METHODOLOGICAL CONCEPTION OF QUALITY COSTS ANALYSIS AND PROGNOSTICATION

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Abstract: One can observe the growing importance of the management through quality in running of business enterprises. In this article, the notion of "quality" shall mean the quality as perceived by the customer, i.e. the level of fulfilment of customer's expectations regarding the particular product (i.e. its durability and reliability, aesthetic form, convenience and ease of use, affordable price and other features). From the methodological point of view, management through quality can be considered in categories of three sets. Set (A) shall be determined by the costs of modelling technological quality of product (costs of technical equipment and instrumentation, costs of control, etc.). Set (B) shall contain elements of cost of the irrationally declined quality (costs of the defective products, overlong storage of products, warranty repairs, market price fluctuation, etc.) For the purpose of elimination or alleviation of discrepancies between the two former sets shall serve the third set (C) – containing the essential pro-quality decisions. Set (C) as a set of variable elements may indicate certain qualities of adaptability. Information contained in sets: (A), (B) and (C) could be easily applied in those business enterprises which have already installed their own computerised production management systems. Prognostication, possible after certain period of time of exercising monitoring, should mean extrapolation of the observed tendency. Information on costs pertaining to performing of the particular tasks could be used for the purpose of quality costs prognostication. For accomplishing the objective so defined, we propose to apply neural expert systems.

Keywords: quality costs analysis, prognostication, neural expert systems

1   INTRODUCTION

Every business activity means management of information, material and finances flows. These three interdependent streams should be monitored and managed in such way as to produce the best possible economic results for the company. One of the significant elements influencing to the great extent the economic condition of a business enterprise is quality. For companies running business oriented generally on fulfilment of the market demands, quality shall be primarily perceived as the level of fulfilment of the customer's expectations

Generally, one can assert that quality means a product's or service's capacity to meet the consumer's needs - both those declared and expected. A customer may change his way of perception of quality, as he may change his needs, influenced by the market and the new offers, proposed by more inventive competitors. Standard ISO 8402:1994 defines quality as „a set of qualities with the help of which a unit can fulfil [*customer's*] determined or assumed needs. Unit may be either activity, process, product, service, person, organisation or system, or a combination these elements."

Thus, quality it is a multidimensional concept. The relatively best chance to define this notion precisely shall be in relation to the manufactured goods such as mechanical, electromechanical, electrical or electronic products, furniture, etc. - i.e. when product is characterised by the complexity of its structure and potential functions. In such case one may succeed to estimate precisely the increase or decrease in quality, or costs of obtaining of the increment, in percentages, of the selected quality index [4].

2   DEFINITION OF A PRODUCT QUALITY INDEX

We assumed that quality is a multi-parametric characteristic of product, subject to evaluation from the aspect of its conformity with norms and standards determined quantitatively, as well as the individual expectations of a potential customer.

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Application of the quantitative characteristics of processes and products enables determining of objectives for the undertaken pro-quality actions, control over those undertakings, as well as measurement of the achieved results. Condition for introducing of the quantitative description of product quality shall be quantification of the quality indexes, applied in the management processes and production control. Of key importance shall be in this case the measurement of product quality level, based on assignment of quantitative values to the qualitative criteria, by way of which we can describe the examined object or phenomenon.

For the purpose of facilitating analysis of the product quality's impact on quality costs, we proposed to introduce the aggregated quality index $Q_j\{X\}$ [3]. It is assumed that product quality shall be determined by the set $\{X\}$ of measurable indexes $\{X_i\}$. Mathematical exemplification of this relation describing index $Q_j(X)$ value shall depend on the stages of modelling "the product quality structure" in the course of the consecutive technological operations (by analogy to the structure reliability notion). For the i-th technological operation the value of quality index $q_i(X_i)$ shall be defined as probability p_i, that index value X_i shall be contained within the assumed, admissible range of indexes variability X_i^d :

$$q_i = p_i\left(X_i \in X_i^d\right) \tag{1}$$

In case when product is evaluated by the set of statistically independent values of indexes $q_i(x_i)$, for the serial quality structure one can assume the following relation:

$$Q_j(X) = \prod_i^1 q_i(X_i) \tag{2}$$

It can happen, that a set of the product's features X_i may have the alterable influence on index $Q_j(X)$ value. Then it shall be well-founded to introduce a figure called "cumulative quality index" $Q_s(X)$, described by the following equation:

$$Q_s(X) = \sum_j^k w_j Q_j(X) \tag{3}$$

where: w_j – weight coefficient for index $Q_j(X)$. Values w_j meet the condition: $\sum_{j=1}^{k} w_i = 1$. Values of indexes $Q_j(X)$ and $Q_s(X)$ are contained within the range $\{0,1\}$.

