Arab American University

Faculty of Graduate Studies

Department of Administrative and

Financial Sciences

Master Program in Quality Management

The Readiness Assessment of Implementing Quality 4.0 in Food Industries in Palestine

Muna Rizeq Ahmad

202112772

Supervision Committee:

Dr. Sami Sader

Dr. Ashraf Almimi

Dr. Yahya Saleh

This Thesis Was Submitted in Partial Fulfilment of the Requirements for the Master Degree in Quality Management.

Palestine, 2 / 2025

Arab American University

Faculty of Graduate Studies

Department of Administrative and

Financial Sciences

Master Program in Quality Management

Thesis Approval

The Readiness Assessment of Implementing Quality 4.0 in Food Industries in Palestine

Muna Rizeq Ahmad

202112772

This thesis was defended successfully on 23/2/2025 and approved by:

Thesis Committee Members:

Name	Title	Signature
1. Dr. Sami Sader	Main Supervisor	
2. Dr. Ashraf Almimi	Members of Supervision Committee	
3. Dr. Yahya Saleh	Members of Supervision Committee	

Palestine, 2/2025

Declaration

I declare that, except where explicit reference is made to the contribution of others, this thesis is substantially my own work and has not been submitted for any other degree at the Arab American University or any other institution.

Student Name: Muna Rizeq Ahmad

Student ID: 202112772

Signature: Muna Rizeq Ahmad

Date of Submitting the Final Version of the Thesis:18/3/2025

Acknowledgments

First, I thank God Almighty for the strength and health He has given me throughout the journey of completing my mission.

And foremost, I would like to express my gratitude and appreciation to my supervisor Dr. Sami Sader for his support and guidance throughout this research, as his expertise was crucial in shaping this thesis.

I am also grateful to the Arab American University for providing me with the resources and facilities I needed to complete this study.

My deepest gratitude and love to my family, my mother, father, husband, children, and friends for their support, patience, and understanding throughout my educational journey. Your faith in me has been a constant source of motivation.

Thank you to all the participants and contributors to this research for their valuable time and input, without which this work would not have been possible.

Finally, I dedicate this thesis to all those who have inspired me to strive for excellence in my academic endeavors.

Thank you all for making this achievement possible.

The Readiness Assessment of Implementing Quality 4.0 in Food Industries in Palestine

Muna Rizeq Farhan Ahmad
Dr. Sami Sader
Dr. Ashraf Almimi
Dr. Yahya Saleh

Abstract

This study aims to assess the readiness of the Palestinian food industry for Quality 4.0 implementation by analyzing key influencing factors. Using quantitative research methodology, the study evaluates the industry's readiness for digital transformation and the adoption of artificial intelligence technologies associated with the Fourth Industrial Revolution (Industry 4.0) for quality management.

The study included an analysis of the various dimensions and factors related to measuring readiness to implement Quality 4.0 in food factories and were extracted through analyzing previous studies that were conducted in several developed countries and were not previously addressed in the Palestinian context. These factors are top management commitment, technology adoption, supplier management, customer focus, organizational culture, leadership support, vision and strategy, knowledge and awareness, training and awards, financial resources, and industry challenges.

A questionnaire was designed in a scientific and rigorous manner consisting of three sections: demographic information readiness factors for Quality 4.0 implementation, and associated challenges. The survey was distributed to 50 Palestinian food factories, and responses were measured using a five-point Likert scale. Data analysis was conducted using Excel and SPSS programs to extract key insights.

The results revealed varying levels of readiness among food factories in Palestine, with key challenges including adoption of new technologies, infrastructure, financial constraints, and political obstacles. However, the results also highlighted opportunities for improvement, such as enhancing leadership support, strengthening training and development strategies, and developing a clear roadmap for the transition to Quality 4.0. The study also found that most senior management supports quality programs, promotes a culture of continuous improvement, and enhances awareness and knowledge of Quality 4.0 among employees. As a major contribution and initial step, this study proposes a framework to guide factories in improving their readiness to implement Quality 4.0, and provides recommendations to leverage digital transformation, improve product quality, increase efficiency, and enhance market competitiveness

Keywords: Quality 4.0, Industry 4.0, Artificial Intelligence, Readiness, Food Industry

Table of Contents

List of Tables

List of Figures

Chapter One: Introduction

1.1 Overview

The food industry occupies a prominent position in the Palestinian economy("Food Systems Profile - Palestine," 2023). It plays a fundamental role in contributing to the system of national industries. This promising sector means great potential for economic growth, because of its large contribution, which amounts to 24% of the gross Palestinian industrial product (Palestine Federation of Industries, 2024). This industry includes a variety of activities, including agricultural production, food processing, distribution, and consumption (Palestine Federation of Industries,2024). However, like many industries globally, the Palestinian food industry faces a set of evolving challenges, which calls for an innovative solution to ensure its sustainability and competitiveness.

Industry 4.0 has emerged with revolutionary developments, touching on all aspects of modern industries. Companies around the world are adopting Industry 4.0 technologies at a rapid pace to meet modern challenges and prepare for the future (A Comprehensive Guide to Industry 4.0, 2023.). In the context of the food and beverage industries, these technologies open new horizons for enhancing processes, improving quality, and increasing productivity (Yassur, 2024.). Technologies used in Industry 4.0 include intelligent internet, big data processing, big data storage technologies, artificial intelligence, virtual reality, 3D printing technology, nanotechnology, biotechnology, quantum computing, and block chain technology. (Khatib, 2020)

In the context of Palestine, where there is an emerging food industry, adopting these technologies can be of particular importance. These technologies help improve production efficiency and enhance competitiveness in the global market (Dwikat et al., 2022). The Quality 4.0 concept, which integrates Industry 4.0 technology into quality management systems, brings great promise to the food industry (Sader et al., 2022). Using technologies such as the internet of Things (IoT), artificial intelligence (AI), data analysis, and automation,

Quality 4.0 offers the opportunity to revolutionize how quality is controlled, maintained, and improved in food production and distribution processes (Javaid et al., 2021a).

In the Palestinian context, where it faces unique challenges resulting from political, economic, and infrastructural constraints, Quality 4.0 implementation presents both opportunities and challenges. The readiness of Palestinian food industries to implement Quality 4.0 practices is a critical area that warrants careful consideration. This thesis aims to address this gap in the literature by conducting a comprehensive assessment of the readiness of Palestinian food industries to implement Quality 4.0 practices. By exploring the current technological landscape, identifying potential obstacles, and proposing strategies to achieve effective adoption, this research seeks to contribute to enhancing quality standards, operational efficiency, and overall competitiveness of the Palestinian food industry.

1.2 Food industries in Palestine

The food and beverage industry in Palestine has become a major sector for investment due to the Palestinian Investment Encouragement Law of 1998. Palestine provides a good business environment for new and expanding projects in the food and beverage sector. In this sector, factories are modern and automated, and many of them are certified as ISO-certified. Palestinian food and beverage products have increased their market share, reaching 65%-70% in 2016, due to government policies and marketing campaigns that encourage local consumption. The industry depends on the local market for sales, as the products are marketed throughout the West Bank and Gaza and some in East Jerusalem, while 85% of exports go to the Israeli market and the rest to the Middle East and Europe, with a total of one billion US dollars for exports in 2016, as shown in Table 1.1 (Palestine Investment Promotion Agency, 2024).

Table 1.1: Indicators for Food Industries importer in Palestine

Type of Industry	no. of Factories	no. of Workers	investment Amount (in Millions) $	The local market share
Meat products industry	18	722	27,3	90%
Processing and canning fruits and vegetables	20	557	36,6	20%
Industry, vegetable oils and fats	13	302	18.7	20%
Milk & Dairy Product	46	2324	67	55%
Industry wheat flour & cereal products	12	302	48	40%
Feed industry	26	427	28.9	15%
Bread and bakery pros	1500	5900	100	90%
Sugars and sweets	3	1075	22	25%
Pasta and noodles	4	62	23,7	30%
Soft drinks and non-carbonated	24	1414	33.5	30%
Other food products	39	920	10,7	35%

(Palestine Investment Promotion Agency, 2024)

1.3 Research Problem

This study focuses on evaluating the readiness of Palestinian food factories to adopt Quality 4.0. Quality 4.0 refers to the integration

of advanced technologies emerged under the umbrella of Industry 4.0 and the total quality management (TQM) practices (Sader et al., 2022). Quality 4.0 offers several potential

benefits to the food sector, including increased efficiency, effectiveness, and product quality. However, much research highlighted the challenges and opportunities associated with implementing Industry 4.0 and Quality 4.0 in the industry. In the meanwhile, factories face multiple global challenges in implementing Quality 4.0, including a lack of skills, high cost of new technologies, resistance to change within organizations, a lack of specific strategies to implement Quality 4.0 (Sader et al., 2022) adopting a flexible organizational culture is also essential to ensure successful implementation of Quality 4.0.The Palestinian food industry faces several challenges that hinder its ability to develop and enhance quality management systems and operational efficiency. These challenges include outdated production systems, limited investment in modern technologies, resistance to change in institutional organization, in addition to factors related to infrastructure, inadequate training of the workforce, and lack of digital integration, which hinder efforts towards improving quality standards and competitiveness. The aim of this research is to assess the readiness of Palestinian food factories to adopt a modern data-based quality management methodology. By assessing key readiness factors including technological capability, top management commitment, organizational culture, and dedicated financial support, this study will provide insight into the challenges facing factories and the potential benefits of adopting advanced quality management systems. This study will help identify gaps and provide recommendations for a smooth transition towards smarter and more efficient quality practices in the industry.

1.4 Research Objectives

This thesis aims to assess the readiness of Palestinian food factories to implement Quality 4.0, a model that integrates advanced technologies from Industry 4.0 with TQM practices .The main objective is to assess the challenges and opportunities and investigate the factors that influence the adoption of Quality 4.0 in the Palestinian food industry .This study also contributes to the literature on assessing the readiness to implement Quality 4.0 as there are no studies in this field

in the Palestinian context .To achieve this ,this study provides actionable insights and recommendations to stakeholders for the successful implementation of Quality 4.0 .For this reason ,the main objectives of this thesis are listed as follows:

1. Evaluate of the key factors affecting the readiness of Palestinian food factories to implement Quality 4.0.
2. Evaluation of the role of leadership and senior management support, technology and organizational culture in shaping the readiness to implement Quality 4.0.
3. Study the impact of workforce training, awareness raising, financial resources and stakeholder engagement (customers and suppliers) on the successful adoption of Quality 4.0.
4. Identify the challenges that hinder the implementation of Quality 4.0 in Palestinian food industries

1.5 Research Questions

To achieve the objectives of the thesis and by focusing on the basic research problem, a set of questions were formulated as follows:

1) What are the main factors affecting the readiness of Palestinian food factories to implement Quality 4.0?
2) How does leadership, top management and the adoption of new technology affect the assessment of readiness to implement Quality 4.0?
3) What is the impact of workforce training, awareness raising, financial investment and supplier and customer engagement on the success of Quality 4.0 adoption?
4) What are the main challenges that hinder the implementation of Quality 4.0 in Palestinian food industries?

1.6 Research Hypotheses

To identify and measure readiness through the key factors for implementing Quality 4.0, the following hypotheses were formulated. More specifically, for each of the factors and how it affects readiness, ten hypotheses will be examined in this study.

1) H1: Top Management Commitment positively impacts the readiness of Quality 4.0 implementation
2) H2: Clear vision and Strategy for Quality 4.0 positively impacts the readiness of implementation in Palestinian food industries.
3) H3: Technology Adoption positively impacts the readiness of implementing Quality 4.0 in Palestinian Food Industry.
4) H4: leadership positively impacts the readiness of Quality 4.0 implementation
5) H5: Training and Rewards systems positively impacts the readiness of Quality 4.0 in Palestinian food industries
6) H6: Knowledge and Awareness regarding Quality 4.0 positively impacts the readiness of implementation
7) H7: Financial funding positively impacts the Readiness for Quality 4.0 implementation in Palestinian food industries
8) H8: Customer Focus positively impacts the readiness of Quality 4.0 implementation
9) H9: Supplier Management process is positively impacts the Readiness for Quality implementation in Palestinian food industries
10) H10: The organizational culture positively impacts the readiness of implementing Quality 4.0 in Palestinian Food Industry.

1.7 Rationale and Significance

The implementation of Quality 4.0 in the food industries of Palestine has the potential to bring about significant benefits, including increased efficiency, improved product quality, and enhanced competitiveness. Therefore, it is crucial to assess the readiness of the food industries to adopt this new paradigm and understand the challenges and opportunities that lie ahead. This research is significant because it provides valuable insights into the current state of technology, organizational culture, and infrastructure in the food industries, and informs stakeholders on the best strategies to ensure the successful adoption of Quality 4.0.

This research also has important implications for the development of the food industries in Palestine. The findings of this research would inform government agencies, industry organizations, and food producers on the necessary steps to take to prepare the food industries for the transition to Quality 4.0. This ensures that the food industries are well equipped to take advantage of the benefits that this new paradigm offers and remain competitive in a rapidly changing market.

Furthermore, this research contributes to the academic community by adding to the body of knowledge on the implementation of Quality 4.0 in the food industries. It will also provide a basis for future research on the subject and help to inform the development of best practices for the implementation of Quality 4.0 in other countries and industries. In addition, the model that will be developed to measure readiness will address issues that are unique to Palestine, such as political determinants, which may not exist anywhere else in the world.

In conclusion, the readiness assessment of Quality 4.0 in the food industries of Palestine is a crucial and timely research problem that will have important implications for the development of the food industries and the adoption of new technology and practices. This research is significant and justifiable because it will inform stakeholders on the best strategies to ensure the successful adoption of Quality 4.0 and contribute to the body of knowledge on the subject.

1.8 Definitions of key terms:

- Quality 4.0: It is the use of modern technologies such as artificial intelligence, the Internet of Things, cloud computing and customer services to create adaptable, automated and predictive quality systems that enhance human interaction in quality management to improve performance, drive excellence and enhance innovation.(Antony et al., 2022)
- Industry 4.0: The fourth industrial revolution defines the integration of smart technologies like AI, IoT, automation into manufacturing to enhance efficiency and productivity
- Readiness assessment: A process of evaluating the readiness of organization to implement Quality 4.0, or systems, in this case, for the transition to Quality 4.0.

- Artificial Intelligence: A branch of computer science that focuses on creating software and machines that can simulate human intelligence
- Big Data analytics: examining large and complex data to investigate patterns, correlations and insights to make decisions and improve business operations

1.9 Thesis Structure:

This research consists of five chapters. It is structured as follows:

Chapter One: contains several sections, an introduction and a general overview of the research topic, the study problem, its objectives, the research questions and hypotheses, as well as the significance of the research. It ends with a presentation of the research sections.

Chapter Two: explains the theoretical data and previous studies that were searched and reviewed in the research related to the subject of Industry 4.0 and Quality 4.0 and the most important application practices and assessment of readiness to implement Quality 4.0.

Chapter Three: focuses on the methods used to conduct the study, it consists of research design and conceptual model and methods for data collection, discuss the method used for sampling and data analysis

Chapter Four: presents the results of the thesis, analysis of these results and their discussion, description of the statistical test, descriptive analysis and the challenges associated with adopting Quality 4.0 in food industries in Palestine

Chapter Five: concludes the thesis by presenting the conclusions, recommendations, outlining the contribution to the field and discussing the limitations

Chapter Two: Literature Review

2.1. Overview

This chapter discusses the evolution of quality management, from inspection to quality 4.0, and addresses the importance of applying quality alongside Industry 4.0. It also provides a comprehensive and general overview of Industry 4.0 and its application in small and medium-sized enterprises (SMEs), and an analysis of the maturity and readiness models that were presented in previous studies and were accepted or rejected. It discusses the obstacles that appear when implementing Quality 4.0 and provides insights into these problems. It also highlights the importance of continuous development in addition to the role that improved productivity, operational effectiveness, and quality control play in creating success for the organization. In addition, the chapter covers the status of Palestinian industries in using Industry 4.0 and adopting Quality 4. 0.

2.2. Industry 4.0

The development of water and steam-powered mechanical production facilities led to the First Industrial Revolution in the late 18th century (Kagermann, Wahlster, & Helbig, 2013). The end of the 19th century witnessed the second industrial revolution driven by electrically powered mass manufacturing and labor division (Kagermann, Wahlster, & Helbig, 2013). The third industrial revolution began in the early 1970s with the use of modern electronics and information technology to automate production processes (Kagermann, Wahlster, & Helbig, 2013). The fourth industrial revolution is the first to be announced prior to its actual implementation (Drath ,2014). Several companies and research organizations, including working group industry 4.0 (Drath ,2014), platform industry 4.0 and industry 4.0 collaboration lab (Drath ,2014), are working for the fourth industrial revolution.

Hermann et al., (2016) defined Industry 4.0 as a term encompassing technologies and concepts for organizing the value chain. They described how CPS (Cyber physical process) monitors physical process within structured smart factories, create virtual copies of physical

world and make decentralized decisions. These systems communicate in real time over IoT (Internet of Things) and offer both internal and across organizational services. This concept represents an important advancement in manufacturing and production processes. Over the past years, the general view of the industrial sector has changed, and it has begun to look at the added value provided by industrial companies, reducing costs, and moving towards global competition (Alcácer & Cruz-Machado, 2019a).

The German manufacturing strategy, a pioneer in the industry, is leveraging Industry 4.0 technologies to address challenges in manufacturing systems, creating new business models and ways of manufacturing, and renewing the industry for digital transformation (Hofmann & Rüsch, 2017). Industry 4.0 was brought to the world in 2011 by German government (Motyl et al., 2017; Griecoet al., 2017), It aims at enhancing operational productivity and efficiency (Peruzzini et al., 2017) by integrating automation and inter connection into traditional industries and connect physical to virtual world (Leyh, Martin, et al., 2017). Industry 4.0 refers to technologies and processes that enable self-sufficient production models, integrated operations, decentralized decisions, and minimal human interactions (Castelo-Branco et al., 2019). In recent years, manufacturing industries seek to adopt advanced technologies such as robotics automation and digitalization to increase efficiency, reduce cost in manufacturing processes, increase capacity of production, improve quality and development and innovation (Khang et al., 2024) which is known as industry 4.0(Kaushik & Singh, 2021). Manufacturing industries differ from automated systems, some smart manufacturing integrate internet of thing IoT, AI, and machine learning to create full of connections, intelligent production process, increase productivity, efficiency and flexibility by real time data and communication between people, equipment and machines, (Khang et al., 2024). Industry 4.0 is a term of integrating IoT, IIoT(Industrial internet of things), AI (Artificial Intelligence) and CC (Cloud computing) to revolutionize the manufacturing process by collecting and analyzing real time data (Kshetri & Voas, 2022), optimizing production process, and minimizing downtime, improving product quality, profitability and productivity (Xu et al., 2018).

Industry 4.0 uses the IoT to collect and analyze data from different parts of the production process (Yang et al., 2020), which enable manufacturers to identify inefficiencies

and improve operations. IoT uses sensors and devices embedded in machines to collect performance data, enhancing safety and efficiency (Khang et al., 2024). By using IoT, the benefits are real time monitoring, predictive maintenance, improved supply chain management, enhanced safety, quality control, automation, enhance customer experience, smart factories, data analytics and reduce costs and downtime, and optimize the supply chains (Khang et al., 2024).

Despite of the advantages of using IoT and IIoT in industry 4.0, there are also disadvantages (Hsiao et al., 2019): risk of cyber-attacks and data breaches (Ries & Duan, 2022), complexity of designing and implementing IoT, IIoT systems can presents challenges which require experience in multiple scopes including software hardware and networking , cost will be limited especially for SMEs, interoperability , integrated systems and devices depending on multiple issues which hinder interoperability between different systems, privacy concerns which appears in highly-regulated industries specially when collecting sensitive data, and limited connectivity.

