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Assessing the Implementation of Statistical Process Control in Food Industries: An Empirical Study from a Developing Country Context

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Research Paper

***Abstract**: This study delves into an examination of the correlation between the utilization and integration of seven widely recognized Statistical Process Control (SPC) tools, namely flow charts, check sheets, Pareto charts, cause-and-effect diagrams, scatter charts, histograms, and control charts. These tools are represented by variable Statistical Methods (SM) training. The research also investigates the relationship between these SPC tools and five critical success factors within the context of Palestinian food companies. These factors encompass Managerial Actions (MA), the Process Approach (PA), Decision-Making (DM), Audit and Review (AR) of SPC practices, and Quality Obstacles (QO) related to their implementation. The research adopts a quantitative methodology, wherein pertinent data is gathered through the administration of a questionnaire to 75 quality managers employed within Palestinian food companies. Subsequently, the data is subjected to analysis via the utilization of partial least squares structural equation modeling (PLS-SEM). The study's findings indicate that approximately 50% of the selected food companies have adopted SPC tools. Furthermore, the research has identified connections among the critical success factors that contribute to improving the implementation of SPC tools within the food industry. Concretely, the results demonstrate*

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that MA, a PA, DM, and QO exert substantial influences on SPC implementation SM in Palestinian food enterprises. In contrast, neither AR nor DM exhibit significant impacts on SPC implementation. The study's findings emphasize the critical role of implementing SPC tools in reducing the occurrence of defective food products. Senior management in the food industry must take proactive measures to address and eliminate impediments to the integration of SPC tools. This research provides empirical insights to enhance SPC implementation in the food industry, focusing on critical success factors like MA, the PA, DM, and QO. Ultimately, SPC integration positively enhances the effectiveness of quality improvement initiatives in the food industry, leading to increased competitiveness and improved customer satisfaction. Despite the prevalent utilization of SPC within the manufacturing industry, the successful application of SPC tools in the food sector remains inadequately explored in the scholarly domain. Existing studies have often limited their scope to a subset of SPC tool applications. Therefore, this study makes a noteworthy contribution to the extant literature by presenting the outcomes of a distinctive investigation conducted within a developing-country context. It offers a comprehensive evaluation of SPC tool implementation in the food industry and scrutinizes the essential critical success factors associated with this process. Notably, to the best of the authors' knowledge, this study represents the inaugural endeavor of its kind in the Palestinian context.

Keywords*: Statistical Process Control; Developing Countries; Critical Success; Factors; Food Industry.*

1.0 Introduction

In today's dynamic economic and market landscapes, meeting customer demands is of paramount importance. To attain this objective, organizations must economize, innovate across their operations, and incessantly enhance product quality, service excellence, and operational performance (Siddh et al., 2017). Due to the impracticality of inspecting or testing every product for quality, it is imperative that products are manufactured correctly from the outset. To achieve this, all stakeholders, encompassing operators, engineers, quality control personnel, and managers, should diligently oversee process performance, reduce variability in critical parameters, and maintain statistical stability in the processes (Sargut, 2006). The quality system should encompass technical and soft quality improvement aspects to enable continuous improvement across all business operations, enhancing competitiveness (Kanan et al., 2023a, 2023b). While statistical process control (SPC) is common in manufacturing, its adoption in the food industry remains limited (He & Liu, 2002) This technique relies on the robust statistical foundation of control charts, a method that has proven its effectiveness since its inception (Allen et al., 2017; Costa et al., 2020).

In the contemporary and fast-paced business environment (Alawadhi et al., 2022; Alawamleh et al., 2021), food companies must excel to remain competitive and profitable (Siddh et al., 2021). This study demonstrates SPC's role in improving product quality, highlighting the evolving concept of quality. Traditionally, quality was perceived as products and services meeting user needs and often equated with "fitness for use" (Oakland, 2014). Under this approach, when the output falls within specified limits around a target value, it is considered acceptable. This quality definition, aligned with Deming's perspective, emphasizes that "Quality should meet customer needs, both current and future" (Oakland, 2014). The overall quality of a product or service is determined by its capacity to fulfill stated or implied requirements (Prasad et al., 2017). Quality is a pivotal factor impacting consumer choices among competing products and services (Al Tarawneh et al., 2023; Jawabreh et al., 2023; Montgomery, 2019; Salhab et al., 2023). It plays a vital role in driving business success, fostering growth, enhancing competitiveness, and improving the work environment. Understanding and improving quality are essential for achieving these goals. Montgomery (2019) asserts that quality improvement aims to reduce process and product variability. It encompasses efforts to ensure products and services meet requirements and undergo continuous enhancement. Variability is a common driver of poor quality, and statistical methods like SPC are key tools for quality control and improvement (Montgomery, 2019).

Patidar, Shukla, and Sukhwani (2022) highlight the global importance of food quality (Patidar et al., 2022). (Siddh et al., 2015) argue that food manufacturers often prioritize production efficiency and defect reduction to boost industry and profit gains (Siddh et al., 2021). Although SPC implementation is non-mandatory in the food sector, (Lim & Antony, 2016) suggest its potential benefits across various products and scales. However, food companies typically prioritize legal compliance and may hesitate to invest in additional programs (Lim & Antony, 2016; Siddh et al., 2018; Siddh et al., 2017). Demonstrating the impact of new techniques like SPC on process performance in the food industry remains challenging (Al-Rawashdeh et al., 2023; Lim et al., 2016; Saleh et al., 2023; Shniekat et al., 2022).

