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Supply chain agility's impact on the sustainable procurement system's optimization and the facilitating role of workflow integration in MENA's foodstuffs sector

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Abstract

This study explores the role of supply chain agility in promoting sustainable procurement in the foodstuffs sector. It examines the mediating effect of system and process integration in operationalizing sustainable procurement applications. The research, conducted through structured questionnaires to key professionals within Saudi foodstuffs companies, uses Partial Least Squares Structural Equation Modeling (PLS-SEM) to evaluate the constructs of supply chain agility, sustainable procurement, system and process integration, and the effect of precise prediction on the effectiveness of the organization via the ARIMA technique. The findings suggest that supply chain agility significantly influences sustainable procurement, enabling organizations to create cost-saving opportunities in compliance with stringent environmental regulations.

Keywords: Flexibility, Responsiveness, Sustainable procurement, Supply chain innovation, System and process agility.

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1. Introduction

Finding methods to cut expenses and boost productivity in the procurement process is known as procurement optimisation. It seeks to maximise value generation through the use of modelling of criteria decision making and flexible frameworks supported by quick responsiveness and adaptability according to senses, innovation factors in data inputs due to global change rules. Saudi Arabia's foodstuffs industry is prioritizing sustainable procurement processes due to increasing sustainability pressure and strict regulations to maximise efficiency and environmental compliance [1, 2]. Supply networks must be flexible and adaptable to changes and disturbances in order to meet the sustainability goals [3]. The sustainability goals require supply chains to be agile and responsive to changes and disruptions [4]. Supply chain agility helps businesses adjust to shifting market conditions and environmental requirements, which improves sustainable purchasing [5]. By guaranteeing that all supply chain elements are interoperable, streamlining information flow, and promoting stakeholder collaboration, system and process integration mediates the relationship [6]. The successful adoption of sustainable procurement requires effective integration, which will improve resource management, reduce waste, and enhance adherence to sustainability guidelines. According to the literature, prior studies have clearly shown how supply chain agility directly affects operational results [7]. Saudi Arabia's rapid growth in the foodstuffs industry and growing environmental and sustainability concerns highlight a significant difference between our perspectives on system and process integration and the current state of sustainable procurement within the sector [8]. In order to offer insights into best practices and the integration of systems and processes for sustainable procurement through supply chain agility, the study employs a quantitative approach to analyze data from leading foodstuffs businesses in Saudi Arabia [7]. This study aims to provide valuable recommendations for foodstuffs companies to improve their sustainable procurement procedures, adding to existing knowledge [9]. In order to accomplish agility and sustainability goals, this study recommends a comprehensive approach to supply chain management methods, taking system and process integration into account as a mediating variable [10, 11]. This study explores the foodstuffs industry's evolving market, focusing on commercial sustainability and operational efficiency, addressing the problem statement and developing research questions to help businesses succeed:

RQ1: The study explores the influence of supply chain agility on the implementation of sustainable procurement strategies in the foodstuffs sector in Saudi Arabia.

RQ2: The study investigates how supply chain agility and sustainable procurement are connected through system and process integration.

RQ3: The study explores the role of system and process integration in the foodstuffs industry and agile supply chain strategies in promoting sustainable procurement.

A theoretical framework for sustainable procurement in Saudi Arabia's foodstuffs industry is presented in this study. An overview of the literature on system and process integration and supply chain agility is included. Statistical tools and data collection procedures are part of the methodology. The hypothesis is supported by the results, and the research's theoretical and practical ramifications are thoroughly examined.

2. Literature Review

Depending on the kind of goods or services being purchased and the procedure used, procurement can be divided into eight categories such as, 1. Direct Procurement: “This entails purchasing products and services, including essential elements and raw materials, that are directly utilized in the manufacturing of goods or services that a company provides.” 2. Indirect Procurement: “This covers purchases like assets of amenities, maintenance tools, and IT support that aren't directly related to the manufacturing process. 3. Goods Procurement refers especially to the purchase of tangible goods like inventories, equipment, or infrastructure. Services Procurement entails paying for services like maintenance, legal assistance, and expert consulting rather than goods. Project Procurement is centered on acquiring products and services for particular projects, frequently with deadlines and financial constraints associated with project completion. Sustainable Procurement promotes sustainability by highlighting the importance of purchasing items and goods with consideration for their effects on the ecosystem and society. 7. E-Procurement involves managing purchasing activities through software and internet platforms as part of the digital procurement process. Global Procurement refers to purchasing from foreign vendors, often to reduce expenses or access specialized goods not available locally. All types of procurement parameters in supply chain organizations are shared along two dimensions: time and trust contents of the database. The Jidoka Procurement Optimization Model (JPOM) focuses on analyzing the significant parameters affecting the price of goods over time, relying on accurate forecasting to enhance supply chain efficiency.

2.1. Supply Chain Agility into Time Dimension

The temporal dimension, which has been explained as shown in Figure 1 to assess the accuracy of data and modernity before selection for forecasting, which might impact supply chain agility, the model includes five clusters: While modernity and accuracy decline during cluster (C), it is possible to utilize data from prior cluster (D) with some errors since no data in cluster (E) is reliable. (A) indicates the doubt cluster of data, so no decision should be made regarding information before the stability scenario; (B) is a recommended cluster for analysis. Experts from beneficiaries are using brainstorming to modify these limits statistically. The time interval between (t_1) and (t_2) depends on modernity, but the interval between (t_2) and (t_3) reveals the maximum agility span. The intervals (t_4) and (t_5) should be avoided before running the forecasting of procurement parameters. Supply chain agility is crucial for quick market response in the foodstuffs sector due to the complex regulatory environment, ensuring quality criteria are met and products are delivered on time [12, 13]. Foodstuffs agility is a special strategy that gives businesses a competitive edge in fast-paced markets by enabling them to react swiftly to cyclical demand variations, reduce the risk of supply chain disruptions, and guarantee smooth operations [14]. Agile requires the use of complex systems and procedures for swift decision-making and comprehensive supply chain execution. The industrial sector plays a crucial role in societal economic stability and job creation. Machine learning (ML) applications are essential in various industries, such as food and grocery, agriculture, and supply chain management (SCM). Food products are perishable, and ML techniques are used to forecast demand accurately. ML can improve performance and efficiency in ASC, solving challenges like soil health, disease management, and crop yield. A conceptual framework was developed to illustrate the contribution of ML techniques in SCM activities, such as production, risk assessment, demand forecasting, and supplier selection. ML can also be used in a fast-changing supply chain environment, helping managers understand inventory scenarios and select replenishment policies. ML algorithms have been used to analyze data from social media and analyze customer sentiments, improving supply chain efficiency [15]. The analyst relies on gathering information from various sources in this section by employing questionnaires with an unplanned number of clients in various purchasing or service industries based on procurement kinds. We can choose data with stakeholder consensus thanks to this filter. In the procurement process from e-commerce platforms, this dimension is interested in grouping and categorising clients based on their culture, reputation, and experience. As a result, there are four reliability clusters for the purest content shown in Figure 2. Therefore, responsiveness, flexibility, and innovation are the main analytical parameters in the procurement optimization framework.

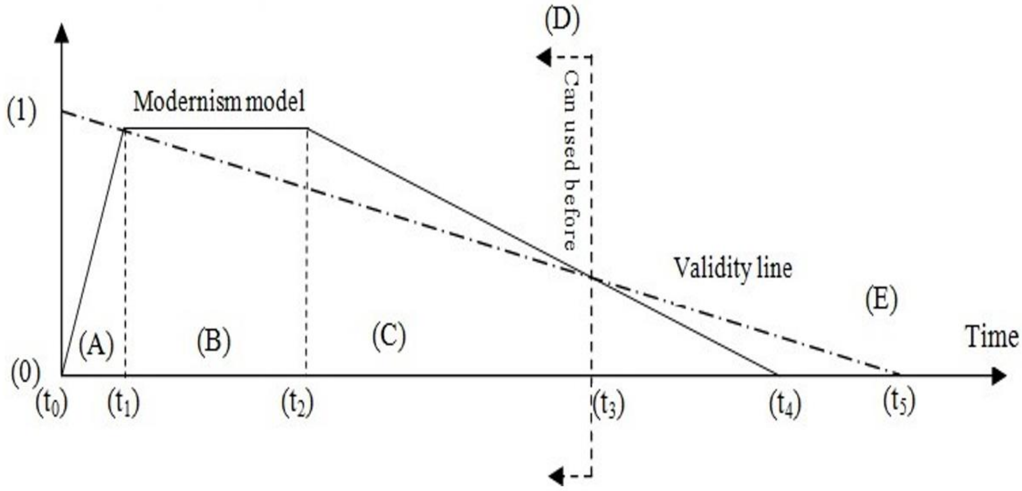

Figure 1.
The time dimension filter for selective data model.

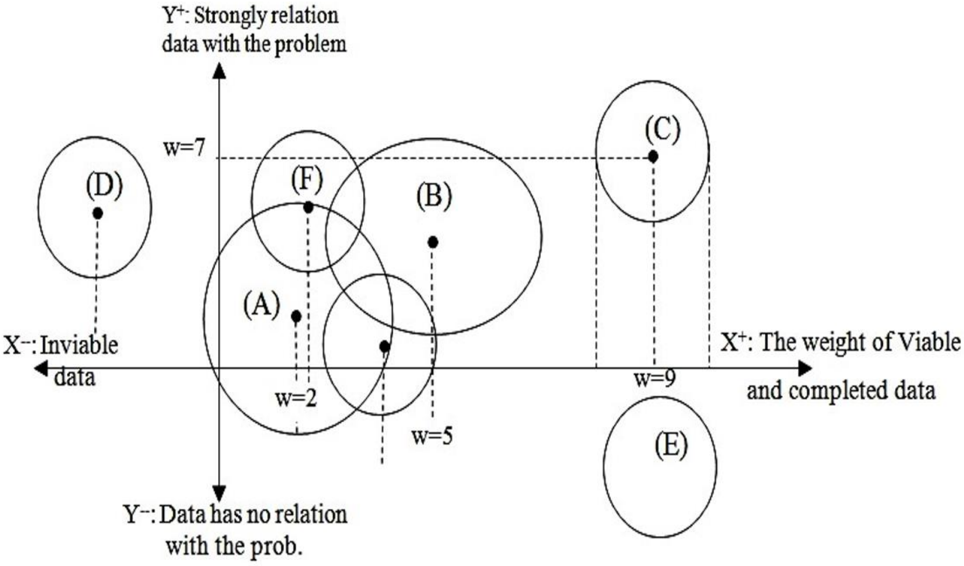

Figure 2.
The truest content dimension filter for a selective data model.

2.1.1. Responsiveness

In the foodstuffs sector, agility is essential for promptly responding to shifts in customer expectations or supply and demand. Procuring sustainable medications should adapt to changing legal requirements and environmental demands. The ability to adapt sourcing strategies and operations in response to new data or shifts in the market is necessary for supply chain agility [16]. Companies dealing with environmental impact, non-renewable resource depletion, and sustainability compliance should have a responsible supply chain to align with their social responsibility policy, as research shows responsive responses lead to quicker reactions to sustainable goals [17]. The responsiveness is divided into two cases: those who place the order and complete it to receive C&R, and those who avoid receiving and escape from the delivery representative ADR.

Table 1.
Jidoka characteristics in a sample of avid clients use e-commerce platforms and physical stores in Egypt and KSA, 2020-2024 (n = 1422)[a].

