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ULOGA EFQM MODELA I POSLOVNIH MODELA U UNAPREĐENJU PERFORMANSI KVALITETA: PRISTUP ZASNOVAN NA MAŠINSKOM UČENJU

Key words:
EFQM;
business excellence;
SMEs; quality performance indicators; ANN

THE ROLE OF EFQM AND BUSINESS MODELS IN ENHANCING QUALITY PERFORMANCE: A MACHINE LEARNING APPROACH

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EFQM model ima ključnu ulogu u praćenju performansi malih i srednjih preduzeća (MSP), pružajući sveobuhvatan okvir za procenu organizacione izvrsnosti. Podjednako važnu ulogu imaju i poslovni modeli, koji oblikuju strateški pravac i operativnu efikasnost ovih preduzeća. Ova studija ispituje uticaj usklađivanja EFQM modela sa poslovnim modelima na performanse kvaliteta u malim i srednjim preduzećima (MSP) u Srbiji. Studija slučaja je izvršena na realnim podacima iz 20 preduzeća koja su aplicirala za Oskar Kvaliteta, a za analizu složenih međuzavisnosti između poslovne izvrsnosti, inovacija poslovnih modela i performansi kvaliteta primenjene su veštačke neuronske mreže (VNM). Rezultati pokazuju da povećanje integracije EFQM modela sa poslovnim modelom od 5% značajno poboljšava ključne pokazatelje performansi kvaliteta. Uzimajući u obzir neizvesnost poslovanja i ograničene resurse preduzeća iz sektora MSP poboljšanja stagniraju nakon povećanja usaglašenosti od 20%, što sugeriše optimalni prag za stratešku implementaciju. Ovi rezultati naglašavaju vrednost strukturiranih okvira za poslovnu izvrsnost u poboljšanju operativnih performansi, dok istovremeno pokazuju efikasnost primene mašinskog učenja u optimizaciji procesa donošenja odluka. Studija pruža korisne uvide za MSP koji žele da poboljšaju kvalitet performansi kroz ciljano usklađivanje EFQM modela i sopstvenog poslovnog modela.

The EFQM model plays a key role in monitoring the performance of small and medium-sized enterprises (SMEs), providing a comprehensive framework for assessing organizational excellence. Equally important are business models, which shape the strategic direction and operational efficiency of these enterprises. This study examines the impact of aligning the EFQM model with business models on quality performance in small and medium-sized enterprises (SMEs) in Serbia. A case study was conducted using real data from 20 enterprises that applied for the Quality Oscar, and artificial neural networks (ANNs) were used to analyze the complex interdependencies between business excellence, business model innovation, and quality performance. The results show that a 5% increase *in the integration of the EFQM model with the business model significantly improves key quality performance indicators. Considering the business uncertainty and limited resources of SMEs, improvements plateau after a 20% increase in alignment, suggesting an optimal threshold for strategic implementation. These findings highlight the value of structured frameworks for business excellence in improving operational performance, while also demonstrating the effectiveness of machine learning in optimizing decision-making processes. The study provides valuable insights for SMEs aiming to improve quality performance through targeted alignment of the EFQM model and their own business model.*

1. Introduction

In today's dynamic and competitive business environment, organizations continually strive for excellence to maintain their relevance, competitiveness, and long-term sustainability. Achieving business excellence requires a systematic approach that encompasses various facets of organizational performance. One of the prominent frameworks facilitating this pursuit of excellence is the European Foundation for Quality Management (EFQM) model [1]. The EFQM model, serves as a comprehensive framework designed to guide organizations towards achieving and sustaining excellence in their operations. Rooted in the principles of continuous improvement and organizational learning, the EFQM model provides organizations with a structured approach to assess, benchmark, and enhance their performance across key dimensions [2]. At the heart of the EFQM model lies the concept of business excellence, which transcends mere operational efficiency to encompass holistic organizational success. Business excellence entails not only meeting customer expectations but also exceeding them, fostering innovation, cultivating a culture of continuous improvement, and demonstrating a commitment to societal well-being and sustainability [3].