2.3. Industry 4.0 Implementation in SMEs

Matt et al. (2021) summarized various studies on the adoption of industry 4.0 technologies in SMEs across various countries (Malayzia, Italy, Austria, Korea, Germany, Denmark-Germany, Czech Republic, Turkey, Romania and Poland) based on surveys conducted by several researchers (Ghobakhloo & Ching, 2019; Cimini et al., 2020;Rauch et al., 2020a;Ko et al., 2020;Kilimis et al., 2019;Yu & Schweisfurth, 2020 ; Pech & Vrchota, 2020;Gergin et al., 2020;Türkeș et al., 2019;Ingaldi & Ulewicz, 2019). The key insights from their researches into the adoption of industry 4.0 technologies are:

1. Advanced automation & robotics shows that Germany and Italy have a high adoption rate, while Iran, Malaysia, Denmark-Germany and Turkey shows a medium level of adoption

2. Additive manufacturing (3D printing), a process of creating three dimensional objects from a digital file: generally, adoption is low across most countries while Poland has a medium adoption rate
3. Simulation: most countries have medium adoption rates
4. VR/AR (Virtual/Augmented Reality): all countries have low adoption.
5. Horizontal/Vertical Data integration: the adoption seems high in most countries.
6. IIoT (Industrial Internet of Things) the adoption is high in Germany, Italy and Turkey while other countries show low adoption.
7. Cloud computing: Germany, Turkey, and Italy showing High Adoption, while other show low adoption
8. Cybersecurity, high adoption seen in Germany, while other showing medium or low rate of adoption
9. Big Data Analytics: high adoption observed in Italy, Germany, Turkey, and the other show medium adoption rate
10. AI (Artificial Intelligence): AI adoption low in all countries

Globally certain technologies like data integration and IIoT have high adoption rates, while AI and VR/AR are still low adopted in most SMEs (Rojas-Berrio et al., 2022).

2.4. Industry 4.0 Maturity and Readiness Models

Industry 4.0 maturity and readiness models serve a valuable framework for assessing organizations readiness in adopting industry technologies (Akdil et al., 2018a). These models provide structured approaches to evaluate various aspects such as technology integration, organizational capabilities and strategic alignment. These models aim to assess organizations understanding of their current situation status in industry adoption and identify areas for improvement (Ünlü et al., 2023a), identify specific indicators across different dimensions, including technology, people, processes, and strategy (Ünlü et al., 2023b). These readiness assessments models offer a scalable framework which allow organizations to assess their readiness at different levels of maturity and provide progress from lower to higher maturity

levels and giving recommendations and best practices for successful implementation (Hajoary, 2020). Maturity and readiness assessment tools highlight the importance of continuous improvement, encourage organization to evolve and adapt to the changes of technologies (Angreani et al., 2020).

Ünlü et al. (2023b) reviewed and analyzed 22 maturity and readiness models to assess the adoption of industry 4.0 based on 10 criteria: year of publication, focus, type of model, structure, research methodology followed during design, base frameworks, tool support, community support, objectivity, and extend of usage in practice. The reviewed models are as follows:

Akdil et al., (2018b) proposed an industry 4.0 maturity model to help companies understand their current state in the field. The model includes 13 fields, grouped in three dimensions: smart products/services, business processes, and organizations. Assessment criteria based on industry 4.0 principles and technologies. A questionnaire-based survey is used to identify the company's maturity level with 4 stages :0 "absence", 1 existence, 2 survival and 3 maturities. The model was applied to a retail company, but there is no knowledge about its practical usage.

The Manufacturing Enterprise System Association (MESA) developed MOM/CMM to establish a robust and repeatable manufacturing operation management model. It covers 4 process areas such as production operation management, inventory management, quality test operations, and maintenance operation management, with 832 weighted questions for improvement strategies. The tool, Microsoft Excel Macro, is self-guided and offers comprehensive and quick assessment models.

DREAMY (De Carolis et al., 2017) is a maturity model designed to assess a manufacturing company's readiness for digital transformation. Inspired by the Capability Maturity Model Integration (CMMI) framework, it evaluates five main process areas: design and engineering, production management, quality management, maintenance management, and logistics management. The model has five-scale maturity levels 1 to 5 and is validated with a questionnaire. The model also proposes a methodology for guiding manufacturing companies towards digitalization, which includes maturity assessment, strength and

weakness identification, opportunities identification, and digital transformation roadmap definition.

Ganzarain & Errasti (2016) proposed a three-stage maturity model for SMEs to identify opportunities for diversification in Industry 4.0. The model includes envision which includes capacity and resources analysis and Industry 4.0 understanding, enable which consist of the requirements identification and Industry 4.0 technologies identification, and enact stage which include training capacity, Industry 4.0 projects and risk management, with five levels: initial, managed, defined, transform, and detailed business model. The model was first analyzed in the Basque Country and there is no feedback and knowledge about usage.

Geissbauer et al., (2016) developed a maturity model to assess companies' readiness for digitization, consisting of four levels with these dimensions (digital business models & customer access, digitization of product & services, vertical & horizontal value chains integration, data analytics, agile IT architecture, security, organization, compliance, legal & tax, employees and digital culture). They suggested companies create initial projects, define capabilities, become data experts, transform into digital enterprises, and plan an ecosystem approach. PwC also designed an online self-assessment tool to identify a company's position regarding Industry 4.0, based on a questionnaire with weighted questions for each dimension. The tool is applicable to many companies, but no data is available on its usage.

Gökalp et al., (2017) proposed Industry 4.0-MM, a model inspired by Spice, to assess a manufacturing company's maturity level in Industry 4.0. The model includes aspects like Asset Management, Data Governance, Application Management, Process Transformation, and Organizational Alignment, with six capability levels. However, no case studies have been conducted, requiring future validation.

The IMPULS Industry 4.0 Readiness Model (Lichtblau et al., 2015) assesses the readiness of German and Malaysian SMEs in implementing Industry 4.0. The model includes 18 fields grouped under six dimensions: strategy and organization, smart factory, operations, smart products, data-driven services, and employees. The model measures the capabilities of these dimensions using six levels from 0 to 5. The results show that the size of the company

is the most important successor in five dimensions. The model also suggests action items for newcomers and learners

Jung et al., (2016) proposed a model to assess a manufacturing company's readiness to improve operational performance using data-intensive technologies. The model includes three steps: profile the current state, assess the current state, and develop an improvement plan. The questionnaire is categorized into four dimensions: organizational maturity, IT maturity, performance management maturity, and information connectivity maturity. The model is validated by testing the statistical significance between Smart Manufacturing Systems Readiness Level (SMSRL) and operational performance, showing positive correlations, there is no knowledge about the usage in the practice of the model, except the validation.

Lee et al., (2017) developed a smartness assessment framework for factories in manufacturing companies. The model includes 10 sub-dimensions categorized by main dimensions (performance, leadership, process & system, and automation) and five maturity levels (checking, monitoring, control, optimization, and autonomy). The model was validated by applying it to 20 companies in Korea, with an average turnover of 25.7 million dollars. The results showed that applying the analytic network process provided more precise results, considering interdependencies between criteria.

Leyh et al., (2016) and Leyh, Schäffer, et al., (2017) proposed a maturity model to classify a company's IT system landscape in Industry 4.0 requirements, based on literature review and inspired by Capability Maturity Model Integration (CMMI190) and Core Supply Chain Operations Reference-Model Maturity Model (CSOAMM). The model includes four dimensions (vertical integration, horizontal integration, digital product development, and cross-sectional technology criteria) and evaluates maturity through five stages. However, it only focuses on technological aspects and is not validated.

Rockwell Automation, (2014) "Connected Enterprise Maturity Model" aims to reduce costs and improve capabilities by transforming technologies and organizational cultures. The model consists of five maturity stages, including assessment, secure network, controls, working data capital (WDC), analytics, and collaboration with four dimensions in assessment

stage (information infrastructure, control devices for data movement, networks for information movement, and security policies). Developed for IT/OT companies, it has been applied in Microsoft and Cisco.

Schumacher et al., (2016). developed a maturity model for assessing Industry readiness, incorporating organizational aspects. The model includes nine dimensions: strategy, leadership, customers, products, operations, culture, people, governance, and technology. Each dimension is evaluated using a questionnaire. The model was rated 3.2 out of 4 based on expert interviews and a case study in an Austrian manufacturing enterprise. Results showed the lowest maturity level was in strategy and highest in products.

Scremin et al., (2018). developed the Adoption Maturity Model (AMM) to assess Industry 4.0 maturity in manufacturing companies. The model includes strategy, maturity, and performance axes, with eight indicators and 30 maturity items. The model was applied to 10 manufacturing companies in Italy and Canada, and case studies were analyzed to determine maturity thresholds and adoption maturity indicators. The study also highlighted the limitations of the proposed model.

Schuh et al., (2017). proposed a six-staged maturity model to guide companies towards becoming learning, agile, and adaptable to Industry 4.0. The model includes four main dimensions: resources, information systems, organization structure, and culture. Each stage is assessed using multiple-choice questions. The model was created through four steps, including case studies and workshops with academic and industry contributions. The validation of the model confirmed its principles. However, many companies do not fully understand Industry 4.0 and focus on measures instead of pursuing a common goal. The Acatech Industrie 4.0 Maturity Index was applied to 26 companies and their plants, providing a roadmap for reaching the upper maturity level in all dimensions.

Pacchini et al., (2019). developed a model to assess a manufacturing company's readiness for Industry 4.0, based on the structure of SAE J4000 and Spice standards. The model includes four levels: Level 0 (not present), Level 1 (incompletely implemented), Level 2 (almost fully implemented), and Level 3 (fully implemented). The model includes eight dimensions of enabling technologies: big data, IoT, cloud computing, autonomous robots,

additive manufacturing, cyber-physical systems, augmented reality, and artificial intelligence. The model was tested in a case study with a multinational diesel engine manufacturer in Brazil, revealing a high degree of adaptation.

The Smart Industry Maturity Index (SIRI) (E. D. B. Singapore, 2020) was launched by the Singapore Economic Development Board and TÜV SÜD to assess manufacturing facilities and support Industry 4.0 transformation. The model consists of three layers: process consists of (customer orientation, business model, operation and value chain), technology contains (advanced technologies, big data, cybersecurity, IoT (Internet of Things), and organization contains (strategy, vision and culture, workforce capabilities, structure, ecosystem and partnerships), eight pillars, and 16 dimensions of assessment. The SIRI was performed on 200 Singapore-based manufacturing companies across 12 sectors. The Singapore Government established the SIRI Assessor Program to ensure objectivity and cover training and certification.

In Shi et al., (2019), The Smart Manufacturing Kaizen Level (SMKL) is a tool designed to help manufacturers improve their system implementation sustainably, focusing on maturity level which contains (collecting, visualizing, analyzing, and optimizing) and management level that include (installation or worker, workstation, factory, and supply chain). It includes a matrix for productivity Kaizen and a case study for automation productivity improvement.

Mittal et al., (2018) proposed a maturity model for SMEs to support digital transformation towards smart manufacturing and Industry 4.0. The model consists of organizational dimensions, toolboxes, and maturity levels. The model includes five dimensions (finance, people, strategy, process, and product) and seven toolboxes, each with different maturity levels based on required inputs. Two case studies were conducted to demonstrate the model's effectiveness.

Colli et al., (2019). proposed a maturity assessment approach using Problem-Based Learning to contextualize a company and provide improvement recommendations. The approach includes a maturity model with 6 levels and five dimensions: governance, technology, connectivity, value creation, and competencies. The 360DMA process consists

of five stages, including awareness creation, scope definition, data collection, evaluation, and solution selection.

Bibby & Dehe, (2018) developed a model to measure Industry 4.0 maturity in a defense sector focal firm. The model includes three dimensions: factory of future, people & culture, and strategy, with 13 key attributes, this model was developed based on the previous two models: IMPULS and PricewaterhouseCooper's assessment model. Tested with 14 experts, the model showed a maturity level of 59.35, outperforming the sector average of 55.58

Wagire et al., (2021). developed a maturity model to assess an organization's current state and suggest areas for improvement in Industry 4.0 transformation. The model, based on literature review, interviews, and case studies, weighs maturity items and dimensions under seven dimensions: (people & culture, Industry 4.0 awareness, organizational strategy, value chain & processes, smart manufacturing & technology, products & services-oriented technology, Industry 4.0 base technology). The model was applied to an Indian automotive sector organization, revealing a level 2 digital novice as an improvement opportunity.

Rauch et al., (2020b). developed an assessment model for SMEs to define their strategy for Industry 4.0 transformation. The model consists of four dimensions: operations, organization, socio-culture, and technology, with 21 sub-dimensions and 42 Industry 4.0 concepts. Validated in a field study with 17 SME companies, the model showed low maturity levels, but participants found it useful for assessing their company's status.

Table 2.2 summarizes various Industry 4.0 maturity and readiness models, focusing on key assessment factors such as technology, advanced manufacturing, data analytics and exchange, capabilities and skills, organizational culture. These models provide structured frameworks to help industries to assess their readiness and maturity for Industry 4.0 implementation.

Table 2.2: Industry 4.0 Maturity and Readiness Models

Model	Author	Elements of Assessment
industry 4.0 maturity model	*Akdil et al., 2018*	*smart products/services, business processes, and organizations*

MOM/CMM	*The Manufacturing Enterprise System Association (MESA)*	*production operation management, inventory management, quality test operations, and maintenance operation management*
DREAMY	*De Carolis et al., 2017*	*design and engineering, production management, quality management, maintenance management, and logistics management*
three-stage maturity model for SMEs towards Industry 4.0	*Ganzarain & Errasti (2016)*	*Envision: capacity and resources analysis* *Enable: requirement and industry 4.0 technologies identification and Enact: training capacity and industry 4.0 project and risk management*
Industry 4.0 Building the Digital Enterprise	*Geissbauer et al., 2016in*	*digital business models & customer access, digitization of product & services, vertical & horizontal value chains integration, data analytics, agile IT architecture, security, organization, compliance, legal & tax, employees and digital culture*
Industry 4.0 MM	*Gökalp et al., 2017*	*Asset Management, Data Governance, Application Management, Process Transformation, and Organizational Alignment*
IMPULS Industry 4.0 Readiness	*Lichtblau et al., 2015*	*strategy and organization, smart factory, operations, smart products, data-driven services, and employees*
Overview of a Smart Manufacturing System Readiness Assessment	*Jung et al., 2016*	*organizational maturity, IT maturity, performance management maturity, and information connectivity maturity*
Smartness Assessment Framework for smart Factories using Analytic Network Process	*Lee et al., 2017*	*performance, leadership, process & system, and automation*
SIMMI 4.0	*Leyh et al., 2016; Leyh, Schäffer, et al., 2017*	*vertical integration, horizontal integration, digital product development, and cross-sectional technology criteria*

Connected Enterprise Maturity Model	*Rockwell Automation, (2014)*	*information infrastructure, control devices for data movement, networks for information movement, and security policies*
Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises	*Schumacher et al., (2016)*	*strategy, leadership, customers, products, operations, culture, people, governance, and technology*
AMM	*Scremin et al., (2018)*	*strategy, maturity, and performance*
Acatech Industrie 4.0 Maturity Index	*Schuh et al., (2017)*	*resources, information systems, organization structure, and culture.*
The Degree of Readiness for the implementation of Industry 4.0	*Pacchini et al., (2019)*	*big data, IoT, cloud computing, autonomous robots, additive manufacturing, cyber-physical systems, augmented reality, and artificial intelligence*
SIRI	*E. D. B. Singapore, 2020*	*Customer Orientation, business model, operation and value chain, advanced technologies, big data, cybersecurity, IoT (Internet of Things), strategy, vision and culture, workforce capabilities, structure, ecosystem and partnerships*
Smart Manufacturing Kaizen Level	*Shi et al., (2019)*	*Maturity level: collecting, visualizing, analyzing, and optimizing* *Management Level: installation or worker, workstation, factory, and supply chain*
the Smart Manufacturing-Maturity Model for SMEs	*Mittal et al., (2018)*	*finance, people, strategy, process, and product*
Maturity Assessment Approach for Conceiving Context specific Roadmap in the Industry 4.0 Era	*Colli et al., (2019)*	*governance, technology, connectivity, value creation, and competencies.*
Defining and Assessing Industry 4.0 Maturity Levels in a defense sector	*Bibby & Dehe, (2018)*	*factory of future, people & culture, and strategy*
Development of Maturity Model for Assessing the Implementation of Industry 4.0	*Wagire et al., (2021)*	*people & culture, Industry 4.0 awareness, organizational strategy, value chain & processes, smart manufacturing & technology, products & services-oriented*

		technology, Industry 4.0 base technology
Maturity level-based Assessment Tool to enhance the implementation of Industry 4.0 in SMEs	*Rauch et al., 2020*	*operations, organization, socio-culture, and technology*

Based on the extensive literature review of the maturity models for Industry 4.0 maturity assessment and various dimensions that are mentioned and the criteria that are considered for evaluating an organizational readiness for implementing Industry 4.0, we conclude the models include the following common dimensions:

1. Advanced manufacturing
2. Technology connectivity
3. Data Exchange
4. Organizational culture
5. Strategy
6. Workforce capabilities and skills

Although different models include these dimensions, they are often designed for economies with advanced technological infrastructures. Given the unique characteristics of the Palestinian food industry, an adaptive approach is essential to ensure relevance and application

2.5. Quality 4.0

The fourth industrial revolution, or "Industry 4.0", has been transforming industry and business with digitization and automation since the early 2000s. Industry 4.0 brought numerous innovative technologies to production and management, such as artificial intelligence, big data, digital communication, and so on (Yassur, 2024). The era of Industry 4.0 has also seen the development of "Quality 4.0", which could be considered as the current

modern way to manage quality in an industrial setting (Hassoun, Jagtap, Garcia-Garcia, et al., 2023a).

According to the American Society for Quality, "Quality 4.0 (or Q4.0) is a term that has recently started to appear as digitization is becoming more widespread in industry (Hassoun, Jagtap, Garcia-Garcia, et al., 2023a). It builds upon established quality management philosophies and standards, but at the same time aims to take advantage of the many new technological tools and approaches that are available." Quality 4.0 has been quickly adopted by a wide range of industries, especially in the automotive, pharmaceutical, and fast-moving consumer goods industry (Hassoun, Jagtap, Garcia-Garcia, et al., 2023a). As for the food industry, which is facing increased globalization and consumer demand for safe and high-quality food, it is critical to adopt an efficient and effective quality management system to ensure not only the efficiency of the production but also compliance with stringent regulatory standards. By implementing Quality 4.0 it is believed that the food industry could benefit from enhanced quality control and assurance, increased operational efficiency and productivity, and reduced failures and downtime (Javaid et al., 2021b). Therefore, the importance of studying and understanding Quality 4.0 and its impact on the food industry is increasing (Huang et al., 2022).

This thesis provides comprehensive coverage on Quality 4.0, from a general introduction to how this idea evolved to its technical features, successful cases in other industries, and best practices in the food industry. Also, this thesis discusses potential barriers and limitations in its adoption and how to make the implementation of Quality 4.0 successful. Special attention is paid to the application of Quality 4.0 in the food industry, to see how these ideas and technologies could be transformed and utilized in the specific area.

2.5.1. Background of Quality 4.0

The tremendous speed of technological progress over the past decades has led many to conclude that we are currently witnessing the Fourth Industrial Revolution (Foidl & Felderer,

2016). The term “Industry 4.0” has been used since its inauguration at the Hannover Messe trade fair in 2011 (Jarašūnienė et al., 2023). However, “Industry 4.0” is a term related to the manufacturing industry and refers to the use of cyber-physical systems, the Internet of Things, cloud computing, and cognitive computing in industry (Zaydin et al., 2018). On the other hand, the term “Quality 4.0” has emerged relatively recently (Zaydin et al., 2018). “Quality 4.0” includes the principle and methodology behind Industry 4.0 and focuses on significant digital transformation in the aspect of quality management (Siforo et al., 2020). More specifically, this term refers to the era in which quality management is shifting from a process-driven model to a data-driven, technology-enabled phenomenon(*QUALITY 4.0*, 2024).

The achievement of "Quality 4.0", which implies the integration of advanced analytics and digital network with traditional quality management methods, will make potential impacts on different aspects of product quality, ranging from the measurement, diagnosis, and prediction of quality issues to the design of the quality management system(Sony et al., 2020a;Siphoro et al., 2020). Although the impact of Quality 4.0 is yet to be seen once its methodologies are established and widely adopted, some early signs already indicated that Quality 4.0 approaches and tools make a difference on product quality. For instance, various studies have applied data mining and machine learning algorithms to the mappings of the quality improvement project. These methods can assist the quality engineer to understand the complex relationship between the process parameters and the quality outcomes (Javaid et al., 2021c).