Values of weight coefficients w_i shall be determined with application of the theory of blurred sets [10].

3   QUALITY COSTS STRUCTURE

The basic problem when dealing with the "multi-sectional quality costs analysis" is specifying a coherent, explicit definition, acceptable for both economists and engineers [5,6,7,8,9]. The economist shall perceive quality costs as a „sum of costs incurred for producing goods of the particular quality, which shall meet the customer's needs and expectations".

Standard ISO 9004-3 defines quality costs as a sum of expenditure borne by the manufacturer in order to accomplish and maintain certain quality level within the business enterprise, together with expenditure securing maintaining of the product quality outside the business enterprise.

The other problem shall be distribution of those costs, and assignment of the relevant cost items to the organisational units of the manufacturer. Also in this matter one can see a wide range of approaches of the authors of analytical-accounting systems.

In TQM system distinguished are three groups of operational quality costs:
- conformity costs – i.e. costs of prevention of producing defective goods or poor quality goods, produced prior to the occurrence of errors, as well as costs of conformity evaluation
- lack of conformity costs
- lost opportunities costs.

According to ISO 9004-1 standard entitled „Quality control and quality system elements – Guidelines" – the method of grouping quality costs and their analysis are treated as one out of three possible approaches to evaluation of the quality system effectiveness.

Quality costs can be divided into:
- prevention costs
- appraisal costs
- defects costs – internal and external

<u>Process costs</u> relate to the costs of conformity or lack of conformity of process, and can be divided into:
- conformity costs – the costs of fulfilment of all assumed and agreed customer's needs, on condition that at the same time the process advances correctly,
- lack of conformity costs – the costs caused by incorrect progress of the particular process

<u>Quality loss</u> means mostly the measurable losses, internal and external, such as:
- measurable loss - losses on defects
- immeasurable loss – customer's dissatisfaction, lost opportunities (external); organisational failure, declined effectiveness resulted from the defects correction (internal)

Distribution of costs based on ISO 9004 standard divides costs in two major groups:
- operational quality costs,
- external quality costs, borne for securing the expected quality level, i.e. relating to representation and evidence required for the impartial proof of quality.

Costs related to modelling the new or maintain existing quality level of manufactured goods, as well as costs resulting from the inadequate product quality should be evidenced by the company according to the legally binding registration procedures regarding all accounting operations. They are often subject to analyses in certain areas. Most often analysed are costs resulting from inadequate quality of products, together with costs of control and customers' complaints.

All the above-mentioned cost are contained within the entire costs borne by any business enterprise, because they are component of total costs of business operations. For the purpose of the quality costs calculation they should de distinguished form the sum of all costs. It is a difficult task, because the difference between "total costs" and "quality costs" is hard to define. Those costs are recorded in the accounts kept by the company, as different positions of analytic accounts.