	C&R [b] *n*(%) ADR [c] *n*(%) P [d]		
Sex			
Male	200 (74.34)	961 (83.34)	<0.01
Female	69 (25.26)	192 (16.65)	
Age (years)			<0.01
<25	23 (8.55)	195 (16.91)	
25–34	62 (23.04)	358 (31.04)	
35–44	73 (27.13)	277 (24.02)	
45–54	58 (21.56)	204 (17.69)	
>54	53 (19.7)	119 (10.32)	
Occupation [e]			<0.01
Graduation	48 (17.84)	63 (5.46)	
under graduation		100 (8.67)	
Loyalty to platform (months)			<0.01
0–6 184 (68.4) 7–12 16 (5.94)		480 (41.63) 155 (13.44)	
13–36 27 (10.04) 36–60 7 (2.6)		215(18.64) 74 (6.41)	
>60 35 (13.01)		229 (19.86)	
Type of contract of employment			<0.01
Permanent 62 (23.04)		438 (37.98)	
Temporary 204 (75.83) Other 3 (1.11)		620 (53.77)	
		95 (8.23)	
client size (utilization >=83%)			<0.01
≤150 clients/hr.	175 (65.05)	803 (69.64)	
>150 clients/hr.	94 (34.9)	350 (30.35)	
Economic activity			<0.01
Agriculture goods	50 (18.58)	94 (8.15)	
Semi-finished Industry	96 (35.68)	307(26.62)	
Finished foodstuffs	54 (20.07)	330 (28.62) 422 (38.33)	
Services	69 (25.65)		
Delivery type			<0.01
Usual	238 (88.47)	1090 (94.53)	
Atypical [f]	31 (11.52)	63 (5.46)	
Order Tackling (5S) Principles			<0.01
Usual	186 (69.14)	995 (86.29)	
Atypical [g]	83 (30.85)	158 (13.7)	
Delivery delay			<0.01
<0.25 h	58 (21.56)	364 (31.56)	
0.25 – 0.5 h	128 (47.58)	583 (50.56)	
>0.5 h	83 (30.85)	206 (17.86)	
Time to deliver			<0.01
08–11 hour	27 (10.03)	222 (19.25)	
11–24-hour	29 (10.78)	138 (11.96) 571 (49.52) 252 (21.85)	
1–02 days	166 (61.71)		
02–03 days	47 (17.47)		
Week day			0.04
Saturday	41 (15.24)	130 (11.27)	
Sunday	26 (9.66)	325 (28.18)	
Monday	26 (9.66)	156 (13.52)	
Tuesday	15 (5.57)	185 (16.04)	
Wednesday Thursday	48 (17.84)	90 (7.8)	
	113 (42.00)	267 (23.15)	

Note: *a*: Sample includes all C&R through a random population selection
b: C&R: Complete and receive orders (n = 269).
C: ADR: avoid receiving and escaping from the delivery representative (n = 1153).
d: p-values for X^2 test. *f:* Different from everyday responsiveness service. *g:* Different from everyday flexible.

2.1.2. Flexibility

In the foodstuffs business, supply chain flexibility is essential because of the wide range of product types, stringent control laws, and different development releases that may result in product recalls or unanticipated increases in demand, necessitating flexible manufacturing processes [18, 19]. Sustainable buying is a successful approach that incorporates environmental issues and flexibility, making supply chains more adaptable to consumer demand for greener products, supplier modifications, and the adoption of new sustainability standards [20].

2.1.3. Innovation

Enhancing procurement sustainability requires innovation in the foodstuffs sector. It entails creating new technologies for supply chain transparency, eco-friendly materials, and sustainability metrics tracking in order to improve supply chain management's efficacy and efficiency [21-24]. New perspectives on supply chain management can improve sustainable procurement by developing unconventional solutions for complex sustainability problems, as research shows creative supply chains with sustainability-incorporated operations perform better [25, 26].

2.2. System and Process Integration

In order to guarantee smooth operations, integration is the seamless synchronization of supply chain elements such as data, resources, and procedures. Integrating systems and procedures is essential for achieving sustainable procurement goals in the foodstuffs sector. Integration promotes economic prudence, cooperation, communication, and waste reduction. Additionally, by distributing ongoing data analysis across the chain, it transforms agile skills into sustainable procurement Alkhazaleh and Marei [27] and Jebreel et al. [28]. Baryannis et al. [29] review of AI techniques in supply chain risk management found that researchers primarily focus on mathematical programming, neglecting areas such as prediction, learning, decision-making, big data, and hybridization Baryannis et al. [29]. Li et al. [30] study on mat-heuristics highlights the need for further exploration.

2.3. Operationalizing Sustainable Procurement

Sustainable procurement in the foodstuffs sector is crucial for long-term objectives such as reduced environmental impact, increased social responsibility, and economic efficiency. A comprehensive strategy addressing sustainability in supply chain management, supplier selection, and procurement choices is essential. Studies show that implementing sustainable procurement leads to cost savings, increased brand recognition, and improved sustainability adherence [30-32]. The literature study emphasizes the role that system integration and supply chain agility play in successful sustainable procurement, especially in the foodstuffs industry in Saudi Arabia, and how these elements combine to accomplish operationalization [33]. The following sections will delve deeper into the intricate connections that work together to improve the sustainability outcomes of the sector.

3. Hypothesis Development

3.1. Flexibility -> System and Process Integration

With the help of system and process integration that guarantees smooth communication, coordination, and decision-making while upholding sustainability goals, supply chain flexibility enables businesses to modify their plans in response to market demands, environmental changes, or disruptions [34]. Consequently, the research posits that:

H_1: In the foodstuffs industry, flexibility greatly improves system and process integration.

3.2. Innovation -> System and Process Integration

Innovation in supply chain management involves improving the value-added process from purchase to consumption. The foodstuffs industry faces complex issues such as cost control, environmental sustainability, and regulatory compliance. Effective innovation in this field requires seamless integration of emerging technologies and processes with existing systems and procedures through system and process integration [35, 36]. This subsequently contributes to increasing the efficiency of supply chain performance by understanding its alignment with current practices. Based on this understanding, the following hypothesis is proposed:

H_2: In the foodstuffs industry, innovation greatly improves system and process integration.

3.3. Responsiveness -> System and Process Integration

Being responsive in the foodstuffs sector requires a supply chain that can quickly adapt to market changes, demand, and external disruptions. This requires analysis and process integration to improve coordination, communication, and responsiveness through real-time information exchange [37, 38]. According to the research, an integrated system in a supply chain improves its agility and sustainability by providing management capabilities for quick output identification and problem solving.

H_3: Reactivity significantly enhances system and process integration in the foodstuffs industry.

3.4. System and Process Integration -> Operationalizing Sustainable Procurement

In order to integrate sustainability concerns from supplier evaluation to product delivery and to improve efficiency, cut waste, and maximize resource utilization, the foodstuffs business requires system and process integration [39, 40]. Consequently, the research proposes the following hypothesis:

H_4: The implementation of sustainable procurement in the foodstuffs industry greatly benefits from system and process integration.

3.5. Flexibility -> System and Process Integration -> Operationalizing Sustainable Procurement

The success of sustainable procurement programs can be greatly improved by integrating system and process flexibility into supply chain operations. This allows for adjustments based on business events and long-term corporate sustainable objectives [41]. Through efficient, sustainable supply chain procedures, the combination of flexibility and integration improved operational performance for sustainable procurement. Thus, the following theory is put forth:

H_5: Through system and process integration, flexibility greatly enhances the operationalization of sustainable procurement in the foodstuffs industry.

3.6. Innovation -> System and Process Integration -> Operationalizing Sustainable Procurement

Sustained procurement is a powerful platform that requires integrated processes and collaborative systems, enabling resource companies to effectively enhance and maintain the environmental performance of their supply chain [42, 43]. This provides the natural interlink between system and process integration, a ripple effect that increases the capacity to deliver innovation. Consequently, the research posits that:

H_6: Through system and process integration, innovation greatly improves the operationalization of sustainable procurement in the foodstuffs industry.

3.7. Responsiveness -> System and Process Integration -> Operationalizing Sustainable Procurement

Integrating systems and processes in a supply chain can enhance sustainable procurement operationalization, ensuring effective and timely implementation of changes in the supply chain environment [44]. According to the theory put forward, procurement agility a critical component in the ever-changing food industry is improved when responsiveness and integration are combined:

H_7: The food industry's responsiveness significantly enhances the operationalization of sustainable procurement through system and process integration.

4. Integrating Theoretical Perspectives: Resource-Based View and Institutional Theory in the Foodstuffs Sector

This study examines how Saudi food companies might adopt sustainable buying methods with the aid of supply chain agility and system integration. It finds distinctive, valued resources that provide a long-term competitive advantage by applying the Resource-Based View (RBV) and Institutional Theory. According to the research, these resources can enhance regulatory compliance, environmental friendliness, and operational efficiency [45, 46]. Institutional theory emphasizes the influence of external factors such as laws and social norms on organizational behavior. In the food industry, commitment to bio-based manufacturing is crucial for sustainability. To align procurement with sustainability goals and regulatory standards, integrated systems and processes in the supply chain are essential. The study highlights the difficulties in adopting sustainability by combining RBV and Institutional Theory to describe how internal resources and external influences affect sustainable procurement in the food industry.

4.1. Research Framework

The research explores the importance of supply chain agility in the foodstuffs sector for responsive and adaptive behaviors. It emphasizes the role of system and process integration in implementing sustainable procurement practices, embedding sustainability dimensions throughout the entire procurement continuum. The study offers strategic suggestions for improving sustainable procurement practices. The research framework reveals that supply chain agility directly and indirectly impacts sustainable procurement through system integration, combining upstream and downstream production processes for comprehensive operability in a competitive environment, as illustrated in Figure 3.

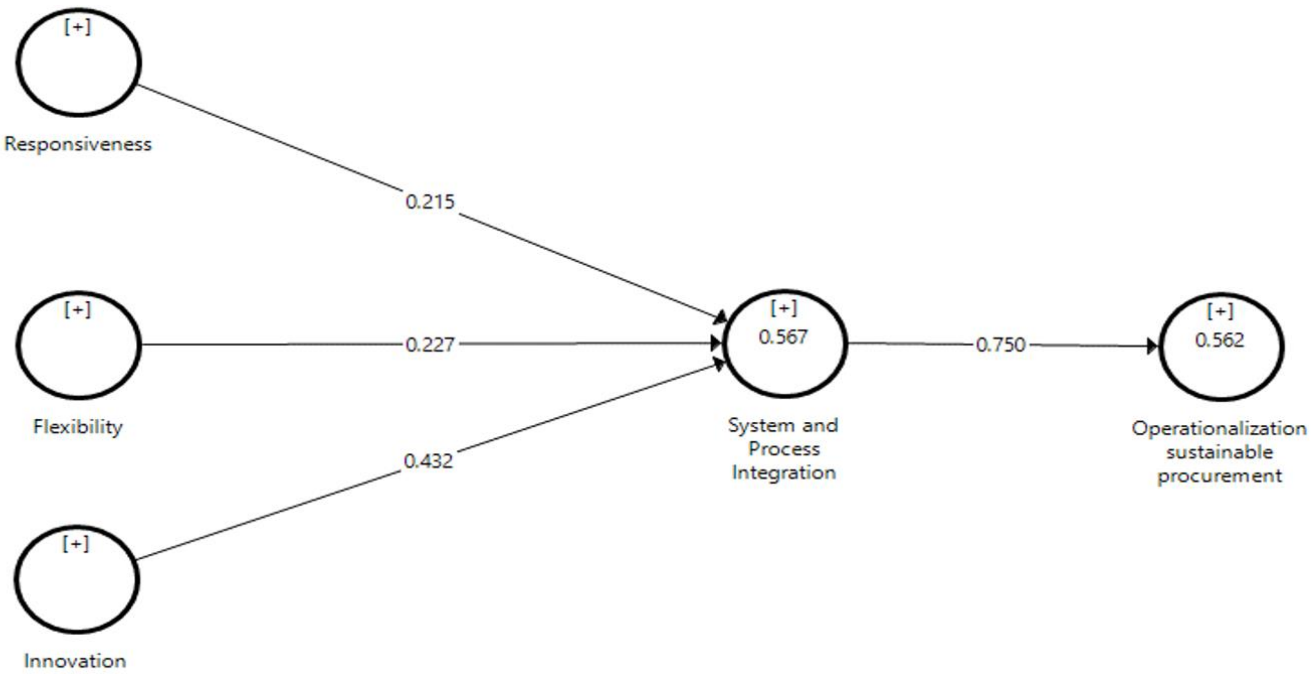

Figure 3.
Research model.

