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The Long-Term Benefits of Quality Costs in Achieving Sustainable Development: A Benefit-Cost Analysis

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Abstract: The future of the world is a topic that continues to generate debate and intrigue across generations, due to uncertainties and evolving concerns. As the industrial revolution, technological advancements, and urbanization have progressed, numerous challenges have arisen. Environmental pollution, income inequality at national and international levels, wars, and social conflicts all serve to underscore the significance of addressing future expectations. As a result, environmental, social, and economic sustainability has emerged as a pressing issue. In response, various economic and political calls have stressed the importance of sustainability. This study examines the relationship between sustainability and quality costs using a case example and explores a long-term benefit-cost analysis. It is suggested that, although quality costs may be higher in the short term, they yield greater benefits in the long run, thereby contributing to sustainable development.

Keywords: Sustainable development; Quality costs; Benefit-cost analysis; Environmental, social, and economic sustainability; Case study

1. Introduction

Sustainability has emerged as a critical issue in contemporary society, often evoking parallels with a newly discovered, unprophecied "religion". However, upon closer examination of the world, it becomes apparent that adherence to this "religion of sustainability" is not as widespread as one might expect. The concept of sustainability centers on the concern for future generations and their ability to enjoy the same resources and quality of life as the present generation. This concern encompasses environmental, social, and economic aspects, including responsible consumption, transportation choices, and the consequences of natural disasters.

The continued existence of the universe and the Earth suggests that resources will likely be available for future generations. However, various factors threaten sustainability, such as wars, fires, accidents, and irresponsible consumption. These barriers can potentially be overcome by focusing on quality and optimizing quality costs. By investing in preventive activities, unintentional failures can be avoided, and failure costs can be reduced. Moreover, prevention activities can contribute to a more livable world for future generations by addressing issues such as irresponsible consumption, wars, fires, and accidents.

Quality costs are typically divided into two categories: prevention-measurement values and failure (internal-external) costs. In most cases, reducing or limiting failure costs necessitates sufficient investment in prevention-measurement values to eliminate failure costs and prevent their occurrence. Theoretically, if failures are minimized or eliminated, sustainability can be successfully achieved on a global scale, resulting in a high sustainability index for the relevant subject.

To elucidate the relationship between quality costs and sustainability, two specific cases were examined: renewable energy consumption as an alternative to fossil fuels and the prevention of forest destruction. The objective of this study is to demonstrate to the current generation that it is possible to reduce prevention costs and failure costs to zero and contribute to sustainability.

In the following sections, the language has been modified according to the requirements of top academic

journals, such as Nature and Science, with a focus on passive voice and avoidance of personal pronouns. Structural and logical changes have been made to adhere to journal guidelines, and citations have been preserved. The content has been expanded as necessary to provide a more comprehensive understanding of the topic while maintaining originality.

2. Sustainability Index

As societal and environmental concerns gain prominence, companies and financial institutions increasingly face pressure to adopt sustainable practices that effectively mitigate environmental impacts (Grijalvo & García-Wang, 2023). This trend has driven communities, governments, NGOs, insurance companies, investors, and individuals to seek products and production processes with positive societal impacts (Zago et al., 2018). Consequently, evaluating the sustainability impacts of business models has become essential for transitioning to a circular economy and promoting sustainable business practices (Bhatnagar et al., 2022).

In recent years, investors and other organizational bodies have expressed growing interest in identifying companies that operate sustainably and demonstrate social responsibility (Giannarakis et al., 2017; Ersoy et al., 2022). Furthermore, global businesses prioritize the adoption of social responsibility to gain a competitive advantage and ensure long-term value creation. This interest has led to the development of sustainability indicators and indexes that assess companies' sustainability performance and are linked to financial markets (López et al., 2007). Sustainability indexes aim to enhance transparency in capital markets, attract more investors, and increase share trading volume, similar to other forms of corporate governance (Zago et al., 2018).

The Sustainability Index is a tool employed to evaluate companies' environmental, social, and economic performance to improve transparency in capital markets, attract more investors, and increase share trading volume. The Dow Jones Sustainability Index (DJSI), a prominent sustainability index, was created by Dow Jones in September 1999 to track the performance of leading companies in corporate sustainability. The DJSI provides indicators to assess companies' approaches to non-material asset evaluation, human capital development, organizational issues, strategic planning, corporate governance, and investor relations. Companies adjust their sustainability reports to meet the evaluation organization's requirements. Sustainability criteria are divided into three categories: economic, environmental, and social. The Sustainability Index identifies top sustainability performers in each sector. The Dow Jones Sustainability Index has global and regional interpretations for Europe (DJSI Stoxx), Canada and the US (DJSI North America), and Asia and the Pacific (DJSI Asia/Pacific). Companies' sustainability performance is quantified before inclusion in any DJSI index using four information sources: (i) a specific company survey, (ii) accurate company documents, (iii) media and stakeholder analysis, and (iv) direct communication with the companies. Additionally, this information must be updated annually (Schaeffer et al., 2012).

