FACTA UNIVERSITATIS
Series: **Economics and Organization** Vol. 9, N° 4, 2012, pp. 495 - 506

Review paper

QUANTIFICATION OF QUALITY: THE INDICATORS OF JUSTIFICATION OF THE IMPROVEMENT OF PROCESSES AND PRODUCT QUALITY *

UDC 005.6

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Abstract. *At the beginning of the 21st century quality is still considered as the dominant factor of enterprise's competitiveness. Actually, it represents the basis for providing sustained competitiveness. Quality is usually connected to providing customers' satisfaction and their loyalty in order to increase an enterprise's market share and, consequently, profitability. However, quality improvement effects are not always obvious and therefore quality improvement projects may be rejected or disapproved by higher managers only due to misunderstanding of effects. Therefore, quality managers have to explain them in their own language – through financial indicators, in numbers, the effects of quality improvement. The aim of this paper is to show that quality improvement provides bottom-line results, but that final effects are in financial sphere. The paper is based on two hypotheses: (1) poor quality, noted by customers, produces financial losses and (2) traditional financial indicators may be modified and used for evaluations of quality improvement effects. The first hypothesis assumes explanation of loss function, formulated by Taguchi, who aimed to show that quality absence, through competitiveness' decreasing, provides losses to an enterprise. The second hypothesis assumes analysis of costs of quality and usage of information about these costs for calculating traditional indicators, such as: break-even point, leverage, return on investment, payback period.*

Key Words: *quality, costs of quality, Taguchi's loss function, financial indicators.*

Received August 27, 2012 / Accepted November 4, 2012
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* **Acknowledgement:** The paper is a part of the research done within the project 179066. The authors would like to thank the Ministry of Education and Science of Republic of Serbia

1. INTRODUCTION

Competitiveness improvement represents "a race without an end," since every enterprise tries to find a way to take the best possible position compared to its competitors. In the modern business environment it is not constant and predictable, and customers are in a privileged position. Due to the globalization they can choose products from all around the world, so the battle for customers is no longer at the level of just one state, but at the level of the whole world. Therefore, the manufacturers need to examine the needs and affinities of customers and to deal with the continuous development of products to remain competitive on the market.

Actually, maintaining or increasing the competitiveness of enterprises includes continuous review of business at strategic and at operations level. There are several compelling reasons that highlight the importance of a strategic approach to quality. First, the process of formulating the strategy must be properly guided, or in a quality way (Beckford, 2002). Secondly, the introduction of new products and processes and improvement of existing represents the basis for strategy based on differentiation, in terms of the new offer to consumers. Third, quality improvement influences the image of the enterprise in the consumers eyes, which connects them to the enterprise in the long-term or permanently and seems like a kind of enterprise's property (Rao et al, 1996). The importance of quality can more easily be understood at the operations level. It is connected to the way business processes have been performed, their results, specification limits or standards, and the deviations from those standards. Therefore, regardless of the level of observation, quality is an important determinant of competitiveness. Although quality is a variable and relative category, the fact is that quality improvement must be constantly present in managing an enterprise. In this sense, quality management is considered an integral element of business management, and product and process quality is seen as the basis for providing quality of doing business.

Possibilities for improving quality of products and business processes are limitless. Under conditions of limited resources, these possibilities should be maximally exploited, because they involve substitution of limited, material resources, with unlimited, non-material resources. No matter where in the enterprise it is conducted, and regardless of the method of implementation, improvement should result in increasing quality level and / or reducing costs level. When it comes to improving quality, improvement projects usually concern manufacturing processes, because they represent the largest source of opportunities for the improvement. However, quality improvement can be achieved in non-manufacturing processes, actually in all segments of the value chain.

When it comes to quality improvement, it is important that is continuous. Continuous improvement involves a systematic approach to bridge over the gap between customers' expectations and the performances of the processes or the outputs, as processes' results. Also, only continuous improvement, based on facts and exact measurement and analysis will result in quality improvement and costs reduction in the long run (Knod, Schonberger. 2001). Though quality improvement is usually observed from the position of the customers, it has great implications on costs reduction, and consequently on financial results. Therefore, it is considered important for managers to realize how much they lose when quality is missing or it is not at a satisfactory level from the customers' point of view.