Specifically, SPC tools in the food industry include new methods, processes, innovative production techniques, and limit control (Jose Carlos de Toledo et al., 2017; J. C. d. Toledo et al., 2017). Despite SPC being widely adopted in manufacturing for process control and improvement, its application in the food industry remains underexplored. Existing research indicates that SPC effectively enhances process performance in manufacturing (Binsaddig et al., 2023; Lim & Antony, 2016; Skawińska & Zalewski, 2022). This study aims to assess the utilization and implementation of the seven SPC tools in the Palestinian food industry, addressing gaps in the current literature. The distinctive features of this study can be summarized as follows:

- This study constitutes a pioneering endeavor in Palestine, particularly within the context of the food industry sector. The rationale for this specific sectoral focus stems from its substantial role in driving the Palestinian economy's growth. Notably, Palestinian manufacturing industries contribute approximately 17.6% to the gross domestic product (GDP), with the food industry constituting around 22.2% of the manufacturing sector and contributing approximately 4% to the GDP (Palestinian Central Bureau of Statistics PCBS, 2017).
- The quality of food products assumes paramount significance due to its direct implications for human health and safety. Consequently, the Palestinian Authority (PA) has dedicated substantial efforts to quality control across diverse food products. Moreover, the food sector has garnered growing interest from investors, as household expenditure on food constitutes an estimated 31% of total living expenses (PCBS, 2017). This underscores the imperative of producing high-quality food items and the consequent demand for a more competitive industry.
- The food industry exhibits the highest workforce engagement and utilization compared to other sectors, boasting an employment rate of 18.5% (PCBS, 2017).

- This study represents the inaugural effort to investigate the connection between the adoption of the seven established SPC tools and the essential factors required for their effective implementation within the Palestinian food industry. The examination and modeling of these anticipated relationships have addressed one of the gaps that inspired the initiation of this research.
- The study revealed the pivotal, yet previously overlooked, role of the tertiary food industry in enhancing SPC implementation.
- The research offered empirical evidence from Palestine, a developing nation, to assist the food industry in effectively embracing and implementing SPC tools, thereby fostering the sustainability of a competitive economy.

The subsequent sections of this article follow this structure: In Section 2, we delve into the pertinent literature, elucidating the seven well-known SPC tools, their evolution, the advantages and challenges related to their implementation, and a review of relevant prior studies. We also formulate our research hypotheses within this section. Section 3 delineates the research methodology employed in this investigation. It encompasses the research approach, data collection instruments, the study's target population and sample, and the tools employed for data analysis. Section 4 presents the results of our analysis, with a specific emphasis on the outcomes derived from partial least squares structural equation modeling (PLS-SEM). Sections 5 and 6 are devoted to the discussion of the research findings and their implications, respectively. Section 7 concludes the article by offering pertinent recommendations, while Section 8 addresses the research's limitations and suggests potential avenues for future research.

2.0 Literature Review

SPC is a robust toolkit aiming to reduce variance, improve process stability, and enhance capability (Montgomery, 2019). Its core objective is identifying and rectifying variations due to process instability, enabling decision-makers to assess process accuracy and ensure quality control.

Seven fundamental SPC tools, often known as quality control (QC) tools, are commonly utilized:

1. **Flow Charts:** They offer visual representations of the process flow, aiding in comprehension, enhancement, and documentation of the process (Shakil et al., 2013a, 2013b).
2. **Check-Sheets:** They assist in data collection and analysis by portraying the relative frequency of different data categories (Leavengood & Reeb, 2002).
3. **Pareto Charts:** By employing the 80/20 rule, these charts aid in concentrating on vital issues and prioritizing problems accordingly (Grosfeld-Nir et al., 2007).
4. **Cause-and-Effect Diagrams (also known as Ishikawa or fishbone diagrams):** These diagrams aid in identifying potential problem causes by categorizing and visually presenting them (Ahmed & Ahmad, 2011).
5. **Scatter Charts:** By unveiling correlations between paired data sets, these charts assist in identifying relationships between variables (Koutras et al., 2007).

6. **Histograms:** These diagrams illustrate frequency distributions and compare them to predetermined specifications (Jagadish et al., 1998).
7. **Control Charts:** Employed to scrutinize process variations over time, these charts guarantee process consistency (Woodall et al., 2004).

As a whole, these tools promote quality control, process improvement, and preemptive problem mitigation through their fundamental principles.

2.1 Evolution of SPC in the Food Industry

The statistical approach to quality control traces its roots to the control scheme developed by Walter Shewhart at the Bell Telephone Laboratory in the 1920s. However, it was not until the late 1940s that Edwards Deming embraced Shewhart's work and recognized the potential benefits of statistical techniques, including control charts, for the manufacturing sector. Pereira and Aspinwall (1991) noted that the adoption of statistical quality control (SQC) methods in the food industry did not become widespread until the mid-1950s.

Table 1: Evolution of SPC in the Food Industry (Source:(Lim & Antony, 2016))

"Development of SPC application for food quality	Focus on Canning and Preserving industry	The Importance of Managerial Aspects	The Major Concern is Food Products Safetyand Consumer Protection			Organizational Learning in SPC
	Basic statistical techniques for monitoring foodquality	Preventive qualitycontrol Statistical methodsas a management tool	Quality assurance in the food industry An improvement in national standards	SPC in food quality management Consumer focus in the foodbusiness	Quality standards and certifications	SPC in business improvement programs Statistical thinking Quality improvement activities linked with strategic planning
	1950s	**1960s**	**1970s**	**1980s**	**1990s**	**2000s 2010s**
Quality tools, techniques, and programs	• Inspection • Sampling Plan • Control Chart	• Design of Experiment • SPC • Process Capability • Zero Defects	• Total Quality Control • Quality Costs	• Total Quality Management (TQM) • ISO 9000 • HACCP		• ISO 9000:2000 • Lean Six Sigma"

Among the reviewed literature, 41% conducted case studies, and three studies employed SPC with the Six Sigma methodology. In the remaining sources, all SPC studies showcased the incorporation of other quality tools like design of experiments (DOE) (Lim & Antony, 2016). Table 1 outlines the progression of SPC in the food industry (Lim et al., 2016; Traoré et al., 2020).