By uncovering the pattern and clustering the similar quality pictures, the effectiveness and efficiency of the current quality management strategy can be enhanced, and finally, a better product quality is anticipated (Javaid et al., 2021d). Quality 4.0 appears to be portrayed as a strong enforcement to the paradigm shift from the reactive and detective mode of ensuring product quality to the proactive and preventive measures through the mastery of the enormous quality-related data available and the power of the cyber world (Karthik Sundaram & Prem Shanmugam, 2019)

2.5.2. Definition and Evolution of Quality 4.0

Defining and implementing advancements in quality are always challenging and difficult. The definition of quality shifted from fitness for use and customer satisfaction to invariable (Montgomery, 2019). The evolution of quality has several stages. First was Quality control (QC), which was founded and focuses on examining and measuring inputs and outputs to guarantee product standards, which is one step in the progression of quality (Montgomery, 2019). Gradually, it evolved into quality assurance (QA), a function that guaranteed quality throughout the production process in addition to monitoring it (Montgomery, 2019). Next came the emergence of enterprise-wide quality planning, which matched overall company strategies with quality procedures. As a result, lean six sigma and total quality management (TQM) were combined (Zulqarnain et al., 2022). Quality 4.0 focuses on digitalization and smart techniques to develop autonomous systems that balance quality and productivity optimally. (Zulqarnain et al., 2022). Figure 2.1 illustrates the transformation from quality 1.0 to Quality 4.0.

Figure 2.1: Transformation from Quality 1.0 to Quality 4.0 (Zulqarnain et al., 2022):

Definition of Quality 4.0 according to Antony et al. (2023): It is the employment of automation and digitization and providing competitiveness as an advantage for the organization in order to improve customer experience and increase profitability. Industry 4.0 is mentioned in Quality 4.0 (Aldag & Eker, 2018). A shift in manufacturing processes that integrate digital, physical, and natural elements. This revolution has brought about significant technological advancements, such as data, analytics, connectivity, scalability, and collaboration. It connects people, machines, and data, democratizes technologies, and transforms culture, leadership, collaboration, and compliance (Jacob, 2018). Also (Jacob,2018) clarified that Quality 4.0 expands upon and enhances conventional quality techniques rather than replacing them.

Trends in quality improvement include wider adoption of six sigma and lean methodologies, promoting efficiency across industries, and increasing emphasis on sustainability. These trends emphasize the importance of quality management across all businesses, encompassing all aspects of manufacturing (Chron,2021). Quality 4.0 is defined as a complete socio-technical system created to utilize broad expertise for goal achievement and ongoing improvement (Radziwill, 2018). Optimizing the collaboration of people, technology, and quality management systems is essential to achieving success in Quality 4.0 (Watson, 2019). Reviews of the literature show that it may influence a number of performance metrics, including operational effectiveness, customer value proposition, and financial success (Antony et al., 2021). However, because of its socio-technical nature, its implementation presents challenges, making self-assessment preparedness models essential prior to adoption (Akdil et al., 2018). Alzahrani et al. (2021) highlighted the importance of getting ready factors in a variety of industries by providing knowledge, organizational culture, leadership, and support (Alzahrani et al., 2021). Despite its accepted importance, there is a lack of a standardized tool to assess readiness. According to (Küpper et al. ,2019) Quality 4.0 is a development that aids in quality enhancement going forward, since digital technologies contribute to quality enhancement in various ways.
For instance, the company can use analytics, real-time data collection, and process monitoring to forecast maintenance requirements and quality issues.

Murugesan , (2023) defines Quality 4.0 as an application of industrial transformation methodologies, and emerging AI technologies to transform quality management to achieve improvements across value chain, including product development, operations, suppliers, logistics and customer experience. As (Murugesan ,2023) mentioned the Quality 4.0 enablers in emerging digital technologies which play a crucial role in Quality 4.0 like cloud native quality software, data analysis and connectivity, virtual reality, and robotic process automation. The aim of Quality 4.0 is to enhance operational and financial metrics unlike the traditional continuous improvement programs (e.g. lean, six sigma, TQM), in Quality 4.0 value proposition it integrated people, technology and processes across the value chain that yield substantial benefits. Quality 4.0 is not just about digitizing existing processes; it involves transforming the way quality processes and teams use technology. Successful Quality 4.0 programs require an executive-level Quality leader, a culture of quality, robust change management processes, and not just digitizing existing processes. It doesn't replace traditional Quality methods but builds on them (Murugesan ,2023; Jacob, 2018). Leaders fund Quality 4.0 through incrementing existing capital expenditure budgets, while followers reallocate budget from other initiatives. Quality 4.0 is a continuous journey and requires significant commitment from various functions, not just Quality. (Murugesan ,2023).

2.5.3. Role of Artificial Intelligence in Quality 4.0

Quality 4.0 represents a transformative approach in quality management, leveraging digital transformation sweeping across industries. This paradigm shift aims to digitize entire systems, elevating traditional quality methods and introducing innovative practices. Advanced technologies like cloud computing are integrated into production processes to address quality issues promptly and conduct real-time quality analyses, enhancing competitiveness (Javaid et al., 2021c). Several challenges are being addressed in quality management by quality 4.0 technologies, these include automated root cause analysis, machine connectivity for parameter adjustment and real time simulation for processing.

These technologies enable high performance team to deliver high quality services and products to customer (Javaid et al., 2021c).

Quality 4.0 focuses on details, reducing the cost of poor quality and tracking quality results. Many industries have started to use sensors and analytics for growing their data collection resolutions (Javaid et al., 2021c). Many enablers greatly aid in the manufacturing scenario's quality 4.0 realization. The enablers are: The idea of blockchain, condition monitoring, cybersecurity information, attempting industrial robotics on the ground, product control and solution enablers, IoT and IIoT practices, etc. are some of the areas where Quality 4.0 is enabled for the production environment. Moreover, a number of enablers and philosophies, such as digitalization overall, energy efficiency, big data flow, optimized solutions, precise measurement techniques, and optimized solutions, also link the effective portrayal of quality 4.0 moralities in industrial spaces.(Barari et al., 2021;Alcácer & Cruz-Machado, 2019b) .Quality 4.0 automates error reduction, saves time, cost, and energy, and introduces innovation to specialist workers, particularly those responsible for quality. These technologies enable greater flexibility and convergence in regular processes and systems. However, they also present limitations in considering quality criteria, particularly in self-organization. Quality 4.0 technologies can address these challenges by leveraging near-real-time data to create innovative offerings with consistent consumer value profiles. (Sony et al., 2020a).

Smart factories should focus on analyzing knowledge from core business processes like construction, manufacturing, sales, and quality control to improve Quality 4.0 technologies. Agility is crucial for start-up firms to return to competitive markets. Real-time recording, digital quality testing, and pre-production testing can help automate production processes, provide consumer insights, and ensure design and production process knowledge (Siphoro et al., 2020; Sajidet al., 2021).

Quality 4.0 aims to network supply chains, ensure efficient information flow, and manage performance. It requires a team-based approach, incorporating quality inspection for efficiency. Emerging technology is constantly evolving, and new innovations have revived interest in output quality using Quality 4.0 technologies. (Torous et al., 2020;Dutta et al., 2021)

2.5.4. Barriers and Limitations in Adopting Quality 4.0

The adoption of Quality 4.0, despite its benefits, faces many barriers and limitations that organizations need to address for successful implementation (Sony et al., 2021). The following are some of the key barriers:

1. High Cost of Implementation & Return on Investment are not measurable.
2. Lack of Resources: Quality 4.0 implementation needs resources in terms of physical resources such as cyber-physical systems (CPS), Internet of Things (IoT), Radio-frequency identification (RFID), sensors, smart manufacturing, etc. (Shin et al., 2018), intellectual such as technical knowledge, databases, intelligent algorithms, etc. (Sony et al., 2020b) human resources such as skilled quality manager engineers and directors, (Johnson, 2019) and financial resources such as cash, credits for operation and maintenance of quality management programs (Chiarini, 2020).
3. Lack of Implementation Knowledge: There is no internationally accepted framework for implementation of Quality 4.0, and the knowledge base of implementing Quality 4.0 should be standardized to be implemented easily by organizations (Zonnenshain & Kenett, 2020)
4. Organizational Culture: Not all organizations have such a conducive organizational culture and encourage employees to take risks and accept new challenges and conduct a positive environment to meet quality goals (Ziaei Nafchi & Mohelská, 2020).
5. Competitive Advantage is not clear: the relationship between Quality implementation and competitive advantage is not clear in the era of Fourth Industrial Revolution, which prevents organizations from understanding how to shape competitive advantages for long-term market survival. (Adamik & Nowicki, 2018).

2.6. Readiness Assessment Factors for Implementing Quality 4.0

Jacob (2017) proposed Quality 4.0's 11 axes. These axes include, as presented in Figure 2.2:

- Analytics
- Data
- App development
- Connectivity
- Scalability
- Competency
- Leadership
- Culture
- Compliance
- Collaboration
- Management system

Quality 4.0 comprises three key components: (1) digitalization of inspection results, (2) automation of inspection processes, and (3) integration of the digital results with the industrial system. This is carried out to close the quality loop (Sader et al., 2022). AI, Big-Data, blockchain, deep learning, enabling technologies (sensors, actuators, RFID, IPv6, etc.), machine learning, and data science are the main instruments of Quality 4.0 (Radziwill, 2018). Big-Data, networking, collaboration, and data display comprise a more condensed category of Quality 4.0 technologies (Jacob, 2017; Sader et al., 2022). Zulfiqar et al., (2023) determine the elements of the readiness assessment for the packaging industry's implementation of Quality 4.0. Important elements like **top** management commitment, leadership, company culture, staff competency, and ISO QMS standard implementation, and Alzahrani et al. (2021) and Armani et al. (2021) supported these factors. The dimensions of Quality 4.0 framework were carried out by LNS Research (an advising research firm that specialized in industrial transformation, offering research, analysis, and recommendations to help companies to improve operational performance through digital transformation, including Quality 4.0), and (Juran, 2019)align these dimensions with principles of continuous improvement and quality control, Quality 4.0 axes as mentioned by LNS research are classified as follows:

1. Data: in the context of quality management, data has played an important role in driving improvement, but many organizations still lack this. Industry 43.0 and AI can provide real time visibility of quality metrics, enabling information. Agile decision making
2. Analytics: LNS research found that 37% of organizations identify poor metrics which are the main obstacles to achieving quality objectives. Current quality metrics are descriptive, but Industry 4.0 technologies like big data, machine learning, and artificial intelligence enable prescriptive analytics, predicting failure and guiding action.
3. Connectivity: Quality 4.0 connects business IT and operational technology, enabling real-time or near-real-time feedback collection. Connectivity allows for the use of inexpensive sensors to link people, products, edge devices, and processes, enhancing efficiency and effectiveness in various industries.
4. Collaboration: Despite the potential benefits of enterprise quality management system (EQMS) software, only 21% of firms have implemented a core EQMS, with Quality 4.0 leveraging new methodologies like social listening and blockchain for improved supply chain visibility.
5. App development: App development is crucial in today's digital world, enabling individuals and organizations to stay agile and connect with customers, employees, and stakeholders. Advanced apps, utilizing augmented and virtual reality, hold potential in Industry 4.0 workplaces.
6. Scalability: LNS Research shows 37% of organizations face challenges in achieving quality objectives due to fragmented data sources and systems. Lack of scalability hinders process reconciliation, and Industry 4.0 tools like cloud computing can help achieve scalability.
7. Management systems: Only 21% of organizations adopt enterprise quality management systems, despite their benefits. To fully benefit from Quality 4.0, organizations should automate processes, harmonize, and connect them, and improve system autonomy, allowing focus on improvement and innovation.
8. Compliance: Quality 4.0 automates compliance activities through tools like social collaboration, data analytics, and integration of business and operational

technology. It allows organizations to share successful approaches, detect potential breaches, and assess current strategies for improvement

9. Culture: according to LNS, Quality 4.0 connects data, analytics, and processes, improving visibility, collaboration, and insights, making a true organization wide culture of quality more attainable.
10. Leadership: Quality roles often prioritize customer satisfaction, but senior leadership often does not, according to LNS Research. Quality 4.0 offers an opportunity for quality teams to align their objectives with strategic aims.
11. Competency: Quality 4.0 utilizes various technologies to enhance competency, including social media, artificial intelligence, machine learning, AR and VR, smart devices, wearables, and learning management systems, to enhance employee appraisal, training delivery, and overall competency.

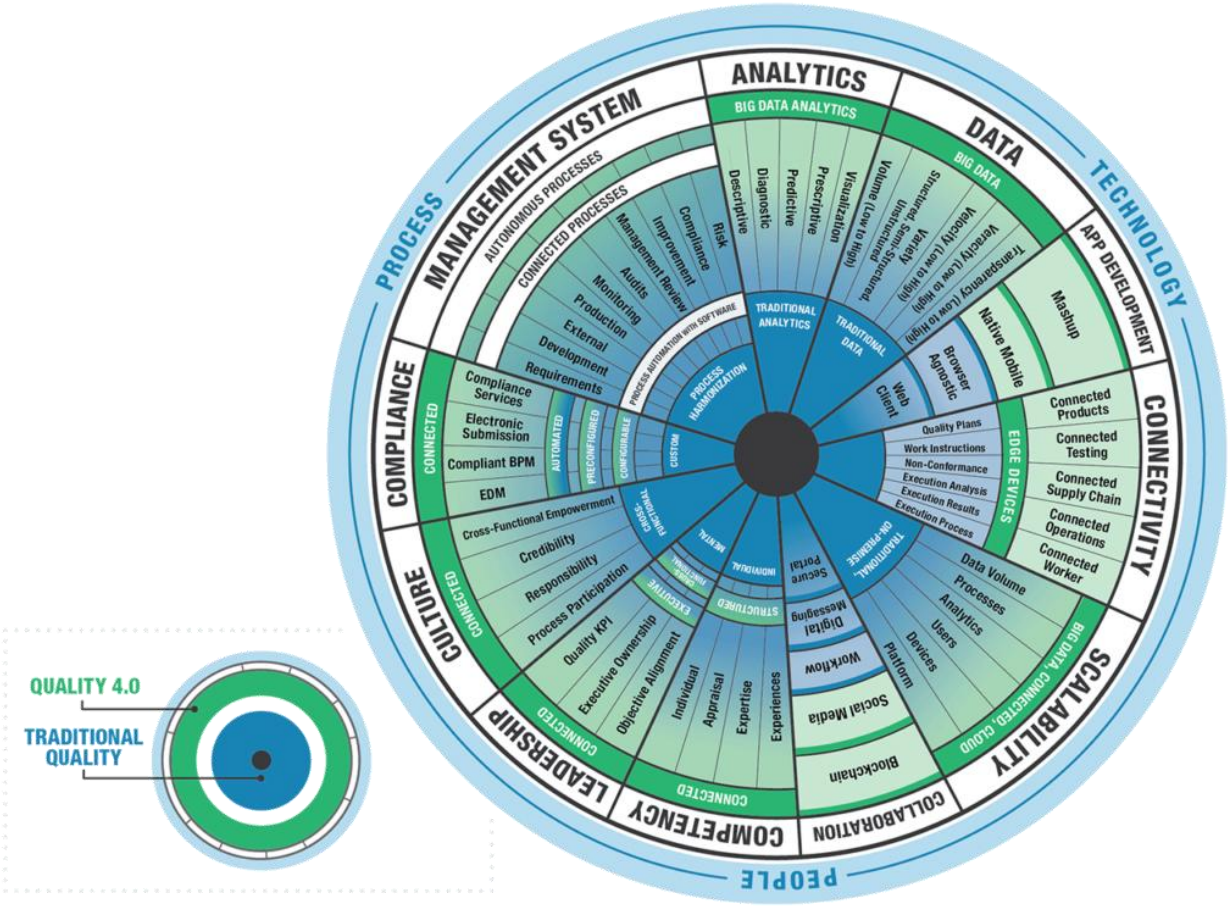

Figure 2.2: The 11 axes of Quality 4.0 framework(Juran, 2019)

Other studies and researches were conducted to design the Quality 4.0 roadmap, Carvalhoa et al., (2024)performed an analysis for maturity and readiness models from collected assessment models from literature that related to the subject of Quality 4.0 roadmap, twenty one models was analyzed to develop Quality 4.0 road map. These models were used by organizations to assess their maturity in the industry 4.0 transition, focusing on various structural areas. These models help identify areas of weakness and provide customized paths for strategic goals. Technology-related dimensions are common (Frenzel et al. ,2021; Ritter & Pedersen, 2020), extending through operational and product lifecycles. Organizational culture, strategy, customer focus, and leadership-related dimensions are also included.

Quality 4.0 represents the integration of digital technologies into quality management systems to enhance efficiency and effectiveness. The proposed roadmap aims to provide a structured approach for organizations to transition towards Quality 4.0 seamlessly. Previous studies by notable researchers such as (Khourshed & Gouhar, 2023; Zulqarnain et al., 2022; Zulfiqar et al., 2023) have highlighted key aspects to consider in developing the roadmap, including the incorporation of advanced technologies like artificial intelligence, big data analytics, and Internet of Things (IoT) in quality processes. Furthermore, these studies have emphasized the importance of assessing the maturity and readiness of organizations in adopting Quality 4.0 practices, with a special focus on dimensions such as leadership commitment, employee skills, and organizational culture. The proposed roadmap synthesizes these insights to offer a comprehensive guide for organizations seeking to embrace Quality 4.0 principles effectively.

(Sony et al., (2021) discuss various readiness factors important for the successful implementation of Quality 4.0, these factors are:

1. **Top management support** is identified as the most important readiness factors, where organizations with strong top management support are more ready to implement Quality 4.0 (Sony et al., 2020a)
2. **Organizational culture:** an organizational culture values transparency, connectivity, collaboration and leverages insights from machine learning and big data is vital, an organization whose culture is open for accepting change will be prepared for Quality 4.0 implementation (Sony et al., 2020a)

3. **Vision and strategy:** it's important to align vision and strategy of organization with digital utilization to gain competitive edge, and the knowledge and awareness of quality professionals regarding Quality 4.0 are crucial for implementing successfully (Sony et al., 2021)
4. **Leadership:** leaders who encourage innovation and embrace new quality management practices aligned with industry 4.0 are better ready to implement quality 4.0(Sony & Naik, 2020)
5. **Knowledge and awareness of Quality 4.0:** Knowledge and awareness of Quality 4.0 are important for its implementation, as modern employees will require a diverse skill set due to automation of repetitive jobs. Quality professionals will need both technical and soft skills (Sony & Naik, 2020)
6. **Customer-centric organization**: This approach aligns quality programs with customer needs, analyzing and producing products to satisfy them (Herrmann et al., 2000) (Osakwe, 2020). Quality 4.0, with its multi-flow big data sharing capabilities, helps meet these requirements. A customer-centric organization is ready to implement Quality 4.0.(Sony et al., 2020b)
7. **Supplier management**: A business with an effective supplier management system can regularly monitor, inspect, audit, and analyze its suppliers to ensure that the company is obtaining high-quality supplies (Park et al., 2001). also, an organization has a good supplier management will be ready to implement Quality 4.0.(Sony et al., 2020b)
8. **Training and reward**: for effective implementation of Quality 4.0 organization use many technologies (Zonnenshain & Kenett, 2020). Hence, existing quality employees must be trained in these technologies and use advanced technology effectively. Accordingly, organizations where the training and reward systems are better, will be prepared from Quality 4.0 implementation (Sony et al., 2020b)

2.7. Importance of Quality 4.0 in Food Industries

The demand for high-quality foods has increased due to market pressures and technological advances. The concept of Food Quality (FQ) has evolved from Food Quality 1.0 to Food Quality 4.0, which focuses on advanced technologies like IoT and artificial intelligence for improved traceability, food safety, and quality assurance (Djekić et al., 2023). This is a new ideology. Historically, food quality not only focuses on the end food products, but also the entire value-added production, from raw materials, processing, logistics, etc. (Carbone, 2017). The traditional "practices approach" involves a standard that needs to be continually updated and monitored, ensuring that the latest practices are implemented. With the dynamic and varied environment in food industries, enforcing the standards in the practices approach is a formidable task (Mialon et al., 2015). Thus, the industries and authorities are trying to explore the possibility to link up and synchronize the knowledge gained from big data on one end and the enforcement of the Food Law on the other end (Jin et al., 2020). By optimizing continuous improvement, monitoring, and predicting the DEF (development, expiry date, and failure) of it, technology under Quality 4.0 has the potential to totally revolutionize the food industries and provide either a faster, cheaper, better, or smarter method (Hassoun, Jagtap, Garcia-Garcia, et al., 2023b). The modern-day manufacturer will no longer apply the old-fashioned long-term over safe factor in production planning and control. Instead, by introducing the real-time monitoring system using technology under Quality 4.0, efficiency will be optimized and automate much of the decision-making processes (Javaid et al., 2021c). The impact from Quality 4.0 is unprecedented and to ensure Food Law can be better enforced to protect consumers. Besides ensuring the tracking and monitoring standards can be fulfilled in a more effective way as mentioned above, Quality 4.0 also helps to identify patterns and conducts root cause analysis through discovery from the existing data (Hassoun, Jagtap, Trollman, et al., 2023).

