

Article

Quality 4.0: The EFQM 2020 Model and Industry 4.0 Relationships and Implications

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Abstract: The European Foundation for Quality Management (EFQM) 2020 model is a comprehensive and updated business model that encompasses sustainability and shares features with Industry 4.0, emphasizing transformation and improved organizational performance, yet with different theoretical and practical foundations. This research highlights the EFQM 2020 model's novelties and its relationships/implications with the Industry 4.0 paradigm, contributing to the Quality 4.0 body of knowledge. Several linkages between the EFQM 2020 model and Industry 4.0 have been identified, namely, at the criteria level and guidance points, which can support successful digital transformation by combining quality and excellence with Industry 4.0. However, given the model's generic and non-prescriptive nature, there is no specific reference to the nine Industry 4.0 pillars. Additionally, the links between direction and organizational culture and leadership criteria and driving performance and transformation are not evident, which might be a concern for business and technology transformation strategies. Managing knowledge, skills, and capabilities is critical for the successful adoption of Industry 4.0. The EFQM model adds a strategic and technologically unbiased perspective to Industry 4.0, providing an integrated business excellence framework for Quality 4.0. With empirical support of the model application, future research is recommended to develop this subject further.

Keywords: business excellence; EFQM 2020 model; Industry 4.0; Quality 4.0; relationships; implications



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1. Introduction

According to Peters and Waterman's [1] work "In Search of Excellence," and the introduction of the Malcolm Baldrige National Quality Award (MBNQA) in the USA (first awarded in 1989) and the European Foundation for Quality Management (EFQM) Excellence Award in Europe (first awarded in 1992), the concept of excellence has been disseminated throughout time within the business and academic community.

Several business excellence models (BEMs) have been proposed, supported by business excellence (BE) criteria framed within a holistic framework supported by a set of core values or fundamental concepts with both business enablers and business results. BEMs also include assessment methodologies that can assist organizational self-assessment or applications to BE awards (subject to externally validated assessments).

Since its introduction in 1991, the EFQM model is recognized as a global structure that helps organizations manage change and improve organizational performance. The model is generic in nature towards ensuring its applicability to organizations regardless of their size, scope, or business sector and has been adopted by thousands of entities worldwide. Academic research suggests that BE fosters organizational competitive advantages and success [2–5].

To ensure its validity and fitness, the EFQM model is subject to periodic reviews and adjustments based on industry and academic research, supported by various topics and methodologies that foster the integration of a wide range of management areas. In 2019, EFQM introduced the novel EFQM 2020 model, following an extensive co-creation review process that involved users, award-winning entities, academicians, and business leaders. The EFQM 2020 model is supported by European values and business ethics and incorporates the United Nations Sustainable Development Goals (SDGs).

However, due to its novelty, academic literature encompassing the EFQM 2020 model is still scarce. Ghafoor et al. [6] performed a bibliometric and thematic review of business excellence journal papers from 1990 to 2020. Although the design of business excellence frameworks (BEFs), and BEF practice and impacts, are identified as the main research areas, no mention is made of research encompassing the BEF (including the EFQM model) and Industry 4.0 context. Nenadál [7] performed a critical analysis of the EFQM 2013 and 2020 models and identified several advantages (more logical and more straightforward in comparison to the previous version) and weaknesses (descriptions of specific recommendations by guidance points are superficial and confusing) of the 2020 version, with a particular focus on Quality 4.0.

The adoption of information and communications technology (ICT), supported by the digital process integration of “smart” objects (machines and products) that merge the physical and the virtual worlds, led to the appearance of the Industry 4.0 (I4.0) paradigm. The so-called fourth industrial revolution generates new resources and capabilities that leverage competitive advantages and is now a framework for modern organizations and business to improve efficiency, quality, information technology, artificial intelligence (AI), and robotics productivity [8].

The quality models approach and practices have evolved from inspection to quality control, quality assurance, quality management, and business excellence. Several models and frameworks have been developed to help organizations manage and improve quality in all activity sectors. These include the ISO 9001 Quality Management International Standards, continual improvement methodologies such as Lean, Six Sigma, or Lean Six Sigma, the teaching of quality gurus such as Juran, Crosby, Deming, or Taguchi, and the business excellence models, namely, the EFQM (Europe), the MBNA (EUA), or the Deming (Japan) models or awards [9].

The link between quality and sustainability has a considerable history. Juran stated quality to be “the ethical imperative for the senior executive” [10]. Deming stated “Quality must be directed to the needs of the client, present and future” [11]. Genichi Taguchi incorporated society into the definition of quality (quality as the loss to society from the moment a product is shipped, and there is a deviation from the target value). ISO 9001:2015 aims at satisfying the customer and relevant stakeholders and complements and reinforces environmental management systems (for example, ISO 14001). Lean or Kaizen approaches reduce waste and improve environmental performance. Quality techniques and tools (namely, Quality Function Deployment or Design of Experiments) can also contribute to sustainability, such as identifying customer needs and designing the product and production process or assessing the product’s environmental impact and its potential alternatives. The Deming Prize guidelines that came into effect in 2018 describe quality as “providing benefits and value with little or no harm to society and the environment”. The EFQM 2020 business excellence model incorporates the United Nations Sustainable Development Goals (SDGs) and a set of European values that support business ethics. Quality management emphasizes improvement (continuous and disruptive). It reduces resources used in operational processes, operational time, and costs and minimizes environmental impacts and natural resource consumption, leading to environmental sustainability. Like environmental sustainability, quality management also shows a significant and positive impact on social sustainability, that is, on organizations’ impact on and their operations in society. Some of the prominent organizational social development indicators are health and safety at work, customers’ and employees’ rights, the balance between professional and personal life,

volunteering, living conditions and social well-being, involvement with the community, or philanthropy and participation in social development programs. Organizations that understand the importance of customers and the relationship with them are aware of the importance of social sustainability by integrating it into the business strategy. The improvements provided by quality management, including enhanced customer satisfaction, reducing errors, and improving operational performance, are some of the main benefits of quality management practices, which directly impact companies' economic sustainability.

In summary, quality management practices and tools must be developed and adapted to support sustainability [12] and have a significant and positive impact on its three dimensions: environmental, social, and economic sustainability [13].

