4.88$	$PLS_3 = 0.04$
Bend	$PPV_4 = 2.54$	$PLS_4 = 0.02$
Non slip fabric	$PPV_5 = 3.76$	$PLS_5 = 0.03$
Wax	$PPV_6 = 1.02$	$PLS_6 = 0.01$
Structure of carbon fiber	$PPV_7 = 14.92$	$PLS_7 = 0.13$
Fabric structure	$PPV_8 = 15.72$	$PLS_8 = 0.14$
Number of fabric layers (1)	$PPV_9 = 14.92$	$PLS_9 = 0.13$
Adjustability of paddle length	$PPV_{10} = 5.57$	$PLS_{10} = 0.05$
Adjustability of blade (on shaft)	$PPV_{11} = 5.06$	$PLS_{11} = 0.04$
Paddle protection	$PPV_{12} = 2.36$	$PLS_{12} = 0.02$
Equipment renovation	$PPV_{13} = 8.44$	$PLS_{13} = 0.08$
Number of fabric layers (2)	$PPV_{14} = 14.92$	$PLS_{14} = 0.13$

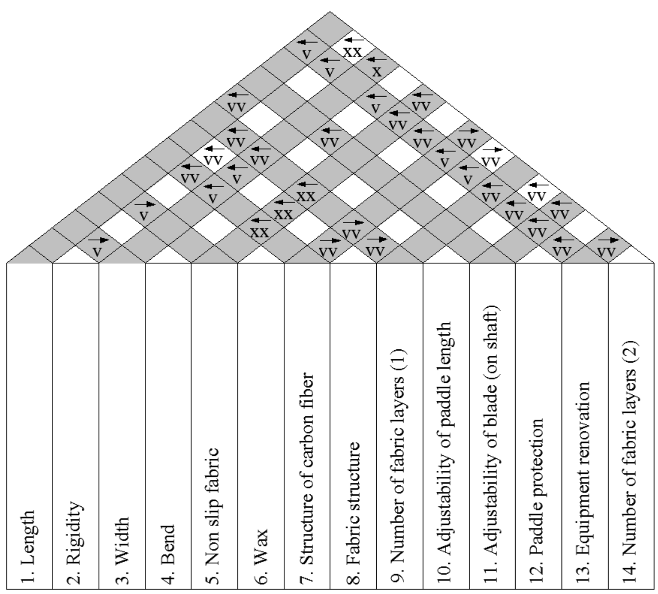

Figure 2. Kayak Paddle Technical Correlation Matrix

Hence, the following correlation between technical requirements was established: 1) length does not make any impact on other technical requirements; 2) rigidity appears of moderate positive impact on width and non-slip fabric; 3) width does not make any impact on other technical requirements; 4) bend does not make any impact on other technical requirements; 5) non slip fabric does not make any impact on other technical requirements; 6) wax does not make any impact on other technical requirements; 7) carbon fibre structure makes: a) strong impact on rigidity, fabric structure and number of fabric layers (1 and 2), b) moderate positive impact on width, c) strong negative impact on non-slip fabric; 8) fabric structure makes: a) a strong positive impact on rigidity and number of fabric layers (1 and 2), b) moderate positive impact on width, c) strong negative impact on non-slip fabric; 9) number of fabric layers (1) makes: a) strong positive impact on rigidity, width, b) strong negative impact on non-slip fabric; 10) adjustability of paddle shaft makes strong positive impact on length; 11) adjustability of blade makes strong positive impact on bend; 12) paddle protection does not make any impact on other technical requirements; 13) equipment renovation makes: a) strong positive impact on non-slip fabric, wax, number of fabric layers (1 and 2), adjustability of paddle shaft, adjustability of paddle blade, paddle protection, b) moderate positive impact on length, rigidity, bend, structure of carbon fibre, fabric structure; 14) number of fabric layers (2) makes: a) strong positive impact on non-slip fabric, adjustability of paddle shaft, adjustability of paddle blade, b) moderate negative impact on width, c) strong negative impact on rigidity.

Priorities of technical requirements in kayak paddle technical matrix were established grounding on the indexes of impact of technical requirements and impact comparative weight. (Table 13).

The greater value of impact indicates the greater impact on satisfaction and is more important, thus, these technical requirements have to be implemented first of all, as they appear a priority, mainly: rigidity, structure of carbon fiber, fabric structure, number of fabric layers.

The Figure 3 presents assessment of technical requirements competitiveness, performed by the Executive of the researched "Brača-sport" organization.