One of the tools that show explicitly the connection between quality and costs is Taguchi's loss function. Taguchi's loss function provides the quantification of quality improvement effects. In that way, he went beyond Crosby, who claimed that quality is „free", because he pointed out that quality is not only free, but it also provides an increase of an enterprise's financial results. Specifically, the loss function shows that the lack of quality in terms of deviation from the target value or target level of output performance, as defined by the consumer, causes certain losses. By reducing the gap between the target and actual output performance levels, losses can be avoided and, consequently, financial performances increased.

2. Costs of Quality – the Relationship between Costs and Quality

Due to the changeable customers' demands and continual increasing of their expectations, quality is relative and changeable. That is why it can be said that meeting the needs of consumers is a race without an end (Waller, 1999). Customers are looking for products that will meet their requirements. In addition, the product may not be given the highest marks by customers on all the criteria. It is enough that the product has what is considered the most significant for consumers, to meet their needs. So the task of the enterprise is to discover, through cooperation with customers, the dimensions and components (functions) of these products, which are the most important for customers and to focus on providing them (Soin, 1992).

In order to better meet customers' needs, an enterprise can act reactively or proactively. The reactive action occurs in two forms: as a response to consumer dissatisfaction when they receive products with unsatisfactory characteristics or as a response to the detection of unsatisfactory characteristics before the products reach the customer. Proactive actions can also be twofold. The first level of proactive action involves preventing the appearance of defects, while the second level assumes continuous approximation of products' characteristics to target values, which are defined by customers or engineers (Lucas, 2002). In this sense it is possible to identify four levels of quality control, including: intervention, detection, prevention and continuous improvement. The first level is the level of intervention which includes reactions to the defects that consumers already have identified, in order to reduce their dissatisfaction, prevent the loss of customers, and learn from the negative experience. The second is detection level, which includes responding to defects, with a focus on detecting defects before products are delivered to consumers, in order to avoid consumer dissatisfaction. Prevention is the third level and it means control of critical activities and phases of the process, in order to prevent the occurrence of defects. Finally, the forth level is the level of continuous improvement, which means that the process, even when it does not produce defects, can be improved through continuous reduction of variation within the defined specifications or through approaching output characteristics to target levels.

Actions related to quality improvement are sometimes avoided by managers with an excuse that they will result in additional costs. This is true when it is about significant, radical innovations, which usually assume new or additional resources for their implementation. However, managers, and employees generally, can take certain actions for quality improvement that cause slight or no additional costs at all, but can raise the quality level of activities performed. On the contrary, most actions concerning quality improvement have a positive impact on costs, in the sense that they result in costs decreasing. However, this implies the necessity for continuous evaluation of the relationship between quality and costs, since it is the only way to ensure effective and efficient operations.

Cost measurement actually involves cost accounting. Cost accounting should help managers to identify costs for products and activities, as well as to determine the costs at the process level. Traditional cost accounting is focused primarily on allocation of costs to products, which makes it inappropriate for making decisions concerning quality and costs relationship (Agrawal, Siegel, 1998). The importance of providing optimal relationship between quality and costs impedes adopting a process orientation, which further assumes application of modern costing, activity-based costing.

Traditional cost accounting systems are directed to the product, not the process, so they are not compatible with the philosophy of total quality management. A new concept of cost, known as activity-based costing, provides cost information concerning the process, and it is compatible with the philosophy of total quality management (Novićević, Antić, 2001).

Activity-based costing enables managers to accurately and realistically identify the costs of each activity and thus perceive the possibilities for reducing costs of the process, and then the outputs, in terms of eliminating activities that do not add value, and cause a waste of resources, or activities that cause extremely high costs, and do not belong to the group of critical to the quality, required by consumers. It is possible to make a decision about eliminating activities which are important to satisfy the needs of consumers, but for which the enterprise was not sufficiently competent, and therefore those activities cause unreasonable high costs. In this case the enterprise may choose outsourcing as an option.