In the present Industry 4.0 and digital transformation paradigm, Quality 4.0 (or Q4.0) has emerged as the combination of quality management and improvement models and approaches with technology to foster critical competencies and factors for organizational success [14,15]. While technology is an essential driver of digital transformation, organizations need supporting business and management models to achieve enduring competitiveness [16]. While Industry 4.0 is more technology centric (technology as a key driver) and quality is customer centric (technology as an enabler), both approaches aim for improved performance and results. Without product and process quality, Industry 4.0 cannot fully improve flexibility and productivity. Conversely, intelligent sensors, automation, and big data can support Statistical Process Control (SPC) or Six Sigma at the process level or provide data for high-level Total Quality Management (TQM) and business excellence models. The research encompassing Quality and Industry 4.0 is scarce. Authors have focused on customers [17], quality, Lean, Industry 4.0 [18], quality scorecards [19], quality management and Industry 4.0 [20], or, more recently, quality as a strategy for Industry 4.0 adoption [21,22].

The EFQM 2020 model incorporates TQM, Industry 4.0, and sustainability principles and approaches. It emphasizes the simultaneous delivery of outstanding performance while managing the Industry 4.0 paradigm transformation. The model can provide organizations with a comprehensive, updated, and integrated business model, and contribute to quality and organizational excellence in the Industry 4.0 era. To sum up, the EFQM 2020 model and Industry 4.0 approaches share common goals, to improve organizational performance, yet with different conceptual foundations.

More specifically, this study attempts to answer the following research questions (RQs):

- RQ1. What are the novel features of the EFQM 2020 model?
- RQ2. What are the relationships and implications between the EFQM 2020 model and Industry 4.0?
- RQ3. Is the EFQM 2020 model a novel Quality 4.0 management system?

Given the EFQM 2020 model's novelty and the literature gap when considering adopting both the EFQM 2020 model and Industry 4.0, this research highlights the major changes brought by the novel EFQM model and the relationships and implications between the EFQM 2020 model and the Industry 4.0 paradigm, which are relevant topics for business excellence model research and practice.

This paper is structured as follows: after the introductory and methodology sections, Section 3 presents the literature review encompassing the EFQM 2020 model, Industry 4.0, and Quality 4.0. The discussion of the EFQM 2020 and Industry 4.0 relationships is carried out in Section 4. The manuscript ends with Section 5 that presents the study conclusions, outlook, and implications.

2. Materials and Methods

A mixed inductive–deductive approach supports this research methodology. An example of the deductive approach is the detailed analysis of the EFQM 2020 model and its comparison with the previous version of 2013. In the deductive approach, the dimensions related to the EFQM models were known. The purpose was to determine, based on the keywords and criterion description, how the EFQM model addresses organizations in

terms of identifying stakeholders' needs and supporting them throughout the business process definition, therefore enhancing creation, capture, and value delivery to achieve outstanding and enduring results.

The inductive approach involves Industry 4.0 knowledge and related developments, e.g., the review process emphasized that Industry 4.0 is supported by technological, human, information, and knowledge resources, and complementarities amongst them [23]. Therefore, managing knowledge, skills, and capabilities to benefit from Industry 4.0 paradigm is a must.

The course of actions performed in this research followed the PRISMA guidelines (Moher et al. [24] and Torraco [25]), as presented in Figure 1. In the first phase of the review (identification), potential papers of interest were identified using a broad set of inclusion criteria to encompass the relevant literature [25]. Since the topic of research has a strong practical nature, in addition to papers published in peer-reviewed academic journals, the review also included "gray" literature (e.g., conference proceedings, magazines, and books), as suggested by Adams [26]. The primary literature search was performed in science databases (e.g., Scopus and Web of Science) with keyword analysis (EFQM 2020, business excellence models, Industry 4.0, cyber-physical systems (CPSs), Internet of Things (IoT), Quality 4.0). The aim was to map the state of the art related to the EFQM business excellence model support for Industry 4.0.

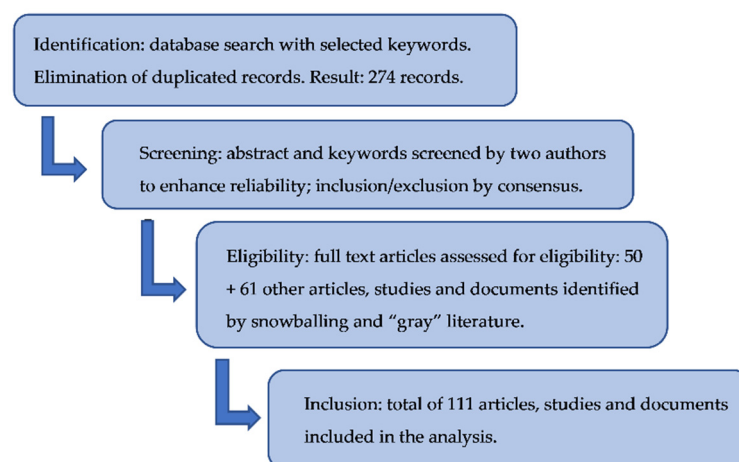


Figure 1. Literature review flowchart (adapted from PRISMA).

After removing duplicated records, the screening phase followed. To enhance the screening reliability, two authors performed the screening phase, excluding papers not focusing on the EFQM model or Industry 4.0. Subsequently, the authors identified the highest impact papers, and in some unclear cases (e.g., inclusion/exclusion decision), the two authors discussed and reached an agreement. After the title and abstract screening, a total of 111 papers and documents were eligible and included for the complete full-text review (eligibility phase and inclusion phase).

The EFQM 2020 model literature review revealed a scarcity of scientific papers addressing the novel model, except for [6,7], suggesting the existence of a research gap. Hence, the contents of scientific papers covering previous EFQM model editions [2–8,27–37] and the EFQM model reference models [38–41] were analyzed to complement this review. Two authors (with EFQM assessment experience) carried out the detailed content analysis of the EFQM 2013 and 2020 models, including a detailed comparison and a critical analysis of the 2020 version. The literature review of Industry 4.0 aimed to identify the current state of the art and its possible relationships with business excellence models. The Industry 4.0 literature review encompassed the content analysis of 16 papers, emphasizing [42–44]. This review highlighted that Industry 4.0 is still in the early stages for most organizations. Digital transformation will require strong leadership, the right human competencies and

skills, and a demand for new work ethics and management systems. Concerning the review of Quality 4.0 articles, the results were also limited. A total of 16 articles were identified for review, with authors addressing the application of quality methods and tools in an I4.0 environment and, more recently, the strategic role for Industry 4.0 adoption.