5. Research Methodology

Simplifying procedures and guaranteeing procurement optimization for business are two aspects of procurement optimization. This includes setting objectives, figuring out requirements, finding reliable suppliers, and calculating the overall cost. The term "procurement optimization" describes methods and procedures that increase the effectiveness and value of procurement operations. Since procurement accounts for a sizable amount of many businesses' expenses, procurement optimization can result in considerable cost savings and increased profitability. It focuses on cutting back on maverick spending, strengthening ties with suppliers, raising transparency, and increasing procurement efficiency. Organizations may improve spend control and free up procurement teams to concentrate on strategic goals by centralizing data, automating and simplifying operations, utilizing analytics, and putting in place appropriate checks and balances [47].

5.1. Questionnaire and Pre-Testing

Table 1 shown the population of questionnaires and measured supply chain agility using eight adapted items from previous research, and system and process integration using eight items from existing literature. Sustainable procurement was assessed using 12 items, incorporating practices in addressing targets and rating them using a 5-point scale. A pre-test with academic experts and industry professionals confirmed the clarity, relevance, and applicability of the questionnaire items, supporting further data-collecting efforts in understanding supply chain agility's impact on sustainable procurement in Saudi Arabia's foodstuffs sector.

5.2. Sample Design and Data Collection

This study focuses on managers and top management in Saudi Arabia's foodstuffs sector, specifically those involved in supply chain management and procurement operations. Data was collected through a structured survey of 150 experienced professionals, focusing on their perception of agile practices and sustainability actions. The study investigates the relationship between supply chain agility and sustainable procurement, with a particular emphasis on system and process integration. The methodology ensures strong findings and current practices in the Saudi Arabian foodstuffs industry.

5.3. Data Analysis

This study focuses on managers and executive decision-makers in Saudi Arabia's foodstuffs industry, emphasizing supply chain management and procurement operations. The focus is on enhancing supply chain agility, system and process integration, and sustainable procurement practices. A structured survey was used to gather 150 responses from supply chain managers, procurement officers, and other stakeholders. The data will contribute to a grounded analysis of the dynamics between supply chain agility, system and process integration, and halal sustainable procurement in the Saudi Arabian food sector.

5.4. Common Method Bias

This study addressed common method bias in Partial Least-Squares Structural Equation Modelling (PLS-SEM) by examining full collinearity and Variance Inflation Factors (VIF) for all variables. The results showed that common method bias was not a concern, as VIF values were less than the threshold level of 3.3. These findings strengthen the mediating role of system and process integration in explaining the relationship between supply chain agility and sustainable procurement in the foodstuffs industry in Saudi Arabia.

5.4.1. ML Algorithms used in SCM

Ni et al. [12] highlight the top 10 most commonly used ML algorithms in supply chain management (SCM). However, the lack of knowledge and unclear explanations of these algorithms hinder their benefits. Despite the potential advantages, they also have limitations such as high error susceptibility and inaccurate interpretation of results, making it crucial to select the appropriate algorithm as illustrated in Figure 4.

5.5. Assessment of the Measurement Model

ARIMA's main weakness is its inability to monitor deviations in procurement trends influenced by responsiveness, flexibility, and innovation, as illustrated in Figure 5 and discussed in Table 2. It is important to extract the ACF and PACF for the deviation distribution, as illustrated in Figure 4 and Figure 5, respectively, that the parameters are significantly different from zero in spike 18, and they are out of the confidence range. Therefore, the next step will be to test the stationary case.

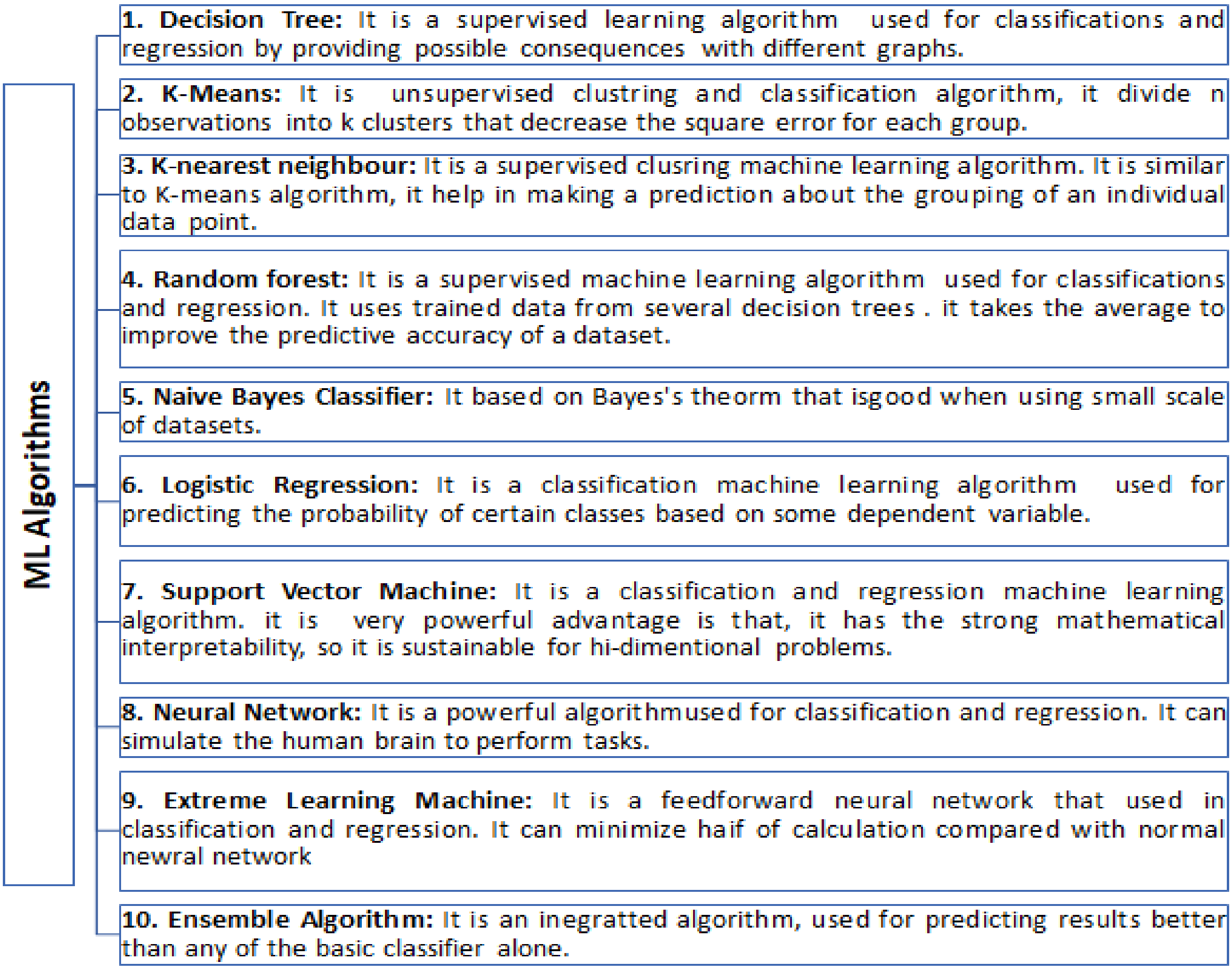

Figure 4.
10 commonly used ML algorithms in SCM.

Table 2.
JPOM cycling functions.

No.	Action	No.	Action
1	Check the data's deviance via K-means and measuring specific dimensions	11	Check stationarity of responsiveness data in DB
2	Insert valid spatio prediction valleys that have a highly significant function in a specific process in the local dataset.	12	Before moving on to the prediction stage, remove or diminish the trend in the recorded data, and check the stationarity of the flexibility data in the database.
3	Feed the database with the forecasted error verification analysis according to k-means.	13	Send predicted σ_s in μm for MLM in DB (x_3) and check stationarity of innovation data in DB
4	Check for deviation span σ_s temporally and send data to the local dataset	14	Receive MLM approval if σ_s <0.01 from DB
5	Create the central dataset for prediction valleys and their related standard spatiotemporal images.	15	JIDOKA action: [Send data of stopping (if σ_s >0.01) or continuing (if σ_s <0.01)] to stop procurement from a specific supplier
6	Provide the evaluation stage with an information pulse that includes prediction valleys and details about the distribution of deviations.	16	Count the jerky valleys in price and feed the DB
7	Activate the MLM machine learning model in the central database.	17	Evaluate the MLM instability and feed the database with procurement capability in flexibility, and affect direction.
8	Receive MLM approval from the central database if the σ_s < 0.01 (process analysis) or not	18	Evaluate the MLM instability and feed the database with procurement capability in an innovative direction.
9	Provide the review stage with a data pulse that includes the prediction valleys and specifics of the distribution of deviations.	19	Reset the procurement model
10	Update the central dataset via ARIMA	20	Continue the JIDOKA cycle

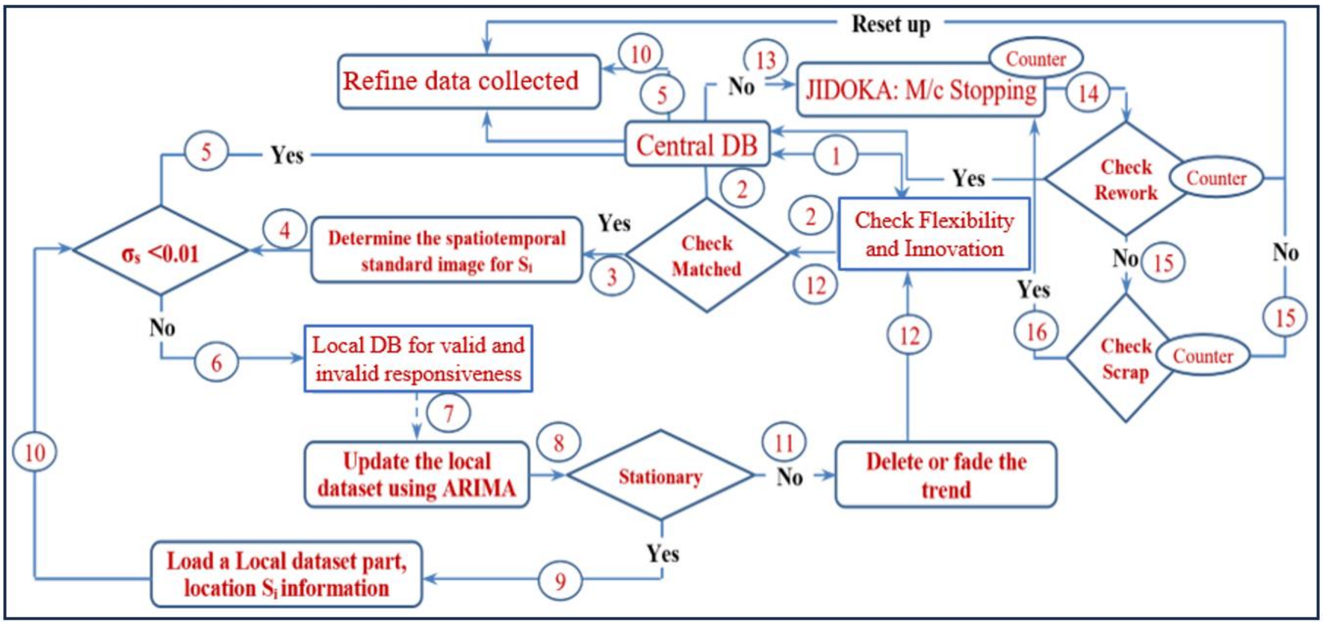

Figure 5.
Proposed Jidoka-ARIMA flow work.