Table 2 summarizes case studies applying diverse SPC tools in various food industry contexts, with the last row offering an overview of the present study.

Prior research has underscored the necessity of fostering cross-functional collaboration within a company to successfully implement SPC and attain the intended objectives. Various studies have highlighted multiple advantages, including the reduction in defective product rates, the mitigation of non-conformance incidents, the introduction of tools like Six Sigma, and the realization of financial gains. Nevertheless, these studies have also brought to light the impediments to SPC implementation within organizations, encompassing the necessity for financial backing for advanced tools and a scarcity of employee expertise in this domain.

Table 2: SPC Application in the Food Industry (Source: (Lim et al., 2016), except the current study)

“Articles and Country	Commodities (Product)	Issues	Quality Charact.	Type of SPC tools	Quality program	Output: Benefits and Duration
(Srikaeo & Hourigan, 2002); Australia	Eggs	There is no evidence of the effectiveness of Hazard Analysis Critical Control Points (HACCP) elements.	Temp., pH, chlorine level	Individual chart	HACCP	The Critical Control Points values validated (All control measures are capable of designing critical limits except chlorine levels). (6 months)
(Augustin & Minvielle, 2008); France	Meat processing and preserving	The low rate of unsatisfactory batches of Enterobacteriaceae and Pseudomonas count detection caused doubt about the efficiency of the traditional control scheme.	Microbial count	Moving Average chart, Box plot, Histogram	HACCP	Validates the assumption that microbiological contamination variances are in control (2% variances above the control limit).
(Dalgiç et al., 2011); Turkey	Meat processing and preserving	There is a demand for a more effective quality control technique to assist HACCP implementation.	Moisture content, pH	Process mapping, Pareto chart, Scatter plot, Ishikawa, X-bar chart, R chart	TQM, HACCP, ISO 22000 ISO 9000, FMEA	Stabilize the moisture content (reading approximately 40%). Able to prioritize five critical problems. Enable plant operators to take action quickly. (3 months)
(Rai, 2008); India	Tea	The critical problem faced in tea production is the weight variation in the tea packet.	Weight	CUSUM, X-bar chart	None	Reduction of out-of-control situations from 66% to 4%.
(Knowles et al., 2004); UK	Sugar confectionery (Medicated sweets)	The variation in the sweet size caused reworks, scraps, and machine downtime.	Sweet thickness	X-bar chart, R chart, Histogram, Scatter plot, Ishikawa diagram	Six Sigma, Taguchi method	Saved £290,000. Improve *Cpk* from 0.5 to 1.6. 12 months
(Daniels, 2005); USA	Bakeries	The major customer filed complaints about the crust strength and the risk of losing the customer.	Crust strength	X-bar chart, Box plot, Pareto chart	HACCP, Six Sigma, DOE	Reduce scrap rate by 40%. Saved £274,983.
(Grigg, 1998); UK	Fish	Product giveaways and unnecessary check weigher rejection.	Package weight	X-bar chart, R chart	None	Reduce product giveaways and rejection rates.
(Negiz et al., 1998); USA	Dairy	In dairy pasteurization, if the product temperature drops below 161°F (15s holding time), the product must be diverted immediately to comply.	Temp.	Hotelling T2 chart	None	20% over-processing was detected. Receive signals for non-compliance.
Current Study (2023); Palestine	All including milk and dairy, pasta and noodles, processed meat, canned foods and vegetables, soft drinks, confectionary and sweets, vegetable oils and fats, wheat, flour, grain, and feed products, water	There is a need to study the level of implementation of the seven SPC tools in the Palestinian food industry and to identify the relationship of the implementation of these tools to the critical factors for the success of implementation.	General, not specific	The seven SPC and QC tools	Various, including the Palestinian Standard (PS), HACCP, ISO 9000, ISO 22000	Providing the results of a new study in a developing-country context in which a comprehensive assessment of SPC tools implementation in the food industry is conducted, as well as an investigation of the relationship with critical success factors for implementation.”

2.2 Benefits of Implementing SPC

The findings of this review reveal that the most commonly cited advantages of SPC implementation encompass the reduction of process variation, increased product quality consistency, and enhanced competitive advantage (Grigg & Walls, 2007). Additionally, benefits include the mitigation of waste, rework, scrap (Mazu & Conklin, 2012), and a decrease in customer complaints (Alsaleh, 2007; Grigg et al., 1998). Most articles recognize that the effective application of control charts plays a pivotal role in reducing product variance. However, there is limited discussion of other SPC tools, which deviates from the comprehensive nature of SPC. SPC is not confined solely to control charts; it encompasses a repertoire of statistical techniques and problem-solving approaches, with control charts representing just one component (Montgomery, 2019).

2.3 Barriers to SPC Implementation in the Food Industry

The implementation of SPC in food factories faces various impediments, and these challenges are outlined in Table 3.