The manuscript then proceeds with a critical content analysis of the EFQM 2020 model and its support for Industry 4.0 and Quality 4.0, followed by the research conclusions and outlook.

3. Literature Review

3.1. The EFQM 2020 Model

Since the seminal work of Peters and Waterman, “In Search of Excellence” [1], the concept of excellence has been alive within the business and academic world, and business excellence models (BEMs) have been proposed as assessment frameworks for organizational excellence. Research results support the view that BEM adoption contributes to several organizational benefits [2], namely, improved performance [4,5], enhanced customer satisfaction [27,28] and employee satisfaction [29,30], profitability, reputation, and operational improvement [31,32].

From the several available BEMs, the Malcolm Baldrige National Quality Award (MBNQA) from the USA, first granted in 1989, and the European Foundation for Quality Management (EFQM) Excellence Award, awarded for the first time in 1992, have been recognized worldwide as the most influential ones [28,33,45].

Since its introduction in 1991, the EFQM model has been supporting organizations of diverse industries and dimensions to improve organizational performance and achieve sustainable business results [34,35], including higher financial and non-financial performance [36]. However, new global trends and changes in the business environment (e.g., Industry 4.0) call for a review and update of BEMs [37]. For the EFQM (2013), “Excellent Organizations achieve and sustain outstanding levels of performance that meet or exceed the expectations of all their stakeholders”.

The EFQM model is periodically updated to respond to the global and business environment dynamics and trends. Therefore, the EFQM 2013 model [38,39], presented in Figure 2, was reviewed to ensure its validity and value.

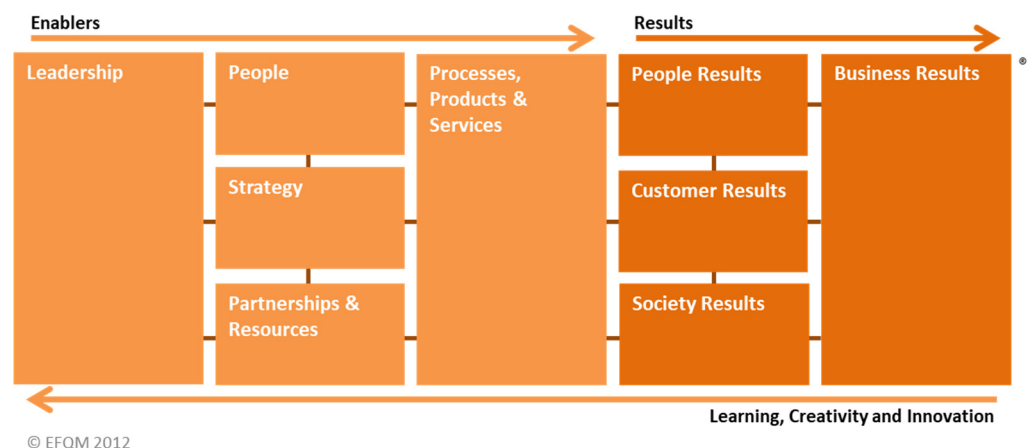


Figure 2. The European Foundation for Quality Management (EFQM) 2013 model (EFQM, 2012).

The novel EFQM 2020 model [40,41], shown in Figure 3, is the outcome of the EFQM 2019 co-creation process that involved a wide range of EFQM stakeholders, from business and academia. The EFQM 2020 model literature review revealed a scarcity of scientific papers addressing the novel model, with the exception of [6,7]. Hence, the contents of papers covering previous EFQM model editions [2–8,27–37] and the EFQM model reference models [38–41] were analyzed to complement this review.



Figure 3. The EFQM 2020 model (EFQM, 2020).

The EFQM 2020 model calls for new mindsets, disruptive approaches, and collaborative leadership to ensure that organizations can simultaneously manage both change and operations with increased agility and improved levels of performance. Furthermore, the EFQM 2020 model is framed in the United Nations Sustainable Development Goals (SDGs) and European business ethics values.

The EFQM 2020 model comprehends three different dimensions, direction (why), execution (how), and results (what), with a total of seven criteria (and twenty-three criterion parts, plus two results Criteria) and the RADAR (Result, Approach, Deploy, Assess, and Refine) assessment tool.

The EFQM 2013 and 2020 models’ criteria and sub-criteria were compared based on the keywords and criterion description. Additionally, since specific guidance points support both EFQM models’ sub-criteria, a similar analysis was made between guidance points for 2013 (total of 119 guidance points) and 2020 (total of 112 guidance points) models. The analysis results are presented in Table 1 and Figure 4 (see Table 2 for Figure 3 legend). The results highlight that Leadership, Strategy, Product Process and Services, and Business Results are the EFQM 2013 model criteria that more strongly influence the EFQM 2020 model. Conversely, the criteria from the EFQM 2020 model that have a stronger adoption of guidance points from the EFQM 2013 model are Purpose, Vision & Strategy, and Organisational Culture and Leadership.

Table 1. EFQM 2020 and EFQM 2013 comparison.

	EFQM 2020	EFQM 2013
Criterion	1. Purpose, Vision & Strategy	1. Leadership
	2. Organisational Culture & Leadership	2. Strategy
	3. Engaging Stakeholders	3. People
	4. Creating Sustainable Value	4. Partnerships & Resources
		5. Processes, Products and Services

Table 1. Cont.