Nonetheless, even ISO 9001:2015 has been promulgated to suit Quality 4.0 ideology, the success of it is still specific upon how well to embrace the truth of a quality mindset change within top management and tries to move away from a perceived and paper-based operation(Oliveira et al., 2024).With the adoption of the digital management system including Quality Management System (QMS) and Electronic Quality Management System (EQMS) becoming one of the key standards now that will assist organizations to transition smoother toward a digitalized Quality System under Quality 4.0(Ralea et al., 2020).

2.8. Best practices in implementing Quality 4.0

Successful implementation of Quality 4.0 in the food industry requires the adoption of advanced technological tools as well as a change in organizational culture and leadership. Studies have identified many best practices that contribute to the successful integration of advanced technologies into quality. Here is a summary of the most important ideas from the literature that discuss the most effective practices for implementing Quality 4.0:

1. Adopting a data-based approach and analyzing it to benefit from the decision-making process, as highlighted in the study by) Hassoun et al., 2023). This approach helps improve monitoring in manufacturing and accurately control quality.
2. Adopting artificial intelligence to predict problems before they occur, which allows proactive decisions to be made to avoid problems through machine learning algorithms, as confirmed by (Javaid et al., 2021)
3. Leadership and senior management support in adopting digital transformation is of great importance for the successful adoption of quality technologies40 as (Sony et al., 2021), showed, and they must also create a culture that encourages innovation and informed improvement.
4. Collaboration between functions by integrating several departments such as production, technology and quality contributes to producing a comprehensive approach to building new advanced systems as shown by Carvalho et al. (2024)
5. Continuous training and skills development on technology related to Industry 4.0 to better deal with the complexities of new systems and contribute to the success of the digital transformation initiative (Hassoun et al., 2023).

2.9. Previous Studies

Many previous studies have mentioned the concept of Quality 4.0 as a strategic shift that helps organizations face current challenges and achieve institutional excellence. The concept of Quality 4.0 is one of the important and prominent developments in the field of quality management and represents a qualitative shift from traditional quality to digital

quality that relies on advanced technologies. This concept integrates a set of advanced technologies such as the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI), along with comprehensive quality practices with the aim of improving performance and efficiency in products and services. Many studies have also focused on developing models to assess the readiness to implement Industry 4.0 and Quality 4.0, taking into account the basic factors that affect the readiness of organizations to adopt these concepts. These models included several aspects, the most important of which are organizational, technical, and cultural within the organization and the efficiency of interaction between them in the work environment to achieve the required integration.

In previous studies, a set of dimensions emerged that contributed to measuring the readiness of organizations to implement Industry 4.0, as these dimensions included advanced assessments and administrative foundations related to the success of digital transformation within organizations, the most important of which are these dimensions:

1. Advanced Manufacturing: It was mentioned in studies about how companies benefit from modern technology such as robots, automated systems, and 3D printing used to improve quality and productivity.
2. Technology Connectivity: The importance of integrating technical systems and the ability to communicate between different systems and devices were mentioned
3. Data Exchange: It focuses on using big data to analyze data in real time and make more accurate and effective decisions
4. Organizational Culture: Studies stated that it is very important for the organizational culture of the organization to be flexible and encourage innovation and change in line with the implementation of Industry 4.0
5. Strategy: This includes developing strategies and a roadmap for digital transformation to achieve excellence
6. Workforce Capabilities and Skills: The importance of developing the technical and administrative skills of workers to keep pace with technological developments was presented.

Previous studies have shown several models for measuring the readiness to implement Quality 4.0 and have contributed to mentioning several important dimensions, the most

prominent of which are: Top Management support, Vision and Strategy, Leadership, Training and rewards, Knowledge and Awareness, Organizational Culture, Customer Centeredness, and Supplier Centeredness.

By reviewing a wide range of previous studies, common factors were identified that affect the readiness of organizations and can be applied in assessment of implementing Quality 4.0 in food factories since there are no factors specific for food factories yet. These factors are adopted in developing the model and framework for this study to implement Quality 4.0, as follows: Top Management commitment, clear strategic vision of Top management towards digital transformation and implementation of Quality 4.0, Leadership support, Adoption of modern technology and provision of advanced infrastructure for implementation of digital transformation and advanced digital technologies, supportive organizational culture. It is necessary to have a culture that is consistent with the principles of Quality 4.0 in terms of cooperation, transparency and flexibility, development of employee skills and a motivational system, availability of funding sources and allocation of funding for the resources needed for modern technologies and infrastructure, focus on suppliers and customers, knowledge and awareness of modern technology and awareness of the importance of implementing Quality 4.0 in improvement processes.

Many studies have concluded that despite the existence of several developed readiness models, there are numerous challenges that hinder organizations from implementing Quality 4.0 and Industry 4.0. The most prominent of these challenges are the lack of qualified technical and human resources to implement Quality 4.0, resistance to change in organizations towards digital transformation, some organizations need to restructure their culture to be in line with Quality 4.0 and the weakness of the infrastructure necessary to implement modern technology such as artificial intelligence, big data and the Internet of Things. Global studies have also shown the importance of developing quality systems to Quality 4.0 in factories, especially the food industry sector, because it is considered one of the industries that benefit most from the application of modern technology in manufacturing products and improving their quality. However, it lacks research that addressed the application of Quality 4.0 in food factories in Palestine, as this research was limited to other global industries only.

Several research gaps emerged that the current study can address based on previous studies, as no study appeared in local studies that addressed the topic of evaluating the readiness to implement Quality 4.0 in Palestinian food industries, and there is no framework that addresses the challenges specific to the Palestinian context, such as political and economic restrictions. Hence, the need arose to design a specialized framework to evaluate the readiness to implement Quality 4.0 in the Palestinian food industries sector in line with global requirements, considering the local challenges appropriate to the Palestinian context. This is what distinguished this study and gave it several qualities, including originality and distinction. It is the first study of its kind in Palestine, which made it unique in applying Quality 4.0 in Palestinian food factories. It was also a distinct opportunity for us through this thesis to work on developing an innovative framework that relies on the factors extracted from the previous study and adapting them to the Palestinian situation. Real data from Palestinian factories were relied upon to add credibility and realism to the results. It is also possible to consider this thesis as a basis for future research to be a reference. To expand the scope of research related to the application of Quality 4.0 in Palestine and the Arab regions.

Chapter Three: Research Methodology

3.1. Overview

This chapter outlines the research design and methods for assessing the readiness of Palestinian food industries to adopt Quality 4.0. This section is crucial because it establishes a foundation for data collection and analysis, ensuring that the research questions are systematically and accurately answered. It also validates the study's findings by detailing specific methodologies, including the types of data collected, their sources and the analysis methods used.

3.2. Research Designs

To assess the readiness of Palestinian food industries for Quality 4.0, this research adopted a quantitative methodology. This methodology facilitates a comprehensive analysis of both technical capabilities and organizational culture within the industry, which are critical factors for assessing readiness for technological advancements such as Quality 4.0. Through the use of questionnaires, the study aims to capture a wide range of data including digital readiness scores and qualitative insights from stakeholders. This combination provides a detailed understanding of the current state of technology, infrastructure and skills in these industries, while identifying barriers and facilitators to Quality 4.0 adoption.

3.3. Research Model and Framework

This study develops a comprehensive framework for assessing the readiness to implement Quality 4.0 in food industries in Palestine. the framework is based on existing quality management and digital transformation models but uniquely adapted to Palestinian

industry context. The conceptual framework consists of ten key factors (independent variables) which are hypothesized to the construct Quality 4.0 Readiness (dependent variable), as shown in figure 3.3, these factors are:

1. Top management commitment
2. Vision and strategy
3. Technology Adoption
4. Leadership
5. Training and Rewards
6. Knowledge and Awareness
7. Financial Fund
8. Customer Focus
9. Supplier Management
10. Organizational Culture

Each of these factors has been selected based on classical quality management factors and modern Quality 4.0 elements. While customer focus, supplier management and organizational culture are aligned with TQM principles, technology adoption, financial funds and Knowledge and awareness emphasizes the industry 4.0 and digital transformation, these are making this model distinct from classical TQM framework.

This study hypothesis formulated in chapter 1 align with this framework. where each independent variable is hypothesized to positive impact to Quality 4.0 Readiness, these hypotheses are represented in Figure 3.3 which illustrate the visual direct relationship between readiness factors and Quality 4.0 readiness (dependent variable).

This framework presents a practical roadmap for Palestinian food industries, it defines the strengths and gaps in their Quality 4.0 readiness and provide strategy for adopting new technologies, workforce training, and process improvements. By applying this model, industries can be able to transit toward modern technologies (AI, data driven and automated quality management systems which define Quality 4.0.

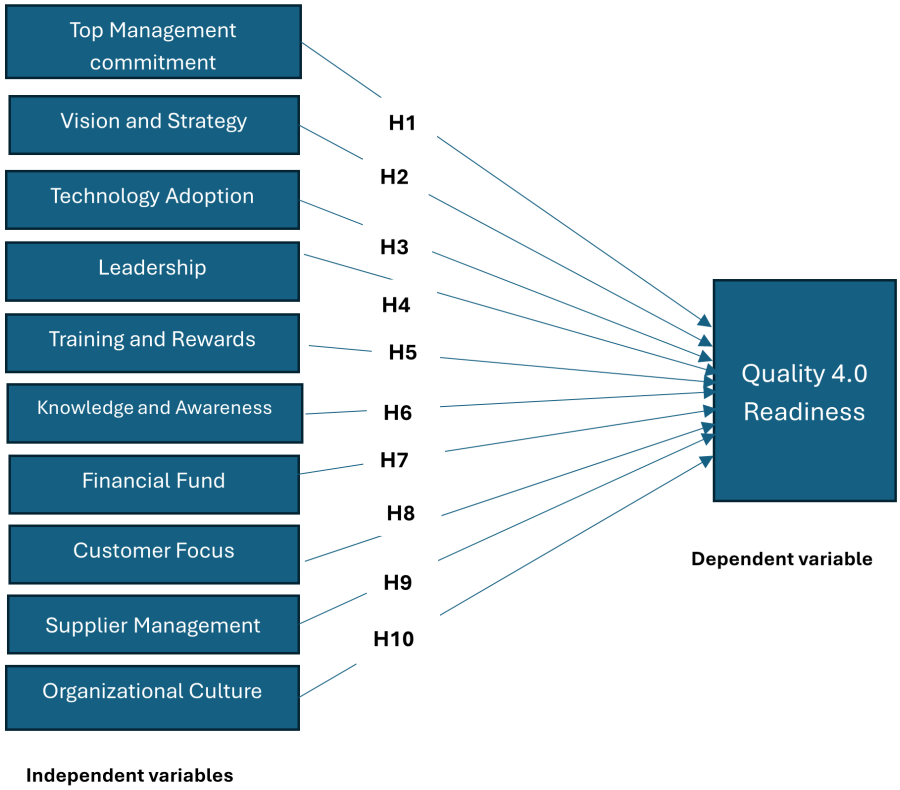

Figure 3.3: research framework for assessing readiness to implement Quality 4.0

3.4. Data Collection Methods

To gather data, the study employed a questionnaire as a primary method of data collection. This approach is effective to gather data from stakeholders and allows for an effective analysis of quantitative data. The questionnaire was designed to assess factors of readiness of implementing Quality 4.0 in Palestinian food industries. In addition the questionnaire includes demographic information to profile the respondents, as well as sections that assess the readiness of implementing Quality 4.0 factors, management commitment, technological adoption, organizational culture , supplier management, financial fund, leadership & support, vision & strategy, training & rewards , customer focus and knowledge & awareness, and the existing challenges related to implementation of Quality

4.0. By utilizing a structured format, including Likert scale measures from 1 to 5, the study aims to quantify stakeholders' perceptions and readiness levels.

This data that was gathered in a systematic manner and were analyzed to determine the main drivers that play a role in the shifting toward Quality 4.0 implementation in Palestinian food sector. This approach is aligned with the best and extent within and futures potentials within the region.

3.5. Questionnaire Design

A structured questionnaire is developed to assess the readiness of implementing Quality 4.0 in food industries in Palestine as a primary data collection, it was developed based on the relevant literatures, aligning key dimensions of Quality 4.0 readiness mentioned in the study.

The questionnaire consists of 3 sections:

1. demographic information
2. Quality 4.0 readiness Dimensions
3. Challenges

Each factor is assessed by Likert Scales Questions, the complete Questionnaire provides in Appendix section.

3.6. Sampling Techniques

In this study, stratified and purposive sampling techniques were employed to select food industries in Palestine based on specific criteria related the adoption of industry 4.0 implementation: which include the industries that implement industry 4.0 technologies or in the planning phase, and geographical location this study will employ in West Bank. Stratified sampling aims to capture differences in readiness's and challenges faced by food industries at various stages, according to the implementation stage and geographical location, and

purposive sampling technique to ensure inclusion the industries capable of providing details and specialized insights to address the research questions, and enrich data quality and facilitate the understanding of the factors that influence the readiness assessment of implementing Quality 4.0 in food industries in Palestine.

3.7. Population and Sample

The number of factories in the food industry in Palestine, according to Palestine Investment Promotion Agency, reached 1705 factories, varying between meat, beverage, canned food, wheat products, grains, sweets, ice cream, cake and bread. This study covered all food factories in Palestine, where a questionnaire was developed for the study embedded in a website developed for this purpose under the domain https://quality4.org/. The Food Industries Union was officially contacted to publish the questionnaire to food factories, during which 20 factories responded fully to the questionnaire. A reminder was sent after two weeks.

After two months, the factories were approached directly through their official contact addresses including their email or social media accounts. During the communication, full details on the study were provided as well as the link to the website. The final number of responses to the questionnaire from the various factories reached 50 complete questionnaires.

By analyzing the visits to https://quality4.org/ website, it became clear that the number of visits to the website was about 1500 requests during the two-month period. Perhaps some factories may not have applied or known about Industry 4.0 and its technologies or Quality 4.0, so they did not fill out the questionnaire.

To ensure the inclusion criteria of factories and to address the fulfillment of the participation of 50 factories in answering the study questionnaire, the questionnaire was sent to factories that were aware of Industry 4.0 technologies or were implementing them, or had future plans to implement them. This inclusion was verified by communicating directly with the Food Industries Federation or the factories themselves. This approach ensured that the

sample was not random but was specifically selected to meet the study criteria regarding readiness to adopt Quality 4.0.

3.8. Data Analysis Methods

SPSS version 22 and Microsoft excel were utilized for conducting the analysis. SPSS software is suitable to study the relationship between the dependent variables and construct (independent variable _Quality 4.0 Readiness) which examines the correlation between the hypotheses, and Microsoft excel was utilized to analyze the demographic data to get insights from analysis and graphs given. The analysis process involved these steps:

1. Data initialization by cleaning and addressing missing values to ensure data quality

2. Coding items, which facilitate the analysis process

3. Compute variables which represent the factors of assessing Quality 4.0 readiness.

3.9. Validation and Reliability

The questionnaire was prepared as a data collection tool and was presented to a number of experts for evaluation, including the supervisor of this thesis, Dr. Sami Sader and Dr. Ashraf Almimi, who reviewed the questions and made their comments. The questionnaire was then modified, and its final version was confirmed. After that a pilot testing was conducted on a number of colleagues to test the questionnaire in terms of its flow, difficulty and ease of filling it out, the time required to complete it, and to ensure the clarity, meaning and suitability of the questions. Finally, a statistical analysis was conducted after collecting the data to verify the reliability and stability of the tool used and to ensure the integration and adoption of the framework.

Specific criteria were applied during data collection, where the questionnaire was distributed to the factories with clear instructions that specific categories should answer the questionnaire, such as (factory manager, quality manager or computer engineer). This was

communicated in the introductory text of the questionnaire and also by including in the demographic information that only job titles were required within these categories, and through direct contact with the participating factories, this ensured the relevance and quality of the responses.

Chapter Four: Results, Analysis and Discussion

4.1. Overview

In this chapter, the results from the analysis are presented, based on the data which were collected through the questionnaire focusing on the assessing readiness of Quality 4.0 in Palestinian food industries, beginning from a descriptive analysis of the demographic information's of the respondents, followed by a section that describes the properties of the variables , this is linked to a discussion of the challenges identified in the study. Next the results of the structural model testing, finally the discussion of the findings and conclusions.

4.2. Descriptive Analysis

The demographic characteristics of the food industry indicated a variety of different food types including beverage, dairy, meat products, chocolate, frozen food and more. Figure 4.4 below shows the count of factories depending on the type of food they produce.