5.5.1. Stationary Test [Step 11]

The stationary case test aims to fade the overall trend by handling data using the deviation distribution's partial autocorrelation. Different parameters are extracted using ACF and PACF, and appropriate SARIMA parameters are chosen using logarithmic transformation as illustrated in Figure 6 and emphasized in Figure 7, where zero till spike (18) and not lay in confidence range $-0.215 \le r_k \le 0.215$. LIung&Box declares the rejection of the original assumption H0 because $Q.\ stat.\ LB^{\ (TBF)} = 383.59 > \ x^2{}_{(18,0.01)} = 34.81$, Now refuse H_0: $\rho_1 = \rho_2 = \Delta\Delta = \rho_k = 0$ and belief of no stationarity in the deviation distribution data.

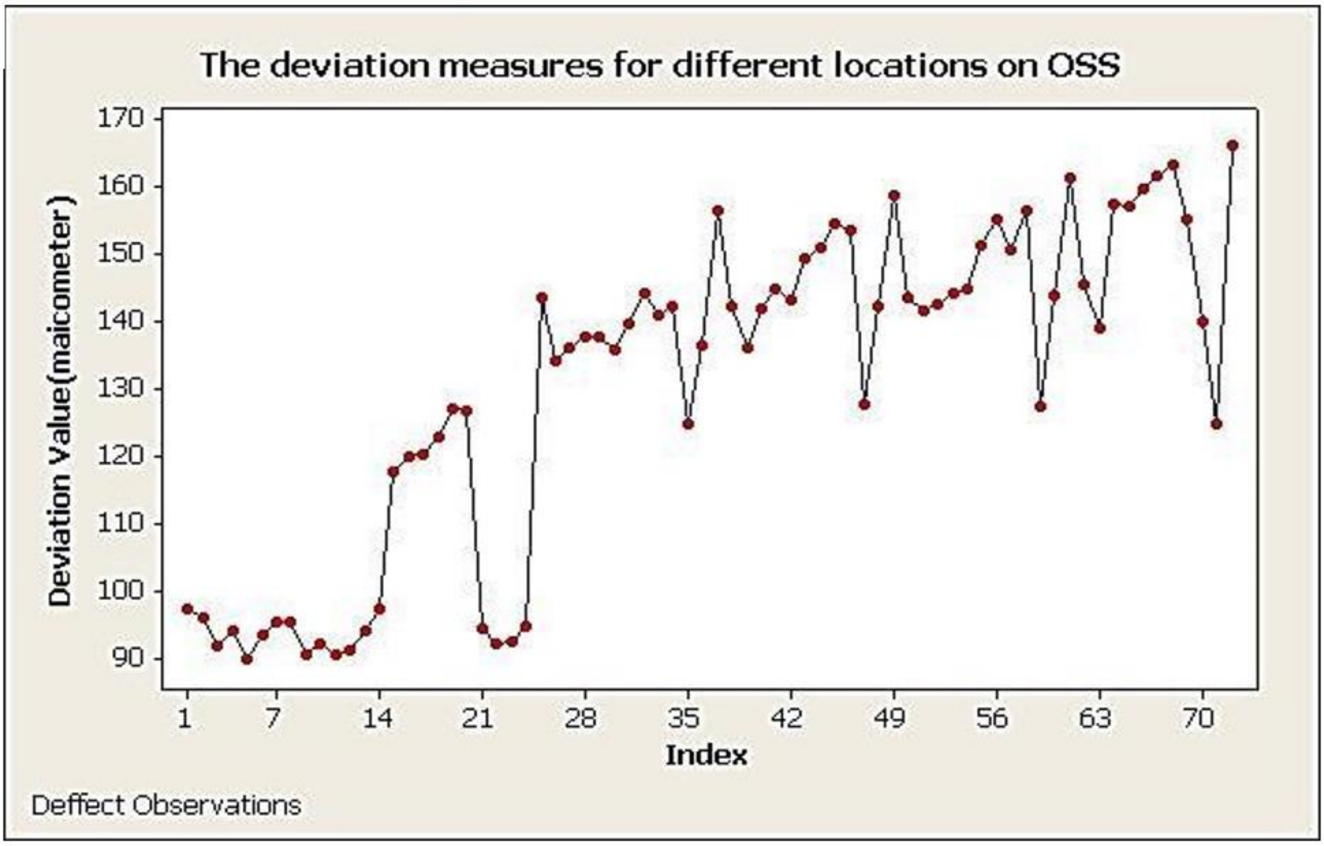

Figure 6.
Primary characteristics of deviation distribution.

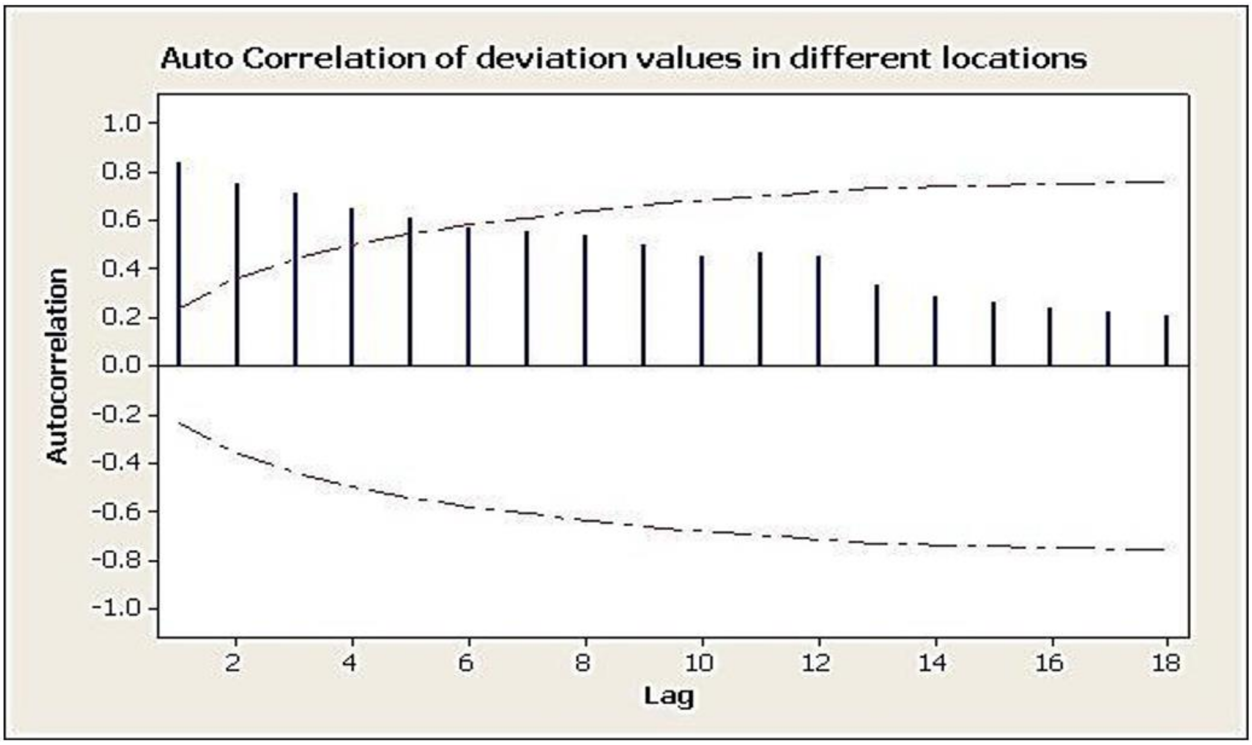

Figure 7.
Autocorrelation of deviation distribution.

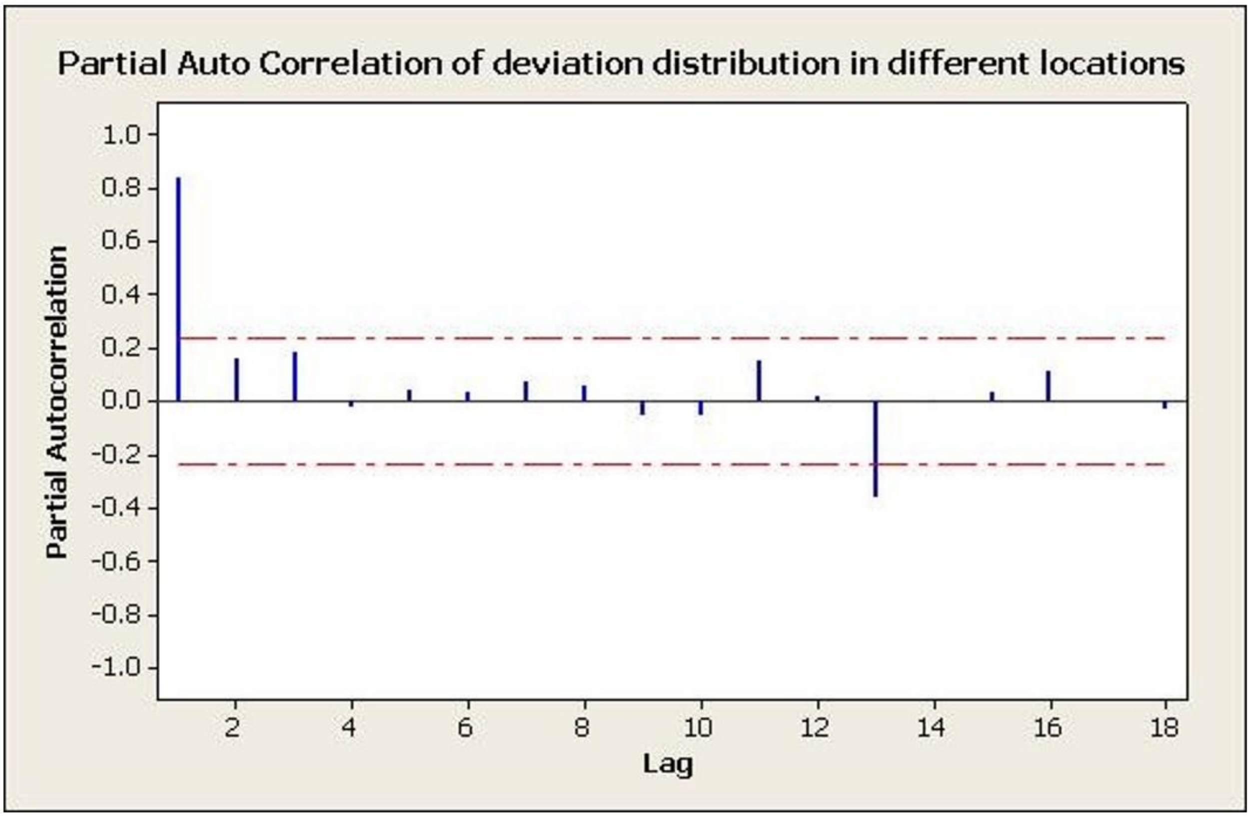

Figure 8.
Final Decision of ARIMA trend.