Information provided by the activity-based costing based on using time equivalents for the major components of the product (Novićević, Jovanović, 2003) can be a support for decision-making concerning quality improvement or for evaluation of the quality improvement effects and relationship between costs and quality. Precisely, they have a great role in identification and measurement of so-called costs of quality. Although different classification of costs of quality can be found in literature, most authors have accepted the structure proposed by Feigenbaum (Feigenbaum, 1986). Due to their role in providing quality, costs can be divided into four groups: prevention costs, detection costs, internal failure costs and external failure costs. Some of the costs that could be classified into four categories, suggested by Feigenbaum, are (Amitava, 1994):

- prevention costs: costs of staff training, supplier evaluation costs, maintenance costs, costs of development of the program for quality improvement, cost analysis and reporting on the quality level,
- detection costs: the cost of admission control, cost of the process and final inspection, product testing costs, cost of materials needed to check the quality, cost of equipment for testing and control,
- internal failure costs: defect analysis costs, replacement costs, costs of treatment and repairs, the costs of re-inspection and testing, costs of eliminating scrap products, opportunity costs (related to lost time), costs of scrap (resources used for production scrap),
- external failure costs: costs of withdrawing products from the market, lost sales, costs of claim within the warranty period, transportation costs of returned products, costs of servicing the product.

3. Evaluation of Quality Improvement Effects – Methodology and Discussion

The effects of quality improvement may be estimated through so-called loss function, formulated by Taguchi. Taguchi considered the reduction of variations that occur during the manufacturing process and in final output essential and the best way to increase quality. He observed quality as avoiding losses caused by variations. These losses can be minimized if the output characteristics are the same or as close to the target values. Target value is the most desired value or standard value, defined through product and process design, determined based on customers' requirements. The real value of units under control may be equal or may deviate from the target value. Deviations are immanent to any process, but the intention of managers should be their elimination, since they cause additional, unnecessary consumption of resources, and sometimes customers' dissatisfaction.

The conventional quality control activities are related to control of the final output and on the preparation of control charts and process control. This kind of control is useful, but not sufficient (Harrington, 2004). Concerning that, the following hypotheses will be tested in this paper:

- Poor quality, noted by customers produces financial losses and
- Traditional financial indicators may be modified and used for evaluations of quality improvement effects.

The first hypothesis may be tested through Taguchi's loss function. The three basic assumptions underlying the Taguchi's perception of quality are: quality consistency, target specifications and loss function. Quality consistency means that the product can be consistent and uniform, regardless of the conditions of production or regardless of changing the conditions of production. The idea is to eliminate the effect of adverse conditions, rather than remove their causes, which is usually much more cost-effective and cheaper. For example, providing the clothing design so that small changes in quality of material quality do not cause the need for changing the design; or in production of chemical products, providing the product design so that small changes in temperature do not affect the quality of the product. Target specifications mean the most appropriate values or measured characteristics, which determine the quality level. According to Taguchi, it is not enough to realize the process and produce a product with performances within the specification limits (upper specification limit – USL and lower specification limit –LSL) or within the tolerance limits. Target value, as its name says, is a goal to be reached, and it is possible to achieve only through continuous process improvement. The third assumption concerns the loss function. The loss function shows how the costs of poor quality are increasing relatively to the deviation of product or process performances from the target performance or from the performance that customers expect.

The loss function shows where the impact of variation in activities' performances is important because the consequences of variations are observed by consumers (users). As it is mentioned, activity-based costing allows the identification of the real costs of activities. Information obtained based on activity-based costing is important for making decisions about eliminating activities or finding ways to reduce the cost of their realization, while information gained based on loss function indicates in which activities it is necessary to eliminate or reduce variations, in order to reduce costs and increase quality. In this way, the necessity of parallel observation of quality and cost as factors of competitiveness is confirmed.

Aspiration to continual quality improvement is a motive for introducing the loss function. Although it does not seem significant, the difference between low quality and defect exists (Carpinetti, Thiago, GeroÂlamo, 2003). The defective products are those whose characteristics are outside of the defined specification limits, while non-quality products are those whose characteristics are within the specification limits, but still relatively far from the target feature and target values. So it can be said that it is not enough to meet the specifications, but it is necessary to constantly seek to reduce variability and achieve target performance.

