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ANALYSIS AND TRENDS OF THE CHANGES IN THE GRAPHIC INTERPRETATION OF THE QUALITY COSTS MODELS

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Abstract: *This paper presents four approaches to the graphic interpretation of the quality costs structure definition models: classical, modern, modified, and visionary approach. These give rise to theoretical graphic quality costs models and illustrate the relationship between the quality costs categories, as well as the relationship between the quality costs categories and the total quality costs and the quality level. The paper comparatively analyzes the underlying assumptions, existing knowledge, and principles characteristic of each approach. This contributes to the shaping of the quality costs categories curves and the overall quality cost curve in the theoretical models. The conducted analysis in the paper will enable forecasting the trend of development of theoretical graphic models and identification of potential stakeholders that contribute to changes in the structure and the behavior of the quality costs categories, and thus the behavior of the overall quality costs.*

Key words: *quality costs, PAF model, trade-off model, graphic models.*

Analiza i trendovi promena u grafičkoj interpretaciji modela troškova kvaliteta. *U ovom radu su predstavljena četiri pristupa grafičkoj interpretaciji modela definisanja strukture troškova kvaliteta: klasični, savremeni, modifikovani i vizionarski pristup. Oni daju povod za teorijske grafičke modele troškova kvaliteta i ilustruju odnos između kategorija troškova kvaliteta, kao i odnos između kategorija troškova kvaliteta i ukupnih troškova kvaliteta i nivoa kvaliteta. U radu se komparativno analiziraju osnovne pretpostavke, postojeća znanja i principi karakteristični za svaki pristup. Ovo doprinosi oblikovanju krivih kategorija troškova kvaliteta i ukupne krive troškova kvaliteta u teorijskim modelima. Sprovedena analiza u radu omogućiće predviđanje trenda razvoja teorijskih grafičkih modela i identifikaciju potencijalnih aktera koji doprinose promeni strukture i ponašanja kategorija troškova kvaliteta, a samim tim i ponašanja ukupnih troškova kvaliteta.*

Ključne reči: *troškovi kvaliteta, PAF model, model kompromisa, grafički modeli.*

1. INTRODUCTION

The quality costs, viewed through the prism of the added value of quality represent a key indicator to measuring the performance of the company work processes and activities [1], especially having in mind that they represent 5-25% of the sales revenues [2]. However, since the quality costs category model element's structure depends on the nature of the company, its size, the type of product, the requirements of the users, the quality maturity, the objectives [3], this contributes to the development of different approaches to understanding quality costs.

In general, the quality costs entail the sum of all costs that would disappear if we do not have any quality issues (Joseph M. Juran, 1974) [4]. In practice, the quality costs quantify the overall efforts related to the achievement and maintenance of quality compliance and repair of quality noncompliance [5]. In this regard, Armand V. Feigenbaum (1956) presented the traditional four faceted structure of the quality cost – PAF model (prevention activities costs, appraisal activities costs, internal and external failure costs) [6]. However, a dichotomous structure is also frequently applied – categorization of quality compliance costs (prevention costs and appraisal costs) and quality noncompliance costs (internal and external failures costs) [6].

The literature presents a descriptive interpretation of the quality costs models, which describes the categories in the models [7], a graphical interpretation which explains the interdependence between the quality costs categories, as well as the relationship between the categories and quality levels (including the total quality costs) [8], and a mathematical interpretation, representing mathematical expressions for calculating of the quality costs elements, categories, and total quality costs [9].

This paper aims to analyze the changes that occur in the graphical interpretation models of the quality costs and to anticipate their trends in the future.

2. GRAPHICAL INTERPRETATION OF THE QUALITY COSTS MODELS

Theoretical research suggests four approaches to the graphical interpretation of the quality costs models: classical (traditional), modern, modified, and a visionary approach which give rise to the graphical theoretic quality costs models [1, 10].

The first graphical quality cost model interpretation reflects the scientific approach of Joseph M. Juran (1951), also known as "The Economics of Quality". This interpretation suggests the existence of an economic quality level, where one achieves the highest quality level with lowest quality costs [1, 5]. Joseph M. Juran, Gryna F. M. and Bingham R. (1962), unify this

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graphic model and the already affirmed PAF categorization and present the classical (traditional) quality cost tradeoff model, which juxtapositions the prevention and appraisal costs with the failure costs, also known as Juran's classical model (figure 1.) [5, 9], a representative of the models developed in the 20th century [1]. According to this approach, as the prevention and appraisal costs increase, the failure costs decrease which leads to the point of the economic quality level (under 100% quality compliance) with lowest total quality costs [1, 2].