Table 13. Priorities of Kayak Paddle Technical Requirements

Index	Technical Requirements													
	1. Length	2. Rigidity	3. Width	4. Bend	5. Non Slip Fabric	6. Wax	7. Carbon Fiber Structure	8. Fabric Structure	9. Number of Fabric Layers (1)	10. Adjustability of Paddle Length	11. Adjustability of Blade (on Shaft)	12. Paddle Protection	13. Equipment Renovation	14. Number of Fabric Layers (2)
BPV_x	5.68	15.07	4.88	2.54	3.76	1.02	14.93	15.72	14.92	5.57	5.06	2.36	8.44	14.92
PLS_x	0.05	0.13	0.04	0.02	0.03	0.01	0.13	0.14	0.13	0.05	0.04	0.02	0.08	0.13

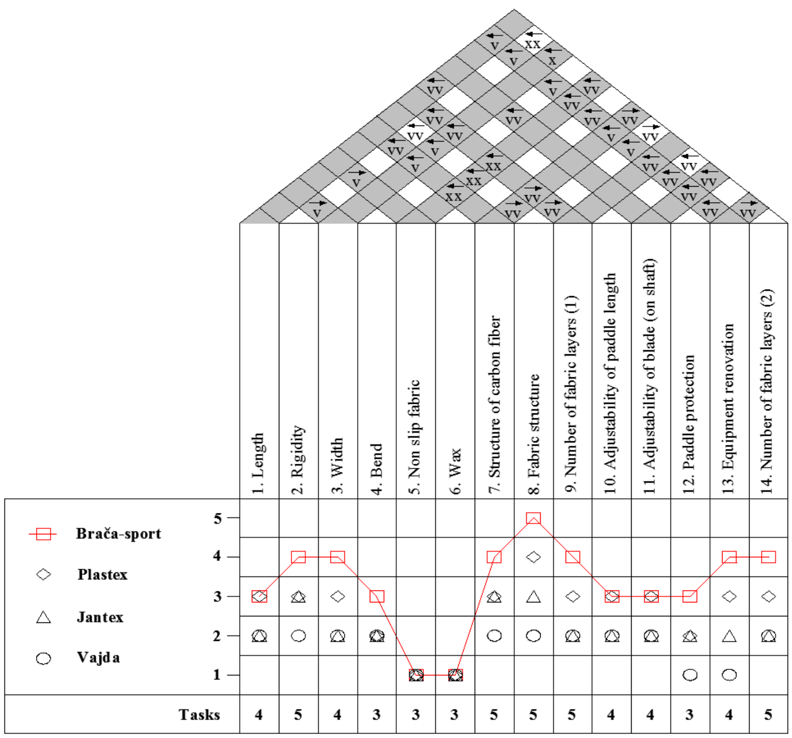

Figure 3. Assessment of Technical Requirements Competitiveness for Kayak Paddle

Having assessed the impact of technical requirements to customers satisfaction and competitiveness, considering the results obtained, the following maximum goals were set for technical requirements with the greatest impact to customers' satisfaction: rigidity (4→5), structure of carbon fiber (4→5), fabric structure (5), number of fabric layers (4→5); for technical requirements with less impact on customers' satisfaction competitiveness became the major factor. Technical requirements with higher assessments than the same ones of competitors have to remain in the same level: width (4), bend (3), paddle protection (3), equipment renovation (4). Technical requirements the assessment of which was the same as the competitors have to gain superiority: non slip fabric (1→3), wax (1→3), adjustability of paddle shaft (3→4), adjustability of paddle blade (3→4).

Six filled matrixes were joined and quality house for kayak sprint event was produced, the results of which could serve for producing the product up to customers' standards (Figure 4).