Measured performances of all outputs or results may be inside the specification limits. This kind of situation is quite satisfactory, and it may be said that all the outputs will provide satisfaction of their users. In other words, statistically, all outputs are under the specification limits. However, sometimes the greatest number of outputs features may be near the limits, while in some other cases the greatest number of outputs characteristics may be close to the target value (Chase, Jacobs, Aquilano, 2004). In the first case, there is great variation of measured characteristics, while in the second case this variation is less. If these differences consumers may not, they will be much more satisfied in the first case, or there will be a great chance that customers become loyal in the first case.

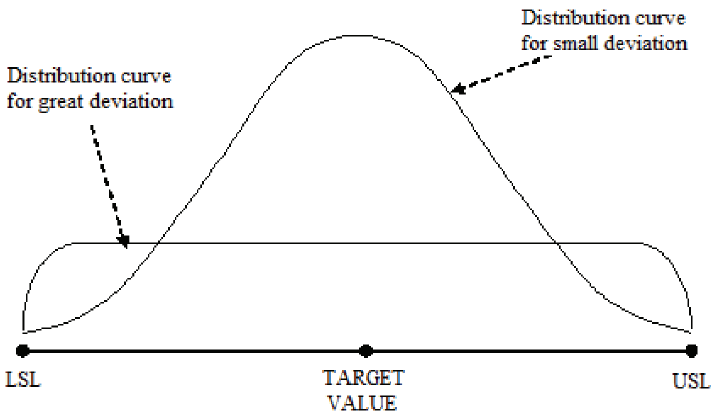

Fig. 1. Distribution curve for great and small deviation

Although statistical data was used to explain the difference between the defect and non-quality outputs, Taguchi was not concerned about the statistics and analysis of the process, but, above all, about the fact that those differences may be noticed by consumers. He felt that without economic, statistical analysis does not mean much, since statistical analysis may show that outputs are satisfactory according to the specification limits, while economic analysis may show that customers are leaving the enterprise since they are not completely satisfied, or at least not satisfied enough to become loyal.

The significance of loss calculation for presenting managers the negative effects of poor quality is shown in the following example. If the subject of measurement is quality characteristics which target value is 100 and tolerance interval ± 5 (95 – 105) the frequency distribution may be shown in Figure 2.

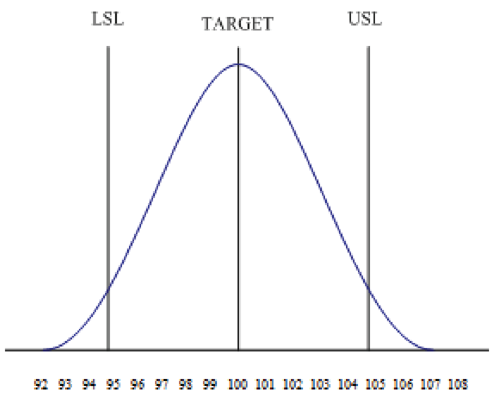

Fig. 2. Frequency distribution

Taguchi claims that the loss that occurs when customers or users note that measured characteristics is not equal target value (and usually have some problems during usage of the products which characteristics has some deviation within the tolerance interval). He suggests that this loss is directly proportional to squared deviations. The loss due to the deviation from the target value can be calculated in the following way (Sower, 2010):

$$L = k\,(X - Tv) \tag{1}$$

The symbols in this equation mean:
L – the loss due to the deviation from the target value,
c – constant, depending on the specific measured characteristic,
R – the real value of the characteristic,
Tv – target value or optimal measure of the characteristic.

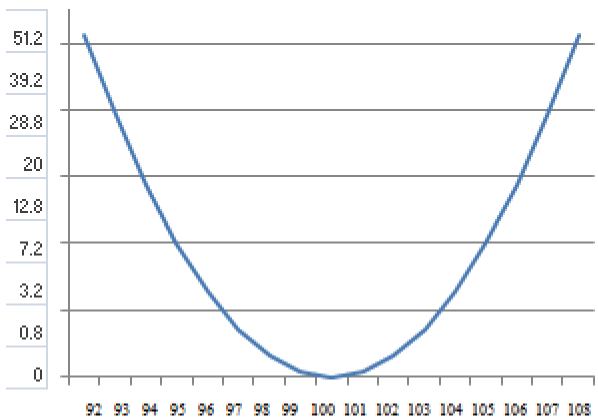

Fig. 3. Graphical presentation of loss function

The parameter c is usually determined empirically for each measured characteristic, based on the research about customers' satisfaction and enterprise's experience, and it is calculated in the following way. If tolerance interval is ±5, and if it is determined that in case when the measured characteristic deviates by 5 units from the target value, and customers demand the reduction of price by 20 units (which is a loss for the enterprise), then parameter c will be equal to 0.8 respectively:

$$20 = c\,(95 - 100)^2$$
$$20 = 25\ k$$
$$c = 0.8$$

It follows that the loss due to the deviation from the target value will bring different losses (McDuff, 2001), as it is shown in Table 1. One might ask whether there is a loss in the case of positive deviation from the target value. In some cases consumers may be satisfied in the case of such deviations (if they get more than they expect), but the fact that they expect measured characteristic equal to 100, then each characteristic higher than that is wasting of enterprise's resources. This certainly causes a loss, not from the consumer point of view, but in terms of the enterprise or shareholders.

Table 1. Loss calculation based on Taguchi's loss function

Real value	Target value	Deviation	Square deviation	Constant	Loss
92	100	-8	64	0.8	51.2
93	100	-7	49	0.8	39.2
94	100	-6	36	0.8	28.8
95	100	-5	25	0.8	20
96	100	-4	16	0.8	12.8
97	100	-3	9	0.8	7.2
98	100	-2	4	0.8	3.2
99	100	-1	1	0.8	0.8
100	100	0	0	0.8	0
101	100	1	1	0.8	0.8
102	100	2	4	0.8	3.2
103	100	3	9	0.8	7.2
104	100	4	16	0.8	12.8
105	100	5	25	0.8	20
106	100	6	36	0.8	28.8
107	100	7	49	0.8	39.2
108	100	8	64	0.8	51.2

Taguchi's loss function can be used to complement the analysis of the target market and determining the target cost, or as a complementary tool in making decisions about the introduction of a new product or a new process. Specifically, employees in marketing, among other things, provide information on the target volume of sales or production, profits, prices competitors, and so on. Where the results of the analysis show that the costs of production of a new product or a new process implementation exceed target costs, a new product or a new process is immediately rejected. However, if the gap is not significant, the team, responsible for the introduction of a new product or process, may try to improve design of process or product and to reduce the costs and make a new product or process profitable. Applying Taguchi loss function, the designer can calculate the savings that will occur as a result of reduced variation of the process performance, and consequently reduce variation of product performance.

The second segment of the quality costs analysis involves the use of the existing financial tools and measures. The analysis of this quality costs analysis issue should give an answer whether the second hypothesis should be accepted or rejected. Based on the fact that the enterprise is primarily an economic entity, in order to improve business processes and products, beside customers expectation and quality issues, the analysis must include financial and cost aspects. Bearing in mind that those who make decisions about process and product improvement are often not familiar with the quality measures, the analysis of investment in quality improvement in financial terms is justified and necessary. Financial analysis of the potential effects of quality improvement actually needs to show that the quality improvement is aimed at achieving greater financial results quantitatively or that it is not a goal in itself.

The analysis of quality improvement from the aspect of costs implies dividing the costs of quality into two categories: fixed and variable. Analogous to economic logic, according to which fixed costs are those that are not dependent on the volume of production (output), and variable costs those that vary due to changes in production (output), quality costs are divided into fixed and variable according to their change as a response to changes in the number of errors and defects. The fixed costs of quality include the first two categories of these costs (prevention costs and detection costs), while the variable costs of quality are the other two categories (internal failure costs and external failure costs). Starting from such categorization, their analysis can be performed through (Sherman, Vono, 2009):

- Quality leverage - shows how quality improvement reflects the total cost of quality (by increasing the fixed and reducing variable costs of quality).
- Quality breakpoint **-** which shows the volume of production needed for the equilibrium between increasing of fixed costs of quality and reduction of variable costs of quality,
- Return on investment in quality improvement - which shows whether the net effect of quality improvement (the difference between variable and fixed costs of quality) is sufficient to cover the investment for quality improvement,
- Payback period - which shows the period of time in which the effects of quality improvement will pay back the investment in quality improvement.