The presented inverse relationship represents a universally accepted principle which explains the balance between the two categories, a matter of concern in the operational management of companies [4], because it accepts less than 100% compliance, i.e. that one should invest in compliance activities until the increase of the compliance costs is less than the benefits [11]. This may be acceptable for a lower level of quality maturity in the initial stages of the quality systems program implementation.

The inverse relationship is pronounced more when one considers external failure costs as opposed to internal failure costs [1].

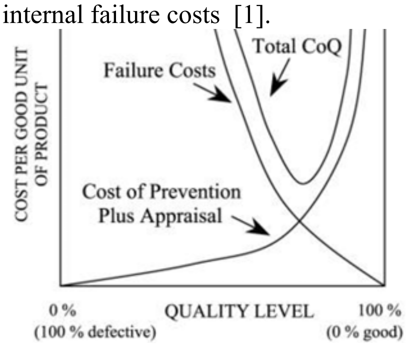

Fig. 1. Traditional COQ trade off model [5].

The assumptions about the imperfection of the prevention and appraisal activities, not considering the effects from quality improvements, as well as the effects from the increased effectiveness and efficiency controls, justify the continuous investments in prevention and appraisal in the classical approach [1].

The evolution of the classical quality cost model is marked by the model for optimal quality level developed by Lundvall, D. M. and Joseph M. Juran (1974) [12], the PAF model by Armand V. Feigenbaum (1991) [13], and the integrated profit model by Miller J. R. and Morris J. S. (2000) [8].

The research of Samir K. Srivastava (2008) presented managerial recommendations for the three quality zones from the model of Joseph M. Juran and Gryna F. M. (1988) (figure 2.) [14].

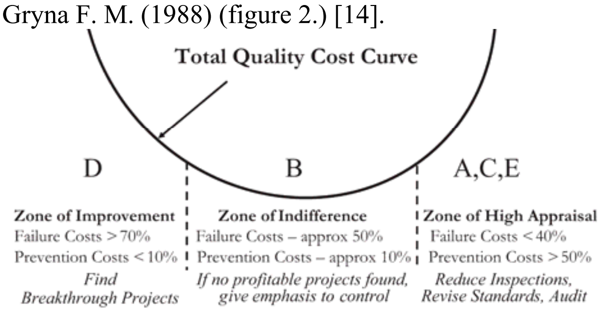

Fig.2. Categorization of sites and recommendations [14]

It is of particular importance, in the zone of indifference – optimal quality level, to continue the efforts to continuously improve and alleviate the investments in prevention [14].

The research of Plunkett J. J. and Dale B. G. (1988), Visawan D. and Tannock J. (2004), as well as Burgess T. F. (1996) showed that the classical approach features inaccuracies and fails to consider the effect of quality delivered to users, while Philip B. Crosby (1979) suggests that the approach fails to motivate the companies to commit to quality [11].

The transition from the classical to the modern approach is reflected in the quality-based learning model, developed by Fine C. H. (1986). There, due to the improved knowledge effect, the compliance cost curve bends downward, thereby reflecting a reduction in the total quality costs and an increase of the quality level [1, 15]. Lorente A. R. M., Rodriguez A. G. and Rawlins L., (1998) published the cumulative effect of the preventive activities and concluded that continuous prevention leads to a higher level of quality and lower costs necessary to maintain the quality level [12], which makes prevention the most cost-effective category for quality spending [11].

According to the research of Ittner C. D., (1996), and Omar M. K. and Murgan S. (2014), who support the continuous improvement approach, reduction of failure costs can be achieved at low or no-subsequent increase in the conformance costs [6, 15, 16]. Moreover, according to Gemal S. Weheba and Ahmad K. Elshennawy (2004), one should distinguish between the prevention costs and quality improvement costs [16].