Table 3: Barriers to SPC implementation in the food industry

“Barriers	References
Resistance to change • Current food organizations have not fully accepted the need for CI techniques. • Fear of failure	(Bjerke & Hersleth, 2001; Hsiang-Chin & Ming-Hsien, 2011)
Lack of management support • Resistance to providing sufficient resources • Lack of management awareness of SPC • Reduced scrap	(Hsiang-Chin & Ming-Hsien, 2011; Mazu & Conklin, 2012)
Lack of statistical knowledge • Unfamiliarity with the use of advanced statistical techniques	(Alsaleh, 2007; Bjerke & Hersleth, 2001)
Poor measurement systems • Lack of awareness of the importance of a capable measurement system	(Gauri, 2003, Grigg, 1998)
Lack of experience • Lack of experience in using quality tools”	(Hsiang-Chin & Ming-Hsien, 2011)

2.4 Limitations of SPC Implementation

Table 4 illustrates the limitations of SPC implementation in the food industry. Drawing from the findings of prior research, these limitations will be juxtaposed with the constraints observed in Palestine in Chapter 5. The most frequently mentioned constraint, as indicated by previous studies, is the absence of a culture that embraces statistical thinking (ST) within the food industry. Following this, there is the Assessing the Implementation of Statistical Process Control in Food Industries: an Empirical

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perception of SPC as a tool primarily for non-statisticians and the absence of context-specific guidelines tailored to the food industry.

Table 4: Limitations of SPC application

“Limitations	Details/examples	References
Lack of ST	• Decision-making based on data is not a customary practice in the food industry.	(Bjerke & Hersleth, 2001; Gauri, 2003)
SPC is considered too advanced	• SPC is perceived as too advanced for the food industry • Multivariate control chart application is too challenging for shop floor employees to handle	(Paiva, 2013)
Costly technique	• SPC is considered a luxury option due to the training and software requirements needed for its application	(Alsaleh, 2007)
Existing manuals cannot comprehend food manufacturing applications	• The currently available manual within the food industry for control and monitoring is arguably too complicated for real application in food manufacturing • Quality parameters depend on multiple factors, increasing the time needed for corrective action”	(Gauri, 2003; Grigg & Walls, 2007)”

2.5 Research Hypotheses

To accomplish the study's objectives, a series of hypotheses was crafted to investigate the connection between the dependent variables, which encompass the implementation of SPC tools, and the independent variables, which encompass the critical factors influencing the successful implementation of SPC in the Palestinian food industry. The subsequent null hypotheses, aligned with the study's research questions, were developed for investigation:

- H1: Managerial actions (MA) do not significantly impact the implementation of the seven SPC tools in Palestinian food industries, as indicated by statistical methods (SM) training.
- H2: The process approach (PA) does not significantly impact the implementation of the seven SPC tools in Palestinian food industries, as indicated by the statistical methods training (SM).
- H3: Decision-making (DM) does not significantly impact the implementation of the seven SPC tools in Palestinian food industries, as indicated by the statistical methods training (SM).
- H4: The auditing and review (AR) of SPC practices do not significantly impact the implementation of the seven SPC tools in Palestinian food industries, as indicated by the statistical methods training (SM).
- H5: Quality obstacles (QO) do not significantly impact the implementation of the seven SPC tools in Palestinian food industries, as indicated by statistical methods training (SM).

3.0 Methodology

This study employs a quantitative approach, encompassing data collection, analysis, and interpretation to meet the research objectives. This is accomplished through the utilization of experimental strategies, surveys, and various data collection methods (Creswell, 2003). The methodological flowchart for the present study is outlined in Figure 1.

The questionnaire is structured into three primary sections. The initial section focuses on gathering demographic information about the respondents. The second section is further subdivided into six subsections, which evaluate the influence of five critical success factors on the implementation of the seven SPC tools. These factors are represented as model constructs, specifically MA, PA, DM, AR, and QO, and they are operationalized through the seven SPC tools, denoted as SM.

Before disseminating the questionnaires, a panel of four local experts reviewed them. These experts assessed the wording, clarity, redundancy, and the items' capacity to effectively reflect each specific construct. A total of 40 items were adapted from previous research, as outlined in Table 5. Each item was assessed using a five-point Likert scale, spanning from 1 (indicating a very low extent) to 5 (indicating a very high extent).

Table 5: Constructs/Items Employed in the Questionnaire

Construct	Number of Items	Source
MA	7	Rungtusanatham (2001) and Rungtusanatham et al. (1999) (Lim & Antony, 2016)
PA	6	
DM	5	
Statistical methods training (SM)	8	(Lim & Antony, 2016) Rohani and Mohamad (2010)
AR	7	
QO	7	(Lim & Antony, 2016) (Lim & Antony, 2016)
Total	**40**	