5.5.2. Fade the Trend

Choose the range that is closest to reducing the data trend, then continue to calculate the deviations until the trend fades $\nabla Y_{t(logarithmic)} = Y_{(logarithmic)} - Y_{t-1(logarithmic)}$ as illustrated in Figure 9 via repeating LBQ ($TBF_{first\ diff}$) = 32.52 < $x^2_{(17,0.01)}$ = 33.41. Therefore, one should not take the 2nd deviance for the TBF data and accept H_0. Which proved via absence of the trend as illustrated in (Figure-10). Then, preferable [d=1], but (Figure 9 and Figure-11) demonstrate the birth-time factor's periodicity behaviour for the geographic span at spike 12.

In order to achieve this, Eqn. (1) is modified to attempt fading the distinctive seasonality feature and identify the important region span with the highest likelihood of deviation events across the time scale ω:

$$\boldsymbol{d_s}(\boldsymbol{t}+\boldsymbol{\delta t}) = \boldsymbol{ln}\left[(\mathbf{1}-\boldsymbol{\vartheta})\boldsymbol{d}_s(\boldsymbol{t}) + \frac{\boldsymbol{\vartheta}^2}{\boldsymbol{z}}\sum_{\boldsymbol{s}'\sim\boldsymbol{s}} \Delta\boldsymbol{d}_{s'}(\boldsymbol{t})\right](\mathbf{1} - \boldsymbol{\omega\delta t}) + \boldsymbol{\theta E_s}(\boldsymbol{t}) \quad (\mathbf{1})$$

Where z is the number of steps that are scheduled to be carried out at position s, and ϑ is just a binary parameter that ranges from zero to unity and indicates the importance of the stage that is impacted (i.e., whether the average activity cycle duration is kept as planned or not). Greater deviation and a higher degree of defect occur with higher values of ϑ, while the opposite occurs with lower values, where Δ denotes the discrete Laplacian operator. In case of LBQ = 20.62 < $x^2_{(15,0.01)}$ = 30.58, the push describing assumption H_0 is acceptable as a seasonal case. The same number of steps $\bar{n}$ for the prediction valleys' of any stage to stay constant, the value by which the prediction valleys' time decays in one time-step δt should be equal to the value by which it increases due to error actions. To maintain fixed faults, the number of steps notified in a timestep must match the number of errors produced at that stage at a rate $\boldsymbol{r_{ijk}}$ as expressed in Equation 2 as illustrated in Figures 12 – 14.

$$\bar{\boldsymbol{n}}\,\bar{\boldsymbol{p}}\,\bar{\boldsymbol{\beta}} = \boldsymbol{\omega}\bar{\boldsymbol{F}}\boldsymbol{\delta t} = \boldsymbol{r_{ijk}\delta t} \qquad (2)$$

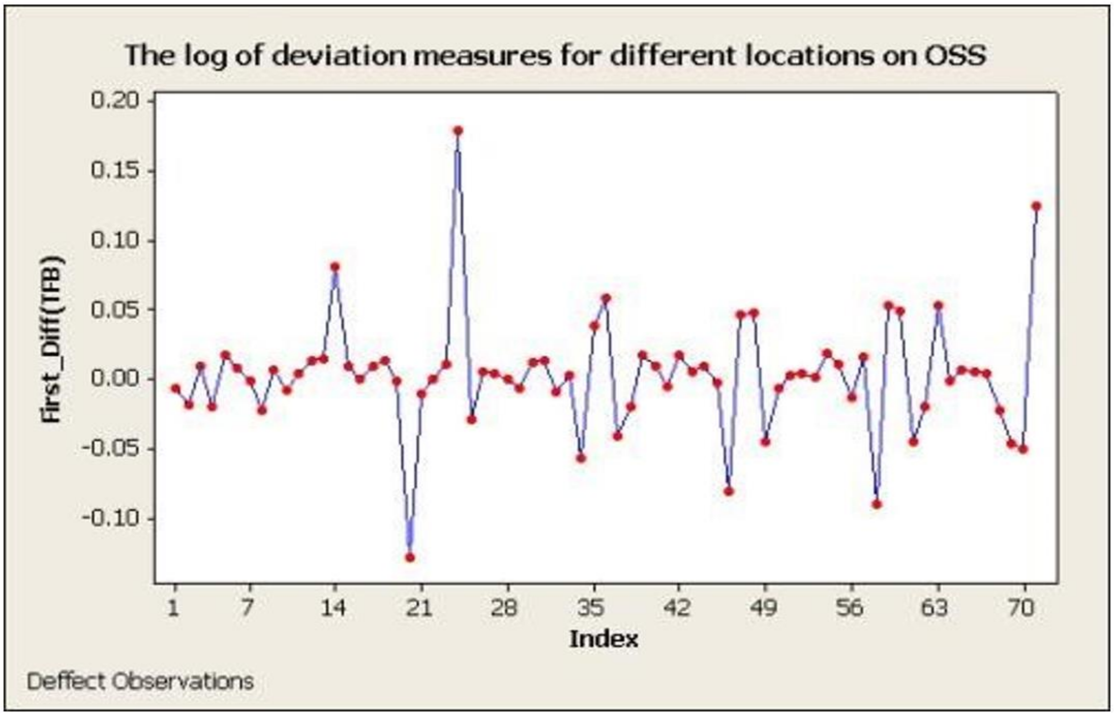

Figure 9.
Absence of trend.

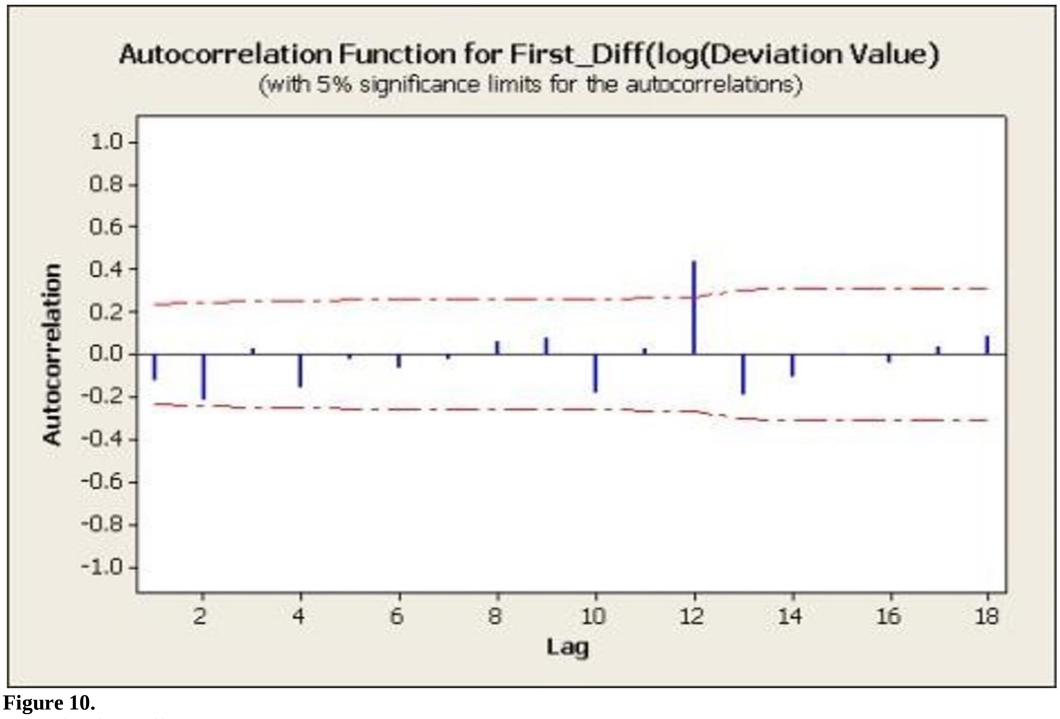

Figure 10.
ACF after first difference.

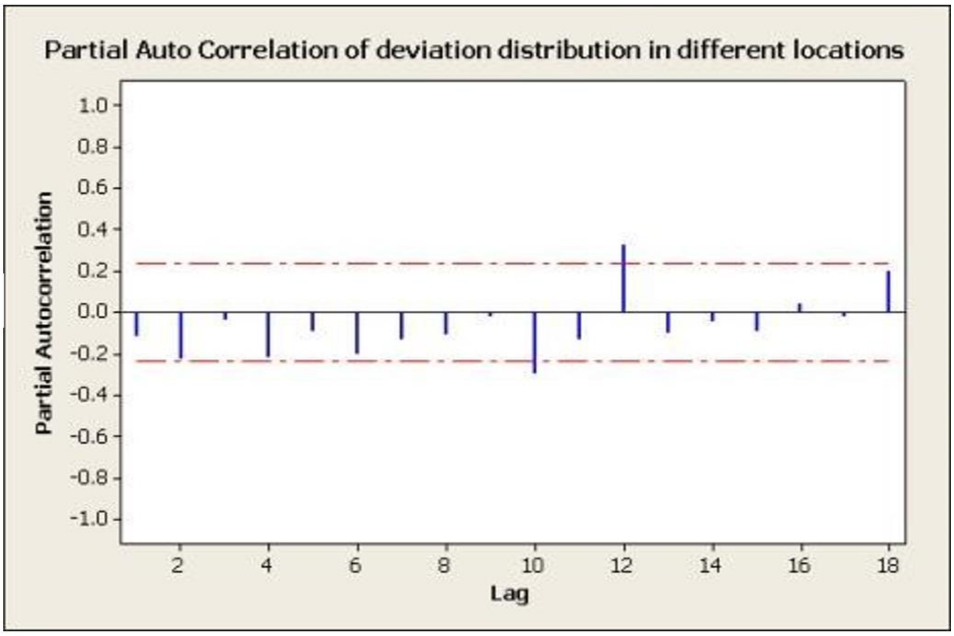

Figure 11.
PACF after first difference.

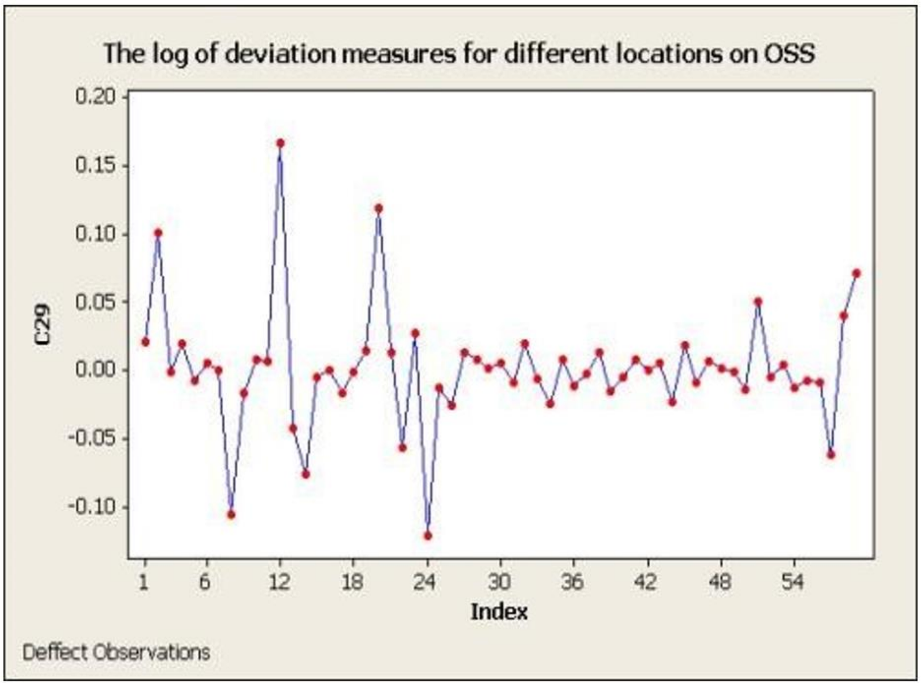

Figure 12.
Absence of trend.