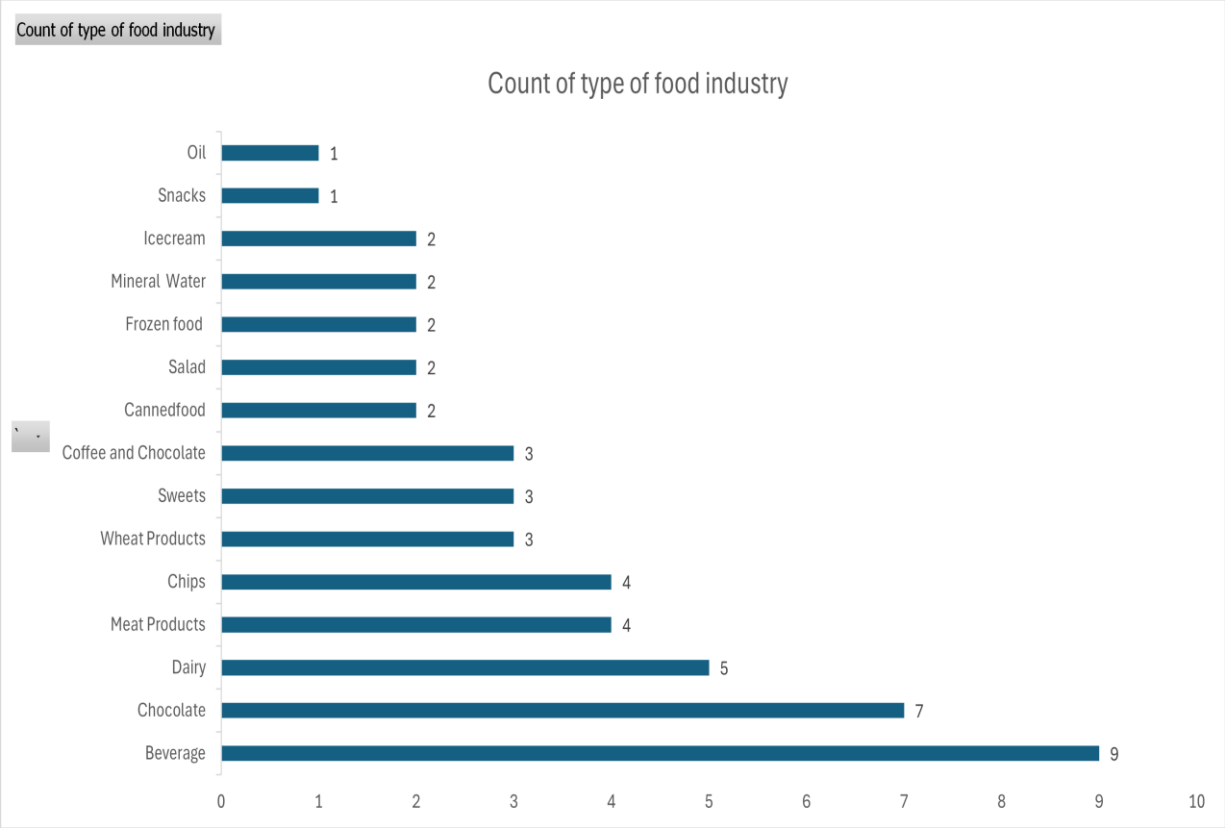

Figure 4.4: Count of type of food industry

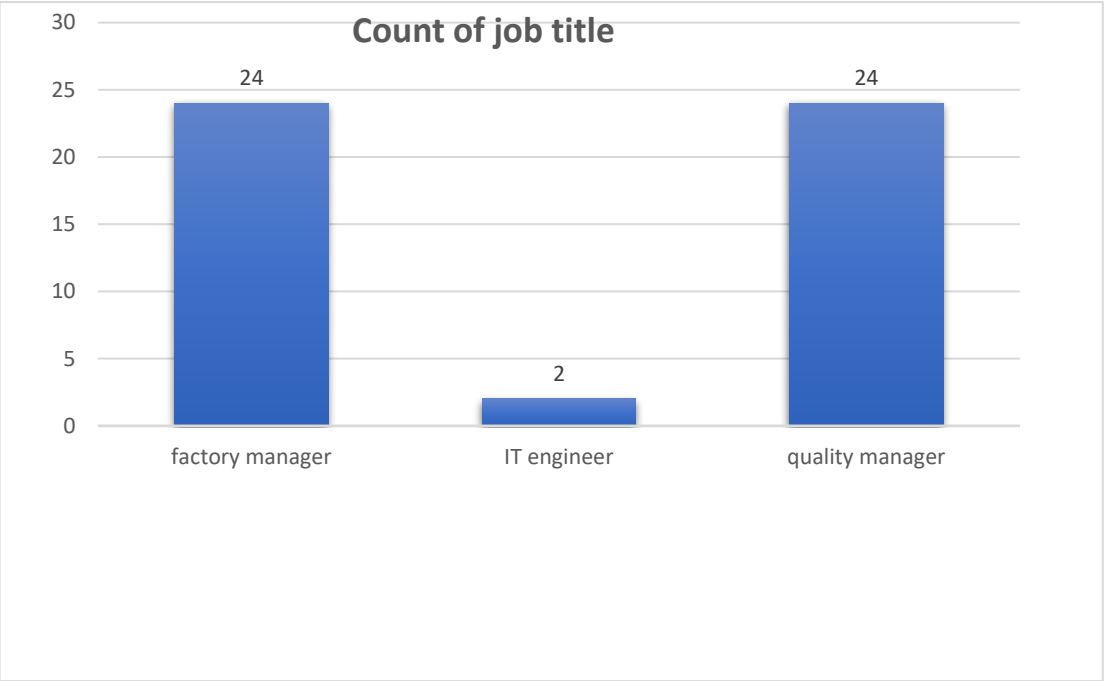

Figure 4.5: count of respondent's job title

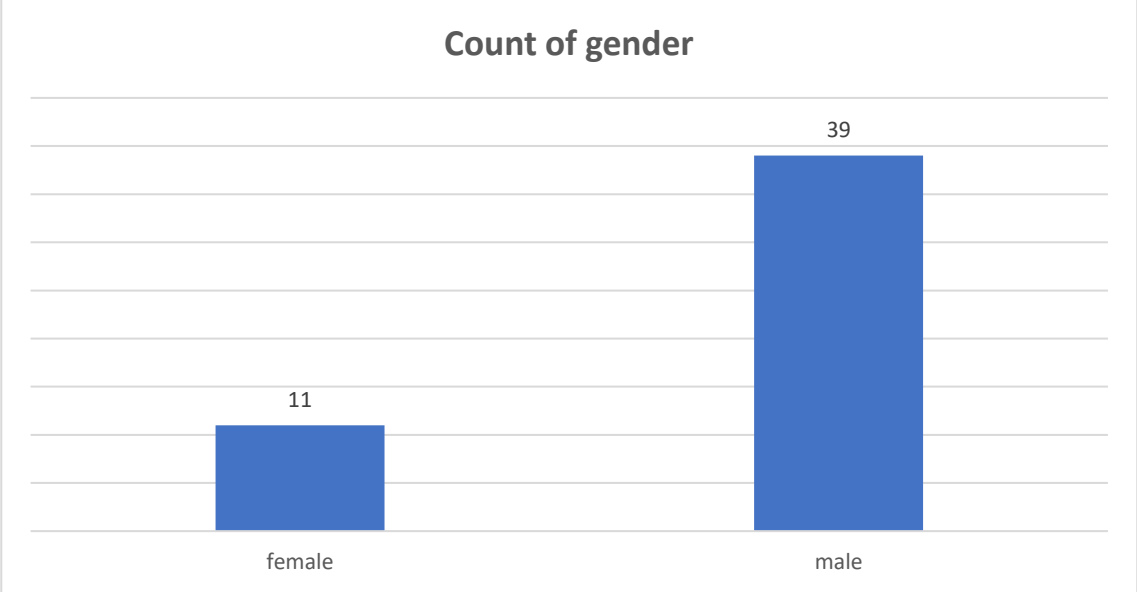

figure 4.6: count of respondent's gender

Based on the distribution of participants by job title (Figure 4.5): Participants responded equally by job title between quality managers and factory managers, with 24 participants in each category, while only two technology engineers responded, While the

gender distribution among the participants was as follows (Figure 4.6): Females: 11 respondents - Males: 39 respondents

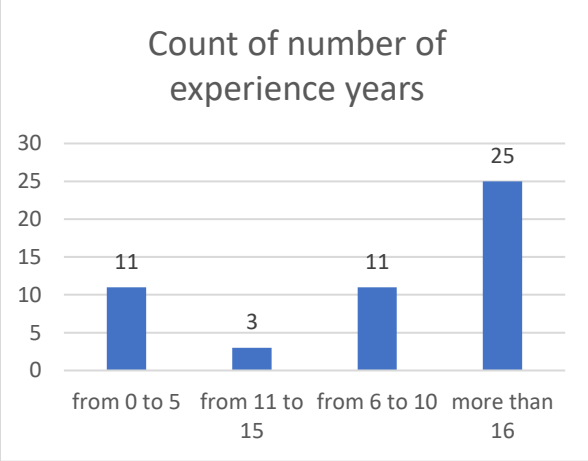

Figure 4.7: Respondents' experience years

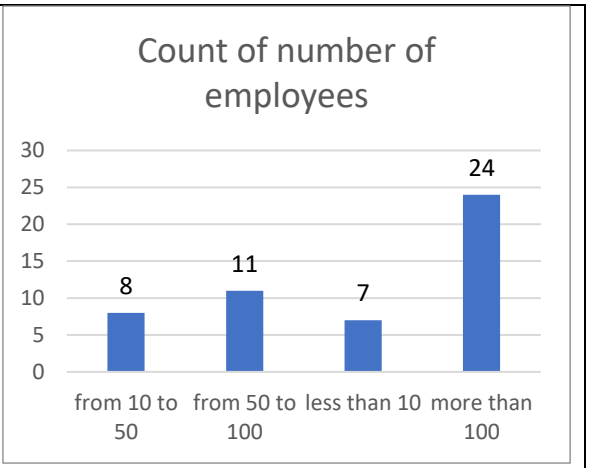

Figure 4.8: Number of employees in factory

According to data provided by (Figure 4.7) and (Figure 4.8) the key observations related to years of experience of the respondents and the number of employees in the factory:

1. Years of experience: from 0 to 5 the respondents were 11, from 6 to 10 11 respondents, from 11 to 15 the respondents were 3, and the most frequent experience range was more than 16 years
2. Number of employees in the factory: less than 10 employees were 7, from 10 to 50 were 8, from 51 to 100 employees were 11 respondents and more than 100 employees the respondents were from 24 factories

According to the list of quality systems used by different factories, as appear on the (Table 4.3) below.

Table 4.3: Frequencies of Quality systems used in factories

Quality system	Frequency
ISO 9001:2015	39
ISO 22000:2018	23
HACCP	31
Lean Six Sigma	5
Statistical Quality Control	28
Quality Assurance	36
Inspection	24
Control Chart	19

Most common quality systems used are ISO 9001:2015 , Quality Assurance, which indicate a strong focus on standardized quality management and assurance in these factories , ISO 22000:2018 and HACCP are for food safety standards which are also used frequently, lean six sigma appears less frequently which indicate that fewer factories are emphasizing continuous improvement methodology, and statistical Quality control , inspection and control chart usage indicate attention to quality control measures but not a little to mention in comparison with broader quality standards. Table 4.4 summarizes the descriptive statistics of the study variables.

Table 4.4: Descriptive Statistics for dependent and independent variables

(N=50)

Variable	Mean	Std. Deviation	Rank
Quality 4.0 Readiness	3.6570	.53203	-
Top Management Commitment	3.9760	.59610	high
Vision and Strategy	3.6533	.68993	medium
Technology Adoption	2.6800	.62019	low
Leadership	3.7320	.65728	medium

Training and Rewards	3.3733	.68393	medium
Knowledge and Awareness	3.3150	.85388	low
Financial Fund	3.7600	.86515	medium
Customer Focus	3.9400	.78446	high
Supplier Management	4.0200	.64452	high
Organizational Culture	4.1200	.63802	high

As shown on Table 4.4, key insights from descriptive Statistics.

1. High Scoring Factors: the variables with the highest means are organizational culture (4.12), supplier Management (4.02), Top Management Commitment (3.976), and Customer Focus (3.94) which suggest that these are perceived as strengths in the factory's readiness for Quality 4.0
2. Low score factors: Technology Adoption (2.68) and knowledge and Awareness (3.32) showing week score, indicating that the factories might need to improve in these areas to embrace Quality 4.0
3. Moderate scoring factors: leadership (3.732) , Financial Fund (3.76), and Training and Rewards (3.3733), these areas show some strength but also need to improve.

4.3 Reliability Analysis

Table 4.5 represents reliability statistics specifically Cronbach alpha which measures the internal consistency of a set of variables used to assess a construct, a value of 0.929 is excellent reliability which indicates that there is a highly consistent measuring the construct (Quality 4.0 Readiness).

Table 4.5 Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items

.929 .933 11

Table 4.6 Inter-Item Correlation Matrix

	TMC	VS	TA	L	TR	KA	FF	CF	SM	OC	Quality 4.0 Readiness
TMC	1.000	.763	.202	.654	.561	.382	.725	.716	.586	.709	.828
VS	.763	1.000	.357	.529	.563	.533	.800	.644	.570	.622	.849
TA	.202	.357	1.000	.294	.424	.304	.226	.172	.072	-.054	.389
L	.654	.529	.294	1.000	.708	.313	.543	.536	.340	.614	.723
TR	.561	.563	.424	.708	1.000	.681	.658	.552	.347	.573	.810
KA	.382	.533	.304	.313	.681	1.000	.542	.255	.195	.382	.629
FF	.725	.800	.226	.543	.658	.542	1.000	.850	.793	.793	.929
CF	.716	.644	.172	.536	.552	.255	.850	1.000	.810	.794	.841
SM	.586	.570	.072	.340	.347	.195	.793	.810	1.000	.610	.709
OC	.709	.622	-.054	.614	.573	.382	.793	.794	.610	1.000	.804
Quality 4.0 Readiness	.828	.849	.389	.723	.810	.629	.929	.841	.709	.804	1.000

Table 4.6 presents the inter item correlation matrix for multiple variables represents the correlation coefficient between pairs of variables, there is a strong correlation and internal consistency between all variables to quality 4.0 readiness except technology adoption by reference to (Cronbach and Shavelson, 2004) that when the Cronbach alpha is above 0.7 the greater the internal consistency of the variables and above 0.5 is accepted also while less than

0.5 unacceptable. It is noted that Cronbach's alpha coefficient for the Technology Adoption variable indicates that there is a weak relationship with the remaining variables.

Table 4.7 Collinearity statistics

Model	Collinearity Statistics	
	Tolerance	VIF
(Constant)		
Top Management Commitment	.268	3.727
Vision and Strategy	.230	4.347
Technology Adoption	.521	1.919
Leadership	.308	3.242
Training and Rewards	.205	4.868
Knowledge and Awareness	.312	3.207
Financial Fund	.090	11.114
Customer Focus	.133	7.498
Supplier Management	.231	4.336

Organizational Culture	.186	5.380

a. Dependent Variable: Quality4Readiness

These values in the (Table 4.7) above assess multicollinearity in regression analysis, which occurs when independent variables correlated highly with each other , VIF (variance Inflation Factor) it calculated to quantify how much the variance of the regression coefficient, a high VIF _above 10 means that there is a significant multicollinearity and the variable is redundant and combining with other variable, in this results Financial Fund appears that there a significant multicollinearity and most studies recommend a threshold of 5 or even 3 to detect serious collinearity , in this study Organizational Culture (5.380) and Customer Focus (7.498) exceed generally advised criteria, indicating that these variables can share duplicate information with other factors in the model. To increase robustness, this can necessitate more research, such as integrating related variables or reevaluating model parameters.

4.4 Correlation Analysis

Table 4.8 summarizes the correlation values between the variables. Which examines how strongly the independent variables are related to the dependent variable (Quality 4.0)

Table 4.8: Correlation Matrix: p-values with Quality 4.0 Readiness

variable	p-value (Quality 4.0 Readiness)	Pearson Correlation (quality 4.0 Readiness)
Top management Commitment	0.000	0.828
Vision and Strategy	0.000	0.849

Technology Adoption	0.003	0.389
Leadership	0.000	0.723
Training and Rewards	0.000	0.810
Knowledge and Awareness	0.000	0.629
Financial Funding	0.000	0.929
Customer Focus	0.000	0.841
Supplier Management	0.000	0.709
Organizational Culture	0.000	0.804

- All p-values are highly significant ($p<0.05$) for all variables in relation to Quality 4.0 Readiness, suggesting that each factor is significantly related to Quality 4.0 readiness, this indicates that all ten hypothesis H1 to H10 are supported by the correlation analysis

- The Pearson correlation analysis reveals the strength and direction of the relations between Quality 4.0 readiness and factors that influence its implementation in Palestinian food industries. The findings are:
    1. Financial funding, customer focus and vision and strategy show very strong positive correlations, indicating that financial resources are important for successful implementation, and having clear strategy for Quality 4.0 and focus on customer needs are important for readiness of quality 4.0
    2. Training and rewards, leadership, Top Management Commitment, organizational Culture, supplier management and knowledge and awareness show strong positive correlations and moderate positive correlation suggesting that these are supportive key enablers of Quality 4.0 Readiness and important to influent on Quality 4.0 Readiness
    3. Technology Adoption has the weakest positive correlation with quality 4.0 Readiness compared to other factors, while the relationship is statistically significant
- Conclusion: while Technology adoption is important for preparing organizations for Quality 4.0 , it has moderate effect on readiness compared with other factors , this suggests that organization must not focus on adopting new technologies that related to Industry 4.0 but also on strengthening other factors and developing new strategies for successful implementation of Quality 4.0 , technology adoption should be as part of broader transformation rather than a standalone solution, and related to the correlation there is indeed a strong impact from all factors to the readiness to implement Quality 4.0.

4.5 Factor Analysis

Factor analysis was conducted to assess the reliability and validity of the measurement model by identifying mean, standard deviation and factor loading of each item. Factor loadings above 0.7 indicate strong correlation between items and their variable. Table 4.9 presents the results of the factor analysis for each variable.

Table 4.9 Factor Analysis

variable	factor	Mean	Std. Deviation	Factor loading
Top Management Commitment	TMC1	3.88	.659	0.928
	TMC2	4.00	.606	0.766
	TMC3	4.12	.689	0.917
	TMC4	3.88	.799	0.882
	TMC5	4.00	.728	0.955
Vision and Strategy	VS1	3.88	.872	0.841
	VS2	3.42	.810	0.833
	VS3	3.66	.798	0.933
Technology Adoption	TA1	3.36	1.045	0.817
	TA2	1.92	.877	0.916
	TA3	3.04	1.277	0.861
	TA4	3.00	1.229	0.931
	TA5	2.52	.995	0.902
	TA6	2.00	.926	0.921
	TA7	2.62	1.086	0.858

	TA8	1.56	.611	0.711
	TA9	2.40	1.088	0.885
	TA10	3.22	1.375	0.939
	TA11	3.84	1.267	0.809
	L1	3.48	.762	0.93
	L2	3.88	.746	0.858
Leadership	L3	3.68	.913	0.949
	L4	4.06	.843	0.867
	L5	3.56	1.013	0.809
	TR1	3.30	.707	0.962
	TR2	3.48	.886	0.851
Training and Rewards	TR3	3.38	.945	0.947
	TR4	3.36	.875	0.877
	TR5	3.56	.907	0.89
	TR6	3.16	.842	0.934
	KA1	3.40	1.050	0.923
Knowledge and Awareness	KA2	2.84	.934	0.939
	KA3	3.56	1.110	0.894
	KA4	3.46	.930	0.882

Financial Fund	F1	3.70	.974	0.857
	F2	3.68	1.096	0.903
	F3	3.90	.839	0.901
Customer Focus	CF1	3.70	.863	0.94
	CF2	3.96	.832	0.913
	CF3	4.16	.889	0.861
Supplier Management	SM1	3.96	.638	0.955
	SM2	4.02	.769	0.913
	SM3	4.04	.856	0.935
	SM4	4.06	.843	0.915
Organizational Culture	OC1	3.66	.895	0.966
	OC2	4.38	.697	0.901
	OC3	4.32	.713	0.916

This data provided in (Table 4.9) factor analysis and description we can look at key aspects such as mean standard deviation and factor loading, which will help to assess the readiness and reliability of the factors. The key insights are:

1. Top management commitment shows that means from 3.88 to 4.12 which indicates that there is a supportive and commitment for implementing quality 4.0 on the other hand the factor loading for the items above 0.7 which means that the items have strong correlation with the construct

2. Vision and Strategy means show mix 3.88,3.42 and 3.66, nearly that all have moderate acceptance for adopting a new strategy to implement quality 4.0 and have a road map, and the factor loading also are above 0.7 for all factors that means there is a significant and strong correlation between factors, and it is reliable.
3. Technology adoption: there is a variation in the means from high of 3.84 for using ERP systems and low for additive manufacturing with score 1.56, which suggests that there a variety usage of industry 4.0 technologies like IOT AI, and cloud computing are somewhat adopted but virtual reality and 3D printing showing low score of usage, also the factor loading showing strong correlation for all items.
4. Leadership: scores of means are from 3.48 to 4.06 which means that there is a competent and supportive from leadership in promoting innovation and fostering quality culture, all items again are having strong correlation and reliable to measure the readiness.
5. Training and reward: means are balanced around 3.3 to 3.56 show a moderate result which suggests that training and rewards are somewhat aligned with quality 4.0 needs but not strong, and need improvement in ongoing training, factors also show that there is a strong relationship with construct
6. Knowledge and awareness: the scores are moderate, suggest that there is a gap in knowledge and employee awareness regarding industry 4.0 technologies, all items are reliable to assess the readiness since the factors loading are above 0.7
7. Financial Fund: average scores are 3.68 to 3.90 which shows moderate financial readiness for Quality 4.0 implementation, while the factors are reliable to assess the readiness since the factor loading more than 0.7
8. Customer focus: means are from 3.7 to 4.16 show that customer focus is well integrated in factories, and it has a strong factor loadings demonstrate that customer data, and digital tool and systems are well used
9. Supplier management: averages are from 3.96 to 4.06 showing strong supplier management practices, and indicators from loading factors contribute strongly to the readiness of quality 4.0
10. Organizational Culture: the average indicating a high supportive culture for Quality 4.0 although the readiness of factory to implement quality 4.0 culture in factories

suggests needs for more improvement in culture, all factors loading are above 0.7 which means that the items have strong relationship with their variable and it will represent it,

Finally, this factor-loading analysis suggests that the measurement model is robust.

4.6 KMO and Bartlett's Test

As shown in Table 4.10, Kaiser-Meyer-Olkin (KMO) is 0.811 which is considered excellent meaning that the data is suited for the analysis factor.

Table 4.10 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.811
Bartlett's Test of Sphericity	Approx. Chi-Square	426.551
	df	45
	Sig.	.000

4.7 Regression Analysis

To examine the relationships between the construct Quality 4.0 Readiness and the key factors, a correlation analysis was conducted. Pearson correlation coefficients were calculated to assess the strength of the relationships, p-value was used to determine statistical significance, and the results presented in Table 4.11.