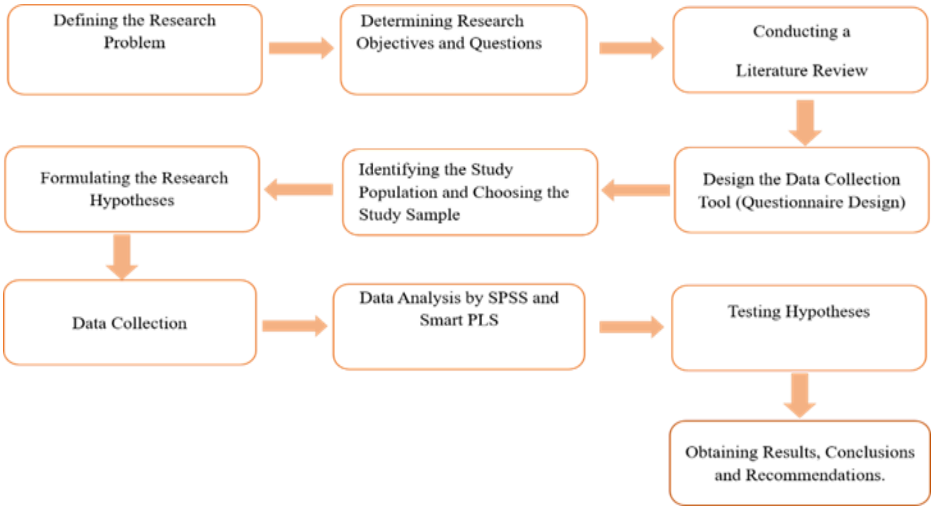

Figure 1. Flowchart of the Research Methodology

3.1 Target Population and Sampling Procedure

This study targeted Palestinian food industry firms as the population of interest. To ascertain the total number of eligible firms, the researchers collaborated with the Palestinian Food Industries Union (PFIU). The PFIU revealed that, at the time of the study, 598 food industry firms were operating in the West Bank region of Palestine, with 278 firms fitting the defined criteria. These criteria included official registration and licensing by Palestinian authorities, a well-defined organizational structure, and the presence of a dedicated quality department or function. As a result, 75 firms met these requirements for data collection.

In this study, individual organizations were the units of analysis. Questionnaires were dispatched to top management via email, with subsequent telephone follow-up to ensure the precise completion of the questionnaires. After three months, 65 valid questionnaires were received, resulting in a response rate of 86.6%. Following Thompson's formula, this percentage is considered satisfactory and meets the requisite statistical power criteria, as endorsed by Hair et al. (2014)

3.2 Data Analysis Techniques

The SPSS software package was employed to conduct a frequency analysis of the demographic profiles of the sampled firms and their respondents. The study utilized both PLS-SEM and structural equation modeling-partial least squares (SEM-PLS) path modeling to examine the relationships between variables, facilitated by the Smart PLS 3.3.2 package. In more detail, the measurement theory was utilized to delineate the connection between constructs and their respective indicators (i.e., the measurement model) to assess the validity and reliability of the measures. Composite reliability (CR) was computed to assess internal consistency reliability, while also estimating convergent and discriminant validity. Subsequently, the connection between variables was scrutinized to validate and ensure the reliability of the measures, and the model's predictive capability was evaluated (i.e., the structural model). This involved determining the coefficients of determination (R^2 values), as well as assessing the magnitude and significance of the path coefficients, the predictive relevance (Q^2), and the effect sizes (f^2).

4.0 Data Analysis and Results

4.1 Demographic Profile

The analysis of demographic profiles for the sampled firms and their respondents, carried out with SPSS, is detailed in Table 6. It's noteworthy that around 72% of the surveyed firms incorporate SPC tools in their operations. However, they tend to avoid the use of certain tools like Pareto charts, scatter diagrams, and cause-and-effect diagrams, categorizing them as advanced. It's essential to recognize that these tools are, in fact, problem-solving tools, and the omission of their application in SPC within the food industry is regarded as significant deficiency.

Table 6: Statistical Analysis of Demographic Profiles for the Sampled Firms and their Respondents

Demographic Variable	Categories (percentages)
	Respondents
Gender	Male (83%), Female (17%)
Education level	Diploma degree (11%); Bachelor's degree (78%); Master's degree (11%)
Positions in the firm	Administrative employee (3%); General manager (5%); Head of a department (18%); Quality manager (32%); Technical manager (16%); Quality controller (25%)
Years of experience	Less than 5 years (12%); 5–10 years (35%); 11–20 years (48%); More than 20 years (5%)
	Food Industry Firm
Number of employees[(a)]	6–49 (46%); 50–249 (41%); More than 250 (13%)
Age of the firm	1–5 years (6%); 6–10 years (28%); 11–30 years (58%); More than 30 years (8%)
Food subsector	Milk and dairy (15%); Pasta and noodles (4%); Processed meat (8%); Processing and canning foods and vegetables (9%); Soft and non-carbonated drinks (3%); Sugars and sweets (21%); Vegetable oils and fats (5%); Wheat, flour, grain, and feed products (3%); Others (15%); Water (10%)
SPC Implementation	Yes (45%); No (55%)
SPC Tools used in food firms	Flow charts (10.3%); Check sheets (24.1%); Pareto charts (0%); Cause-and-effect diagram (0%); Scatter diagram (0%); Histograms (20.6%); Control charts (17.2%); Other descriptive measures of central tendency (means, medians, modes); and dispersion (range, variance, standard deviation) (27.8%)

(a) According to European Union (EU) and the Organization for Economic Co-operation and Development (EU/OECD) classification of the firm's size.

4.2 Descriptive Analysis

As presented in Table 7, the study reported both the mean and standard deviation for each critical success factor (construct). The analysis was conducted using a five-point Likert scale with equally sized categories. The interpretation of the results was as follows: scores falling between 1.00 and 2.33 were categorized as low; scores ranging from 2.34 to 3.66 were considered moderate; and scores from 3.67 to 5.00 were regarded as high.