In the quality costs analysis one should take into consideration the whole life-cycle of a product. Therefore proposed hereby is a little different demonstration of quality costs structure. (Fig.1), based on ISO 9004-3 standard, in order to facilitate its multi-sectional analysis and give foundation to the correct guidance for the costs accounting procedures in the company [2,3].
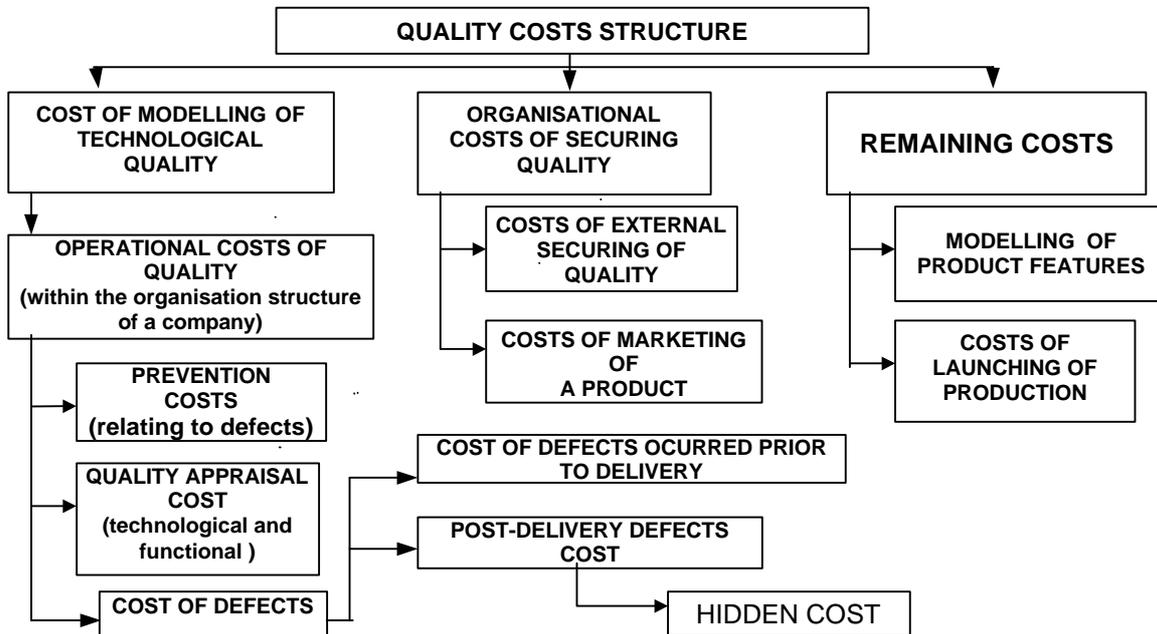

Figure 1. Structure of quality costs, considering life-cycle of a product

For reckoning costs examined within certain period of time, one should apply a unit of value. For this purpose introduced is a concept of the average value of man-hour as the costs index, presented as the following equation:

$$K_{rg} = \frac{K_Q}{K_m} \Sigma rg \qquad\qquad (4)$$

where: K_m – average monthly wages; $\sum rg$ - average number of hours per employee per month; K_Q – cost of realisation of a quality-effective decision.

Dividing costs of realisation of the particular quality-effective decision by the average cost of one man-hour, one can obtain the cost presented in man-hours. It is the cost to the great extent independent from the inflation ratio, the country's economical and political situation, thus maximally impartial and applicable for this appraisal. With the application of introduced quantities K_{rg} and Q_j (or Q_s), in Fig. 2 presented is graphical interpretation of the optimal quality costs level in the co-ordinate system: x - aggregated (or cumulative) quality index, and y – cost expressed in man-hour. On this basis one can delimit areas of decisions, from the point of view of a manufacturer and customer.
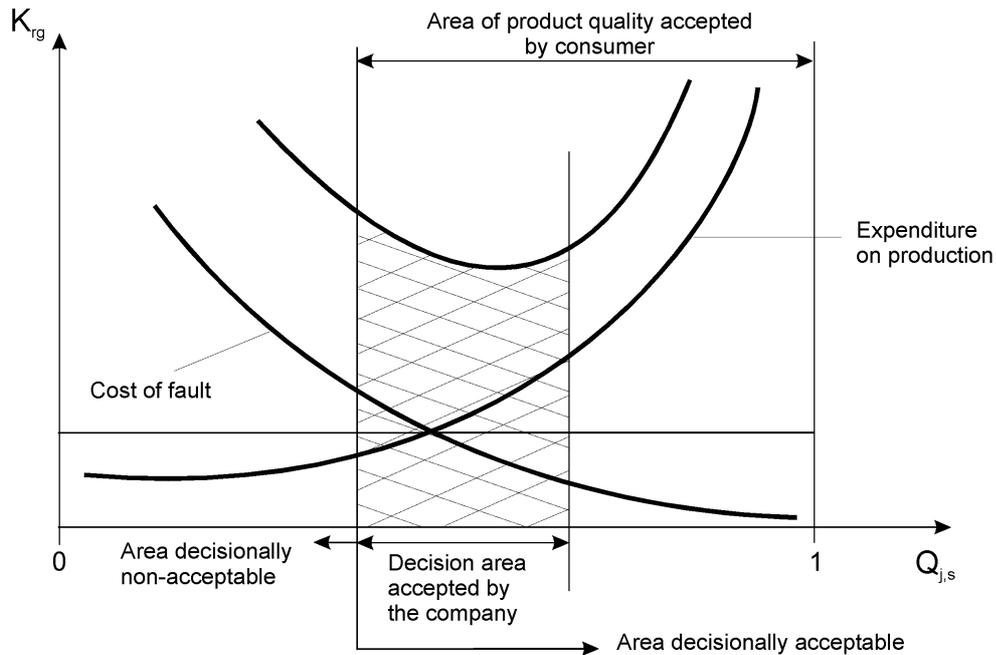