The robust quality standard theory of Genichi Taguchi also contributes to the understanding of the modern approach. It focuses on incorporating quality in the design phase, i.e., a robust design, a design resilient to external influences, would preclude deviations from the target quality value and "losses to society" [11, 17]. Taguchi's Quality Loss Function measures the loss due to variability when quality deviates from a target value even if the actual value falls within the specification limits, as well to estimate the hidden quality costs [17]. Unlike the compliance-oriented quality feature of the classical approach, the presented target-oriented quality is a much more sensitive method for measuring quality [17].

The modern approach (model) originated from Arthur M. Schneiderman (1986) and Joseph M. Juran and Gryna F. M. (1988, 1993). They reviewed the classical model by assuming that the compliance costs convergence trend to infinity had an exponential trend which, at a level of 100% perfection reaches a finite value, for achieving zero failures with finite total quality costs, also known as the zero-failure approach (figure 3.) [1, 5, 7, 8, 9]. Philip B. Crosby, Plunкett J. J., Dale B. G., and Freiesleben J., also suggest that the continuous quality improvement and investments in prevention are economically justified and that the level of perfection is in the point of least total quality costs [9, 12]. Joseph M. Juran and Gryna F. M. (1993) thought that perfection is an economic goal, but only in the long run [8].

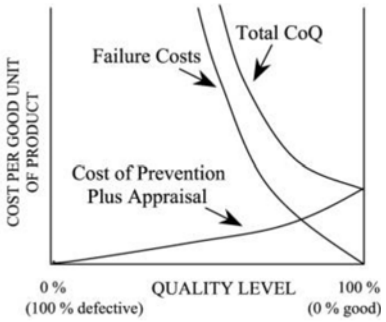

Fig. 3. Modern model of quality cost [5].

According to Arthur M. Schneiderman (1986), this can be done only on the basis of incremental economics [9] and with sufficient investments in prevention activities since that also leads to a reduction of the appraisal costs [7].

Freiesleben J. (2004) also suggests that the picture swift achievement of perfection is unrealistic and therefore suggests a dynamic model which illustrates the continuous quality improvement through technological progress, the lessons learned, and identifying the roots and resolving the reasons for failures, which is in line with the modern approach (figure 4.) [8]. Ittner C. D. (1996), with an empirical study, validated the revised model [15] and emphasized the need to consider the prevention costs and the appraisal costs separately which, according to Oakland J. S., (1993) is difficult to achieve [14].

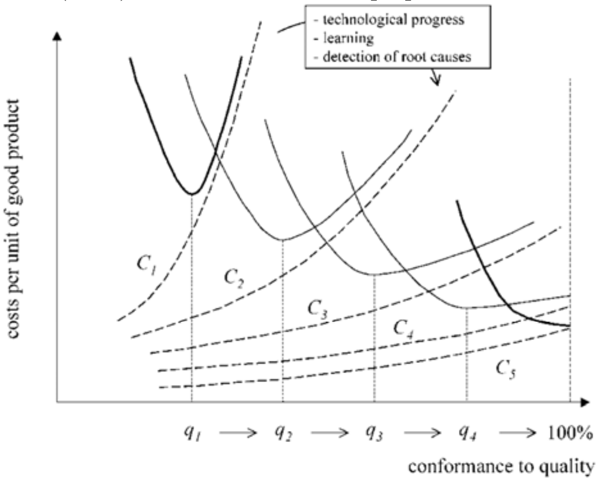

Fig. 4. Model of Freiesleben [8]
(C_i – costs of achieving good quality, q_i – quality level)

The behavior of the modern approach curves is expected with the development of automatics and robotics in the new technologies, which facilitate a reduction of human error, and automatic quality inspection and control, which leads to a less steep increase of the compliance costs curve [1]. From a practical viewpoint, modern management helps move the responsibility of quality from the quality assurance and control department to the corporate level which sets the quality objectives which, in turn, raises the overall level of quality [11].

The comparison between the classical and the modern approach, according to Burgess T. F. (1996) showed that the revised model is sustainable in the long run and the traditional model is applicable in the short term [5]. The researchers Fine C. H. (1986), Dawes E. W. (1989), Marcellus R. L. and Dada M. (1991), and Love (1995) think that the traditional model reflects a static snapshot of the quality costs, while the revised model creates a picture in a dynamic environment [5]. Other researchers, such as Porter L. J. and Rayner P. (1992), Cole R. E. (1992), Shank J. K. and Govindarajan V. (1994), explain that they represent two conflicting views on the cost-effectiveness of quality [5].