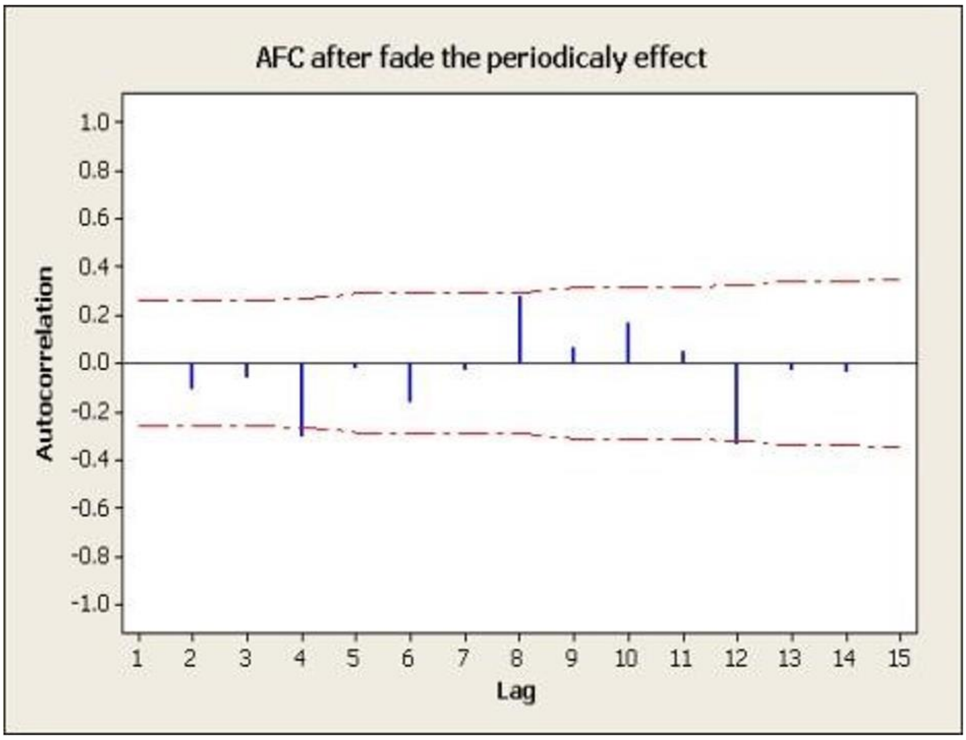

Figure 13.
ACF seasonality first difference.

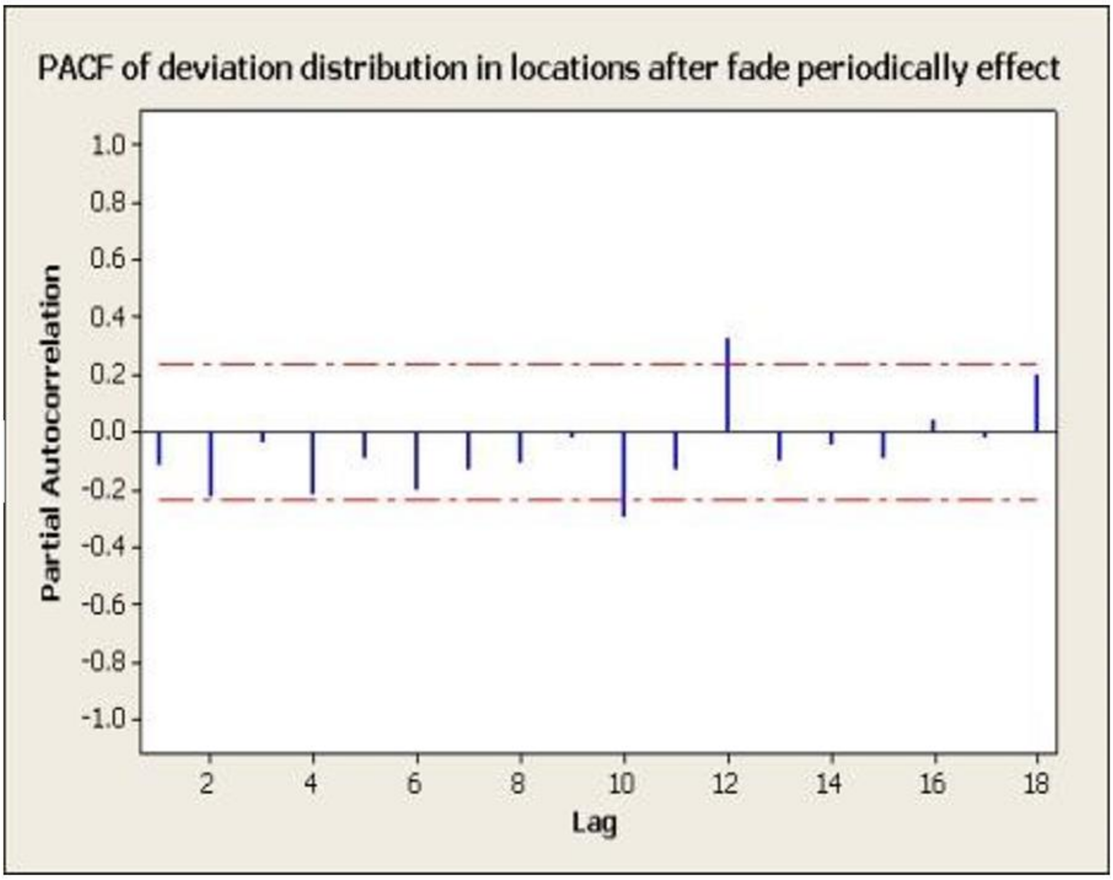

Figure 14.
PACF seasonality first difference.

The expected value of dynamic prediction valleys and faults after one timestep is represented by the continuum limit, which was obtained following a thorough examination of $F_s(t)$ behaviour as expressed Eqn. (3). The number of jerkies denoted by $n_s(t)$ with time and relies on γ^2, when subtracting $d_s(t)$ and dividing Eqn. (3) by δt.

$$d_S(t+\delta t) = \ln\left[d_s(t) + \frac{\vartheta\gamma^2}{z}\Delta d_s(t)\right](1-\omega\delta t) + \beta n_s(t)p_s(t) \quad \ldots (3)$$

Table 3 presents the discriminant validity of Flexibility, Innovation, Operationalization of Sustainable Procurement, Responding, and System and Process Integration in the Saudi foodstuffs sector through confirmatory factor analysis (CFA). All items met or exceeded the recommended threshold of 0.708 (ranging from 0.676 to 0.867) for factor loadings, highlighting the strong representation of each item within its respective construct.

Table 3.
Measurement items and reliability.

Constructs	Items	Factor loadings	Cronbach's Alpha	C.R.	Mean
Flexibility	JidFlx1	0.755	0.865	0.893	0.583
	JidFlx2	0.676			
	JidFlx3	0.781			
	JidFlx4	0.763			
	JidFlx5	0.776			
	JidFlx6	0.823			
Innovation	Inov1	0.827	0.898	0.922	0.662
	Inov2	0.825			
	Inov3	0.852			
	Inov4	0.799			
	Inov5	0.819			
	Inov6	0.758			
Operationalization sustainable procurement	OSP1	0.77	0.89	0.916	0.644
	OSP2	0.807			
	OSP3	0.813			
	OSP4	0.807			
	OSP5	0.81			
	OSP6	0.807			
Responsiveness	Res1	0.801	0.78	0.809	0.725
	Res2	0.701			
	Res3	0.77			
	Res4	0.831			
	Res5	0.825			
	Res6	0.808			
System and Process Integration	SPI1	0.776	0.883	0.911	0.631
	SPI2	0.799			
	SPI3	0.789			
	SPI4	0.707			
	SPI5	0.817			
	SPI6	0.867			

The AVE values of the constructs (ranging from 0.583 to 0.662) were all higher than the recommended threshold of 0.50, indicating that the constructs incorporate sufficient variance within them. All constructs had a composite reliability (CR) value from 0.893 to 0.922, meeting the recommended lower standard of 0.70 and thus demonstrating acceptable internal consistency. However, Cronbach's Alpha values for constructs ranged from 0.856 to 0.898, confirming the reliability of measurement items against the construct. The measurement model results verify the convergent validity and reliability of the constructs, supporting a more solid basis for examining how supply chain agility influences sustainable procurement practices operationalization in the pharma sector via an intervening role of system and process integration. Table 4 Analysis of Discriminant Validity (foodstuffs Sector: Saudi Arabia) Flexibility Innovation Operational of Sustainable Procurement Responsiveness System & Process Integration (Table 2 presents the analysis of discriminant validity. Full-size table. Discriminant validity was tested with the heterotrait-monotrait (HTMT) ratio, which is argued to be more accurate compared to the existing Fornell–Larcker criterion. Literature advises that an HTMT of 0.90 serves as a cut-off value to indicate the dissimilarity of constructs based on one another.

Table 4.
HTMT.

	Flexibility	Innovation	Operationalization of sustainable procurement	Responsiveness	System and Process Integration
Flexibility					
Innovation	0.614				
Operationalization of sustainable procurement	0.817	0.677			
Responsiveness	0.799	0.651	0.839		
System and Process Integration	0.691	0.752	0.831	0.684	

As can be clearly seen in Table 4, All HTMT values do not exceed the value of 0.90 (in all cases, the highest value is 0.839 between Operationalization of Sustainable Procurement and Responsiveness). The discriminant validity of the model is checked by examining the inter-correlation matrix to determine whether Flexibility, Innovation, Operationalization of Sustainable Procurement, Responsiveness, and Systems & Process Integration are indeed separate constructs within this study Table 5: The Fornell-Larcker criterion was adopted to assess the discriminant validity of the constructs in this study, which investigates the impact of supply chain agility on operationalizing sustainable procurement in the foodstuffs industry in Saudi Arabia. This indicates that the diagonal values (square roots of the AVE) for Flexibility (.764), Innovation (.814), Operationalization of Sustainable Procurement (.803), Responsiveness (.791), and System and Process Integration (.794) exceed their respective inter-construct correlations. Each of these shows clear distinction from the others, affirming that there is sufficient discriminant validity in the model.

Table 5.
Fornell-Larcker.

	Flexibility	Innovation	Operationalization of sustainable procurement	Responsiveness	System and Process Integration
Flexibility	0.764				
Innovation	0.546	0.814			
Operationalization of sustainable procurement	0.715	0.608	0.803		
Responsiveness	0.703	0.582	0.757	0.791	
System and Process Integration	0.614	0.681	0.75	0.625	0.794

This guarantees that the different dimensions of constructs are being captured and establishes construct validity, in turn facilitating inferences about relationships, supply chain agility, system and process integration, and sustainable procurement in the foodstuffs sector, as illustrated in Figure 15.