Table 4.11: Correlation Matrix: p-values with Quality 4.0 Readiness

variable	p-value (Quality 4.0 Readiness)	Pearson Correlation (quality 4.0 Readiness)
Top management Commitment	0.000	0.828
Vision and Strategy	0.000	0.849
Technology Adoption	0.003	0.389
Leadership	0.000	0.723
Training and Rewards	0.000	0.810
Knowledge and Awareness	0.000	0.629
Financial Funding	0.000	0.929
Customer Focus	0.000	0.841
Supplier Management	0.000	0.709
Organizational Culture	0.000	0.804

1. All p-values are highly significant ($p<0.05$) for all variables in relation to Quality 4.0 Readiness, suggesting that each factor is significantly related to Quality 4.0 readiness, this indicates that all ten-hypothesis mentioned in chapter one from H1 to H10 are supported by the correlation analysis
2. The Pearson correlation analysis reveals the strength and direction of the relations between Quality 4.0 readiness and factors that influence its implementation in Palestinian food industries. The findings are:

   2.1 Financial funding, customer focus and vision and strategy show very strong positive correlations, indicating that financial resources are important for successful implementation, and having clear strategy for Quality 4.0 and focus on customer needs are important for readiness of quality 4.0

   2.2 Training and rewards, leadership, Top Management Commitment, organizational Culture, supplier management show strong positive correlations and moderate positive correlation suggesting that these are supportive key enablers of Quality 4.0 Readiness and important to influence Quality 4.0 Readiness

   2.3 Technology Adoption has the weakest positive correlation with quality 4.0 Readiness compared to other factors, while the relationship is statistically significant.

In addition to the correlation analysis, a multiple linear regression analysis was used to examine the impact of key factors on Quality 4.0 Readiness, and the results are presented as follows:

- R square and Adjusted R square are both equal 1 which assesses how the independent variables affect the readiness of Quality 4.0, and the results show that the independent variables explain 100% of the variance in Quality 4.0 Readiness, and suggests that the model fits the data perfectly
- ANOVA, the results in ANOVA test shows the sig. value <0.05 which indicates that the regression model is statistically significance
- Conclusion :while Technology adoption is important for preparing organizations for Quality 4.0 , it has moderate effect on readiness compared with other factors , this suggests that organization must not focus on adopting new technologies that related to Industry 4.0 but also on strengthening other factors and developing new strategies for successful implementation of Quality 4.0, technology adoption should be as part of broader transformation rather than a standalone solution.

4.8 Descriptive Analysis of Challenges

Table 4.12 summarizes the results for the challenges towards adopting Quality 4.0/

Table 4.12 Results for the challenges responses Descriptive Analysis

Descriptive Statistics						
Item	N	Minimum	Maximum	Mean	Std. Deviation	Rank (based on mean)
C1	50	3	5	3.82	.850	2
C2	50	2	4	3.00	.639	4
C3	50	2	5	3.66	.798	3
C4	50	2	5	4.06	.913	1
Valid N (listwise)	50					

4.9 Discussion of Results

Assessing the level of Readiness regarding the implementation of Quality 4.0 in the Palestinian Food industries and identifying the key factors of this process were the goals of the current study. Interesting trends regarding the relative strengths and weaknesses for Quality 4.0 are shown by descriptive and statistical analysis.

4.9.1 High Scoring Factors

Factors with high scores according to the results, the three areas that were be thought to be strongest in Palestinian food industries where Organizational Culture (m=4.12), Supplier Management (M=4.02) and Top management Commitment (M=3.98). This outcome further supports the idea that good leadership and organizational culture play a key role in facilitating the successful application of technology and quality management techniques, these factors are consistent with previous studies that identify organizational culture, supplier management, and top management commitment as key enablers for assessing readiness to implement Quality 4.0 as(Zulfiqar et al., 2023) determine in their study. Therefore, a mean score of 3.94 for Customer Focus indicates that the industry is ready for Quality 4.0, indicating that it is aware of the customers' needs, and it was consistent with the findings of the study of (Sony et al., 2021b). where the key factors identified.

4.9.2 Low Scoring Factors

Factors with low scores on the other hand, the indicators with the lowest scores: Technology Adoption and Knowledge and Awareness had respectively mean of 2.68 and 3.32, indicating potential for improvement. This supports the finding that, although Palestinian food industries are somewhat aware of the need for technological improvement, they may not be ready to completely implement the latest innovations that are essential to Industry 4.0. To close the gap in readiness for Quality 4.0, improvement in these areas might be significant, these findings are aligned with the challenges for developing industries in their transition to Industry 4.0 as mentioned in the study of (Dutta et al., 2021).

4.9.3 Correlation Insights

Every variable in the correlation analysis had a positive, significant relationship with Quality 4.0 Readiness(p-value<0.05). strong positive relationships were found among these with Financial Funding (r=0.93), Vision and Strategy (r=0.85), and Customer Focus (r=0.84). These findings suggest that a customer-oriented approach, clear strategic direction and sufficient financial Funding are the key elements of any successful implementation. It is possible to conclude that an organization's readiness is dependent on both internal capability and a strong financial-strategic foundation.

However, Technology Adoption has the lowest correlation value (r=0.39), suggesting that while technology is significant, it is not enough fully ready for Quality 4.0. This suggests a comprehensive strategy for change in which the use of technology will align with leadership, organizational Culture, and other supportive factors.

4.9.4 Reliability and Factor Analysis

The items assessing Quality 4.0 Readiness were very reliable because of the outstanding internal consistency, as evidenced by Cronbach's Alpha value of 0.929. All the variables, factors loading findings were over 0.7, suggesting that the measurement model was robust and that each factor had a good correlation with its corresponding items.

In Conclusion The results of this study highlight the impact and importance of Quality 4.0 Readiness key factors: organizational Culture, Top management commitment, Financial Fund, Technology Adoption, Supplier management, Knowledge and awareness, leadership, customer focus, training and rewards. Food industries in Palestine show strong readiness in certain areas, the challenges were addressed for the successful implementation of Quality 4.0 in this study like political, geographical and infrastructure factors. These findings align with the previous studies and emphasize the need for integrated and comprehensive strategy to transit to implement Industry in economies.

4.10 Implications for Practice

These results indicate that Palestinian food factories obviously still have a lot of work to do in terms of technology adoption and Awareness and knowledge, even though they are

comparatively well-prepared in terms of Organizational Culture, Leadership, and Financial Resources. It is better to think of Technology Adoption as a component of a more comprehensive, integrated strategy rather than as a top priority because it showed the smallest link with readiness. In addition to these significant factors, any business must have a robust technological foundation to fully address the difficulties posed by Quality 4.0. to improve the readiness for Quality, the following are some recommended steps:

1. Develop a strategy for technology adoption by assessing the technological needs and implement foundational technologies like ERP systems and machine learning
2. Investing in training and development of employees' skills and fostering understanding of new technologies, and engaged leadership in continuous learning with best practices in Industry 4.0
3. Strengthening financial plans by allocating budgets for investment in new technologies and training
4. Address gaps in infrastructure and regulations by collaborating with telecommunication companies to improve internet connectivity or any alternative and cooperation by regulatory authorities to allow investment in modern technologies and reduce fees and taxes on them.

4.11 Challenges in Adopting Quality 4.0 in Food Industries in Palestine

The challenges Palestinian food industries are facing with implementing Quality 4.0 are complex and interconnected on both an internal and external level. The following conclusions have been drawn from the questionnaire's descriptive statistics:

1. Financial Resources

For Quality 4.0 to be implemented successfully, financial considerations are also crucial. With an average score of 3.82 (SD = 0.85), this response makes it abundantly evident that having financial resources is a necessary precondition for acquiring technology and essential infrastructures. Many manufacturers face significant financial constraints that limit their ability to invest in cutting-edge technologies for the adoption of Quality 4.0.

2. Policies and Regulations

Restrictive laws and regulations are a major challenge to Palestine's adoption of Industry 4.0. The respondents' perception of policies is a barrier to implementing Industry 4.0, as indicated by the mean score of 3.00 with a standard deviation of 0.64. This must deal with regulatory bureaucratic hold-ups that might hinder the adoption of innovative technologies.

3. Israeli Occupation

Advanced technology imports are severely limited by the Israeli occupation. The mean of the declarations was 3.66 (SD = 0.80). As a result, the respondent claimed that import limitations prevent Palestinian enterprises from accessing essential technology that could improve Industry 4.0.

4. Internet and Connectivity

However, as most of the technologies used in Quality 4.0 rely on reliable internet connectivity, it should be mentioned that this is a prerequisite. With a mean score of 4.06 (SD = 0.91), this task was among the most important. Absolutely, not all of Palestine has enough Internet infrastructure; as a result, there is need for significant development in rural regions. These modifications could potentially make it more difficult to use IoT, AI, big data, and similar technologies to allow Quality 4.0.

These difficulties imply that to implement Quality 4.0 in Palestinian food industries, a process of changes to legislation, financial investments, and infrastructure development had to be started.

Chapter Five: Conclusions and Recommendations

5.1 Overview

The research problem addressed in this study is to assess the readiness of Palestinian food industries to implement Quality 4.0, a digital transformation in quality management practices that integrate new technologies related to Industry 4.0 such as automation, data analytics, internet of things. The aim of this study is to assess the current state of Palestinian factories to adopt Quality 4.0, considering factors such technology adoption, top management commitment, supplier management, customer focus, financial fund, leadership support, knowledge and awareness, training employees and rewards systems and organizational culture. The research seeks to identify the key barriers and drivers that influence implementing Quality 4.0 in Palestine and providing a framework for measuring this readiness. by focusing on diverse sample of food factories in Palestine, the study aims to fill the gap in the existing literature on Quality 4.0. especially in the context of developing countries where digital transformation is still in their earlier stage of adoption.

5.2 Conclusions

Based on the analysis of the data collected on the assessment of the readiness to implement Quality 4.0 in Palestinian food industries, the following conclusions can be drawn:

1. The diversity of the Palestinian food sectors, including beverages, dairy products, meat, chocolate and frozen foods. It gave a broad perspective on the readiness of different sectors of the food industry to implement Quality 4.0.
2. Demographic diversity in roles, experience and gender: questionnaire participants were well distributed across key management positions, with a notable presence of quality and factory managers. However, fewer technology engineers participated, the majority had significant experience, and the most common experience range was over

16 years. This indicates a high level of experience and understanding of quality processes within the industry. There was a disparity between the number of respondents, with males dominating the response, as they were 39 out of 50.

3. Factory size and workforce: Factories varied in size, with the majority employing over 100 people. This suggests that larger plants dominate the sample, which may impact overall readiness for Quality 4.0, as larger plants may have more resources and infrastructure to support Quality 4.0 implementation.
4. Quality system adoption: ISO 9001:2015 emerged as the most common quality system, followed by Quality Assurance and HACCP. The widespread use of these standardized quality management and food safety systems suggests that plants are already focused on maintaining high standards. However, the low adoption of Lean Six Sigma and statistical quality control suggests less focus on continuous improvement and advanced quality control methods.
5. Strengths in readiness factors: Factors with high scores such as organizational culture, supplier management, Top management commitment, and Customer focus indicate that these are strengths in factories' readiness for Quality 4.0. These factors reflect a positive organizational environment and lead to quality improvement.
6. Areas for improvement: Technology adoption, knowledge, and awareness scored lower, suggesting that factories may face challenges in adopting digital technologies and fully understanding the scope of Quality 4.0. These areas are critical for future improvement, especially in the context of Industry 4.0 integration.

In conclusion, while Palestinian food factories demonstrate a strong foundation in organizational culture, management support, and adoption of quality systems, there is a clear need to improve technology adoption and Knowledge and Awareness. Moving from the planning stage of technology development and use in quality management to actual implementation, addressing these gaps will be critical to ensuring a successful transition to Quality 4.0 and harnessing the benefits of Industry 4.0 technologies.

5.3 Recommendations

Based on the result of the study on assessing the readiness of Quality 4.0 in Palestinian food industries, the following recommendations are proposed to improve the readiness for implementation Quality 4.0:

1. Enhance Technology Adoption, there is a noticeable gap in technology adoption, related to the advanced technologies, it is important to invest in digital infrastructure and provide training to cover the technology gap, factories should prioritize the integration of Industry 4.0 technologies and encourage sharing of knowledge to foster digital literacy.
2. Increase Knowledge and Awareness on Quality 4.0: it is recommended to initiate awareness programs on the benefits of implementing Quality 4.0, it can be included in workshops academic institutions, or industry consultants to build understanding among management and employees.
3. Strengthening continuous improvement by adopting lean six sigma and statistical Quality Control methods, factories should invest in continuous improvement to align with the principles of Quality 4.0 to enhance efficiency and product quality.
4. Factories leadership should foster a culture of innovation and open to change to faster the adoption of implementing Quality 4.0
5. Supporting small businesses: Small businesses need financial support or alliances with large companies to bridge the gap and mitigate the measures that hinder the implementation of Quality 4.0.

5.4 Contribution to the Field

By giving insights into the readiness factors needed for effective implementation in the Palestinian food industry, this study adds to the growing body of research on Quality 4.0. It emphasizes how corporate culture, infrastructure, technology adoption, and top management support all contribute to the smooth transition to Quality 4.0. The study highlights significant

challenges like inexperience, lack of resources, and change resistance and provides ways to get around them. It also explains the potential advantages of Quality 4.0, such as improved competitiveness, product quality, and operational efficiency—all of which are critical for raising Palestinian food industries' level of global competitiveness. In addition to expanding knowledge of Quality 4.0 implementation in poor nations, this work establishes the basis for further studies in similar industrial contexts.

5.5 Limitations

1. Limited sample size: The study included data from only 50 factories and focused on factories that are using Industry 4.0 technology or planning to do so, so it was difficult to determine the sample size correctly and this also limited the possibility of generalizing the questionnaire broadly to food factories in Palestine.
2. Geographical scope: The research focused only on Palestinian food factories in the West Bank, which may not represent the readiness for Quality 4.0 in other regions or industries.
3. Poor current conditions: The current political conditions and the current poor road conditions did not help us to travel to factories due to their distribution in more than one geographical area in order to visit them and fill out the questionnaire in person and conduct interviews with stakeholders.
4. Self-filled data: Especially since each response to the questionnaire came from each factory separately, which means using survey methods that the data relies on self-reported information, which may lead to bias or inaccuracy.
5. Time constraints: Due to the limited time for data collection and analysis, some factors or variables may not be explored in depth.
6. Technological factors: The rapid evolution of Industry 4.0 technologies may cause some elements of the study to quickly become obsolete.

References

A Comprehensive Guide to Industry 4.0. (2023). Retrieved May 31, 2024, from https://www.clickmaint.com/blog/industry-4-0

Abd al-Rahman Muhammad Abd al-Rahman Khatib. (2020). The Fourth Industrial Revolution and its impact on the industrial hubs in the northern Palestinian governorates from the point of view of factory managers (Doctoral dissertation, Al-Quds University).Piccarozzi, M., Aquilani, B., & Gatti, C. (2018). Industry 4.0 in management studies: A systematic literature review. Sustainability, 10(10), 3821.

Abukhattab, S., Kull, M., Abu-Rmeileh, N. M., Cissé, G., Crump, L., Hattendorf, J., & Zinsstag, J. (2022). Towards a One Health Food Safety Strategy for Palestine: A Mixed-Method Study. Antibiotics, 11(10), 1359.

Adamik, A., & Nowicki, M. (2018). Preparedness of companies for digital transformation and creating a competitive advantage in the age of Industry 4.0. Proceedings of the International Conference on Business Excellence, 12(1), 10–24. https://doi.org/10.2478/picbe-2018-0003

Akdil, K. Y., Ustundag, A., & Cevikcan, E. (2018a). Maturity and Readiness Model for Industry 4.0 Strategy (pp. 61–94). https://doi.org/10.1007/978-3-319-57870-5_4

Akdil, K. Y., Ustundag, A., & Cevikcan, E. (2018b). Maturity and Readiness Model for Industry 4.0 Strategy (pp. 61–94). https://doi.org/10.1007/978-3-319-57870-5_4

Alcácer, V., & Cruz-Machado, V. (2019a). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. In Engineering Science and Technology, an International Journal (Vol. 22, Issue 3, pp. 899–919). Elsevier B.V. https://doi.org/10.1016/j.jestch.2019.01.006

Alcácer, V., & Cruz-Machado, V. (2019b). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. In Engineering Science and Technology, an International Journal (Vol. 22, Issue 3, pp. 899–919). Elsevier B.V. https://doi.org/10.1016/j.jestch.2019.01.006

Aldag, M. C., & Eker, B. (2018, November). What is Quality 4.0 in the era of Industry 4.0. In Proceedings of the 3rd International Conference on Quality of Life, Kopaonik, Serbia (pp. 28-30).

Alzahrani, B., Bahaitham, H., Andejany, M., & Elshennawy, A. (2021). How ready is higher education for Quality 4.0 transformation according to the LNS research framework?. Sustainability, 13(9), 5169

André M. Carvalhoa, Ana Rita Diasc, Ana Margarida Diasc, & and Paulo Sampaio. (2024).

The Quality 4.0 Roadmap: Designing a capability roadmap toward quality manage ment in Industry 4.0. Quality Management Journal.

Angreani, L. S., Vijaya, A., & Wicaksono, H. (2020). Systematic Literature Review of Industry 4.0 Maturity Model for Manufacturing and Logistics Sectors. Procedia Manufacturing, 52, 337–343. https://doi.org/10.1016/j.promfg.2020.11.056

Antony, J., Sony, M., Furterer, S., McDermott, O., & epper, M. (2022). Quality 4.0 and its impact on organizational performance: an integrative viewpoint. The TQM Journal, 34(6), 2069-2084

Antony, J., Sony, M., McDermott, O., Jayaraman, R., & Flynn, D. (2023). An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions. International Journal of Quality & Reliability Management, 40(2), 582-606.

Armani, C. G., de Oliveira, K. F., Munhoz, I. P., & Akkari, A. C. S. (2021). Proposal and application of a framework to measure the degree of maturity in Quality 4.0: A multiple case study. In Advances in Mathematics for Industry 4.0 (pp. 131-163). Academic Press.

Barari, A., de Sales Guerra Tsuzuki, M., Cohen, Y., & Macchi, M. (2021). Editorial: intelligent manufacturing systems towards industry 4.0 era. In Journal of Intelligent Manufacturing (Vol. 32, Issue 7, pp. 1793–1796). Springer. https://doi.org/10.1007/s10845-021-01769-0

Bibby, L., & Dehe, B. (2018). Defining and assessing industry 4.0 maturity levels – case of the defence sector. Production Planning & Control, 29(12), 1030–1043. https://doi.org/10.1080/09537287.2018.1503355

Bidin, R., Razak, M. N. F., Mohamad, B., Osman, M. N., Bakar, M. S. A., Tham, J. S., ... & Utaberta, N. (2021). Halal Industry's Organizational Performance Factors: A Systematic Literature Review. Pertanika Journal of Social Sciences & Humanities, 29(4).

Carbone, A. (2017). Food supply chains: coordination governance and other shaping forces. Agricultural and Food Economics, 5(1). https://doi.org/10.1186/s40100-017-0071-3

Castelo-Branco, I., Cruz-Jesus, F., & Oliveira, T. (2019). Assessing Industry 4.0 readiness in manufacturing: Evidence for the European Union. Computers in Industry, 107, 22–32. https://doi.org/10.1016/j.compind.2019.01.007

Chiarini, A. (2020). Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research. The TQM Journal, 32(4), 603–616. https://doi.org/10.1108/TQM-04-2020-0082

Chron Contributor ,(2021) .Trends That Are Affecting the Future of Quality Management, , retrieved 15/3/2024 from https://work.chron.com/trends-affecting-future-quality-management-25209.html

Cimini, C., Boffelli, A., Lagorio, A., Kalchschmidt, M., & Pinto, R. (2020). How do industry 4.0 technologies influence organisational change? An empirical analysis of Italian SMEs. Journal of Manufacturing Technology Management, 32(3), 695–721. https://doi.org/10.1108/JMTM-04-2019-0135

Colli, M., Berger, U., Bockholt, M., Madsen, O., Møller, C., & Wæhrens, B. V. (2019). A maturity assessment approach for conceiving context-specific roadmaps in the Industry 4.0 era. Annual Reviews in Control, 48, 165–177. https://doi.org/10.1016/j.arcontrol.2019.06.001

D. Jacob, (2018). What is Quality 4.0? , retrieved 15/3/2024 from ? http://blog.lnsresearch.com/quality40, published Jul 26, 2017

De Carolis, A., Macchi, M., Negri, E., & Terzi, S. (2017). A maturity model for assessing the digital readiness of manufacturing companies. IFIP Advances in Information and Communication Technology, 513, 13–20. https://doi.org/10.1007/978-3-319-66923-6_2

Djekić, I., Velebit, B., Pavlić, B., Putnik, P., Šojić Merkulov, D., Bebek Markovinović, A., & Bursać Kovačević, D. (2023). Food Quality 4.0: Sustainable Food Manufacturing for the Twenty-First Century. Food Engineering Reviews, 15(4), 577–608. https://doi.org/10.1007/s12393-023-09354-2

Drath, R.(2014) Industrie 4.0 - eine Einführung. open automation 3/14, 16-

Dutta, G., Kumar, R., Sindhwani, R., & Singh, R. Kr. (2021). Digitalization priorities of quality control processes for SMEs: a conceptual study in perspective of Industry 4.0 adoption. Journal of Intelligent Manufacturing, 32(6), 1679–1698. https://doi.org/10.1007/s10845-021-01783-2

Dwikat, S. Y., Arshad, D., & Mohd Shariff, M. N. (2022). The Influence of Systematic Strategic Planning and Strategic Business Innovation on the Sustainable Performance of Manufacturing SMEs: The Case of Palestine. Sustainability, 14(20), 13388. https://doi.org/10.3390/su142013388

E. D. B. Singapore. (2020). THE SMART INDUSTRY READINESS INDEX Catalysing the transformation of manufacturing The Smart Industry Readiness Framework The LEAD Framework. www.edb.gov.sg.