Figure 2.

Optimal level of quality costs is delimited by minimum of function, which is a sum of production costs per unit and external losses costs per unit, specified within the common set of value determining the product quality.

For the purpose of delimiting the quality costs optimal level, it seems sensible to appoint the level of reference, which shall be the basis to valuation of such costs. As such benchmark may serve realisation costs of the "existing technological process" at the certain moment of time t_0 being the point of commencing analysis of the manufacture process history (in Figure 1 – see Column 3)

„Existing process" is a process resulting in producing of goods - although functionally satisfying, but - maybe – not accepted by the customer.

With the notion of existing manufacturing process connected is the notion of a standard organisational structure of the company, enabling manufacture of a completely new product, resulting from implementation of, for instance, invention of the existing quality level.

The difference between costs of technological process realisation, resulting in producing goods of acceptable (economically expressed acceptable demand for a product) quality level, and the initial process manufacture costs, could be considered as direct quality cost, and this is the new proposed definition of quality costs.

For the current situation, requiring the exact indication of the moment of commencing observation, it may seem irrational to start the analysis of manufacture process history from the earliest stages of the technological process and production organisation – e.g. from the moment of making decision on implementation of licence or invention.

Assuming t_0 as the starting point of observation seems to be a sensible method, as well as considering of all parameters describing manufacturing process as "existing" parameters constituting reference basis for the observed changes. From the practical point of view, the moment t_0 should be assumed in such way as to enable the company to collect its technical and financial documentation as complete as possible, covering the period of time: $\Delta t_0 = t_a - t_0$ (Fig. 3).
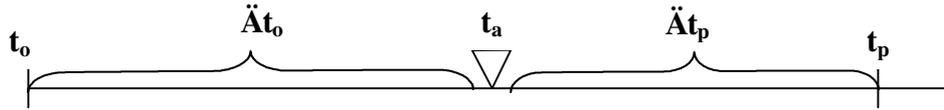
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$$\text{Ät}_o \qquad \text{t}_a \qquad \text{Ät}_p$$
$$\text{t}_o \qquad\qquad\qquad\qquad\qquad\qquad \text{t}_p$$

Figure 3. Illustration of history (Δt_o) and forecast (Δt_p) for product development.
where: Ät_o – period of past time, relating to technical and economical facts; t_a – present time – moment of beginning of analysis; t_o – commencement of analysis; Ät_p – period of prognosis

It is obvious that the higher level of acceptation should result in higher demand - and as a consequence in improvement of the manufacturer's economic indicators (profit from production). Increase in profit per unit (KZ_n) should be deducted from the direct quality costs per unit (KJ_b) giving foundation for calculating net quality costs per unit (KJ_n). The appropriate quality management should secure prevalence of profit over direct quality costs, and so: $KJ_b - KJ_n = KZ_n$.

4   CONCEPTION OF QUALITY COSTS IDENTIFICATION

From a methodological point of view, the management through quality can be considered as "elimination of discrepancies" between the elements of the two following sets:

- set (A) defined as the set of production costs elements (costs of research and implementation studies – costs of technical equipment, tools and control instruments, etc.);
- set (B) consisting of elements of irrationally poor quality costs (internal and external losses, i.e. defective products, scrapping, warranty repairs, overlong storage of certain product of low market demand caused by its unsatisfactory quality, as well as costs of spare parts, court and arbitration proceedings, etc.)