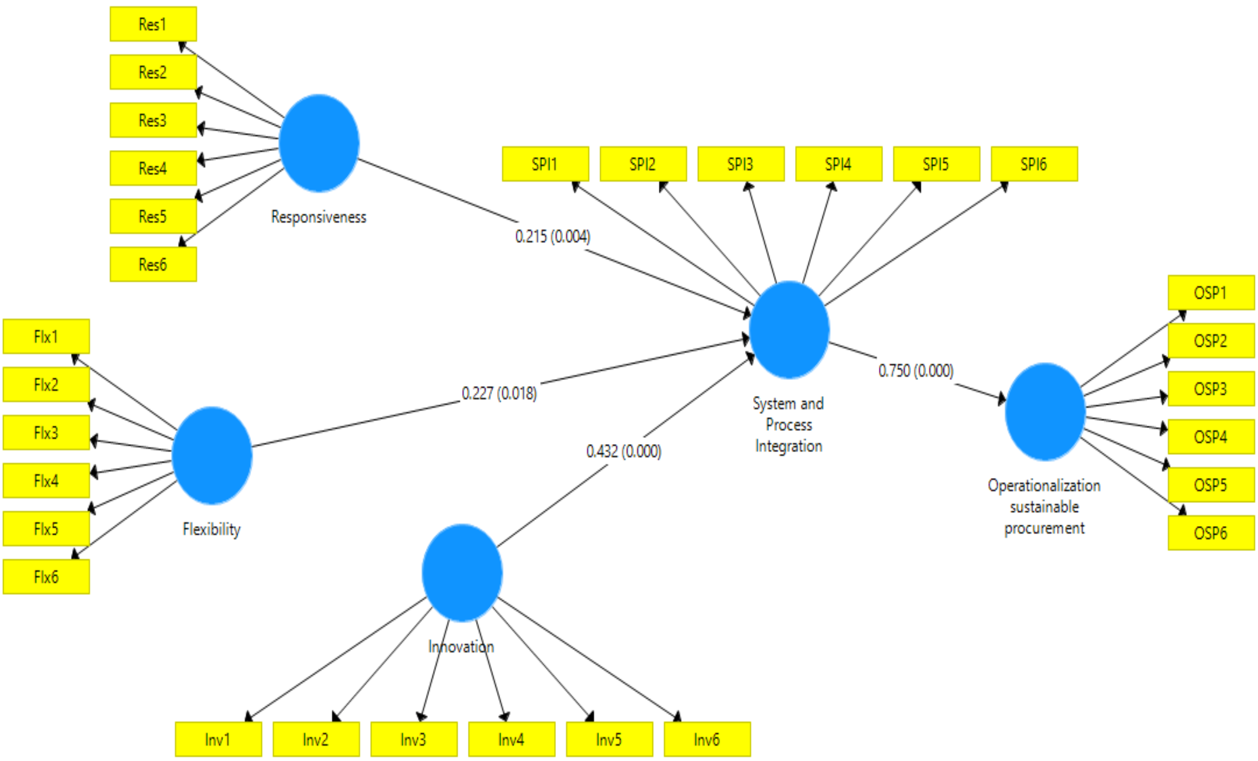

Figure 15.
Measurement model.

5.6. Assessment of the Measurement Model

This study tested the measurement model to explore the constructs associated with supply chain agility impacted on sustainable procurement by operationalizing system and process integration in the foodstuffs industry of Saudi Arabia. For increased construct validity and reliability, the scales of nine composite constructs developed through a systematic literature review about supply chain agility and system integration in general, as well as sustainable procurement, were originally validated based on previous studies and then pilot-tested with industry professionals. We tested the measurement model using survey data from managers and decision-makers at foodstuffs companies with advanced statistical methods such as confirmatory factor analysis (CFA). Table 2: Design of Measures Discriminant Validity and Reliability
The CFA results established that all constructs had both discriminant validity and reliability, indicating the appropriateness of the measures for subsequent analysis. This comprehensive verification system is used to confirm the conclusions of structural equation modeling (SEM), which presents significant strategic implications aimed at advancing sustainability in the food industry. Supply chain agility, system and process integration, and sustainable procurement.

6. Path Result

Procurement literature primarily focuses on models for quantity orders and supplier selection based on inventory evaluation. A questionnaire was completed by 32 manufacturing organizations' procurement professionals to identify key elements. They desire a model that manages orders across multiple vendors, considering suppliers' lead times and quality. They believe multiple pricing and varying holding costs are essential components of their ideal model that must be refined by quick responsiveness, flexibility, and innovation parameters. The respondents have not requested long-term contracts, ordering costs, minimum order quantities, or payment terms, suggesting a need for research on the procurement model required for large and non-manufacturing firms [48].

6.1. Specific Indirect Effects

Table 6 research examines the direct relationships between variables within the foodstuffs sector in Saudi Arabia, focusing on existing connections among supply chain agility effects and the operationalization of sustainable procurement through system and process integration. System and Process Integration ($\beta = 0.227$, p-value < 0.018) is significantly influenced by factors such as flexibility, which positively correlates with system and process integration, highlighting that agile supply chain practices, supported by information technology, enhance linkage between systems and processes. The role of innovation is further confirmed by its significant and positive relationship with system and process integration ($\beta = 0.432$, $p < 0.001$), emphasizing the importance of innovative practices in strengthening supply chain integration. Additionally, responsiveness ($\beta = 0.215$, $p = 0.004$) is identified as a significant factor, underscoring the necessity of a responsive supply chain to facilitate effective integration.

Table 6.
Hypothesis testing estimates.

	Original sample	Sample mean	Standard deviation	T statistics	P values	Result
Flexibility -> System and Process Integration	0.227	0.249	0.096	2.372	0.018	Supported
Innovation -> System and Process Integration	0.432	0.419	0.081	5.332	0	Supported
Responsiveness -> System and Process Integration	0.215	0.212	0.074	2.901	0.004	Supported
System and Process Integration -> Operationalization of sustainable procurement	0.75	0.751	0.041	18.277	0	Supported

The relationship between System and Process Integration and Operationalization of Sustainable Procurement is less important than its relationships to Collaboration with Suppliers ($\beta = 0.210$, $p < 0.05$), Inter-Regional Cooperation ($\beta = 0.212$, $p < 0.01$), with βs above 0.7 among all constructs, showing the significance of system integration and process integration in achieving sustainable procurement objectives in the foodstuffs sector at large scale because it has β and t values nearer to each other. These results show that supply chain agility is significantly and positively associated with sustainability practices through flexibility, innovation, and responsiveness, serving as another key mediator between the factors of system integration and process integration.

6.2. Specific Indirect Effects

The results presented in Table 7 outline the indirect effects of flexibility, innovation, and responsiveness on the operationalization of sustainable procurement through the mediating role of system and process integration within the foodstuffs sector in Saudi Arabia.

Table 7.
Hypotheses testing estimates.

	Original sample	Sample mean	Standard deviation	T statistics	P values	Result
Flexibility -> System and Process Integration -> Operationalization sustainable procurement	0.17	0.187	0.073	2.327	0.02	Supported
Innovation -> System and Process Integration -> Operationalization sustainable procurement	0.324	0.314	0.06	5.418	0	Supported
Responsiveness -> System and Process Integration -> Operationalization of sustainable procurement	0.161	0.161	0.059	2.708	0.007	Supported

First, the table reveals that Flexibility has a significant and positive indirect impact on the operationalization of sustainable procurement through system and process integration, with a p-value of 0.02, indicating strong support for this relationship. Second, Innovation shows a highly significant and positive indirect effect on the operationalization of sustainable procurement via system and process integration, supported by a p-value of less than 0.001. Finally, Responsiveness also demonstrates a significant and positive indirect impact on the operationalization of sustainable procurement through system and process integration, with a p-value of 0.007. The results also underline the importance of system and process integration as a mediator between supply chain agility, specifically flexibility, innovation, and responsiveness, which benefit sustainable procurement goals in the foodstuffs sector.

```
                ** Convergence criterion not met after 25 iterations **
Final Estimates of Parameters
Type         Coef  SE Coef       T      P
AR   1    -0.1362   0.1649   -0.83  0.414
MA   1     1.0532   0.0097  108.53  0.000
SMA  12    0.9415   0.1383    6.81  0.000
Constant  0.46981  0.01824   25.75  0.000
Differencing: 1 regular, 1 seasonal of order 6, # of observations:  Original series
65, after differencing 52, Residuals:    SS = 5795.49 (backforecasts excluded), MS =
137.99 DF = 52
Modified Box-Pierce (Ljung-Box) Chi-Square statistic
Lag             6       24     36           48
 Chi-Square   12.7     14.6   34.6           *
 DF              8            20     32    *
 P-Value     0.124            0.801  0.347 *
```

$LBQ\ (TBF_{first\ seasonality\ diff}) = 12.7 < x^2(12{,}0.01) = 26.22$ That proves the non-significance (stochastic) and the model is effective and efficient to predict the deviation value.

7. Finding

The best decision for the ARIMA model, which achieves a p-value < 0.01 for MA(q), otherwise it is rejected. Therefore, the regime should predict the valleys' prices and their expected lifetime over time, taking into account the preferable moving average value | and Ø = 1.2649 to address instability that appears at [0: 0.29] for MA (Ø=1.2 at maximum probability or 3 for all wave bands). The preferred model, SARIMA (1, 1, 1) x (0, 1, 1)6, is efficient and effective as illustrated in Figures 17, 18.

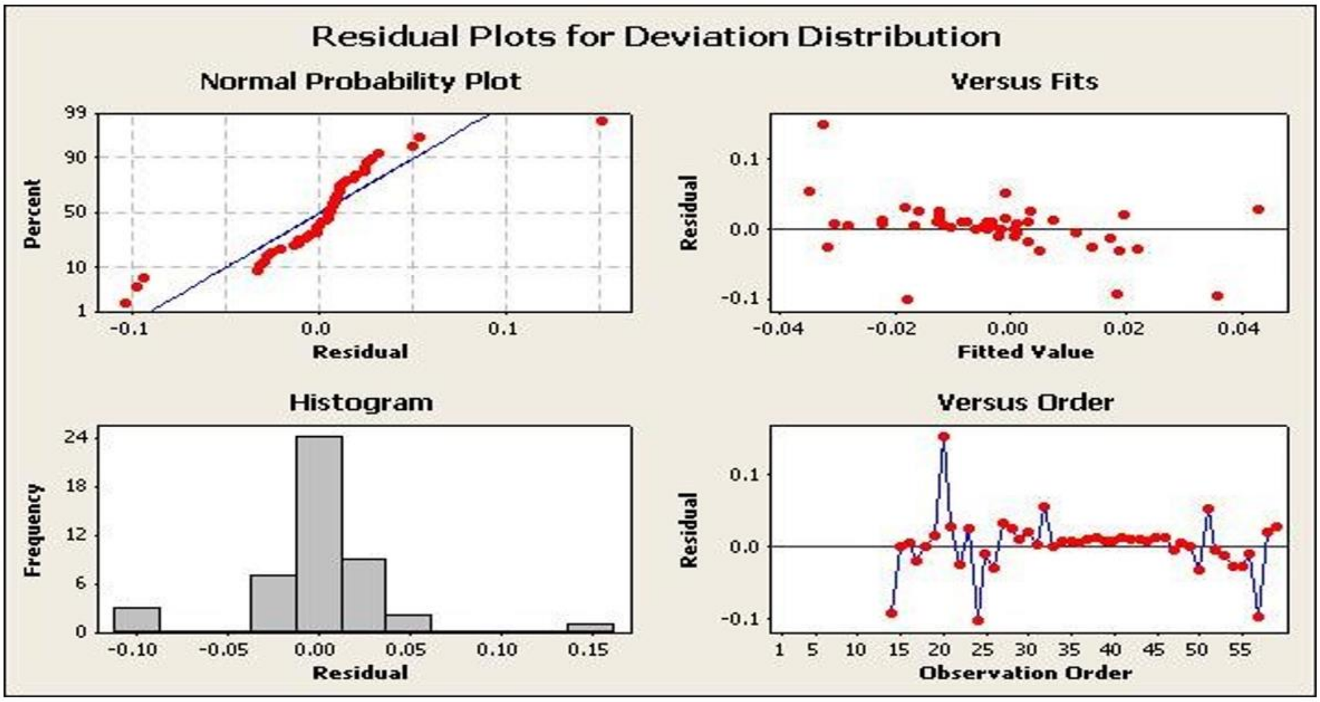

Figure 16.
Residual plots for seasonality deviation behavior.