In Turkey, the BIST Sustainability Index has been computed since 2014 to provide investors with information about companies' social, corporate, and environmental management (Özçim, 2022). On November 21, 2022, the BIST Sustainability 25 Index was established. These indexes are expected to identify companies' approaches to environmental issues such as decreasing water resources, global warming, and climate change, directing investors to cleaner investments (BIST, 2022). Sariyer & Taşkın (2022) analyzed companies' performance in the Borsa Istanbul (BIST) Sustainability Index by clustering them based on environmental, social, and governance scores. The findings indicate that companies with higher environmental, social, and governance ratings do not perform well in terms of environmental, social, and governance issues.

3. The Cost of Quality

In light of the dynamic nature of economic, technical, and competitive environments, an increased emphasis on product quality has been observed, leading to the adoption of total quality management in enterprises (Tomov & Velkoska, 2022). Concurrently, the concept and measurement of quality costs have emerged as topics of vital interest for businesses (Çabuk, 2005). Quality costs, considered as an indicator of quality, are closely related to the concept of quality (Satanova & Sedliacikova, 2015).

The cost of quality (COQ) for an organization encompasses any costs resulting from efforts to ensure product quality, regardless of whether it is low or high (Gupta & Campbell, 1995). It has been agreed that quality costs comprise four categories: prevention costs, appraisal costs, internal failure costs, and external failure costs. The first two categories represent discretionary or control costs, while the latter two are associated with failure costs (Gupta & Campbell, 1995).

Prevention costs are incurred to proactively address potential quality issues, thereby playing a crucial role in shaping product quality (Gupta & Campbell l, 1995). These costs may include quality planning, control systems, reporting, new product development reviews, supplier quality assurances, and training and improvement programs.

Appraisal costs, similar to prevention costs, are proactive expenditures that ensure products or services adhere to established quality standards (Gupta & Campbell, 1995). Examples of these costs comprise quality planning,

control systems, reporting, new product development reviews, supplier quality assurances, and training and improvement programs.

In contrast, failure costs arise due to the inability to produce a quality product. Internal failure costs are associated with defective products detected before leaving the manufacturing facility, such as costs of scrapping, rework, and downtime. External failure costs occur after shipment to the customer and may entail costs related to handling complaints, warranty replacements and repairs, loss of customers, and product recalls.

The influence of specific factors in selecting a quality control method has been emphasized by Sousa & Nunes (2019). Their proposed model advocates for minimizing total quality costs while ensuring the reliability of the data provided by the chosen quality control method. This model accentuates the selection of quality control mechanisms that result in the lowest quality costs.

Tomov & Velkoska (2022) propose an integrated perspective on quality costs throughout a product's lifecycle, contributing to a more sustainable society (Tomov & Velkoska, 2022). The contemporary approach to quality suggests a distinct category for costs related to quality acquisition, thereby promoting the development of theoretical knowledge on the necessity for quality cost definition models. However, it has been observed that traditional definitions of quality costs overlook the environmental, economic, and social dimensions of sustainability.