The critiques of Dale B. G. and Plunkett J. J. (1988) suggest that both approaches are considered under the assumption of a perfect quality design due to zero failures on 100% quality level, which would be expected for the costs for internal failures, but not for the costs of external failures [16]. From a different viewpoint, both approaches create confusion and do not foster continuous improvement since they present a level of quality for which the prevention and appraisal costs exceed the failure costs [16].

Freiesleben J. (2004) disputes the compliance cost behavioral trend in the classical model because if quality has an upward trend, then we should not expect an increase of the compliance costs. Furthermore, as the level of quality increases and the preventive costs have an upward trend, then the appraisal costs should have a downward trend, because as the level of quality increases, the failures reduce [8], which is corroborated by empirical research [2]. Moreover, neither approach considers the hidden quality costs which, according to Joseph M. Juran and Gryna F. M. (1993), should also contain the sale losses, especially in the modern approach [8]. Research shows that the correlation between the prevention costs and the internal failure costs in real time is not possible and therefore it is necessary to consider the time delays when considering the trade-off relationships within quality costs [4].

The empirical research of Plewa M., Kaiser G., and Hartmann E. (2016) suggests a modification of the modern approach (figure 5) with an elaboration that there exists a highest point of the compliance costs, after which the compliance costs reduce and positively corelate with the failure costs and the total quality costs, provided that the levels of quality are equal to or greater than 90% quality compliance [2].

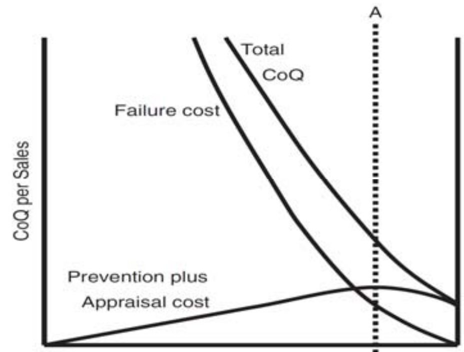

Fig.5. Modification of the modern model [2].

The visionary approach to the graphical interpretation refers to continuous organizational quality improvement (figure 6) [10], which rests of the thesis of Philip B. Crosby (1979) that quality is free [2].

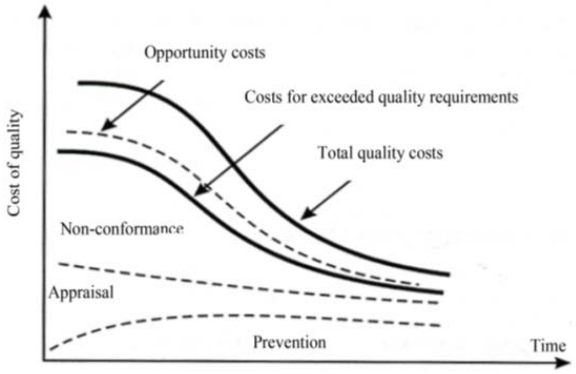

Fig. 6. Visionary approach of quality cost model [10].

The correlation between the quality costs categories is positive. The research of Sturm S., Kaiser G., and Hartmann E. (2019) showed that higher levels of quality and lower total quality costs are noticeable in the long run and that the categories of the quality costs exhibit the same behavioral trend in the long run, and they are expected to disappear [6].

In addition, the empirical research of Glogovac M., and Filipovic J., (2018) showed that companies committed to substantively fulfilling the requirements of ISO 9001:2015, focusing on the user, corrective measures, leadership, competences, awareness, knowledge, and continuous improvement with a view to their adequacy for the quality cost system, do achieve better results [3].

3. CONCLUSION

The presented graphic interpretations represent a static snapshot of the current status of the quality costs categories (and the total quality costs) for a particular level of quality.

Future graphic interpretation should be expected to present the behavior of the prevention costs separately from the appraisal costs and to present their correlation with the costs of internal failures, external failures and the opportunity costs for different conditions and quality maturity phases. In addition, it is necessary to analyze and order the influence cost quality elements, which will stimulate thinking about analyzing and discovering the reasons for such influences. One should especially study the influence of the effect of enhanced knowledge and the application of the quality management tools, techniques, and methods, to the performance of the prevention activities and appraisal activities in relation to the time factor.

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