Central to the pursuit of business excellence is the effective monitoring and evaluation of organizational performance. By systematically tracking key performance indicators (KPIs) aligned with strategic objectives, organizations can gain valuable insights into their strengths, weaknesses, opportunities, and threats [2]. This performance monitoring enables informed decision-making, facilitates timely interventions, and supports the implementation of corrective actions to drive continuous improvement.

This paper proposes the use of Artificial Neural Networks (ANN) as a prediction tool to achieve optimal improvement within the EFQM model framework. ANN, a computational model inspired by the biological neural networks of the human brain, has demonstrated significant capabilities in modeling complex relationships within datasets [4]. By leveraging ANN, organizations can analyze vast amounts of data related to various EFQM criteria and performance indicators, enabling them to identify patterns, trends, and potential areas for enhancement more effectively. Integrating ANN into the EFQM model allows organizations to predict future performance based on historical data, enabling proactive decision-making and strategic planning. By predicting outcomes, organizations can prioritize improvement initiatives, allocate resources more efficiently, and streamline their efforts towards achieving excellence across different aspects of their operations [5].

Moreover, ANN's adaptability and ability to learn from new data make it a valuable tool for continuous improvement within the EFQM framework. As organizations evolve and market dynamics change, ANN can dynamically adjust its predictions and recommendations, ensuring that improvement efforts remain aligned with current objectives and realities [5].

2. Literature review

2.1. Business excellence

The EFQM model represents a comprehensive framework for achieving business excellence through continuous improvement and empowering organizations. This model emphasizes the importance of having a clear vision and strategy, effective human resource management, and continuous engagement of employees at all levels. Through the application of excellence criteria, organizations can systematically assess their performance in various areas, identify key areas for improvement, and implement appropriate strategies. The benefits of the EFQM model are numerous, including improving the quality of products or services, increasing customer and employee satisfaction, and enhancing competitiveness in the market [1]. However, implementing the EFQM model can be challenging, requiring commitment, resources, and changes in organizational culture [2]. Nevertheless, organizations that successfully integrate the principles of the EFQM model often achieve long-term success and sustainable competitive advantage in the market [3]. The EFQM 2020 model has been built on the foundations of all previous excellence models and the teachings of quality gurus. As per [1], the primary emphasis of the updated EFQM 2020 model has transitioned from excellence to exceptional outcomes. This revised iteration incorporates the United Nations Sustainable Development Goals (SDGs) and extends its applicability to a broader range of contexts. Furthermore, it can be easily aligned with existing business models [6,7].

2.2. Artificial neural networks

Artificial Neural Networks (ANN) represent computer models inspired by the structure and functioning of biological neural networks in the human brain. These networks form the basis for the development of artificial intelligence and machine learning as they possess the ability to recognize patterns and make decisions based on data [8]. ANN consist of interconnected nodes that simulate biological neurons. ANN are organized into layers. Each connection is associated with a weight representing the strength of the connection between neurons. Each neuron has input and output values. Input values are weighted data values from the previous layer or input data set. These layers typically include an input layer, one or more hidden layers, and an output layer. The input layer receives data, hidden layers process it, and the output layer provides results. Gradient-based optimization methods are used to find a set of weights that minimize a specific objective function or loss function. Gradients of loss functions are calculated through the algorithm, and weights are gradually updated to minimize losses [9].

One of the key characteristics of ANN is the ability to learn. During the training process, the network is exposed to a training data set, where the weights of connections between neurons are adjusted. This is achieved by applying various optimization methods that minimize the error between actual and predicted results. Error is formed based on the difference between the target output and the system's output. This error information is fed back into the system, and the system systematically adjusts its parameters (training rule). The process is repeated until the performances are acceptable [10].

Research results conducted in the last 5 years have shown that smaller training data sets produce neural networks with better performance [8]. ANN are applied in various fields and for different types of problems. In shape recognition, they can be used for image classification or speech recognition. In natural languages, ANN can be applied to tasks such as machine translation or sentiment analysis. In the financial sector, ANN are used for market prediction and risk analysis. They are also used in robotics, medicine, automation, manufacturing, and many other fields [11]. In the industry, ANN have been used for industrial process control, risk management and innovation management, market research, sales forecasting, and marketing [12,13].