Table 1. The principal cost of quality

The principal cost of quality	Authors who explain and develop concepts	References
unavoidable costs + preventable costs	Joseph M. Juran (1951)	(Schiffauerova & Thomson, 2006)
the cost of compliance + the cost of non-compliance	Crosby P. (1979), Denton DK., Kowalski TP. (1988), Suminsky LT. (1994)	(Khaled Omar & Murgan, 2014)
control costs (costs of compliance) + the costs of control failure (costs of non-compliance)	Armand V. Feigenbaum (1991)	(Khaled Omar & Murgan, 2014)
voluntary costs + involuntary costs	Campanella J. (1999)	(Cheah et al., 2011)
quality investment costs + costs of cutting quality ties	Armand V. Feigenbaum (2001)	(Jeffery, 2003)
Broader Quality Cost Concepts	Authors who Explain and Develop Concepts	(Pacana & Stadnicka, 2009)
Producer Quality Losses + Consumer Quality Losses + Societal Quality Losses	Genichi Taguchi (1980)	
Suppliers' Quality Costs + Manufacturer's Quality Costs + Consumer's Quality Costs	Gryna F. M. (1988), Dale B. G. Plunkett J. J. (1991), G. H. Hwang, E. M. Aspinwall (1996)	(Jaju et al., 2009); (Lorente et al., 1998); (Hwang & Aspinwall, 1996)
Suppliers' Quality Costs + Manufacturer's Quality Costs + Retailers' Quality Costs	Krystel K. Castillo-Villar, Neale R. Smith, James L. Simonton (2012)	(Castillo-Villar et al., 2012)
Suppliers' Quality Costs + Manufacturer's Quality Costs + Retailers' Quality Costs + Consumers' Quality Costs	Alglawe A., Schiffauerova A., Kuzgunkaya O., Shiboub I. (2019)	(Alglawe et al., 2019)

Reference: Tomov & Velkoska (2022)

The concept of quality costs has undergone a significant transformation to better align with sustainability and circular economy principles. This reimagined approach, referred to as the contemporary concept of quality costs, is founded on three pillars (as shown in Table 1).

Firstly, it integrates all three dimensions of sustainability—environmental, economic, and social—into the calculation and consideration of quality costs. This comprehensive inclusion ensures a holistic approach towards sustainability, addressing a previous gap in quality cost definitions that often neglected these aspects.

Secondly, it recognizes the entire product lifecycle, from engineering and design to production and use, and ultimately to end of life. This consideration operates in synergy with circular economy principles, a system that prioritizes resource efficiency and waste minimization, resulting in a more sustainable approach to quality costs.

Lastly, this concept requires the involvement of all supply chain stakeholders, who must account for quality costs arising at every stage of the product lifecycle. This integrative approach fosters a feedback loop among stakeholders, enabling each to comprehend the quality costs incurred by others, thus promoting collaboration and shared responsibility.

In summary, the contemporary paradigm encourages decision-makers to invest in enhancing quality. The underlying assumption posits that superior quality leads to reduced costs associated with quality failures, fostering a more sustainable approach to production and consumption (Smith & Cabral, 2022; Tomov & Velkoska, 2022).

It is noteworthy that the understanding and management of quality and its associated costs have consistently been subjects of interest and evolution in both academia and industry. The contemporary concept of quality costs represents a single step forward in a journey spanning decades and is likely to continue evolving in the future to better serve the needs of an increasingly interconnected and environmentally conscious world.

3.1 Classification of Quality Costs

Feigenbaum's initial categorization of quality costs in his 1991 publication "Total Quality Control" is recognized as seminal work, which proposes that quality costs can be partitioned into two sectors: conformance costs and non-conformance costs (Koç & Demirhan, 2007). This section provides an examination of these costs.

3.1.1 Prevention CostsIt

The origin of prevention costs is attributed to efforts directed towards research and defect reduction, aiming to minimize the risks associated with product nonconformance. These costs encompass the expenses incurred during the design and implementation of a quality system within an organization (İçerli, 2020). Not only are these costs applicable during the system's establishment, but they also persist throughout subsequent activities. Expenses related to quality planning, designed to achieve customer expectation standards, testing, quality measurements, calibration, and maintenance are considered components of prevention costs.

3.1.2 Appraisel costs

Appraisal costs are expenditures incurred in pursuit of attaining the desired quality standards for a product (Yükçü, 1999). These costs comprise those associated with input control before production, testing, inspection, reviews, and evaluations conducted to meet the quality standards established during the design phase (Çabuk, 2005). The components of these costs include (Yükçü, 1999):

- ✓ Pre-production verification
- ✓ Acceptance inspection
- ✓ Laboratory and acceptance testing
- ✓ Inspection and testing
- ✓ Inspection and test equipment
- ✓ Materials consumed during inspection and testing
- ✓ Analysis and reporting of inspection and test results
- ✓ Field performance testing
- ✓ Approvals and certifications
- ✓ Inventory valuation

3.1.3 Internal failure cost

Internal failure costs arise when an organization fails to meet the designed quality standards of a product before it reaches the consumer (Çabuk, 2005). The spectrum of internal failure costs can be characterized as follows (Yükçü, 1999):

- ✓ Waste and damaged product
- ✓ Replacement, remanufacturing, and repair costs
- ✓ Costs of troubleshooting and defect/failure analysis
- ✓ Expenses related to inspection and test repetition
- ✓ Costs resulting from subcontractor errors
- ✓ Costs related to exchange permissions and privileges
- ✓ Loss of earnings due to non-compliance with quality
- ✓ Time loss