Table 7: Level of implementation of SPC tools

Item	Mean	Std. Deviation	Implementation level
MA	3.13	0.685	Moderate
PA	3.30	0.614	Moderate
DM	3.92	0.697	High
AR	3.79	0.883	High
QO	2.65	0.619	Moderate
Total	**3.36**	**0.703**	**Moderate**
Statistical Methods Training (SM)	**3.57**	**0.845**	**Moderate**

4.3 Structural Equation Modeling-Partial Least Squares Analysis

43.1 Assessment of Measurement Models

The assessment of the measurement model entails the evaluation of the construct's reliability and validity, with a particular emphasis on convergent validity. Convergent validity signifies the degree of agreement among items measuring a single concept (Ramayah et al., 2018; Wannassi et al., 2023). Multiple tests, including factor loadings, composite reliability (CR), and average variance extracted (AVE), can be employed to evaluate convergent validity.

To establish convergent validity, two criteria must be met. First, the factor loading values for items should surpass the recommended threshold of 0.60 (Hair Jr et al., 2014). Second, the composite reliability (CR) should exceed 0.70 (Hair et al., 2010). In this study, the CR values, as depicted in Table 8, range from 0.849 to 0.934, indicating a high level of convergent validity.

Third, the Average Variance Extracted (AVE) is used to assess the variance of indicators related to measurement error. A value exceeding 0.50 is necessary to support the concept's application. In this study, the AVEs, presented in Table 8, ranged from 0.546 to 0.671, meeting the criteria for convergent validity.

Table 8: Results of measurements model–Convergent validity

Constructs	Items	Item Loading	CR	AVE
MA	MA01	0.728	**0.849**	**0.546**
	MA02	0.517		
	MA03	0.678		
	MA04	0.608		
	MA05	0.720		
	MA06	0.532		
	MA07	0.858		
PA	PA02	0.798	**0.862**	**0.557**
	PA03	0.695		
	PA04	0.660		
	PA05	0.844		
	PA06	0.721		
DM	DM01	0.617	**0.909**	**0.669**
	DM02	0.882		
	DM03	0.889		
	DM04	0.909		
	DM05	0.778		
Statistical Methods Training (SM)	SM01	0.787	**0.914**	**0.581**
	SM02	0.951		
	SM03	0.818		
	SM04	0.849		
	SM05	0.845		
	SM06	0.711		
	SM07	0.507		
	SM08	0.508		
AR of SPC Practices	AR01	0.579	**0.928**	**0.654**
	AR02	0.893		
	AR03	0.753		
	AR04	0.917		
	AR05	0.896		
	AR06	0.855		
	AR07	0.706		
QO	MQO01	0.826	**0.934**	**0.671**
	MQO02	0.859		
	MQO03	0.870		
	MQO04	0.820		
	MQO05	0.768		
	MQO06	0.808		
	MQO07	0.777		

The Fornell–Larcker criterion was used for discriminant validity assessment. This criterion calculates the square root of the AVE values for each construct and compares them to the correlations with other latent variables. According to the rule, the AVE for each construct should be higher than its highest linear association with any other construct. As shown in Table 9, the empirical results confirm that the Fornell–Larcker discriminant validity criteria are satisfied.

Table 9: Fornell–Larcker criterion—Discriminant validity

Construct	AR	DM	MA	PA	QO	SM
AR	**0.809**					
DM	0.666	**0.818**				
MA	0.626	0.580	**0.672**			
PA	0.581	0.723	0.525	**0.747**		
QO	−0.260	−0.456	−0.121	−0.480	**0.819**	
SM	0.771	0.769	0.526	0.586	−0.377	**0.762**

The Heterotrait–Monotrait ratio of correlations (HTMT) criterion was employed to confirm discriminant validity. According to Henseler et al. (2015), HTMT values below. 0.90 demonstrate high reliability. As presented in Table 10, the computed HTMT values in this study were below 0.90, affirming the robust discriminant validity of the research model. Figure 2 depicts the constructed measurement model of the study.

Table 10: HTMT ratio—Discriminant validity

Construct	AR	DM	MA	PA	QO	SM
AR						
DM	0.731					
MA	0.757	0.651				
PA	0.624	0.821	0.679			
QO	0.281	0.471	0.315	0.485		
SM	0.842	0.864	0.608	0.655	0.395	