Quality leverage represents the trade-off between fixed and variable costs and shows how the increase of the quality level reflects the reduction of total cost of quality, and consequently the growth of profit (as the ultimate goal). Quality leverage can also be seen as a risk indicator in the sense of profit increasing based on the changes in the structure of costs of quality (ratio of fixed and variable costs of quality). Quantitatively, quality leverage can be determined on the basis of the relationship between the fixed costs of quality, on the one hand, and the difference between variable and fixed costs of quality, on the other hand. This ratio is usually called quality leverage factor.

As in the case of business leverage, it is desirable that quality leverage factor is smaller. A high quality leverage factor suggests that small changes or fluctuations in production volume can significantly affect the effects of quality improvement, in the sense of positive or negative financial effects of quality improvement.

Starting from the categorization of costs of quality into fixed and variable costs, the justification of investment in quality improvement can be provided through break-even analysis (Figure 4).

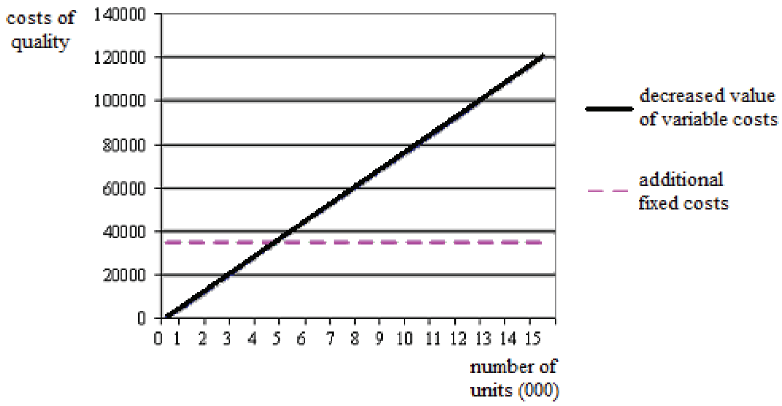

Fig. 4. Quality improvement critical point (Sherman, Vono, 2009)

A critical point is in the intersection of total costs curve and revenue curve. Through its projection on the x-axis the volume of production (activity) at which total costs are equal to total revenues (benefits) can be identified. When it is about quality improvement project, the critical point is determined by the projected costs of quality or through changes in the costs of quality based on quality improvement.

The projection of the mentioned point (point of intersection of fixed costs curve and variable costs curve) on the x-axis makes it possible to determine whether a particular project of quality improvement is payable. The volume of production or activity that is determined based on the projection of the point of intersection fixed costs curve and variable costs curve can be characterized as critical point volume (analogous to breakeven chart), because it shows the volume of production or activity below which it is not worth investing in quality improvement (investment in quality improvement outweigh the savings that can be achieved by concrete improvement).

Return on investment is a performance measure used to evaluate the efficiency of investments. Investing is performed for achieving certain benefits in the future, or for achieving certain yield. Return on investment can be determined by dividing the net financial benefits (savings or profit) with the amount of investment, and it is desirable that this ratio has greater value. Using the analogy with the investment projects, one can calculate return on quality (Weller, 1996). Return on quality can be calculated based on the same data as break-even point. In this case the investment represents the amount of additional fixed costs of quality, since those costs occur in order to improve the quality level, through preventing errors occurrence or through correcting them as soon as they appear. On the other hand, savings as consequence of quality improvement are equal to the amount of decreased variable costs of quality, since this decreasing appears as a consequence of investment in fixed costs of quality. Therefore, return on quality actually represents the ratio of decrease in variable costs of quality and increase in fixed costs of quality, and it is desirable that its value is as high as possible.

Payback period is the time it takes to pay back the investment, or that net income cumulative or savings exceed the amount invested. It can be determined by dividing the invested value by the sum of the average amount of income or net annual savings, or as the reciprocal value of the return on investment. It is desirable that the project which should be invested in has a shorter payback period, although this is not always the rule. By using the same analogy, as in case of return on quality, quality payback period is calculated by dividing increase in fixed costs of quality with the decrease in variable costs of quality. This is just an additional indicator since it does not show whether the investment in quality improvement is justified, but only when the investment will pay off.