And while research on quality 4.0 is abundant, the application of Artificial Neural Networks to the topic of quality models and business excellence is scarce [14]. Literature review offers application of ANN in: defining maturity level [15], as prediction tool for business excellence model performance [16] and for predicting QMS performance [17].

3. Methodology

The proposed model is an integral part of the doctoral dissertation [17]. The proposed model consists of two independent variables: the level of Business Excellence achieved and the percentage of alignment between the business model and the EFQM model. Additionally, there are three dependent variables, which are the three best-ranked quality performance indicators.

Determining the level of Business Excellence is achieved through: (1) Identification of key dimensions; (2) Self-Assessment and/or External Assessment; (3) Data Collection of quantitative data; (3) Scoring and Evaluation.

The percentage of alignment between the EFQM model and the business model varies depending on the specific context, objectives, and implementation strategies of the organization. Achieving alignment involves assessing how well the principles, criteria, and practices outlined in the EFQM model correspond to the goals, processes, and structures of the organization's business model. To determine the percentage of alignment, organizations typically conduct a comprehensive analysis comparing criteria of the EFQM model with corresponding components of their business model [5]. This analysis may involve evaluating overlaps, synergies, gaps, and areas for improvement. Qualitative assessments and expert judgments may be used to determine the level of alignment.

The dependent variables are the three highest-ranked quality performance indicators according to the importance criterion for the group of SMEs from the manufacturing sector operating in the territory of the Republic of Serbia. These quality performance indicators have been adopted from [18].

4. Case study and results

This study utilized data from 20 enterprises operating within the territory of the Republic of Serbia, all of which are categorized as small and medium-sized enterprises (SMEs). All 20 enterprises had previously applied for the Quality Oscar, awarded by the Foundation for Quality and Excellence Culture (FQCE). The evaluation and award process entirely adhere to the principles of the European Foundation for Quality Management (EFQM).

Artificial neural networks were employed to analyze the complex interdependencies between the level of business excellence, business models innovation and quality performance within this specific context. The data encompassed various metrics related to business excellence and quality performance, collected through the evaluation processes conducted by the enterprises itself. The preprocessing of data involved normalization and feature scaling to ensure uniformity and accuracy in the analysis. Machine learning algorithms, including feed forward neural networks, were then trained on this preprocessed dataset to predict optimal strategies for enhancing business excellence.

The evaluation of the neural network models was conducted through rigorous testing and validation procedures, assessing the accuracy and reliability of predictions. The results obtained from the trained models provided valuable insights into the optimal level of alignment of business excellence for SMEs operating within the Serbian business environment and their business models.

The weights assigned to the first hidden layer of the network are:

w_1= 3.022; w_2= -3.2542; w_3= 2.8239; w_4=4.4508; w_5=-2.365; w_6=4.7403;w_7= 4.1025; w_8=1.52; w_9= -1.5296; w_{10}=3.2017; w_{11}= -1.2289; w_{12}= -2.544; w_{13}=-3.2038; w_{14}= -2.7507; w_{15}=0.90505; w_{16}= 4.6366; w_{17}= 2.5023; w_{18}= 1.1968; w_{19}= 2.7913; w_{20}= 2.7729

The bias values at the first hidden layer of the network are:

b_1=-4.3995; b_2= -4.8654; b_3=1.9333; b_4= -3.0293; b_5=-2.9414; b_6=0.99101; b_7=-1.4801; b_8=2.5443; b_9=5.1132; b_{10}=4.9397