Food Systems Profile - Palestine. (2023). In Food Systems Profile - Palestine. FAO; European Union ; CIRAD; https://doi.org/10.4060/cc7323en

Frenzel, A., Muench, J. C., Bruckner, M., & Veit, D. (2021). Digitization or digitalization?–Toward an understanding of definitions, use and application in IS research.

Ganzarain, J., & Errasti, N. (2016). Three stage maturity model in SME's toward industry 4.0.Journal of Industrial Engineering and Management, 9(5), 1119. https://doi.org/10.3926/jiem.2073

Geissbauer, R., Vedso, J., & Schrauf, S. (2016). Industry 4.0: Building the digital enterprise.

Gergin, Z., İlhan, D. A., Üney-Yüksektepe, F., Gençyılmaz, M. G., Dündar, U., & Çavdarlı, A. İ. (2020). Comparative Analysis of the Most Industrialized Cities in Turkey from the Perspective of Industry 4.0 (pp. 263–277). https://doi.org/10.1007/978-3-030-31343-2_23

Ghobakhloo, M., & Ching, N. T. (2019). Adoption of digital technologies of smart manufacturing in SMEs. Journal of Industrial Information Integration, 16, 100107. https://doi.org/10.1016/j.jii.2019.100107

Gökalp, E., Şener, U., & Eren, P. E. (2017). Development of an Assessment Model for Industry 4.0: Industry 4.0-MM (pp. 128–142). https://doi.org/10.1007/978-3-319-67383-7_10

Grieco, A., Caricato, P., Gianfreda, D., Pesce, M., Rigon, V., Tregnaghi, L., & Voglino, A. (2017). An Industry 4.0 Case Study in Fashion Manufacturing. Procedia Manufacturing, 11, 871–877. https://doi.org/10.1016/j.promfg.2017.07.190

Hajoary, P. K. (2020). Industry 4.0 Maturity and Readiness Models: A Systematic Literature Review and Future Framework. International Journal of Innovation and Technology Management, 17(07). https://doi.org/10.1142/S0219877020300050

Hassoun, A. Jagtap, S., Garcia-Garcia, G., Trollman, H., Pateiro, M., Lorenzo, J. M., Trif, M., Rusu, A. V., Aadil, R. M., Šimat, V., Cropotova, J., & Câmara, J. S. (2023a). Food quality 4.0: From traditional approaches to digitalized automated analysis. Journal of Food Engineering, 337, 111216. https://doi.org/10.1016/J.JFOODENG.2022.111216

Hassoun, A., Jagtap, S., Garcia-Garcia, G., Trollman, H., Pateiro, M., Lorenzo, J. M., Trif, M., Rusu, A. V., Aadil, R. M., Šimat, V., Cropotova, J., & Câmara, J. S. (2023b). Food quality 4.0: From traditional approaches to digitalized automated analysis. Journal of Food Engineering, 337, 111216. https://doi.org/10.1016/j.jfoodeng.2022.111216

Hassoun, A., Jagtap, S., Trollman, H., Garcia-Garcia, G., Abdullah, N. A., Goksen, G., Bader, F., Ozogul, F., Barba, F. J., Cropotova, J., Munekata, P. E. S., & Lorenzo, J. M. (2023). Food processing 4.0: Current and future developments spurred by the fourth industrial revolution. Food Control, 145, 109507. https://doi.org/10.1016/j.foodcont.2022.109507

Hermann, M., Pentek, T., & Otto, B. (2016). Design Principles for Industrie 4.0 Scenarios. 2016 49th Hawaii International Conference on System Sciences (HICSS), 3928–3937. https://doi.org/10.1109/HICSS.2016.488

Herrmann, A., Huber, F., & Braunstein, C. (2000). Market-driven product and service design: Bridging the gap between customer needs, quality management, and customer satisfaction. International Journal of Production Economics, 66(1), 77–96. https://doi.org/10.1016/S0925-5273(99)00114-0

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. Computers in Industry, 89, 23–34. https://doi.org/10.1016/j.compind.2017.04.002

Hsiao, Y. C., Chang, C. H., & Wu, T. Y. (2019). "IoT and industry 4.0: A literature review." Journal of Industrial Integration and Management, 4(3), 1950003

Huang, Z., Shahzadi, A., & Khan, Y. D. (2022). Unfolding the Impact of Quality 4.0 Practices on Industry 4.0 and Circular Economy Practices: A Hybrid SEM-ANN Approach. Sustainability (Switzerland), 14(23). https://doi.org/10.3390/su142315495

Ingaldi, M., & Ulewicz, R. (2019). Problems with the Implementation of Industry 4.0 in Enterprises from the SME Sector. Sustainability, 12(1), 217. https://doi.org/10.3390/su12010217

Javaid, M., Haleem, A., Pratap Singh, R., & Suman, R. (2021a). Significance of Quality 4.0 towards comprehensive enhancement in manufacturing sector. Sensors International, 2, 100109. https://doi.org/10.1016/j.sintl.2021.100109

Javaid, M., Haleem, A., Pratap Singh, R., & Suman, R. (2021b). Significance of Qality 4.0 towards comprehensive enhancement in manufacturing sector. In Sensors International (Vol. 2). KeAi Communications Co. https://doi.org/10.1016/j.sintl.2021.100109

Javaid, M., Haleem, A., Pratap Singh, R., & Suman, R. (2021c). Significance of Quality 4.0 towards comprehensive enhancement in manufacturing sector. In Sensors International (Vol. 2). KeAi Communications Co. https://doi.org/10.1016/j.sintl.2021.100109

Javaid, M., Haleem, A., Pratap Singh, R., & Suman, R. (2021d). Significance of Quality 4.0 towards comprehensive enhancement in manufacturing sector. In Sensors International (Vol. 2). KeAi Communications Co. https://doi.org/10.1016/j.sintl.2021.100109

Javaid, M., Haleem, A., Singh, R. P., Suman, R., & Gonzalez, E. S. (2022). Understanding the adoption of Industry 4.0 technologies in improving environmental sustainability. Sustainable Operations and Computers, 3, 203-217.

Jin, C., Bouzembrak, Y., Zhou, J., Liang, Q., van den Bulk, L. M., Gavai, A., Liu, N., van den Heuvel, L. J., Hoenderdaal, W., & Marvin, H. J. P. (2020). Big Data in food safety- A review. Current Opinion in Food Science, 36, 24–32. https://doi.org/10.1016/j.cofs.2020.11.006

Johnson, S. (2019). Quality 4.0: A trend within a trend. In Quality 4.0: A trend within a trend.

Jung, K., Kulvatunyou, B., Choi, S., & Brundage, M. P. (2016). An Overview of a Smart Manufacturing System Readiness Assessment (pp. 705–712). https://doi.org/10.1007/978-3-319-51133-7_83

Juran. (2019, June 15). Quality 4.0: The Future of Quality? https://www.juran.com/blog/quality-4-0-the-future-of-quality/

Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative Industrie 4.0: Final report of the Industrie 4.0 Working Group. Forschungsunion: Berlin, Germany, 12-25.

Karthik Sundaram, & Prem Shanmugam. (2019). 50 Years of Growth, Innovation and Leadership Quality 4.0: A Paradigm Shift of In-line Inspection in Body-in-White. www.frost.com

Kaushik, A., & Singh, D. (2021). The impact of advanced manufacturing technologies on performance in an Indian manufacturing industry: a case study. International Journal of Indian Culture and Business Management, 23(2), 153. https://doi.org/10.1504/IJICBM.2021.115889

Khang, A., Abdullayev, V., Hahanov, V., & Shah, V. (2024). Advanced IoT Technologies and Applications in the Industry 4.0 Digital Economy. CRC Press. https://doi.org/10.1201/9781003434269

Khourshed, N., & Gouhar, N. (2023). Developing a Systematic and Practical Road Map for Implementing Quality 4.0. Quality Innovation Prosperity, 27(2), 96–121. https://doi.org/10.12776/QIP.V27I2.1859

Kilimis, P., Zou, W., Lehmann, M., & Berger, U. (2019). A Survey on Digitalization for SMEs in Brandenburg, Germany. IFAC-PapersOnLine, 52(13), 2140–2145. https://doi.org/10.1016/j.ifacol.2019.11.522

Ko, M., Kim, C., Lee, S., & Cho, Y. (2020). An Assessment of Smart Factories in Korea: An Exploratory Empirical Investigation. Applied Sciences, 10(21), 7486. https://doi.org/10.3390/app10217486

Kshetri, N., & Voas, J. (2022). A literature review of blockchain technology in Industry 4.0 and the IIoT. International Journal of Information Management, 63, 102503.

Küpper, D., Knizek, C., Ryeson, D., & Noecker, J. (2019). Quality 4.0 takes more than technology. Boston Consulting Group (BCG), 20

Lee, J., Jun, S., Chang, T.-W., & Park, J. (2017). A Smartness Assessment Framework for Smart Factories Using Analytic Network Process. Sustainability, 9(5), 794. https://doi.org/10.3390/su9050794

Leyh, C., Bley, K., Schäffer, T., & Forstenhäusler, S. (2016, September). SIMMI 4.0-a maturity model for classifying the enterprise-wide it and software landscape focusing on Industry 4.0. In 2016 federated conference on omputer science and information systems (fedcsis) (pp. 1297-1302). IEEE.

Leyh, C., Martin, S., & Schäffer, T. (2017). Industry 4.0 and Lean Production – A Matching Relationship? An analysis of selected Industry 4.0 models. 989–993. https://doi.org/10.15439/2017F365

Leyh, C., Schäffer, T., Bley, K., & Forstenhäusler, S. (2017). Assessing the IT and Software Landscapes of Industry 4.0-Enterprises: The Maturity Model SIMMI 4.0 (pp. 103–119). https://doi.org/10.1007/978-3-319-53076-5_6

Lichtblau, K., Volker Stich, D.-I., Bertenrath, R., Blum, M., Bleider, M., Millack, A., Schmitt, K., Schmitz, E., & Schröter, M. (2015). INDUSTRIE 4.0-READINESS.

Matt, D. T., Modrák, V., & Zsifkovits, H. (2021). Implementing Industry 4.0 in SMEs: Concepts, Examples and Applications. In Implementing Industry 4.0 in SMEs: Concepts, Examples and Applications. Springer International Publishing. https://doi.org/10.1007/978-3-030-70516-9

Mialon, M., Swinburn, B., & Sacks, G. (2015). A proposed approach to systematically identify and monitor the corporate political activity of the food industry with respect to public health using publicly available information. Obesity Reviews, 16(7), 519–530. https://doi.org/10.1111/obr.12289

Mittal, S., Romero, D., & Wuest, T. (2018). Towards a Smart Manufacturing Maturity Model for SMEs (SM3E) (pp. 155–163). https://doi.org/10.1007/978-3-319-99707-0_20

Montgomery, D. C. (2019). Introduction to statistical quality control. John wiley & sons.

Motyl, B., Baronio, G., Uberti, S., Speranza, D., & Filippi, S. (2017). How will Change the Future Engineers' Skills in the Industry 4.0 Framework? A Questionnaire Survey. Procedia Manufacturing, 11, 1501–1509. https://doi.org/10.1016/j.promfg.2017.07.282

Oliveira, D., Alvelos, H., & Rosa, M. J. (2024). Quality 4.0: results from a systematic literature review. The TQM Journal. https://doi.org/10.1108/TQM-01-2023-0018

Osakwe, C. N. (2020). Customer centricity: an empirical analysis in the micro-sized firm. Journal of Strategic Marketing, 28(5), 455–468. https://doi.org/10.1080/0965254X.2019.1566268

Pacchini, A. P. T., Lucato, W. C., Facchini, F., & Mummolo, G. (2019). The degree of readiness for the implementation of Industry 4.0. Computers in Industry, 113, 103125. https://doi.org/10.1016/j.compind.2019.103125

Palestine Federation of Industries. (2024, May 30). Main Palestinian industries. Retrieved May 31, 2024, from https://pfiu.org/ar/who-are-we/main-pal-industries

Palestine Investment Promotion Agency. (2024, March 27). Food and beverage industry.

Palestine Investment Promotion Agency. Food and beverage industry. Retrieved 27/3/2024, from http://www.pipa.ps/ar_page.php?id=1af277y1766007Y1af277

Park, S., Hartley, J. L., & Wilson, D. (2001). Quality management practices and their relationship to buyer's supplier ratings: a study in the Korean automotive industry. Journal of Operations Management, 19(6), 695–712. https://doi.org/10.1016/S0272-6963(01)00065-1

Pech, M., & Vrchota, J. (2020). Classification of Small- and Medium-Sized Enterprises Based on the Level of Industry 4.0 Implementation. Applied Sciences, 10(15), 5150. https://doi.org/10.3390/app10155150

Peruzzini, M., Grandi, F., & Pellicciari, M. (2017). Benchmarking of Tools for User Experience Analysis in Industry 4.0. Procedia Manufacturing, 11, 806–813. https://doi.org/10.1016/j.promfg.2017.07.182

Quality 4.0, Quality Glossary Definition: Quality 4.0, American Society of Quality (ASQ). Retrieved on 20-3-2024 from www.asq.org

Radziwill, N. M. (2018). "Let's Get Digital | ASQ", ASQ.Org, available at:, retrieved 16/3/2024 from https://asq.org/quality-progress/articles/lets-get-digital?id=526b64168f1f4f2c80648300336bad1a

Ralea, C., Dobrin, O.-C., Barbu, C., & Tănase, C. (2020). Proceedings Of The 13 Th International Management Conference "Management Strategies For High Performance" Looking To The Future: Digital Transformation Of Quality Management Looking To The Future: Digital Transformation Of Quality Management. Https://Www.Researchgate.Net/Publication/338501613

Rauch, E., Unterhofer, M., Rojas, R. A., Gualtieri, L., Woschank, M., & Matt, D. T. (2020a). A Maturity Level-Based Assessment Tool to Enhance the Implementation of Industry 4.0 in Small and Medium-Sized Enterprises. Sustainability, 12(9), 3559. https://doi.org/10.3390/su12093559

Rauch, E., Unterhofer, M., Rojas, R. A., Gualtieri, L., Woschank, M., & Matt, D. T. (2020b). A Maturity Level-Based Assessment Tool to Enhance the Implementation of Industry 4.0 in Small and Medium-Sized Enterprises. Sustainability, 12(9), 3559. https://doi.org/10.3390/su12093559

References Development Department, B. L. (2024). About the Federation - Palestinian Food and Agricultural Industries Federation. Palestinian Federation of Food and Agricultural Industries. Retrieved from https://pfiu.org/ar/who-are-we/about

Ries, J., & Duan, Y. (2022). "Industry 4.0, IIoT and the digital transformation of manufacturing: A review and future research agenda." International Journal of Production Economics, 243, 108505

Ritter, T., and C. L. Pedersen. 2020. Digitization capability and the digitalization of business models in business-to-business firms: Past, present, and future. Industrial Marketing Management 86:180–90. doi: 10.1016/j.indmarman.2019.11.019.

Rockwell Automation. (2014). The Connected Enterprise Maturity Model.

Rojas-Berrio, S., Rincon-Novoa, J., Sánchez-Monrroy, M., Ascúa, R., & Montoya-Restrepo, L. A. (2022). Factors Influencing 4.0 Technology Adoption in Manufacturing SMEs in an Emerging Country. Journal of Small Business Strategy, 32(3). https://doi.org/10.53703/001c.34608

Sader, S., Husti, I., & Daroczi, M. (2022). A review of quality 4.0: definitions, features, technologies, applications, and challenges. Total Quality Management & Business Excellence, 33(9–10), 1164–1182. https://doi.org/10.1080/14783363.2021.1944082

Sajid, S., Haleem, A., Bahl, S., Javaid, M., Goyal, T., & Mittal, M. (2021). Data science applications for predictive maintenance and materials science in context to Industry 4.0. Materials Today: Proceedings, 45, 4898–4905. https://doi.org/10.1016/j.matpr.2021.01.357

Sami Sader, Istvan Husti & Miklos Daroczi (2022): A review of Quality 4.0: definitions, features, technologies, applications, and challenges, Total Quality Management &Business Excellence, DOI: 10.1080/14783363.2021.1944082

Schuh, G., Anderl, R., Dumitrescu, R., & Krüger, A. (2017). acatech STUDY Industrie 4.0 Maturity Index.

Schumacher, A., Erol, S., & Sihn, W. (2016). A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. Procedia CIRP, 52, 161–166. https://doi.org/10.1016/j.procir.2016.07.040

Scremin, L., Armellini, F., Brun, A., Solar-Pelletier, L., & Beaudry, C. (2018). Towards a Framework for Assessing the Maturity of Manufacturing Companies in Industry 4.0 Adoption (pp. 224–254). https://doi.org/10.4018/978-1-5225-3468-6.ch012

SHI, X., BABA, T., OSAGAWA, D., FUJISHIMA, M., & ITO, T. (2019). A Maturity Model for Sustainable System Implementation in the Era of Smart Manufacturing. 2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), 1649–1652. https://doi.org/10.1109/ETFA.2019.8869446

Shin, W. S., Dahlgaard, J. J., Dahlgaard-Park, S. M., & Kim, M. G. (2018). A Quality Scorecard for the era of Industry 4.0. Total Quality Management & Business Excellence, 29(9–10), 959–976. https://doi.org/10.1080/14783363.2018.1486536

Siphoro, K. T., Bakama, E. M., Mukwakungu, C. M., & Sukdeo, N. (2020). Transition to Quality 4.0 and lean4.0 from traditional lean and quality systems: The case of a packaging company in South Africa. 2020 IEEE International Conference on Technology Management, Operations and Decisions (ICTMOD), 1–5. https://doi.org/10.1109/ICTMOD49425.2020.9380619

Sony, M., & Naik, S. (2020). Critical factors for the successful implementation of Industry 4.0: a review and future research direction. Production Planning & Control, 31(10), 799–815. https://doi.org/10.1080/09537287.2019.1691278

Sony, M., Antony, J., & Douglas, J. A. (2020a). Essential ingredients for the implementation of Quality 4.0. The TQM Journal, 32(4), 779–793. https://doi.org/10.1108/TQM-12-2019-0275

Sony, M., Antony, J., & Douglas, J. A. (2020b). Essential ingredients for the implementation of Quality 4.0. The TQM Journal, 32(4), 779–793. https://doi.org/10.1108/TQM-12-2019-0275

Sony, M., Antony, J., Douglas, J. A., & McDermott, O. (2021). Motivations, barriers and readiness factors for Quality 4.0 implementation: an exploratory study. TQM Journal, 33(6), 1502–1515. https://doi.org/10.1108/TQM-11-2020-0272

Tetra Pak. (2024). Industry 4.0: Food safety & quality. Retrieved from https://www.tetrapak.com/insights/cases-articles/industry-4-food-safety-and-quality

The Importance of Halal Certification in the Food Industry. (2024, March 27).

The Importance of Halal Certification in the Food Industry. Retrieved 27/3/2024, from https://wholesalefoodgroup.com.au/importance-of-halal-certification/#:~:text=The%20Assurance%20of%20Product%20Quality,hygiene%2C%20which%20benefits%20all%20consumers.