CONCLUSION

The question that managers usually ask when it comes to quality improvement is whether quality is worth or whether it is worth to improve quality. If, according to Taguchi, poor quality makes losses, it is quite certain that the presence of quality, even when it does not make additional revenue, provides benefits through avoidance of losses. However, practice has shown that continuous improvement of quality has a positive effect on the success of the enterprise, meaning that quality improvement is worth it. According to the General Accounting Office in the United States, under which the study was carried out, analysis of 20 finalists for the Malcolm Baldrige National Quality Award, quality improvement causes many positive effects. The results of the study showed that, as a result of quality improvement, these enterprises have increased market share, profitability, customer satisfaction, reduced costs and improved relations between employees. Thus, the results show that quality improvement contributes to the improvement of all other criteria relevant for winning the Malcolm Baldrige Quality Award in the United States. When Crosby pointed out that "quality is free", he meant to say that poor quality costs much more than quality improvement, to the extent that one can even say that quality is free. In this sense, it can be said that in the modern business environment, where consumers are more demanding, an enterprise must see quality not only as an important aspect of operations, but also of strategic business management.

Measurement and analysis of costs of quality, as well as showing the potential effects of quality improvement, is the basis of choice and acceptance of quality improvement projects. Every effort for quality improvement has to be supported by the higher management levels. However, those managers usually do not get involved in the improvement projects directly and sometimes do not realize the effects of quality improvement, since they may not be so obvious. They need numbers which will show them that quality improvement will provide financial benefits. That is why managers directly involved in quality improvement (quality managers) need to find the way to present the financial benefits of quality improvement projects. For this purpose, they may use some traditional indicators, modified to correspond to quality improvement projects. This approach to analysis of quality improvement projects is completely in line with the profit orientation, because the increase of the quality level should not be the aim for itself, but must have financial justification, in the sense that the positive effects or savings from quality improvement project have to be higher compared to the investment required for its implementation.

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KVANTIFIKOVANJE KVALITETA: POKAZATELJI OPRAVDANOSTI UNAPREĐENJA KVALITETA PROCESA I PROIZVODA

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Na početku 21. veka kvalitet se još uvek smatra dominantnim faktorom konkurentske prednosti preduzeća. Zapravo, on predstavlja osnovu za dostizanje održive konkurentnosti. Kvalitet se obično dovodi u vezu da obezbeđenjem zadovoljstva i lojalnosti potrošača radi povećanja tržišnog učešća i, posledično, profitabilnosti. Međutim, efekti unapređenja kvaliteta nisu uvek očigledni, te projekti unapređenja kvaliteta mogu biti odbačeni, odnosno neodobreni od stane viših menadžera jedino zbog njihovog nerazumevanja tih efekata. Stoga im menadžeri kvaliteta moraju objasniti efekte unapređenja kvaliteta na njihovom jeziku, preko finansijskih indikatora, brojevima. Cilj rada je da pokaže da unapređenje kvaliteta obezbeđuje rezultate u operativnoj sferi, ali i u finansijskoj sferi. Rad je zasnovan na dvema hipotezama: (1) izostanak kvalitet, uočen od strane potrošača izaziva finansijske gubitke i (2) tradicionalni finansijski indikatori mogu se modifikovati i primeniti radi evaluacije efekata unapređenja kvaliteta. Prva hipoteza podrazumeva objašnjenje funkcije kvaliteta, formulisane od strane Taguchi-ja, čija je namera bila da pokaže da izostanak kvaliteta, preko smanjenja konkurentnosti, izaziva gubitke u poslovanju preduzeća. Druga hipoteza podrazumeva analizu troškova kvalitea i korišćenje informacija o njima radi izračunavanja tradicionalnih indikatora, kao što su: prelomna tačka, leveridž, prinos na investicije, period povraćaja.

Ključne reči: *kvalitet, troškovi kvaliteta, Taguchi-jeva funkcija gubitka, finansijski pokazatelji.*