The weights assigned to the output layer of the network are:

w_1=1.745; $w2$= -2.8156; w_3=-1.4939; w_4=-3.9387; w_5=-0.16212; w_6=-1.0653; w_7=0.76764; w_8=0.19312; w_9= -0.0047236; w_{10}=0.96804; w_{11}=-0.81576; w_{12}=-3.5153; w_{13}=-1.587; w_{14}=-0.010025; w_{15}=3.1783; w_{16}=-0.30639; w_{17}=1.0898; w_{18}=0.87774; w_{19}=0.63859; w_{20}=-0.33763; w_{21}=1.9282; w_{22}=-3.2616; w_{23}=-1.3975; w_{24}=-0.092181; w_{25}=-0.87219; w_{26}=-0.6359; w_{27}=1.2452; w_{28}=1.1462; w_{29}=-0.91336; w_{30}=-0.22506

The bias values at the second output layer of the network are:

b_1=-3.0479; b_2=0.091777; b_3=0.27813

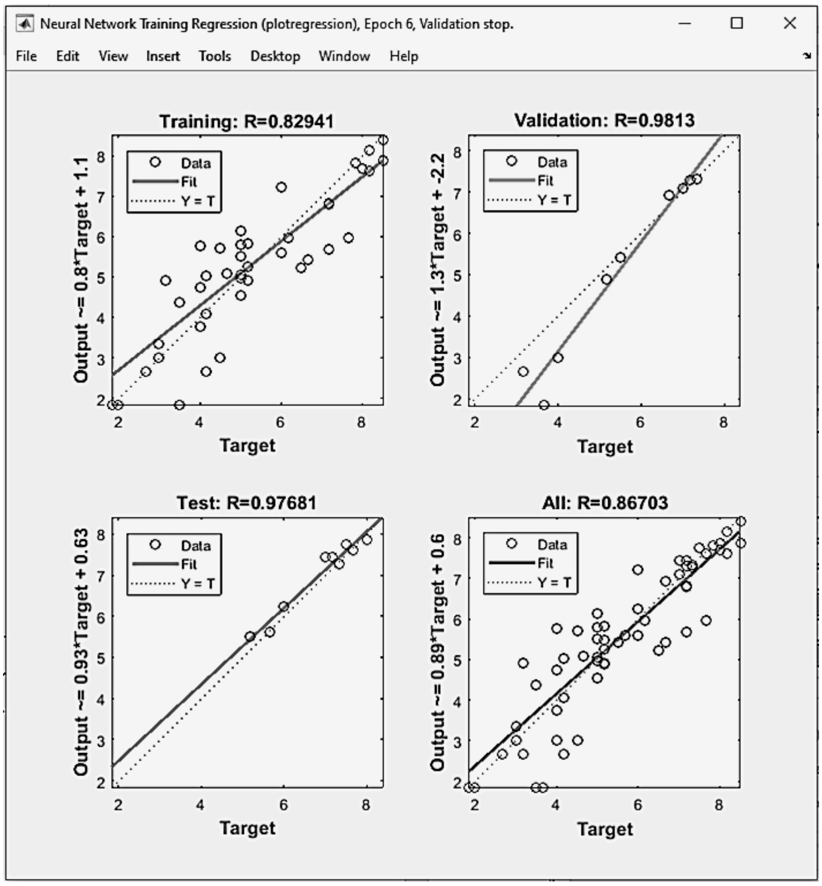

Figure 1. Correlations between actual values and values proposed by the network

In Figure 2, the value of the KPI, customer complaints, for the considered group of companies is shown, as well as the value of this indicator when improving the alignment of EFQM and business model.