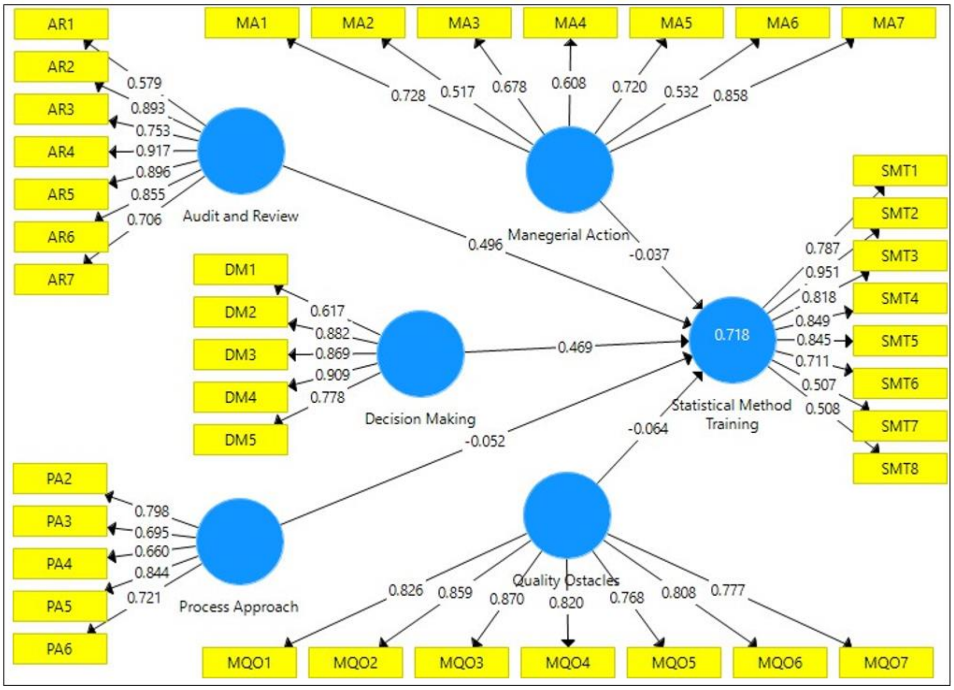

Figure 2. The measurement model

4.4.2 Assessment of Structural Models

The next phase entails evaluating the structural model to investigate the connections between latent variables. Following the guidelines of Hair et al. (2014) for PLS-SEM analysis of the structural model, the main assessment criteria encompass the significance and magnitude of the path coefficients, as well as the R^2 values in the PLS- SEM results. According to Hair et al. (2014), R^2 values of 0.75 (indicating high), 0.50 (indicating moderate), or 0.25 (indicating weak) are suitable for endogenous constructs. In addition to R^2, f^2 analysis is useful for estimating the effect sizes of individual latent variables on the dependent variables, as recommended by Chin (2009). Cohen (1988) delineated f^2 values of 0.02, 0.15, and 0.35 to interpret small, medium, and large effect sizes of the predictive variables, respectively. The goodness-of-fit (GoF) value for the model was determined to be 0.062 and 0.643, indicating adequate global PLS model validity. The results of these empirical tests are presented in Table 11.

Table 11: The R2 and the f2 results.

Construct	**R^2**	**R^2-Adjusted**	**f^2**	**Result**
			Statistical methods training (SM)	
AR	---	---	0.402	Large effect size
DM	---	---	0.274	Medium effect size
MA	---	---	0.003	Small effect size
PA	---	---	0.004	Small effect size
QO			0.010	No effect size
SM	**0.718**	**0.694**		**High**

The Q^2 criteria were employed to evaluate the model's capacity to predict data from excluded cases. A Q^2 value greater than zero for endogenous constructs signifies the model's predictive relevance for that construct, following the guideline of Hair et al. (2014). As shown in Table 12, the values of Q^2 for the endogenous latent variables are all greater than zero, affirming the model's adequate predictive quality.

Table 12: Cross-Validated Redundancy Approach (Q^2)

Construct	***SSO**	****SSE**	**Q^2 (=1–SSE/SSO)**
AR	455.000	455.000	
DM	325.000	325.000	
MA	455.000	455.000	
PA	325.000	325.000	
QO	455.000	455.000	
SM	520.000	311.325	0.401

** SSO is the sum of squares of observations*
***SSE is the sum of squares of prediction errors.*

It is crucial to note that the Q^2 value is derived using the cross-validated redundancy approach, as depicted in Table 12. This approach centers on the path model assessments of the scores for both the antecedent constructs (structural model) and the target endogenous construct (measurement model) in data prediction. Therefore, the prediction through cross-validated redundancy aligns seamlessly with the PLS- SEM approach. After employing the PLS-SEM algorithm to estimate the structural model, path coefficient testing was conducted to validate the proposed hypotheses and assess the significance of path coefficients. Path coefficient values, which vary between -1 and +1, were examined, with values closer to +1 indicating strong positive relationships and those closer to -1 indicating strong negative relationships. Hypothesis testing was carried out using PLS bootstrapping, and the results can be found in Table 13. The results indicated a robust and statistically significant positive impact of auditing on the implementation of SPC tools, with a P-value below 0.05, providing support for the formulated hypothesis (H1) (β = 0.496, T-value = 0.066, P-value = 0.000).Similarly, a substantial positive influence of decision-making on the implementation of SPC tools was observed, with a P-value below 0.05, corroborating the proposed hypothesis (H2) (β = 0.469, T-Value = 0.085, P-value = 0.000). In contrast, a non-significant negative relationship was identified between managerial actions and the implementation of SPC tools, with a P-value exceeding 0.05 (β = −0.037, T-Value = 0.085, P-value = 0.672), indicating that H3 is not supported. Furthermore, a non-significant negative association between the process approach and the implementation of SPC tools was identified, as the P-value exceeded 0.05, which leads to the rejection of H4 (β = −0.052, T-Value = 0.131, P-value = 0.691). A similar non-significant negative relationship was observed between the major quality obstacles and the implementation of SPC tools (β = −0.064, T-Value = 0.090, P-value = 0.480), indicating that H5 is also not supported due to a P-value exceeding 0.05.

Table 13: Path coefficient of the research hypotheses

Hypothesis	Path	Standard Beta (β)	Standard Deviation (STDEV)	T-value	P-value	Result
H1	MA → SM	−0.037	0.087	0.423	0.672	**Not Supported**
H2	PA → SM	−0.052	0.131	0.395	0.691	**Not Supported**
H3	DM → SM	0.469	0.085	5.510	0.000	**Supported**
H4	AR → SM	0.496	0.066	7.460	0.000	**Supported**
H5	QO → SM	−0.064	0.090	0.708	0.480	**Not Supported**