	5. Driving Performance & Transformation	4. Partnerships & Resources
		6. Customer Results
	6. Stakeholder Perceptions	7. People Results
		8. Society Results
	7. Strategic & Operational Performance	9. Business Results
Criterion parts	23 Criterion Parts and 2 Results Criterion	32 Criterion parts
Criteria weightings	600 points for Direction and Execution and 400 points for Results	500 points for Enablers and 500 points for Results

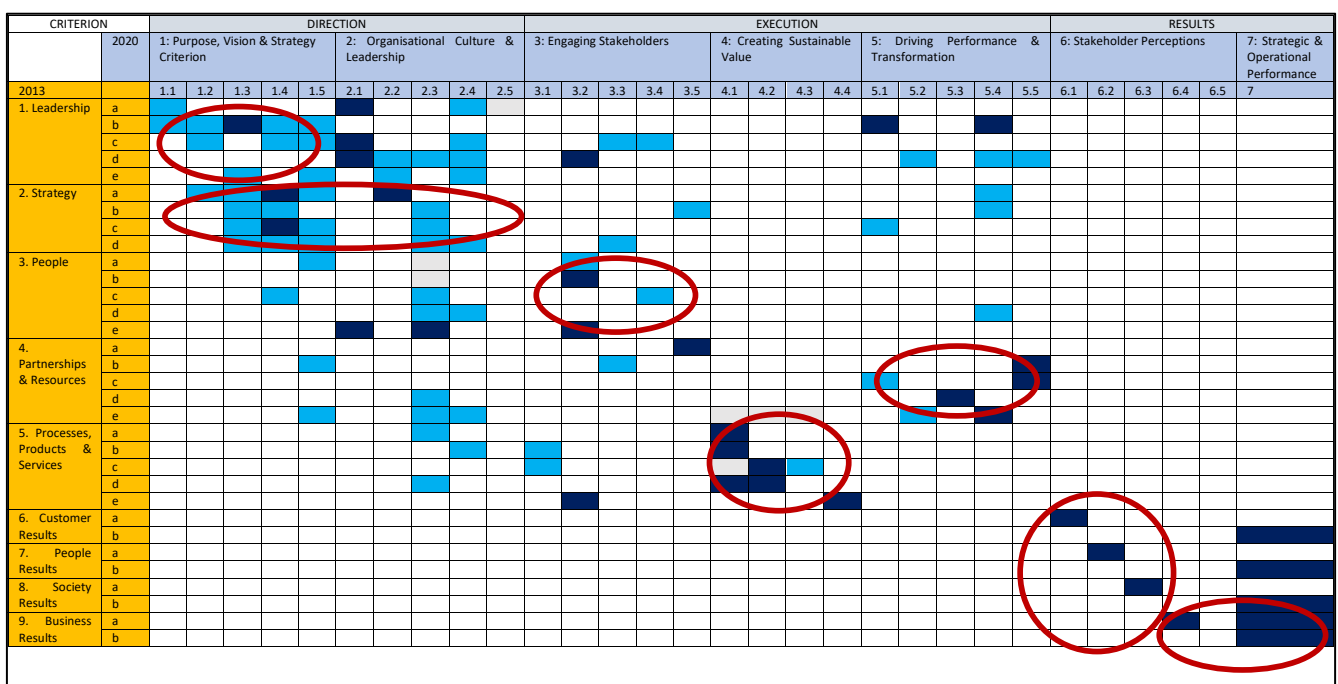


Figure 4. EFQM 2013 versus EFQM 2020.

Table 2. Legend for Figure 4.

	High Correlation between Sub-Criteria
	Medium correlation between sub-criteria
	No correlation between sub-criteria

To exemplify the detailed content analysis between EFQM 2013 and EFQM 2020, EFQM 2013 criterion 1a. states that “Leaders develop the mission, vision, values and ethics and act as role models”. Furthermore, guidance point no. 2 clarifies that “leaders in excellent organisations champion the organisation’s values and are role models for integrity, social responsibility and ethical behaviour, both internally and externally, to develop and enhance the organisation’s reputation”. Conversely, one EFQM 2020 criterion is “2.1 Steer the Organisation’s Culture & Nurture Values,” and states that an outstanding organization (guidance points) “Nurtures its values, translating these into desired norms & behaviours that it promotes, communicates, and clearly demonstrates through its actions, . . . , raising awareness of the importance of adopting a responsible approach to the environment, . . . Identifies, recognises, and promotes other role models . . .”. Hence, the conclusion based on the italic keywords is that there is a strong correlation between these two sub criteria.

The 2020 EFQM model is positioned for outstanding organizations that create sustainable value, emphasizing their ecosystem and identifying, prioritizing, and monitoring stakeholder expectations. The model is based on five key concepts, Culture, Leadership, Transformation & Performance, Flexibility & Adaptation, and Focus on the Future. Cause and effect relationships need to be considered (e.g., the link between criterion 3—Stakeholder Engagement, and criterion 6—Stakeholder Perceptions). Risks and opportunities should be assessed, and the analysis of data and performance should lead to predictive measures to prepare for the future and contribute to outstanding enduring performance. Comparing the EFQM 2020 model with the 2013 version, the construct of the model has changed from the nine criteria (five enablers plus four results) of the 2013 model (and 32 sub-criteria) to seven criteria (five enablers and two results). There are now 25 sub-criteria, with more flexibility and less bureaucracy, as Bandyopadhyay and Leonard [45] suggested.

As highlighted in Figure 3, Strategy and Business Results from the 2013 criteria significantly influence the 2020 model criteria. However, the People criterion (3) of the 2013 model is not directly related to a 2020 model criterion and is now spread across several criteria of the EFQM 2020 model, with People as a critical organizational stakeholder: criterion 1.1 (Purpose and Vision should inspire all the organisation decisions and its People); criterion 1.2 (Identification & Understanding of Stakeholder needs, including People); criterion 2.1–2.4 (creation of the desired work environment for People); criterion 3.2 (People—Attract, Involve, Develop and Retain); criterion 6 (Perception of Stakeholders), including People; and criterion 7 (Measure other aspects of performance in people management). However, there is a shortage of recommendations concerning people management, such as the definition of skills, competencies, and people’s performance levels. The same is related to promoting teamwork and inspiring people to participate in activities that could benefit society at large [7].

Process management is also not explicitly referenced in the EFQM 2020 model. Nevertheless, criteria such as 1.4 (Develop Strategy), 1.5 (Design and Implement a Governance and Performance Management System), and 5.1 (Drive Performance and Manage Risk) convey expectations about management systems and governance.

In the 2013 model, “harnessing Creativity & Innovation” was covered in 1.e (flexibility and change management), 2d (Guidance point to set clear goals for innovation), 3.c (guidance point on innovation scope and creativity and innovation culture), and 4.e (guidance point on managing learning and collaboration networks). Creativity and innovation are specifically addressed in criteria 2.3 (Enable Creativity and Innovation, with six guidance points) and 5.3 (Drive Innovation & Utilise Technology, with five guidance points), emphasizing these two critical success factors.