3.1.4 External failure costs

External failure costs are incurred after the product has been delivered to the end consumer. These costs can arise through shipping, delivery, and post-sale warranty services and are often recognized as the most financially burdensome. Examples of such costs include complaint investigations, returned products, warranty claims, and customer losses (Yükçü, 1999). The types of external failure costs include:

- ✓ Complaints
- ✓ Warranty obligations
- ✓ Rejected and returned products
- ✓ Settlements
- ✓ Loss of sales
- ✓ Costs related to customer interactions
- ✓ Product liability

4. Case Recommendations

While literature exploring quality costs predominantly focuses on a business perspective, these concepts can also be applied at an individual level, with preventative measures in health or infrastructural planning serving as a form of prevention cost. For example, preventive heart and vascular treatments can be employed to avert heart attack failure, thus reducing potential failure costs. In the context of threats to settlements, such as flooding, actions like afforestation, dam construction, and the cleaning and creation of water channels may be considered prevention activities and costs.

Sustainability, when considered on a global and universal scale, inherently possesses preventive qualities. It aims to preempt and mitigate failure costs at a planetary level. This study seeks to draw attention to two critical threats to global sustainability and highlights potential preventive activities and their associated costs. Two case studies have been devised to demonstrate the relationship between sustainability and quality costs, offering tangible examples of how these concepts interact.

4.1 Case Study: Increased Consumption of Renewable Energy

The philosophy of sustainability emphasizes the conservation of fossil fuels for future generations. One of the most effective strategies for reducing external failure costs is promoting the consumption of renewable energy sources over fossil fuels. This global movement towards renewable energy involves equipping various facilities, including homes, manufacturing plants, public buildings, and others, with renewable energy infrastructures, such as solar, wind, and wave energy systems. These investments, made in a 100-year increment plan, serve as prevention costs. As these costs spread globally, it is expected that failure costs will decrease and the consumption of new fossil fuels will diminish, positively affecting the sustainability index. This case study presents a theoretical relationship between quality costs and the sustainability index over time, with the data visualized in Figure 1 and detailed in Table 2.

Table 2. Costs of quality -sustainability index table (fossil fuel incident)

Years	Prevention Cost(currency)	Cost of Failure (currency)	Sustainability Index
2024-2099	990.000.000	880.000.000	100
2100-2199	690.000.000	440.000.000	200
2200-2299	490.000.000	220.000.000	400
2300-2399	300.000.000	50.000.000	800
2400-2499	350.000.000	0	1200
2500-2599	400.000.000	0	1500
2600-2699	450.000.000	0	2000
2700-2799	500.000.000	0	3000
2800-2899	550.000.000	0	4000
2900-2999	600.000.000	0	5000

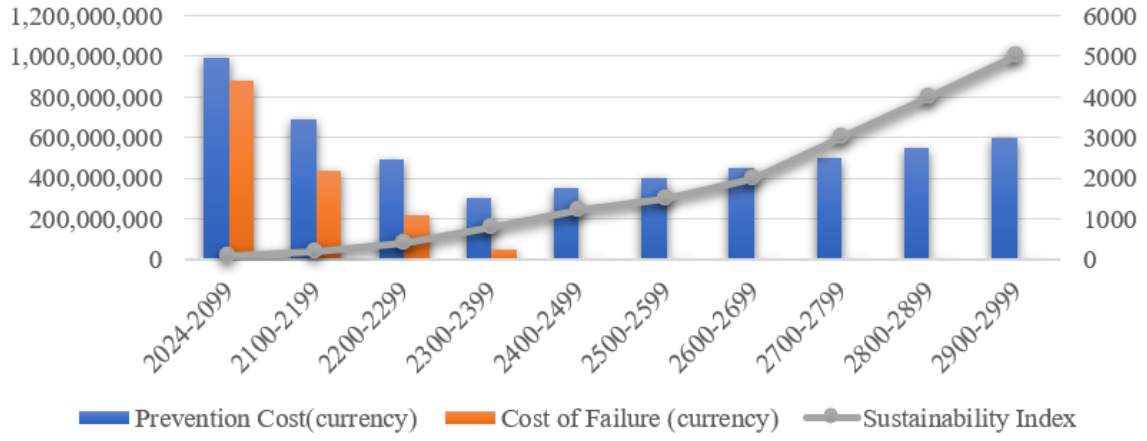

Figure 1. Quality costs-sustainability index (fossil fuel case)

In the initial stages of this plan, a high priority is placed on preventative investments, leading to widespread renewable energy utilization. Some fossil fuel consumption persists until preventative investments are completed, contributing to failure costs. By the fifth time period, however, fossil fuel consumption is projected to cease

entirely, indicating full sustainability achievement and a positive impact on the global sustainability index.