5.0 Discussion

Data from the Federation of Food Industries in Palestine indicates that a substantial portion of the food companies in the area are small and employ outdated machinery. Notably, among the surveyed companies, 44.6% implementing SPC were classified as small-sized, constituting 46% of the total companies surveyed. This observation implies that a company's size is a critical factor influencing its capacity to embrace SPC, potentially driven by the competitive dynamics among small firms vying for a larger market share. Questionnaire data reveals that many food industry firms in Palestine do not adhere to best practices when implementing SPC. Key limitations include the absence of clear implementation plans from top management, the lack of a quality-oriented culture within the workplace, reliance on outdated technology and methods, insufficient skills among machine operators (Skawińska & Zalewski, 2022), and management's reluctance to address feedback and complaints regarding process parameter fluctuations (Cabrera et al., 2020). Furthermore, some firms only partially implement SPC tools, exhibit inconsistency in addressing defects, and notably, they neglect to adopt relatively advanced problem-solving SPC tools, such as Pareto, scatter, and cause-and-effect charts. Companies that have managed to overcome these obstacles and implement certain SPC tools have enjoyed notable benefits. These advantages encompass a reduction in non- conforming products, a lower risk of product recalls, fewer customer complaints, and improved process visibility (Rique Junior et al., 2021). It's important to acknowledge that some degree of variation in production parameters is typical and may arise from minor distinctions in materials, workforce, machinery, tools, and other factors. These disparities are commonly referred to as common or random causes of variation. The statistical findings indicate that the first, second, and fifth hypotheses were rejected, signifying a statistically significant relationship between MA, PA, and QO, and the implementation of SPC, as indicated by SM. Conversely, the third and fourth hypotheses were supported and not rejected, suggesting no statistically significant relationship between DM and AR and the implementation of SPC, also indicated by SM. These results are consistent with previous studies, such as those conducted by Bjerke and Hersleth (2001) and Gauri (2003), which underscore the importance of managerial approval and ongoing support in the implementation of these tools. Following the approach advocated by (Siddh et al., 2021), it is advisable to implement quality practices in a coordinated and integrated manner, rather than in isolation. This entails having different practices work together to improve overall organizational performance. In the context of implementing the SPC tool, it is essential for management to ensure the availability of required resources. Additionally, management should possess a clear understanding of the advantages of integrating SPC into their organizations and be willing to approve proposed SPC projects, as highlighted by Husain et al. (2019).

6.0 Research Implications

This study makes a significant contribution to the literature on SPC implementation in the food industry, particularly within developing countries. It offers empirical insights into the challenges and opportunities related to SPC implementation and examines key factors influencing its success, such as top management support, employee training, and effective communication. This research enhances our understanding of the feasibility of implementing SPC in developing country contexts, where limited resources and infrastructure can present substantial implementation hurdles. The practical implications of this study are noteworthy. The findings offer valuable guidance to food industry managers and practitioners in devising and implementing effective SPC systems, ultimately leading to improved product quality, waste reduction, and heightened customer satisfaction. Additionally, the study underscores the significance of adequately training and resourcing employees engaged in the SPC process, which can result in increased understanding and motivation to utilize SPC effectively. Furthermore, the importance of top management support and effective communication in successful SPC implementation is highlighted, enabling managers to develop strategies to reinforce these aspects within their organizations.

7.0 Conclusions and Recommendations

This study reaffirms the findings of prior research, affirming the role and efficacy of SPC implementation in diverse sectors, with specific attention to the food industry.

Utilizing an extensive literature review, the study formulated pertinent hypotheses and developed an innovative model for evaluating SPC implementation. By examining data gathered from a sample of Palestinian food companies, this research unveils several noteworthy insights:

- The research confirms that both AR and DM have a significant positive influence on the implementation of SPC tools (SM). This highlights the importance of focusing on these factors for achieving favorable outcomes. Additionally, the study reveals that relatively advanced problem-solving SPC tools, like Pareto, scatter, and cause-and-effect charts, are not commonly used in Palestinian food industries.
- The study suggests that SPC implementation in the food industry is linked to obtaining quality certificates, emphasizing the role of quality assurance in addition to quality control and improvement.
- Quality-related issues within companies, including outdated machine technology, insufficient machine maintenance and handling, and the absence of a qualityfocused culture in the work environment, significantly contribute to the challenges in adopting advanced SPC tools, which can impact the overall success of these companies.

Based on these findings, the following recommendations are offered to Palestinian food firms:

- The Federation of Food Industries should prioritize the promotion of a strong quality culture within workplaces and advocate for senior management to assume a leadership role in SPC implementation by offering crucial support. To fully realize the potential of SPC tools in enhancing product quality, it is essential that top management comprehends the profound impact of SPC on organizational performance.
- The establishment of quality improvement teams and councils is crucial, consisting of members from various departments, including quality, production, and the laboratory. These teams should receive consistent training to effectively strategize for SPC implementation in food industries.
- Continuous planning for SPC training is of paramount importance. Firms should prioritize ongoing and regular training programs that encompass employees at all organizational levels. This comprehensive approach should include instruction on various quality tools and techniques aimed at improving process and product quality. The implementation of such continuous training programs can elevate awareness among all employees, contributing to the company's pursuit of goals that enhance its competitive advantage. Specialized training in the use of advanced problem-solving SPC tools, such as Pareto, scatter, and cause-and-effect charts, is essential and should be an integral part of these training initiatives.
- Palestinian food firms should tackle the obstacles and limitations associated with SPC implementation, with a particular focus on advancing their machinery and technology.
- Ongoing quality assessments of raw materials must be carried out prior to acceptance, and any raw materials failing to meet the established standards.
- should be declined. The quality of raw materials is a primary factor in maintaining product standards.

Scheduled calibration of production machinery and regular quality control assessments should be performed.

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