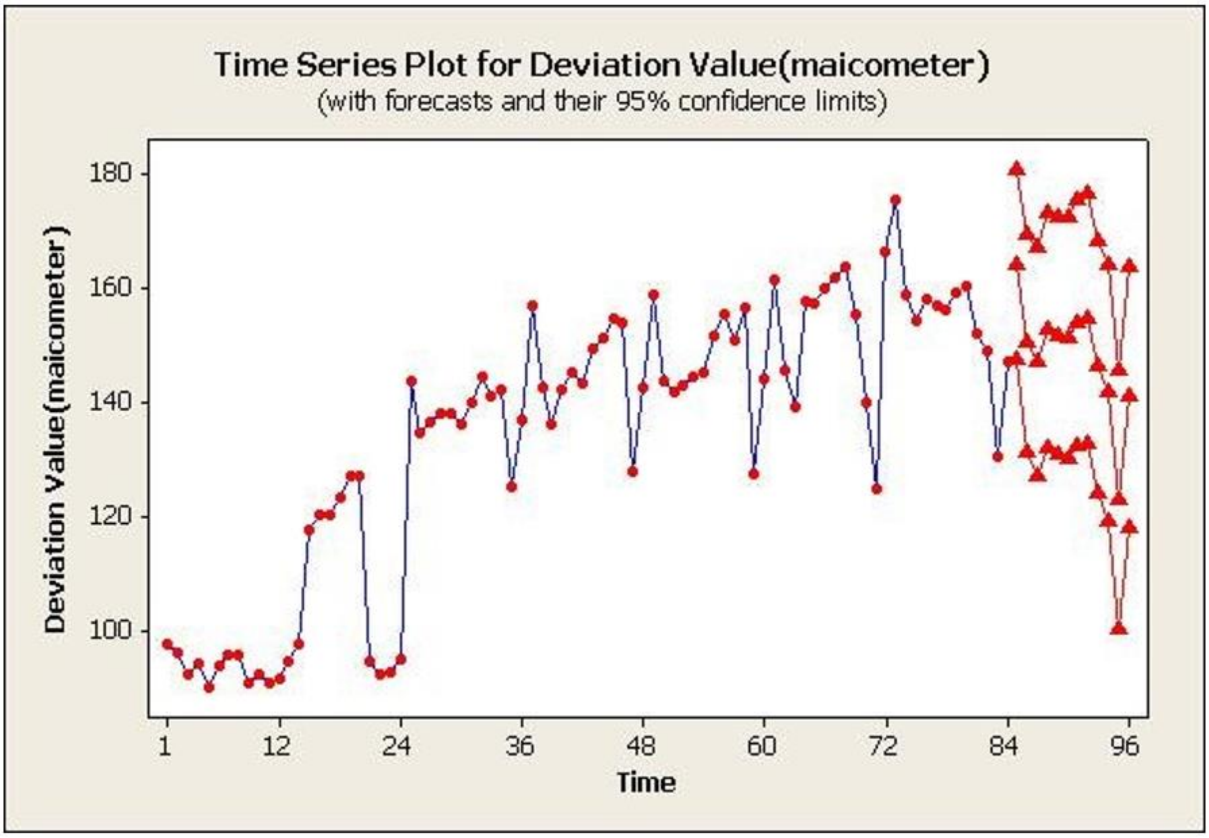

Figure 17.
The Prediction phase for the deviation distribution.

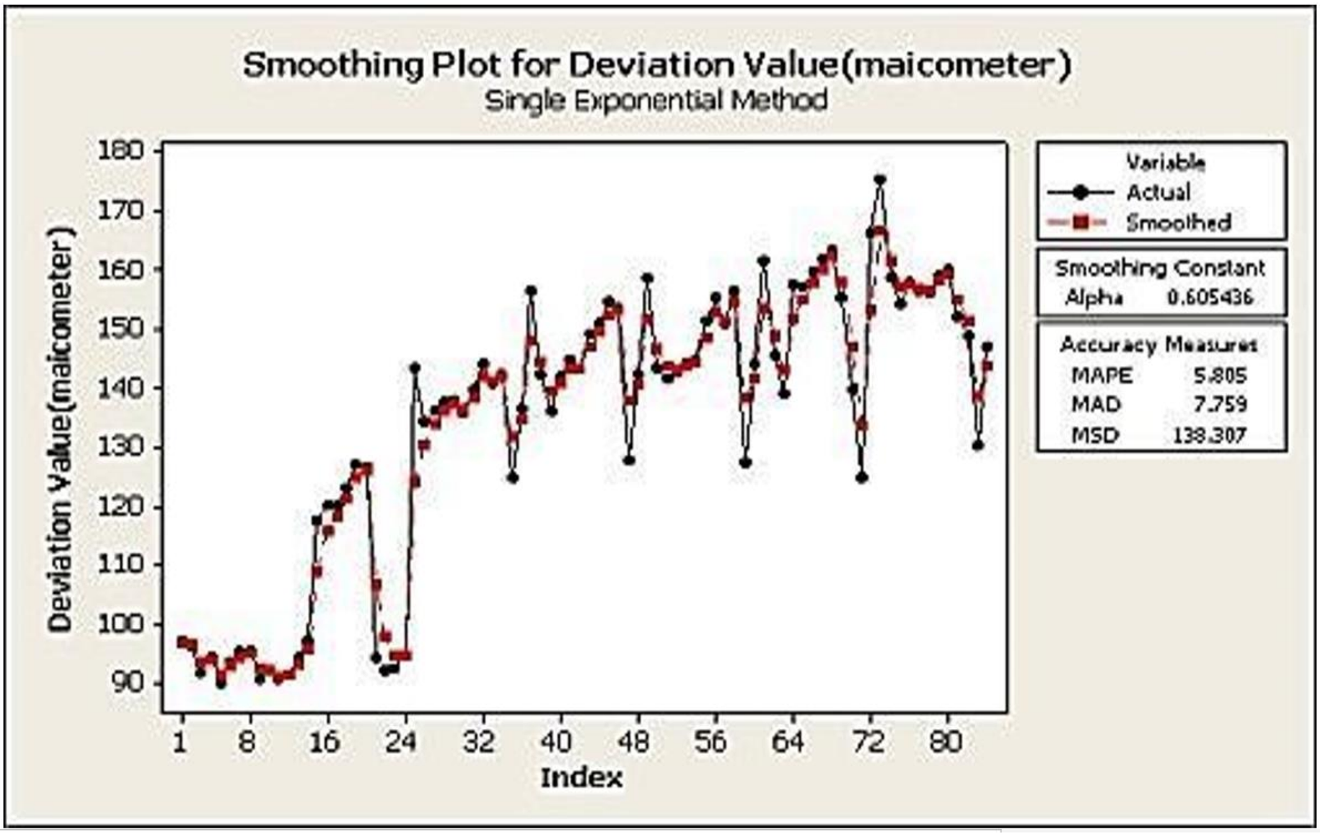

Figure 18.
The comparison between the proposed MLM and SES for the deviation distribution.

8. Discussion and Conclusions

This investigation has been able to validate a few significant outcomes and supports system and process integration as an intervening variable in how supply chain agility fosters the functioning of sustainable procurement throughout the foodstuffs sector within Saudi Arabia. The study suggests that agile practices are significantly correlated with the operationalization of sustainable procurement, contributing to sustainability targets within a highly regulated industry of foodstuffs. Implications are responsive and adaptive supply chains [5]. Finally, this research discovers that system and process integration would enhance the association between supply chain agility and sustainable procurement at a statistically significant level, which indicates a well-coordinated linkage to transform agile capabilities into sustainable procurement practices. The results also reveal that system and process integration mediate the positive effects of supply chain agility on sustainable procurement, which calls attention to the necessity for integrated approaches to sustainability initiatives. This knowledge is pertinent to stakeholders in the foodstuffs industry, as it formulates a sophisticated framework that can be utilized strategically by drug developers and policymakers in designing sustainable procurement strategies combining agility and integration, thereby focusing on creating high operational and environmental performance.

8.1. Theoretical Implications

The research contributes multiple theoretical perspectives to the extant literature focusing on supply chains' agility, system and process integration, and sustainable procurement in the foodstuffs industry. This study theoretically contributes to research by illuminating the roles of supply chain agility in sustainable procurement; system integration and process integration are the two important mediators. The results extend the related literature of resilient supply chains by pointing out that integrating agile practices with coordinated systems and processes is a key mechanism for sustainability objectives. In addition to this, the study provides insight into how these amalgamated methodologies could be adopted in the foodstuffs industry, which is now more focused on operational efficacy and environmental regulation. These findings generate ample research directions, mainly concentrating on the integration of supply chain agility and system approach together with sustainability in different industries, thus providing a sturdy foundation to investigate these relationships across various sectors.

8.2. Managerial Implications

This research provides strategic priorities for Saudi Arabian foodstuffs organizations, specifically to improve sustainable procurement capabilities while promoting supply chain agility and system integration. For managers looking to operationalize sustainable procurement, these findings can serve as a blueprint for designing strategies that emphasize the juxtaposition between agile supply chain practices with strong system and process coordination. This study also helps us to understand the significance of the link between supply chain agility and SCP through system integration, from just a support function to a central driver. This holistic view will help change managers have the systems and processes in place to be more efficient and sustainable over time, increasing not only organizational performance results but also leading to greater changes that are resilient over time. According to the study, foodstuffs companies also need to balance operational efficiency with innovative practices in order to ensure that their supply chain strategies are sufficiently agile but also closely related to sustainability objectives. Facilitating enterprises to use these insights helps in upgrading their market competitiveness and also serves the larger purpose of industry sustainable development.

8.3. Limitations of the Study

Although the study provided significant theoretical and empirical contributions in explaining how supply chain agility, particularly in operationalizing sustainable procurement within the foodstuffs sector of Saudi Arabia, there are some limitations that should be acknowledged. Before interpreting results, one must bear in mind that the focus of the study is on the foodstuffs sector, and its results might not be applicable to other industries, given that these sectors may vary significantly structurally and operationally. As with all such sectoral analyses, the findings here may not be generalized to industries that experience very different supply chain dynamics. Furthermore, the study focused on system and process integration as a mediator of the relationship between supply chain agility and sustainable procurement, while overlooking alternative mediators or technologies that may be equally important for understanding this linkage. The research was also time- and resource-limited, which may have impacted the sample size and data saturation. Since the sample consisted largely of middle and first-line managers, this might mask or distort the perspectives of senior executives who may hold different views about how they would like sustainability to be integrated with supply chain practices. Additionally, the research did not consider the fact that the managers had heterogeneous social and educational backgrounds, which might affect their perceptions and judgments regarding agility in supply chains and sustainability in procurement. These limitations highlight the need for future studies to expand this research and explore other factors that influence the relationship between supply chain agility and sustainable procurement.

8.4. Conclusions

This study makes a significant contribution to the literature by exploring how system and process integration mediates the impact of supply chain agility on operationalizing sustainable procurement within the foodstuffs sector in Saudi Arabia. The research investigated the effective integration of agile supply chain practices and how they synergize with system and process coordination to enhance sustainable procurement outcomes. The findings demonstrate that the positive relationship between supply chain agility and sustainable procurement is significantly strengthened by system and process integration, thereby improving operational efficiency and aligning with sustainability goals. This study highlights the importance of integrated approaches in ensuring that agile supply chain practices are effectively translated into sustainable procurement strategies, providing foodstuffs firms with a strategic framework for enhancing both environmental and operational performance. The results support the argument that system and process integration should be considered a core managerial practice for optimizing sustainable procurement and overall supply chain performance in the foodstuffs sector.

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