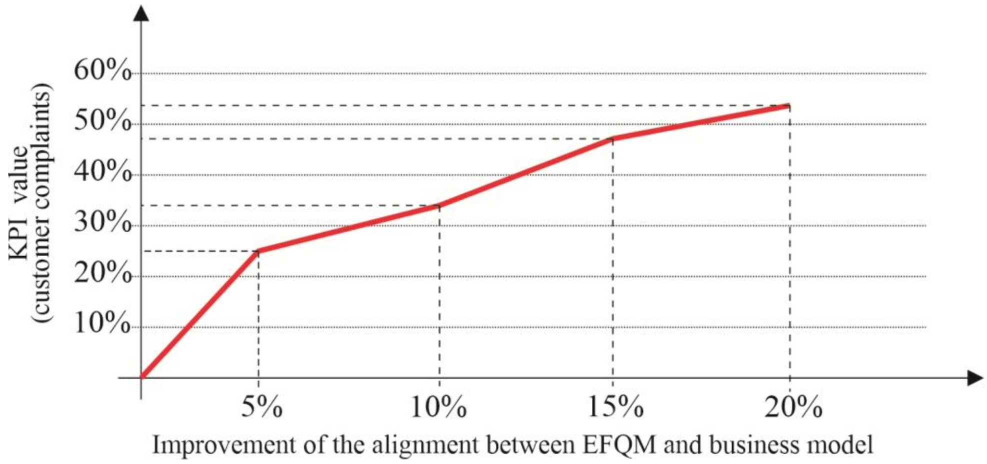

Figure 2. The value of the quality performance indicator, customer complaints

Based on Figure 2, it is evident that with a 20% increase in the alignment between EFQM and the business model, customer complaints will decrease by 54%. Figure 3 shows the value of the cost of poor quality performance indicator.

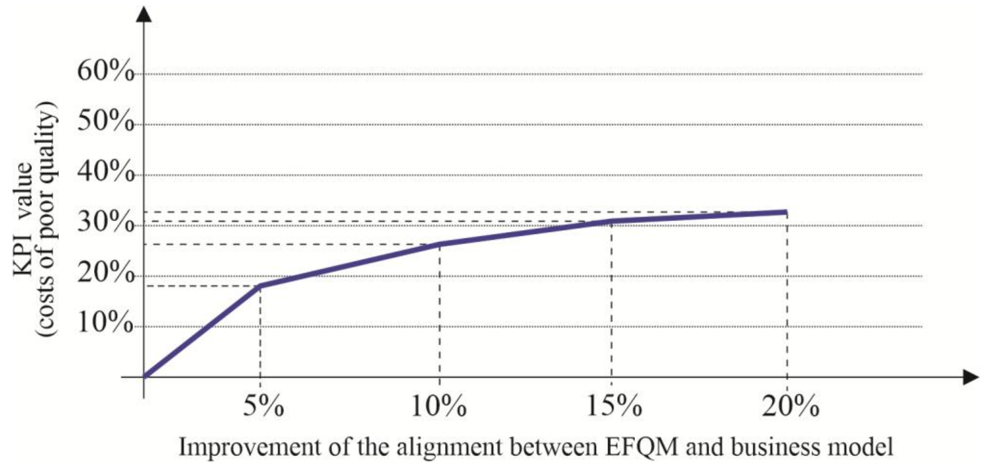

Figure 3. The value of the quality performance indicator, cost of poor quality

According to Figure 3, the values of the cost of poor quality performance indicator will improve by 31%, or 33% with a 15% or 20% increase in the level of EFQM alignment with the business model, respectively. The improvement in the cost of poor quality performance indicator is almost equal with a 15% or 20% enhancement in alignment. Figure 4 shows the value of the performance indicator timely closure of non-conformities.

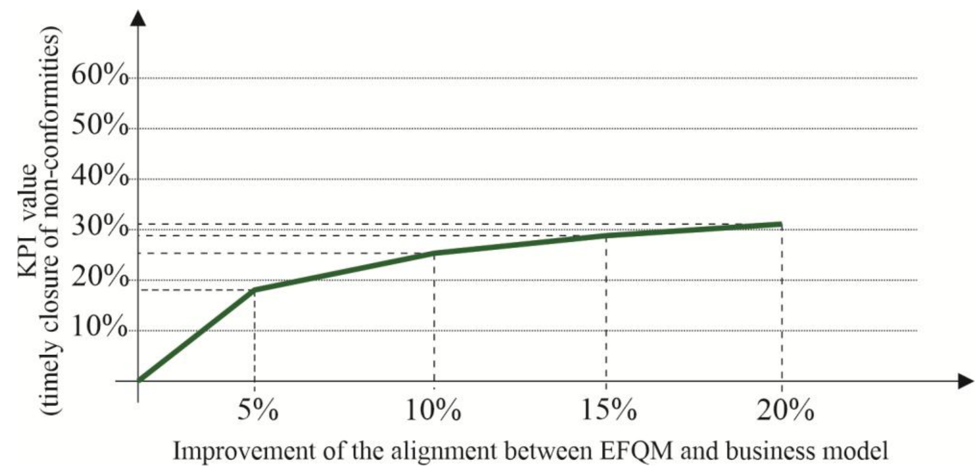

Figure 4. The value of the quality performance indicator, timely closure of non-conformities