4.2 Case Study: Prevention of Forest Damage

This case focuses on investments aimed at expanding forest cover worldwide and preventing unnecessary damage. Measures against forest fires and controlled tree felling with immediate reforestation are considered as prevention costs. The goal is to minimize forest damage, resulting in a significant reduction in forest fires and other damages.

Implementation of these measures is expected to nearly eradicate forest fires and damages. Consequently, erosion, landslides, and flood-related failures will also be mitigated, enhancing the global sustainability index. Financial aspects and failure costs of these investments are anticipated to progress following the sustainability index. In the early years, significant investments will be made to prevent forest damage, constituting prevention costs. This will result in a reduction and eventual eradication of forest fires, having a positive impact on the sustainability index. The sample data based on this case analysis is presented in Table 3 and visualized in Figure 2.

Please note that all provided tables and figures are not included in the text. It is assumed that they will be added during the formatting and publishing process.

In summary, these case studies aim to shed light on the relationship between quality costs and sustainability, a significant yet underexplored area of study. It is hoped that these examples will encourage further research into these intersections and prompt consideration of these factors in policymaking and planning efforts.

Table 3. Cost of quality-sustainability index table (forest destruction prevention case)

Years	Prevention Cost(currency)	Cost of Failure (currency)	Sustainability Index
2024-2099	870.000	440.000	100
2100-2199	460.000	80.000	180
2200-2299	120.000	10.000	220
2300-2399	100.000	0	300
2400-2499	110.000	0	350
2500-2599	120.000	0	400
2600-2699	130.000	0	450
2700-2799	140.000	0	500
2800-2899	150.000	0	550
2900-2999	160.000	0	600

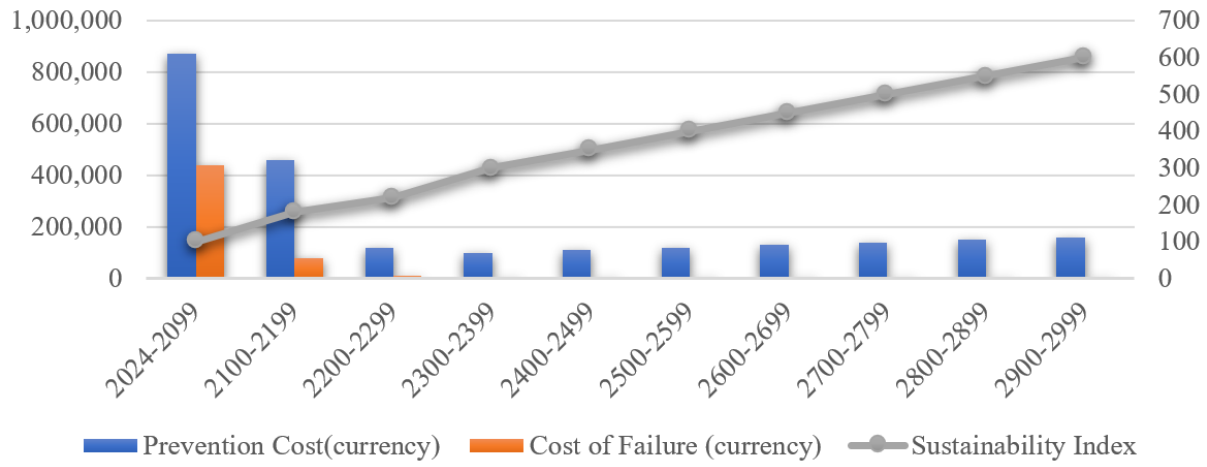

Figure 2. Cost of quality-sustainability index (forest destruction prevention case)

5. Conclusion

Preventive measures and costs, when applied universally, have been shown to contribute positively to sustainability by conserving resources. In contrast, failures resulting from a lack of prevention can negatively impact sustainability due to the wasteful and improper use of resources.

For the creation of a sustainable world, it is crucial that prevention activities and their associated costs are prioritized across all domains, with the ultimate goal of minimizing or even completely eliminating the costs of failure.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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