Torous, J., Jän Myrick, K., Rauseo-Ricupero, N., & Firth, J. (2020). Digital Mental Health and COVID-19: Using Technology Today to Accelerate the Curve on Access and Quality Tomorrow. JMIR Mental Health, 7(3), e18848. https://doi.org/10.2196/18848

Türkeș, M., Oncioiu, I., Aslam, H., Marin-Pantelescu, A., Topor, D., & Căpușneanu, S. (2019). Drivers and Barriers in Using Industry 4.0: A Perspective of SMEs in Romania. Processes, 7(3), 153. https://doi.org/10.3390/pr7030153

Ünlü, H., Demirörs, O., & Garousi, V. (2023a). Readiness and maturity models for Industry 4.0: A systematic literature review. Journal of Software: Evolution and Process. https://doi.org/10.1002/smr.2641

Ünlü, H., Demirörs, O., & Garousi, V. (2023b). Readiness and maturity models for Industry 4.0: A systematic literature review. Journal of Software: Evolution and Process. https://doi.org/10.1002/smr.2641

Ustundag, A., Cevikcan, E., Akdil, K. Y., Ustundag, A., & Cevikcan, E. (2018). Maturity and readiness model for Industry 4.0 strategy. Industry 4.0: Managing the digital transformation, 61-94.

Wagire, A. A., Joshi, R., Rathore, A. P. S., & Jain, R. (2021). Development of maturity model for assessing the implementation of Industry 4.0: learning from theory and practice. Production Planning & Control, 32(8), 603–622. https://doi.org/10.1080/09537287.2020.1744763

Watson, G. (2019). “The ascent of Quality 4.0”. American Society for Quality.

What is Quality 4.0? And What It Isn’t. (2023, March 28). https://www.lnsresearch.com/. Retrieved March 20, 2024, from https://blog.lnsresearch.com/what-is-quality-4.0-and-what-it-

isnt#:~:text=At%20LNS%20Research%2C%20we%20define,%2C%20logistics%2C%20and%20customer%20experience.

Xu, L. Da, Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. International Journal of Production Research, 56(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806

Yang, Y., Zhang, L., & Sun, L. (2020). "Industry 4.0 and industrial Internet of Things (IIoT)-based smart manufacturing: A case study." International Journal of Production Research, 58(18), 5598–5610.

Yassur, Y.(2024, June 1). *The Impact of Industry 4.0 on Food and Beverage Manufacturing*. Matics. https://matics.live/blog/the-impact-of-industry-4-0-on-food-and-beverage-manufacturing/

Yu, F., & Schweisfurth, T. (2020). Industry 4.0 technology implementation in SMEs – A survey in the Danish-German border region. International Journal of Innovation Studies, 4(3), 76–84. https://doi.org/10.1016/j.ijis.2020.05.001

Ziaei Nafchi, M., & Mohelská, H. (2020). Organizational Culture as an Indication of Readiness to Implement Industry 4.0. Information, 11(3), 174. https://doi.org/10.3390/info11030174

Zonnenshain, A., & Kenett, R. S. (2020). Quality 4.0—the challenging future of quality engineering. Quality Engineering, 32(4), 614–626. https://doi.org/10.1080/08982112.2019.1706744

Zulfiqar, M., Antony, J., Swarnakar, V., Sony, M., Jayaraman, R., & McDermott, O. (2023). A readiness assessment of Quality 4.0 in packaging companies: an empirical investigation. Total Quality Management and Business Excellence, 34(11–12), 1334–1352. https://doi.org/10.1080/14783363.2023.2170223

Zulfiqar, M., Antony, J., Swarnakar, V., Sony, M., Jayaraman, R., & McDermott, O. (2023). A readiness assessment of Quality 4.0 in packaging companies: an empirical investigation. Total Quality Management & Business Excellence, 34(11-12), 1334-1352

Zulqarnain, A., Wasif, M., & Iqbal, S. A. (2022). Developing a Quality 4.0 Implementation Framework and Evaluating the Maturity Levels of Industries in Developing Countries. Sustainability, 14(18), 11298. https://doi.org/10.3390/su141811298

Appendices

ملحق 1 : استبانة باللغة العربية تقييم جاهزية تطبيق الجودة 4.0 في الصناعات الغذائية في فلسطين

مقدمة :

هي مفهوم حديث في إدارة الجودة يتكامل مع التطور التكنولوجي الكبير (Quality 4.0) الجودة 4.0 للأدوات الرقمية والتي تستخدم لتحسين جودة المنتجات والخدمات. تعتمد الجودة 4.0 على المبادئ والتقنيات ، والتي تشمل الذكاء الاصطناعي، إنترنت الأشياء، (Industry 4.0) الأساسية، لصناعة 4.0

.البيانات الضخمة، الروبوتات، والأتمتة

تهدف هذه الاستبانة الى قياس جاهزية تطبيق مفاهيم الجودة 4.0 في قطاع الصناعات الغذائية في فلسطين، وتأتي هذا الاستبانة كجزء لدراسة بحثية للحصول على درجة الماجستير في ادارة الجودة من الجامعة العربية الامريكية والتي تهدف الى فهم مدى تبني المصانع الغذائية للتقنيات الحديثة والتحول الرقمي .في إدارة الجودة والإنتاج

نأمل استفادتنا من خبرتكم كمشاركين في هذا المجال لتقديم ملاحظاتكم حول الفرص والتحديات التي .تواجه الصناعات الغذائية في استخدام تكنولوجيا الجودة 4.0

:تتكون هذه الاستبانة من عدة اقسام وهي كالآتي

المعلومات الديموغرافية، عوامل تقييم الجاهزية لتطبيق الجودة 4.0، أنظمة إدارة الجودة المستخدمة، التحديات والفوائد لتطبيق الجودة 4.0

يرجى العلم بأن بيانات هذه الدراسة هي لأغراض البحث العلمي وسيتم مراعاة الخصوصية بها، بإمكانكم اختيار عدم ذكر اسم المصنع في المعلومات الديموغرافية، شاكرين حسن تعاونكم

وتفضلوا بقبول فائق الاحترام

الطالبة: منى رزق احمد

المشرف: د. سامي الصدر

الجزء الأول: المعلومات الديموغرافية

يرجى الإجابة على كافة الاسئلة

1. ما هو اسم المصنع؟ (بإمكانك تركه فارغا حسب رغبتكم بعدم ذكر اسم المصنع.....

2. ما هو نوع الصناعات الغذائية التي يقوم المصنع بتصنيعها.....

3. ما هو المسمى الوظيفي / الدور داخل المصنع؟

a) مدير المصنع

b) مدير الجودة

c) مهندس تقني

d) أخرى (يرجى ذكر المسمى الوظيفي..... (

4. الجنس

a) ذكر

b) انثى

5. كم عدد سنوات الخبرة لديك في الصناعات الغذائية

a) 0-5

b) 6-10

c) 11-15

d) 16وأكثر

6. ما هو حجم المصنع (عدد الموظفين)؟

a) اقل من 10

b) من 10 الى 50

c) من 50الى 100
d) أكثر من 100

.7ما هي أنظمة/أدوات الجودة المطبقة لديكم (يمكن اختيار أكثر من نظام/أداة) :

a) ISO 9001:2015
b) ISO 22000:2018
c) HACCP
d) Lean & Six-Sigma
e) Statistical Quality Control
f) Quality Assurance
g) Inspection
h) control chart

الجزء الثاني: عوامل تقييم الجاهزية للجودة 4.0

القسم الاول: دعم الإدارة العليا

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	هناك دعم من الادارة العليا لتطبيق الجودة 4.0 في مصنعك					
	تفهم الادارة العليا اهمية الجودة 4.0 في تحثيث اهداف المصنع					
	هناك استعداد من القادة في تنفيذ الجودة 4.0					
	لدى الادارة الكفاءة لتحقيق الجودة 4.0					
	لدى الادارة التزام نحو تنفيذ الجودة 4.0					

القسم الثاني: الرؤيا والاستراتيجية للجودة 4.0

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	لدى المصنع جاهزية لتطبيق نظام ادارة جودة حديث يتماشى مع تكنولوجيا الثورة الصناعية الرابعة					
	لدى المصنع خارطة طريق لتنفيذ الجودة 4.0					
	هناك توافق بين رؤية واستراتيجية المصنع مع الجودة 4.0					

القسم الثالث: اعتماد التكنولوجيا لإدارة الجودة

ملاحظة: 1. غير مطبق 2. مرحلة التخطيط 3. مطبق بشكل جزئي 4. قريب من التطبيق الكامل 5. مطبق بالكامل

	السؤال					
	تستخدم مؤسستك إنترنت الأشياء لعمليات إدارة الجودة					
	تستخدم مؤسستك الذكاء الاصطناعي لعمليات إدارة الجودة					
	تستخدم مؤسستك تحليلات البيانات الضخمة لعمليات إدارة الجودة					
	تستخدم مؤسستك الحوسبة السحابية لعمليات إدارة الجودة					
	ت تستخدم مؤسستك التعلم الآلي (machine learning) لعمليات إدارة الجودة					

	تستخدم مؤسستك الواقع الافتراضي لعمليات ادارة الجودة					
	تستخدم مؤسستك انترنت الاشياء الصناعية					
	تستخدم مؤسستك التصنيع الاضافي (الطباعة ثلاثية الابعاد)					
	يستخدم في المصنع أدوات ذكاء الاعمال (business intelligence)					
	تستخدم مؤسستك انظمة الامن السيبرانية					
	يوجد لدى المصنع انظمة ادارة الموارد (ERP)					

القسم الرابع: القيادة والتعاون

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	يوجد في المصنع تنسيق مركزي لتوجيه الجهود والموارد نحو اهداف محددة لتنفيذ مبادرة الجودة 4.0					
	تعزز قيادة المصنع الابتكار والتواصل الفعال مما يؤدي لتحسين اداء المصنع وتحقيق اهدافه					
	يتم اشراك جميع العاملين في المصنع وتشجيعهم على المشاركة من اجل تطبيق الجودة 4.0					
	تقوم القيادة بتوفير الدعم اللازم لتعزيز ثقافة الجودة وخاصة الجودة 4.0 واهمية استخدامها					
	يتم تبادل المعرفة والخبرات بين الشركات والمصانع مما يدعم تحسين الاداء وتحقيق التطور					

القسم الخامس: التدريب و التطوير

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	مدى قدرة العاملين على دعم تطبيق خصائص الجودة المتعلقة بالثورة الصناعية الرابعة					
	يتمتع الموظفون بالكفاءة اللازمة للتعامل مع الجودة المرتبطة بالثورة الصناعية الرابعة					
	يتم تحديد احتياجات وتدريب الموظفين على مفاهيم وتقنيات الجودة 4.0					
	خصص المصنع فريقا أو موظفين لمبادرات الجودة 4.0					
	التدريب المقدم على تقنيات إدارة الجودة يتم بشكل مستمر					
	يوجد نظام مكافآت لتعزيز اعتماد ممارسة ادارة الجودة الجديدة					

القسم السادس: المعرفة والوعي بالجودة 4.0

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	لدى المتخصصين في المصنع المعرفة والوعي بكيفية تنفيذ خصائص الجودة المتعلقة بالثورة الصناعية الرابعة					
	الموظفون في المصنع لديهم المعرفة بفوائد منهجية الجودة 4.0 المتوافق مع تطبيق تكنولوجيا الثورة الصناعية الرابعة4.0					
	لدى المصنع الخبراء والمهندسين القادرين على تفعيل وتوظيف التكنولوجيا لخدمة الجودة 4.0					
	يقوم المصنع بتطوير مهارات الجودة والمعرفة لتنفيذ الطريقة الحديثة للجودة والمتوافقة مع الثورة الصناعية الرابعة					

(القسم السابع: الدعم المالي (الميزاينة المخصصة

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	لدى المصنع موارد مالية لازمة لتحقيق الجودة 4.0					
	يخطط المصنع لتخصيص ميزانية لتنفيذ الجودة 4.0 في السنوات المقبلة					
	هناك برامج محوسبة لإدارة القرارات المالية في المصنع					

القسم الثامن: التركيز على العملاء

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	هناك وسائط رقمية ذات كفاءة للتعامل مع العملاء					
	يتم استخدام بيانات العملاء مثل (المبيعات ، ردود الافعال ، الاحتياجات) في الجودة 4.0					
	لدى المصنع انظمة محوسبة للمبيعات وخدمات العملاء					

القسم التاسع: التركيز على الموردين

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	يضمن المصنع التحسين المستمر من خلال تقليل تكلفة الجودة والخسائر الهدر عبر دورة الانتاج الشاملة					
	يقوم المصنع بوضع اكواد قابلة للمسح الضوئي على المنتجات					

	يوجد لدى المصنع نظام ادارة موردين					
	يتم في المصنع مراقبة الموردين بانتظام					

القسم العاشر: الجاهزية والثقافة التنظيمية

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	المصنع جاهز لتطبيق الجودة 4.0					
	هناك ثقافة التحسين المستمر والابتكار داخل المصنع					
	القيادة داعمة في تبني تقنيات إدارة الجودة الجديدة					

القسم الحادي عشر: التحديات السياسية

ملاحظة: 1. منخفض جدا 2. منخفض 3. معتدل 4. عالي 5. عالي جدا

	السؤال					
	الموارد المالية لها دور في تطبيق الجودة 4.0					
	السياسات والتشريعات تقيد تطبيق الصناعة 4.0 في فلسطين					
	الاحتلال الإسرائيلي يمنع استيراد التقنيات المتطورة لتطبيق الصناعة 4.0					
	الانترنت السريع والاتصال الموثوق له تأثير على تطبيق الجودة 4.0					

Abbreviations

Abbreviation	Explanation
TMC1	There is support from top management for implementing Quality 4.0 in your factory
TMC2	Top management understands the importance of quality 4.0 in achieving the factory's goals
TMC3	There is a willingness from leaders to implement quality 4.0
TMC4	Management has the competence to achieve quality 4.0
TMC5	Management is committed to implement Quality 4.0
VS1	The factory is ready to implement a modern quality management system compatible with industry 4.0 technologies
VS2	The factory has a roadmap for implementing quality 4.0
VS3	There is alignment between the factory's vision and strategy with the application and utilization of quality 4.0 tools
TA1	The factory uses internet of things IOT for quality management operations
TA2	The factory uses artificial intelligence for quality management operations
TA3	The factory uses big data analytics for quality management operations
TA4	Your factory uses cloud computing for quality management operations
TA5	Your factory uses machine learning for quality management operations
TA6	Your factory uses virtual reality for quality management operations
TA7	Your factory uses industrial internet of things
TA8	Your factory uses additive manufacturing (3D printing)
TA9	Your factory uses business intelligence tools
TA10	Your factory uses cybersecurity systems
TA11	Your factory has an enterprise resource planning (ERP) system
L1	Your factory has centralized coordination to direct efforts and resources toward specific goals for implementing Quality 4.0 initiatives
L2	Factory leadership promotes innovation and effective communication, leading to improved performance and goal achievement.
L3	All employees in the factory are involved and encouraged to participate in the implementation of Quality 4.0.
L4	Leadership provides necessary support to foster a quality culture, especially the importance of using Quality 4.0.

L5	Knowledge and experiences are shared between companies and factories to support performance improvement and development.
TR1	Employees' ability to support the implementation of Quality 4.0 characteristics related to Industry 4.0
TR2	Employees have the required competence to handle Industry 4.0-related quality management.
TR3	The factory identifies employees' training needs on Quality 4.0 concepts and techniques.
TR4	The factory has allocated a team or staff for Quality 4.0 initiatives.
TR5	The training provided on quality management techniques is continuous.
TR6	There is a rewards system to enhance the adoption of new quality management practices
KA1	Factory specialists have the knowledge and awareness of how to implement the characteristics of Quality 4.0 related to Industry 4.0.
KA2	Employees in the factory have knowledge of the benefits of the Quality 4.0 methodology in line with the application of Industry 4.0 technologies
KA3	The factory has experts and engineers capable of activating and utilizing technology for Quality 4.0.
KA4	The factory develops quality skills and knowledge to implement the modern quality method compatible with Industry 4.0.
F1	The factory has the financial resources necessary to achieve Quality 4.0.
F2	The factory plans to allocate a budget for implementing Quality 4.0 in the coming years.
F3	There are computerized systems for financial decision management in the factory
CF1	There are efficient digital tools to deal with customers.
CF2	Customer data, such as sales, feedback, and needs, are used in Quality 4.0
CF3	The factory has computerized sales and customer service systems
SM1	The factory ensures continuous improvement by reducing the cost of quality, losses, and waste across the entire production cycle.
SM2	The factory applies scannable codes to products.
SM3	The factory has a supplier management system.
SM4	The factory regularly monitors supplier performance
OC1	The factory is ready to implement Quality 4.0.
OC2	There is a culture of continuous improvement and innovation within the factory.

OC3	Leadership is supportive of adopting new quality management techniques
C1	Financial resources play a role in implementing Quality 4.0.
C2	Policies and regulations restrict the implementation of Industry 4.0 in Palestine.
C3	The Israeli occupation prevents the importation of advanced technologies for implementing Industry 4.0.
C4	Fast internet and reliable connectivity have an impact on implementing Quality 4.0.
TMC	Top Management Commitment
VS	Vision and Strategy
TA	Technology Adoption
L	Leadership
TR	Training and Rewards
KA	Knowledge and Awareness
FF	Financial Fund
CF	Customer Focus
SM	Supplier Management
OC	Organizational Culture

تقييم جاهزية تطبيق الجودة 4.0 في الصناعات الغذائية في فلسطين

منى رزق فرحان أحمد

د. سامي الصدر

د. أشرف الميمي

د. يحيى صالح

ملخص

تهدف هذه الدراسة إلى تقييم جاهزية المصانع الغذائية في فلسطين لتطبيق الجودة 4.0 من خلال تحليل العوامل المؤثرة الرئيسية. باستخدام منهجية البحث الكمي، تقوم الدراسة بتقييم جاهزية الصناعة للتحول الرقمي وتبني تقنيات الذكاء الاصطناعي المرتبطة بالثورة الصناعية الرابعة (الصناعة 4.0) لإدارة الجودة.

وقد تضمنت الدراسة تحليلاً للأبعاد والعوامل المختلفة المتعلقة بقياس جاهزية تطبيق الجودة 4.0 في مصانع الأغذية والتي تم استخراجها من خلال تحليل الدراسات السابقة التي أجريت في العديد من الدول المتقدمة ولم يتم تناولها سابقًا في السياق الفلسطيني. هذه العوامل هي: التزام الإدارة العليا، وتبني التكنولوجيا، وإدارة الموردين، والتركيز على العملاء، والثقافة التنظيمية، ودعم القيادة، والرؤية والاستراتيجية، والمعرفة والوعي، والتدريب والجوائز، والموارد المالية، وتحديات الصناعة.

تم تصميم استبيان بطريقة علمية ودقيقة يتكون من ثلاثة أقسام: معلومات ديموغرافية ، عوامل جاهزية تطبيق الجودة 4.0، والتحديات المرتبطة بها. تم توزيع الاستبيان على 50

مصنعًا غذائيًا فلسطينيًا، وتم قياس الاستجابات باستخدام مقياس ليكرت من خمس نقاط. تم إجراء تحليل البيانات باستخدام برامج Excel وSPSS لاستخراج رؤى رئيسية.

أظهرت النتائج مستويات متفاوتة من الجاهزية بين مصانع الأغذية في فلسطين، مع وجود تحديات رئيسية بما في ذلك تبني التقنيات الجديدة والبنية التحتية والقيود المالية والعقبات السياسية. ومع ذلك، سلطت النتائج الضوء أيضًا على فرص التحسين، مثل تعزيز دعم القيادة، وتعزيز استراتيجيات التدريب والتطوير، ووضع خارطة طريق واضحة للانتقال إلى الجودة 4.0. ووجدت الدراسة أيضًا أن معظم الإدارة العليا تدعم برامج الجودة، وتروج لثقافة التحسين المستمر، وتعزز الوعي والمعرفة بالجودة 4.0 بين الموظفين.

كمساهمة رئيسية وخطوة أولية، تقترح هذه الدراسة إطارًا لتوجيه المصانع في تحسين جاهزيتها لتطبيق الجودة 4.0، وتقدم توصيات للاستفادة من التحول الرقمي، وتحسين جودة المنتج، وزيادة الكفاءة، وتعزيز القدرة التنافسية في السوق.