According to Figure 4, the values of the performance indicator for the timely closure of non-conformities will improve by 31% or 29% with a 20% or 15% increase in the level of alignment, respectively. Based on the obtained results, it is evident that the greatest improvement in the values of all three observed performances is achieved with a 5% increase in the level of alignment of EFQM model with the business model. The difference in the values of these performance indicators with an improvement of 15% and 20% can be neglected. Any increase in the level of alignment beyond 20% will not significantly improve the observed performances. Respecting these results, it can be argued that even with an increase in the level of alignment by 25% or more, the values of the observed performance indicators would not significantly increased compared to the obtained values with a 20% increase. Considering the necessary improvement costs, it can be said that a 5% increase has the greatest impact on the values of the observed quality performances.

Ultimately, the goal is to optimize alignment between the EFQM model and the business model to ensure that organizational efforts towards excellence are effectively integrated into broader business strategies and objectives.

5. Conclusion

This study explores the relationship between business excellence, business model innovation, and quality performance in Serbian SMEs using artificial neural networks. By analyzing data from enterprises that applied for the Quality Oscar, we examined the impact of aligning the EFQM model with business models on key quality performance indicators.

The obtained results indicate that the most significant improvement in the values of the observed quality performance indicators is achieved with a relatively small increase in the alignment of the EFQM model with the business model – as little as 5%. This suggests that the improvements are largely the result of so-called "quick wins," referring to easily implementable measures that yield visible and measurable results with minimal effort. In practice, these may include clearer definition of responsibilities, the introduction of simple procedures for monitoring results, or improvements in internal communication.

Conversely, further increases in alignment – for example, by 15%, 20%, or more – do not lead to significant additional gains, indicating a saturation effect. This suggests that beyond a certain point, further alignment improvements require deeper, more structural changes in the way the organization operates. Such changes may involve redesigning business processes, adopting new technologies, or initiating cultural transformations within the organization. These interventions are typically more costly, require more time to implement, and pose a higher risk of resistance from employees or unforeseen challenges.

Challenges and Risks in Implementing the Findings in SMEs:

- In the context of small and medium-sized enterprises (SMEs), the practical implementation of these findings may face specific challenges, including:
- Limited Resources: SMEs often lack sufficient financial and human resources for systematic monitoring and measurement of performance, which may hinder their ability to track the effects of alignment improvements.
- Resistance to Change: Employees and managers in SMEs may have well-established habits and informal working practices, meaning even small changes can encounter resistance.
- Limited Awareness of the Importance of Alignment: SMEs may sometimes underestimate the value of quality models such as EFQM, viewing them as bureaucratic tools rather than as a means to improve business operations.

– Risk of Overly Ambitious Changes: The findings suggest that there is no need for large-scale transformations without a clear plan and careful cost-benefit analysis. Excessive investments in alignment efforts that do not yield proportionate benefits could result in financial strain or employee demotivation.

The findings highlight the critical role of structured business excellence frameworks in driving quality performance improvements. In particular, reducing customer complaints, lowering the cost of poor quality, and improving the timely closure of non-conformities were all significantly influenced by better EFQM-business model alignment. This suggests that SMEs can achieve substantial performance gains through targeted, cost-effective improvements rather than broad, resource-intensive changes.

Future research should expand the dataset to include a broader range of industries and explore alternative machine learning techniques for more precise predictive modeling. Additionally, longitudinal studies could assess the long-term sustainability of these improvements. Ultimately, this research underscores the importance of strategic alignment between business excellence frameworks and operational models, offering valuable insights for both practitioners and policymakers seeking to enhance SME performance in competitive markets.

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