There are discrepancies between sets A and B. Making savings in set A generally result in growth of the elements of set B, which eventually means losses resulting from e.g. poor quality of the product. Decrease in measure values of the elements of set B usually results in growth of measure values of the set B elements.

This methodological conception, developed on the basis of quality costs identification, has been founded on the idea applied previously by H. Altszuller [1] for the purposes of analysis of inventiveness.

A set of pro-quality methods constitutes the third set (C). This set has no qualities of universality, but indicate certain characteristics of adaptability. (Fig. 4.)
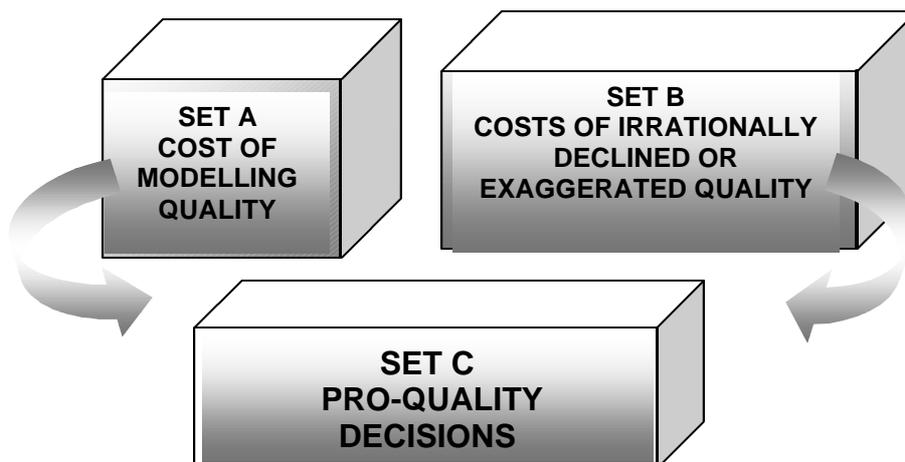

**SET A
COST OF
MODELLING
QUALITY**

**SET B
COSTS OF IRRATIONALLY
DECLINED OR
EXAGGERATED QUALITY**

**SET C
PRO-QUALITY
DECISIONS**

Figure 4. Conception of „three sets" applied to the quality costs identification

From the methodological point of view "management through quality in TQM system can be considered as elimination of discrepancies between elements of sets (A) and (B). Analysis of the past events (history of product development) allows defining and quantifying the elements of set (A, B, C),

relevant to the particular business enterprise. For the formal representation of those issues it is necessary to:

- define and select the representative elements of sets (A) and (B),
- assess the extent of their impact on quality costs.

Elements of sets (A) and (B) can be easily retrieved from archives of those companies, which have installed their own computerised accounting system and technical data processing (aggregation and analyses of trends, measurable parameters results of, e.g. reliability, durability, etc.)
Prognostication of quality costs becomes possible only after certain period of time of exercising the proposed monitoring. It shall mean extrapolation of the observed tendency in the course of reaching pro-quality decisions and modelling of quality costs.

For implementation of the proposed conception, necessary shall be estimating of value for every element of set (C) in monetary units. Such assessment can be done on the basis of analysis of the past accounting operations recorded in the financial documentation of the company. This shall require creating of the information systems (for each set respectively) and, with the help of those, transferring of accounting data to the information system. For this purpose one can apply the previously introduced quantity $K_{rg.}$

Implementation of a method of three sets in the company requires creation of a computer database on the basis of the archival resources, and then further development of sets (A), (B) and (C). The main advantage of a method of three sets is its increasing effectiveness, as the database is being extended, for the purposes of control over production quality.

Having in mind the purposefulness of interconnections between information on modelling technological quality by the manufacturer and information of the product's functional quality indexes, obtained from the customers, we propose application of neural expert systems [11] for the quality costs analysis. The initial values of weights can be assumed as values w_i in equation (3).

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