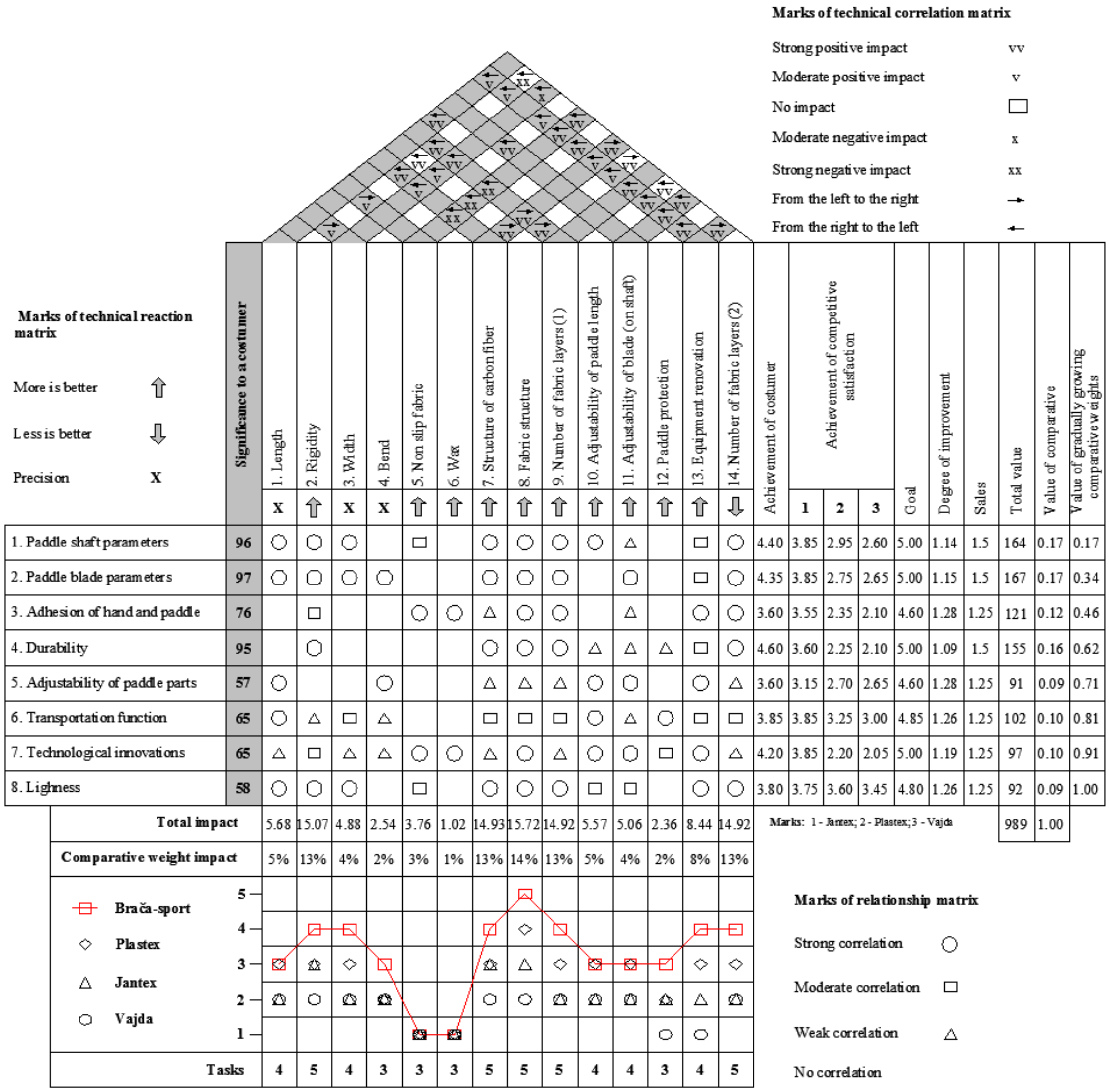

Figure 4. Quality House for Kayak Paddle Sprint Event

DISCUSSION AND CONCLUSION

This research extends QFD method limits of application in production of new and improvement of the current products, including specific field - kayak paddle sprint event, and partly solves lack of scientific research methods application problem in production of sports products.

1. Despite some mentioned drawbacks, quality function deployment is recognized as reliable method, assuring customers' satisfaction, which appears one of the major KFI goals. The method provides an opportunity to focus on production of the most attractive and satisfying customers' needs products. The essential KFI idea is quality integration to the final product and this idea implementation during the whole process of product production bearing in mind customers' needs.

2. The vital means of quality function deployment method is quality house. It has got such a name due to graphical design very similar to a house, consisting of six matrixes, which after filling, provide us with results enabling to establish the major customers' needs and the best ways of their implementation. Customers' needs and benefits matrix presents major customer's needs and occurs as a foundation for other matrixes compiling. Planning matrix discloses significance of customers' needs, competitiveness and goals, showing what needs should be improved. Technical reaction matrix establishes ways for customers' needs implementation. Relationship matrix reveals how technical requirements impact customers' needs satisfaction. Technical correlation matrix presents correlation between technical requirements. Technical matrix discloses major technical requirements, competitiveness, which is assessed by an organization itself and goals which are of great significance to successful KFI method application.

3. Having filled the quality house for kayak paddle, it was established that when seeking to

produce a kayak paddle for sprint event satisfying customer's needs, the greatest significance should be focused on implementation of such needs as: paddle blade parameters, paddle shaft parameters, durability, adhesion of hand and paddle, as the significance of these parameters appears essential for customers. Backing on calculated impact of technical requirements and impact comparative weight indexes, the priorities of technical requirements were established which should be implemented first of all when producing kayak paddle for sprint event: fabric structure, rigidity, structure of carbon layer, number of fabric layers. Research of QFD method application in production of various sports products should be developed further.

APPLICABLE REMARKS

The method presented in the article could be effective for organizations producing a new product, seeking to meet clients' needs, achieve better results, and optimize the manufacturing process for Kayak Paddles, with a particular focus on: the structure of the material of the product, rigidity, the structure of the carbon fiber, and the number of fabric layers.

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