In a literature review about national quality awards and business excellence models, Jankalová and Jankal [46] concluded that there is a relationship between business excellence and sustainability dimensions. The EFQM 2013 model encompassed “Creating a Sustainable Future” within the fundamental concepts of excellence, calling for the “integration of the concepts of sustainability within the organization core strategy, value chain and process design and allocating the resources required to deliver these goals”. Moreover, the concept of “People, Planet and Profit” is considered as a reference and assumes that an excellent organization will respect and comply with the 10 principles of the UN Global Compact. However, this has been further emphasized. Sustainability is now at the core of the EFQM 2020 model, with the framework linking the organization’s purpose and strategy and ensuring its alignment with the United Nations Sustainable Development Goals (SDGs). The SDGs represent a shared expression of stakeholder needs at a global level to ensure simultaneous economic, social, and environmental development [47]. The SDGs are incorporated into criteria 1.3 (Understand the Ecosystem, Own Capabilities & Major Challenges) and 6 (Stakeholder Perceptions). Furthermore, sustainable levels of performance, a sustainable future, and sustainable value are further addressed in criteria 1.1, 2.1, 3.1, 3.5, 4.3, 5.1, 5.2, 5.4, 5.5, 6, and 7. With the incorporation of the SDGs, the

EFQM 2020 model aims to simultaneously deliver performance and ensure transformation, creating enduring value for the organization stakeholders and achieving remarkable and enduring results.

Business models describe how an organization does business [48,49], by describing the activities to execute its strategy [50], summarizing the business logic and approach [51]. According to Baden-Fuller and Morgan [52], business models (BMs) are archetypes of value creation and capture. For Amit and Zott [53], BMs comprehend an activity system of interconnected and independent activities that establishes how a company does business with its customers, suppliers, and partners to satisfy the market's perceived needs and other interested parties. However, in the new EFQM 2020 model, some of the critical dimensions and interactions that support a business model are not evident, e.g., how to link strategy for operationalization; how to communicate the strategy; how to prioritize and manage different stakeholders' expectations; and how to manage competency and skills development which will be critical towards ensuring a smooth transition throughout the business's digital transformation.

3.2. Industry 4.0

Industry 4.0 (I4.0) is commonly described as the fourth industrial revolution, and the concept was first presented in 2011 at the Hanover Fair, with continuity by a working group coordinated by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann (Acatech). I4.0 relies on applying cyber-physical system (CPS) principles, internet and future-oriented technologies, and smart systems. The enhanced connectivity of these human-machine interaction paradigms enables real-time identification and communication for every entity in the value stream to properly handle the business complexity [54–56].

The 4th industrial revolution was preceded by the 3rd industrial revolution ("automation and informatization," with the introduction of computers, automation, and standalone robotic systems), the 2nd industrial revolution ("electrification," with electric power assembly lines and mass production), and the 1st industrial revolution ("mechanization," with mechanical production and steam-powered machines). I4.0 brings together the physical and virtual worlds, supported by key technologies, such as autonomous robots, big data and analytics, augmented reality, additive manufacturing (3D printing), the cloud, cybersecurity, the Internet of Things, horizontal and vertical system integration, and simulations [57]. According to Galati and Bigliardi [58], the academic research covering Industry 4.0 shows considerable growth with a strong technology focus.

Alcácer and Cruz-Machado [42] argue that Industry 4.0 leads to the digitalization era where everything is interconnected with a corresponding virtual representation from business models to environments, production systems, machines, operators, products, and services. Industry 4.0 promotes the adoption of new organizational business models and embedding new business practices that intend to evolve the organizational efficiency level [59], and simultaneously embrace market challenges regarding circular economy and sustainability without neglecting the operation excellence [60]. It is characterized by the advanced digitalization and integration of industrial manufacturing and logistics processes, and the use of the internet and "smart" objects (machines and products) that merge the physical and the virtual worlds with the adoption of information and communications technology (ICT) [61]. Industry 4.0 uses intelligent processes and products supported by autonomous data collection and analysis and with end-to-end integration, resulting in smart, intelligent, and efficient processes, and is supported by nine pillars (or building blocks), namely [62]:

- The industrial Internet of Things (IIoT) allows people and things to be always interconnected, digitalizing all physical systems towards ensuring transformational solutions that will be foundational for future complex business ecosystems [43].
- Cloud computing, using cloud applications and services conveniently combined towards enhancing systems interoperability, data sharing, and the improvement of systems' performance over time [63].

- Big data: “large volumes of high velocity, complex and variable data requiring advanced techniques to enable the capture, storage, distribution, management and analysis of the information” [64].
- Simulation: the development of digital twin models to better understand the dynamics of simulations in business systems applicable to all product lifecycle phases. The combination of real-life data with simulation models improves productivity and maintenance performance, based on realistic data [65,66].
- Augmented reality (AR) improves human performance by providing the information required for a given task [67]. As an example, AR enhances human performances in technical maintenance task execution as it supports improved maintenance decision making [67].
- Additive manufacturing is a technology, also known as rapid prototyping, digital manufacturing, or 3D printing, that enables the development of new products and business models [68].
- Horizontal and vertical system integration, with collaborative scenarios of system integration and real-time sharing [69].
- Autonomous robots with AI and improved adaptation and flexibility can support different manufacturing processes and decrease production costs [69].
- Cybersecurity (CS) is related to a high level of information security and involves technology to protect, detect, and respond to attacks [70,71].

Supported by a bibliometric analysis of Industry 4.0, Muhuri et al. [44] found that the most common keywords indexed in WoS (Web of Science) and Scopus are cyber-physical systems, the Internet of Things, smart factory, manufacturing systems, simulation, and cloud computing. The authors posit that I4.0 research is growing rapidly each year. However, business models for I4.0 are not one of the identified backgrounds and application areas, which corroborates the present research’s interest.

Moreover, the World Economic Forum [72] identified the following future developments within I4.0. Artificial intelligence (AI) can provide new problem-solving solutions and reduce material and energy consumption. Increased automation will improve productivity and efficiency while reducing human stress in human and environmental impacts. I4.0 can enable a sharing approach environment (product as a service) to reduce consumption-related waste and improve the product lifecycle. Providing real-time data to all decision makers improves overall collaboration and decision-making quality. Some of the most emphasized benefits of I4.0 are presented in Table 3.

Table 3. Industry 4.0 benefits.

I4.0 Reported Benefits	Author
Enhanced integration of business processes across the entire value chain, through data flow and cyber-physical systems (CPSs), promoting more flexible structures and data exchange among all the elements.	Wan et al. [73], Bonilla et al. [74].
Improved productivity and efficiency, enhanced planning and forecasting, reduced cost, improved innovation, flexibility, and agility.	Alcácer and Cruz-Machado [42], O’Rielly et al. [75], Lasi et al. [54], Daki et al. [76], Oesterreich and Teuteberg [77].
Support for new business models that allow new ways of value creation, e.g., cloud-based, service-oriented, process-oriented business models.	Kiel et al. [78].
Improved customization and customer experience.	O’Rielly et al. [75], Kiel at al. [78].
Improved quality products and zero defect diagnostics.	Napolitano et al. [79], Ferreira et al. [80].
Intelligent learning analysis.	Biagi & Falk [81].
Simulation and virtualization.	Antonelli et al. [82], Canadasa et al. [83], Gunal [84].
Ecological sustainability, e.g., more efficient resource utilization, and social sustainability, e.g., workers more supported to do their job.	De Sousa Jabbour et al. [85], Wang et al. [86].

The embedding of the I4.0 paradigm, through the adoption of all technologies, the development of new business models, and the adaptation of the new competencies mix, will, in its broader view, contribute to pointing the roadmap towards achieving the factory of the future. The factory of the future (FoF) will be a highly flexible and thoroughly connected factory where data can be accessed anytime, anywhere. The FoF will be supported by Industry 4.0 combined with 5G and optimized with artificial intelligence, and people and intelligent machines working in collaboration as a team. 5G networks support reliable and ultra-fast data transfer and machines react almost instantaneously. Companies can, therefore, access data in real time and make appropriate decisions in line with their value chain.

The relationships and contributions of Industry 4.0 to sustainability are an emergent and vibrant research theme [87]. Researchers emphasize that the successful adoption of Industry 4.0 can positively impact sustainability by improving communication and information flows [88]; fostering knowledge sharing and collaborative work and improving production efficiency and productivity [89,90]; reducing costs and enhancing customer experience [90]; and supporting novel business models [89,90]. Moreover, the combination of Industry 4.0 technologies with improvement methodologies (e.g., Lean) can foster employee morale, reduce lead time, improve product quality, and customize products and reduce waste [77,91,92]. However, researchers have also identified potential negative impacts of Industry 4.0 on sustainability due to labor-saving technologies and increased production and consumption rate due to Industry 4.0 adoption, all of which can generate undesirable increases in resource consumption, income inequality, job losses and labor market disruption, and cybersecurity risks [74,93,94].

Digital transformation is revolutionizing every sector. This new challenge should encourage companies to invest in new technologies, train employees, and have experts in the right positions.

Industry 4.0 will promote new business models that emphasize differentiation by innovation and speed, customization, and better quality. Innovation cycles can be shortened, productivity raised, and quality improved according to Davies [95]. However, Industry 4.0 is still in the early stages for most companies. Sanders et al. [8] conclude that many organizations are still trying to disclose its implications and challenges and understand the right mix of competencies for this new reality. Therefore, digital transformation will require strong leadership, the right human competencies, and overcome the several barriers identified for its successful implementation [61]. Managing I4.0 demands new skills, work ethics, and management systems [72]. Additionally, there are also some reported challenges and predicaments for I4.0, namely, resistance to change [96], increased capital requirements [97], need for effective training and education [98], privacy and security concerns [99] and issues of data ownership [77]. Furthermore, lack of I4.0 integration with the overall business strategy can negatively impact environmental performance [100,101] and generate significant jobs losses [72].

3.3. Quality 4.0

Business and management models are essential to support Industry 4.0 adoption and foster sustainable value creation and competitiveness [16]. Quality 4.0 (or Q4.0) combines quality management with digitalization and technology [14,15], which provides a management and process dimension to the digital transformation technology driver.

Not only product and process quality are required for Industry 4.0 to improve flexibility and productivity, but also the quality management body of knowledge (encompassing models, systems, techniques, and tools) coupled with extensive application experience, which can support the planning, implementation, and improvement of Industry 4.0 processes. Q4.0 can, therefore, improve I4.0 quality and results. Empirical research addressing total quality management (TQM) and information technology (IT) seems to support that view [102] by concluding that while TQM had a significant impact on performance, and IT had a positive impact on TQM implementation, there were no significant performance

improvements due to the direct application of IT. These findings suggest that I4.0 would largely benefit from Q4.0.

Nevertheless, research and innovations encompassing quality and digital transformation and technologies are scarce [37,103]. Consequently, quality and organizational excellence academicians and practitioners should engage in and make novel contributions to the Quality 4.0 theme if they want to ensure future relevance and minimize the risk that the technology dimension overtakes the arena. As highlighted by academicians such as Hyun Park et al. [20], Rowlands [21], and Rowlands and Milligan [22], a clear quality focus and solid management systems are required for achieving comprehensive and enduring benefits from technological advancements. Quality and Industry 4.0 should be strategically and operationally integrated, with quality providing the methodology and tools to drive change and improvement.

In that regard, the EFQM 2020 model, while not explicitly mentioning quality and excellence, has strongly embedded quality management principles and concepts, incorporating a system and improvement approach with a strong stakeholder (and customer) focus. The model provides a strategic dimension to Industry 4.0, complemented by criteria and guidance points that can support its application, monitoring, and improvement. However, due to the generic nature of the model, the criteria and guidance points need to be specifically tailored and detailed further for each business, for application of the quality methods, techniques, and tools. In other words, the EFQM 2020 model encompasses quality management models but should be complemented by more “hard” quality engineer approaches, methods, techniques, and tools.

4. Discussion of the EFQM 2020 Model and Industry 4.0 Relationships and Implications

The mapping between EFQM 2020 and 2013 models can assist thousands of organizations that already adopted the EFQM 2013 version to perform the right transition and adaptation to the novel 2020 model. The EFQM 2020 model deeply emphasizes transformation. Nevertheless, the topic is not explicitly mentioned in the Direction and Organisational Culture & Leadership criteria and only in criterion 5.2 (Transformation for the Future) is this topic explicitly dealt with, which seems quite late and limited, as Driving Performance & Transformation should follow the organizational mission, vision, and strategy, supported by an effective deployment.

Since the EFQM 2020 model highlights transformation and future focus, it should support the successful adoption of Industry 4.0 to create stakeholders’ enduring value and support the proper organizational alignment with the digital transformation trend. However, given the generic and non-prescriptive nature of the EFQM 2020 model, the links between Direction and Organisational Culture & Leadership criteria and Driving Performance & Transformation, specifically criterion 5.2 (Transformation for the Future), are not evident, which might be problematic for the success of transformation and technology transformation strategies.

In the EFQM 2013 model, leaders “should shape the future and make it happen” and criterion 4.d addressed how technology is managed to support the delivery of strategy. Although the need to transform for the future encompasses technology and digital transformation, technology is not an explicit topic spread through the EFQM 2020 model. The previous model was focused on a periodic review of strategy, leadership effectiveness, and communication strategy as the essential elements for marching towards excellence or transformational initiatives. However, this is not present with the same level of importance in the 2020 model, and there is no explicit reference to the nine pillars of Industry 4.0.

The EFQM 2020 model calls for an organization to ask themselves: what do they want to achieve with change? Where do they start from? What is the plan? How will they check on its progress? The EFQM 2020 model mindset is framed by creativity, innovation, and disruptive thinking, which are essential ingredients for Industry 4.0 and FoF attainment. Notwithstanding, EFQM criteria and RADAR, organizational self-assessments, or external assessments can challenge, support, and shape organizations to move towards

new knowledge and performance dimensions. The criteria help organizations to identify what outstanding ones do, good practices, and gaps between the present and the desired practices, while RADAR identifies how the organization is working and what could be improved.

By analyzing the EFQM 2020 model's content [40,41], namely, the model criteria and guidance points, several clear links with Industry 4.0 are identified, as presented in Table 4.

Table 4. EFQM 2020 model and Industry 4.0 relationships.

EFQM 2020 Criteria	EFQM 2020 Model Guidance Points Related to I4.0
1.3 Understand the Ecosystem, Own Capabilities & Major Challenges	<ul style="list-style-type: none"> • Researches and understands the ecosystem, including megatrend implications, and the consequences of it on the United Nations Sustainable Development Goals and Global Compact ambitions. • Assesses and evaluates the data, information and knowledge gathered from across its ecosystem to understand the major challenges for today and in the future.
2.2 Create the Conditions for Realising Change	<ul style="list-style-type: none"> • Facilitates an open mindset towards learning in the pursuit of its strategy, encouraging the improvement and, at times, transformation of the organization.
2.3 Enable Creativity and Innovation	<ul style="list-style-type: none"> • Understands the importance of focusing on creativity, innovation, and disruptive thinking to help in the achievement of organization's purpose, vision, and strategy. • Engages learning and collaboration networks to identify opportunities for creativity, innovation, and disruptive thinking.
5.2 Transform the Organisation for the Future	<ul style="list-style-type: none"> • Identifies the transformation and change needs, considering its purpose, strategy, sustainable value creation objectives, and results and scanning its ecosystem to forecast the main challenges and opportunities for the future. • Adapts current strategy and existing business models to meet future needs and implements new business models based on the challenges and opportunities that are forecast. • Restructures its value creation in a timely manner and other organizational processes based on operational excellence and future needs.
5.3 Drive Innovation & Utilise Technology	<ul style="list-style-type: none"> • Provides the capabilities, resources, and tools that develop and sustain creativity, innovation, and disruptive thinking. • Evaluates and exploits the potential that new technologies have to support ongoing value creation, improvements to its infrastructure, and the responsiveness and adaptability of its processes and projects. • Introduces relevant developments in technology at the right speed that maximize the benefit to be gained.
5.4 Leverage Data, Information & Knowledge	<ul style="list-style-type: none"> • Ensures that it has identified the proper data towards supporting its transformation plans as well as managing the products, services, and solutions it currently offers, and is proficient in acquiring any essential information that may be lacking. • Uses advanced analytics, including predictive models, to extract value from data, gain actionable insights, and make informed decisions. • Converts data into information and knowledge and uses the outcomes to identify potential opportunities for creating further sustainable value. • Makes use of the knowledge held by key stakeholders to generate ideas and innovations, including the potential for working together, to develop products, services, and solutions that create sustainable value. • Ensures that data, information, and knowledge are treated and used in an ethical way, respecting the needs and rights of those providing the data, information, and knowledge. • Secures, protects, and maximizes the unique knowledge, such as the intellectual property, that it owns.

Table 4. Cont.

EFQM 2020 Criteria	EFQM 2020 Model Guidance Points Related to I4.0
5.5 Manage Assets & Resources	<ul style="list-style-type: none"> Identifies and responsibly manages the critical assets and resources that are vital for its strategy, performance, and transformation needs, including financial assets (cash, capital, investments), tangible assets (trading infrastructure, such as supply chain, real estate, technology, and machinery), and intangible assets (proprietary data, self-developed software/technology, brand, goodwill, patents).
6. Stakeholder Perceptions	<ul style="list-style-type: none"> Customer perception results: what the perceptions of the customers are in relation to, for instance, the usage of technology by the organization to help deliver sustainable value. People's perception results: for example, the co-existence of people and robots, the use of artificial intelligence and augmented and virtual reality. Business and governing stakeholders' perception results: the ability of the organization to scan the horizon, spot megatrends, and deal with them successfully. Partners and suppliers' perception results: what the perceptions are of the key partners and suppliers in relation to, for instance, the rate of implementation of new technologies and changes.
7. Strategic & Operational Performance	<ul style="list-style-type: none"> Achievement of strategic objectives. Achievements in driving performance. Achievements in driving transformation. Predictive measures for the future.

The Industry 4.0 review process identified that managing knowledge, skills, and capabilities is critical for the successful adoption of Industry 4.0 to its full extent and plenitude. The right combination of competencies and the proper context to enhance skill development, as well as the alignment of the entire organizational structure, is strategic for achieving a transformational organization, and “intellectual capital management” is a core factor in the success of Industry 4.0 [8]. This is supported by the World Economic Forum [72] that posits “skills gaps—both among workers and among an organisation’s senior leadership—may significantly hamper new technology adoption and therefore business growth”. Turisova et al. [104] applied a modified EFQM 2013 model to assess Slovak managers’ perception of I4.0, focusing on the integration level of complex safety in management systems and the impact of digitalization on occupational health and safety. Although this investigation did not address the novel EFQM 2020 model and had a limited scope (only the enabler criteria of the EFQM 2013 model), it identified the perception of organizational readiness for I4.0 changes in the “Employees (Pe)” criterion as the lowest. Furthermore, the World Manufacturing Forum [105] also recommends promoting social awareness about topics such as AI to help stakeholders address key issues and harness the potential of AI in manufacturing now and in the future.

As identified in Section 3.1, the People criterion (3) of the 2013 model is not directly related to a 2020 model criterion and is now spread across several criteria of the EFQM 2020 model. Moreover, recommendations related to people management (e.g., the definition of skills, competencies, and people’s performance levels), or the promotion of teamwork and inspiring people to participate in activities beneficial for society at large, are not explicit in the novel EFQM 2020 model, which could be a critical shortcoming for Industry 4.0’s successful adoption. To conclude, the EFQM model and Industry 4.0 approaches share common goals, such as to improve organizational performance, yet with different foundations.

With Industry 4.0’s focus moving from the details of technologies and building blocks to a more holistic and business model dimension [90], the EFQM 2020 model is a step in that direction. It is a comprehensive and updated business model that shares with Industry 4.0 the emphasis on transformation and improved organizational performance, and several

linkages between the EFQM model and I4.0 have been identified. Additionally, the new EFQM digital platforms (AssessBase and KnowledgeBase) are good examples of the EFQM vision for digitalization and EFQM key stakeholders have been prepared and trained to take advantage of these tools.

Moreover, sustainability and the United Nations Sustainable Development Goals (SDGs) are emphasized through the EFQM 2020 model. The SDGs represent a shared expression of stakeholder needs at a global level, contributing to enduring economic, social, and environmental development [47], supporting the integration, operationalization, and measurement of sustainable development progress [106].

5. Conclusions and Outlook

To sum up, relating to RQ1 (What are the EFQM 2020 model's novel features?), the EFQM 2020 model adopts a more logical and business-minded structure than the 2013 version. It emphasizes transformation and future focus that can support organizations in successfully adopting Industry 4.0, enhancing digital maturity, contributing to differentiation level, and embracing the path towards excellence [107]. The EFQM 2020 model, with the 23 criterion parts and one results criterion, together with the 112 guidance points and the RADAR assessment tool, provides a more detailed logic and framework than other common strategic frameworks that lack that detailed structure [108]. The EFQM 2020 and EFQM 2013 comparison can help organizations successfully transition to the 2020 model, further emphasizing sustainability by adopting the SDGs.

Nevertheless, due to the generic and non-prescriptive nature of the EFQM 2020 model, the guidance points are generic (as reported by Nenadál [7]). Additionally, some links between the applicable criteria (e.g., Direction and Performance and Transformation) are not evident, and there are no specific references to the nine I4.0 pillars. Moreover, the specific approaches, relationships for the success of transformation and technology transformation strategies, and the recommendations related to people management are not explicit in the novel EFQM 2020 model, all of which might be considered vague and problematic in the implementation phase and could be a shortcoming for the successful adoption of the EFQM 2020 model and Industry 4.0. Hence, concerning RQ2 (What are the relationships and implications between the EFQM 2020 model and Industry 4.0?), Industry 4.0 is indeed well framed in the EFQM 2020 model. However, due to the model's generic nature, an additional level of detail is needed for its successful implementation.

As an overall conclusion, is the EFQM 2020 model a novel Quality 4.0 management system (RQ3)? The EFQM 2020 model is not branded as a quality management model or a business excellence model. It is a holistic business model that aims for sustainable, outstanding results. However, in more detailed content analysis, it incorporates a system approach and is stakeholder focused (naturally including customers). It encompasses sustainability principles and the UN SDGs. Moreover, Industry 4.0 is addressed in several of the model criteria and guidance points, which can contribute to quality and organizational relevance for successful digital transformation, as demanded by academics such as Zonnenshain and Kenett [109].

Nevertheless, some quality and organizational academicians and practitioners may consider it generic and vague and lacking in a prescriptive nature. In a nutshell, the answer to RQ3 might be a mixed one. The EFQM 2020 model is indeed an integrated, holistic, and updated business model that encompasses and supports sustainability and Industry 4.0 principles without explicitly referring to quality or even excellence. The model can be a leading force in the I4.0 transition, providing an integrated strategic framework for quality, excellence, and sustainability, within an I4.0 paradigm. However, it should be complemented by suitable quality approaches, methods, techniques, and tools, for the full potential of Q4.0.

This research has several implications for practitioners and academia. It supports organizations that wish to transition to or adopt the 2020 EFQM model, resulting from an extensive creation process to simultaneously foster performance and transformation.

From a theoretical point of view, it contributes to the novel and scarce body of knowledge addressing the EFQM 2020 model, and its possible relationships and synergies with both sustainability and Industry 4.0, as significant business and societal driving forces. Gunasekaran et al. [20] claimed that the BEM paradigms must consider Industry 4.0 and digital transformation. The EFQM 2020 model can contribute to conciliating the managerial and human side with a more technological perspective and foster the adoption of novel value creation business models that simultaneously emphasize delivering outstanding and enduring performance while preparing for future transformations. It brings a strategic and technologically unbiased perspective to Industry 4.0. Can this be the novel Quality 4.0 paradigm?

Given this research's exploratory nature, future investigations, with empirical support of EFQM 2020 model application, are recommended to further develop this subject. Moreover, Q4.0 calls for additional research addressing the application of quality methods and tools within the I4.0 paradigm, but also the application of Q4.0 to support both I4.0 and sustainability at strategic and operational levels.

The identified possible shortcomings can also induce further research and new tools to assist successful practitioners' implementation and enduring value creation. By analyzing all data available from the entities that adopt the EFQM 2020 model, it will be possible to develop an adequate analytical layer to suggest a dynamic individual roadmap. This will be flexible enough to fit with the organization's business sector and dimension, the value chain level of complexity, and the current availability of resources towards propelling the business's practices that will favor the paths towards excellence. Additionally, as suggested by recent management systems' certification research [110,111], control variables such as country, size, industry level, and culture should be investigated to identify possible different EFQM 2020 and Industry 4.0 adoption patterns.

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