AgBioForum, 25(3): 30-43. ©2023 **AgBioForum**

Food Safety and Security in Eastern Province of Saudi Arabia: Role of Sustainable Supply Chain Management Practices

Abdulaziz Aljoghaiman
Assistant Professor, Department of Management, College of Business Administration, King Faisal University, Al-Ahsa 31982, Saudi Arabia.
Email: aaljughiman@kfu.edu.sa

This study investigates the correlation between sustainable supply chain management (SSCM) and food security, alongside exploring the impact of green logistics management (GLM) on food security. Additionally, it considers food safety knowledge and green logistics management as moderating variables in the relationship between sustainable supply chain management and food security. This study gathered data from 169 individuals, including farmers and employees from different departments in food supply chain industry in the Eastern Province of Saudi Arabia. To fulfil its objectives, the research utilized STATA software with a structural equation modelling (SEM) approach. The research results indicate a strong connection between sustainable supply chain management practices and individuals' food security. The study's findings show a strong connection between green logistics management and individuals' food security. Additionally, research results verified that the connection between sustainable supply chain management and individuals' food security is influenced by both food safety awareness and green logistics management. This study explores the impact of sustainability initiatives on food security in Saudi Arabia's supply chain industry. It highlights the importance of integrating sustainability into supply chain management to enhance food security, with implications for sustainable development stakeholders, professionals, and authorities.

Keywords: Sustainable Supply Chain Management, Green Logistics Management, Food Safety Knowledge, Food Security, Food Industry.

1. Introduction

As environmental, social, and economic concerns rise, Sustainable Supply Chain Management (SSCM) gains significance in modern supply chain practices (Oyedijo et al., 2024). This trend is directly linked to a growing population expressing concern about these issues (Letunovska et al., 2023). Gupta et al. (2024) defines sustainability as the integration of environmental, social, and economic factors into supply chain operations, optimizing economic benefits without adverse effects on society or the environment (Hoang et al., 2024). Over the past two decades, sustainable supply chain practices have gained increasing attention from businesses and governments due to global issues such as social injustice, resource depletion, and climate change (Kumar et al., 2024; Kumar et al., 2023b). Circular economy, green logistics, ethical purchasing, and sustainable sourcing are highlighted as key topics in current supply chain management research by Xiao et al. (2024). Food security is crucial for fostering social equity, societal welfare, and economic advancement, playing a pivotal role.

Studies have demonstrated that sustainable supply chain management solutions impact various supply chain processes, including environmental, social, and economic aspects (Das et al., 2023). Abbas et al. (2023); (Lahane et al., 2023) investigated the environmental impacts of sustainable practices like green sourcing and logistics, highlighting their potential to reduce ecological footprints. Furthermore, Kumar, Choubey, and colleagues (2023) illustrated how sustainable shopping practices can cut carbon emissions and costs. Joshi et al. (2023) emphasized the importance of green logistics, such as eco-friendly packaging and shipping, in reducing supply chain pollution and waste. Additionally, research suggests that SSCM regulations incorporating ethical labour practices and procurement methods can benefit society (Kuwornu et al., 2023). Given its role as a food distribution and trading hub, the Eastern Province of Saudi Arabia requires sustainable supply chain management solutions.

Numerous empirical studies have explored sustainable supply chain management, yet many areas remain under-researched (Mastos et al., 2022). Some studies have investigated how sustainable supply chain management affects food security, highlighting gaps in comprehensive research on the topic (Mohseni et al., 2022). Limited empirical research exists on sustainable food procurement and management in Saudi Arabia's Eastern Province (Islam et al., 2017), despite increasing interest in sustainable agriculture practices and their impact on food security (Oyedijo et al., 2024). Previous research has often overlooked consumer habits and food safety knowledge in building sustainable supply chains for food security (Alfasisi, 2022), indicating the importance of examining individual characteristics alongside agricultural supply chain management. An empirical study is needed to investigate the impact of sustainable supply chain management systems on food security across various socioeconomic and geographical contexts, considering consumer preferences, market dynamics, and regulatory frameworks (Kazancoglu et al., 2021). Understanding the impact of these strategies on food security is crucial.

Addressing these research gaps will improve our understanding of how Sustainable Supply Chain Management (SSCM) techniques affect food security (Fernandez et al., 2021; Iakovou et al., 2016), thereby contributing to the expansion of the food supply chain in Saudi Arabia's Eastern Province. Dammam, Al Khobar, and Dhahran are prominent cities in the Eastern Province, known for their commercial and industrial significance. The region's economy relies on vast oil reserves and a growing petrochemical industry (López-Gálvez et al., 2021). Its strategic location attracts investments and development projects aimed at enhancing industry resilience and sustainability, particularly in food supply chain management, given its inland desert and Arabian Gulf coastline (Mohseni et al., 2022).

Examining sustainable supply chain management and food availability involves stakeholder theory, resource-based theory, and institutional theory (Yadav et al., 2023). Stakeholder theory emphasizes considering the needs of customers, employees, and communities (Hoang, 2021), while resource-based theory sees sustainable SCM practices as critical resources for long-term competitiveness (Barbosa, 2021). Institutional theory highlights the influence of norms on sustainable organizational behaviour (Mohseni et al., 2022). This study investigates how sustainable SCM impacts food security, considering customer behaviour and food safety knowledge as moderators. Findings will inform sustainable development theory and management.

2. Literature Review

The allure of green logistics management lies in its ability to cut environmental impact and enhance operational efficiency, attracting both academics and practitioners to this expanding field of supply chain management (Letunovska et al., 2023). Extensive research has been conducted in green logistics management, focusing on sustainable storage, packaging, reverse logistics, and transportation, ultimately reducing transportation-related carbon emissions and environmental challenges (Ersoy et al., 2022). Possible solutions include utilizing biofuels and electric vehicles, rerouting freight via rail and ocean transportation, enhancing existing routes, and employing blockchain, AI, and IoT technologies to improve logistics transparency (Lahane et al., 2023). This measure can augment the monitoring of environmental performance indicators and facilitate more informed decision-making regarding eco-friendly projects (Joshi et al., 2022). Green logistics management has investigated sustainable packaging materials (Das et al., 2023). Experts recommend the elimination of packing materials, optimization of designs to reduce weight and volume, and adoption of recyclable or biodegradable materials to mitigate the environmental impact of the supply chain (Mastos et al., 2022). Reverse logistics, encompassing product returns, recycling, and remanufacturing, is a focal point of green logistics research, termed as such by Mahroof et al. (2022). Effective reverse logistics management reduces landfill waste and promotes resource recovery and the circular economy (Oyedijo et al., 2024). The study seeks to enhance reverse logistics networks, boost product recovery rates, and engage stakeholders in returned goods and supplies (Hoang et al., 2024). Green logistics management research underscores the necessity for organizations to integrate eco-friendly practices across their supply chain to remain competitive and foster a sustainable future.

Sustainable supply chain management refers to supply chain operations that encompass social, economic, and environmental considerations (Haji et al., 2024). This approach aims to mitigate environmental and social adverse effects while fostering economic growth. In the context of this discourse, "individuals' food security" pertains to ensuring that families and individuals have access to nutritious food at affordable prices (Heydari, 2024). Numerous empirical studies focus on sustainable supply chain management, covering financial viability, social responsibility, and ecological sustainability (Kuwornu et al., 2023). Scholars stress the importance of integrating sustainability across the supply chain, including waste reduction, ethical labour standards, efficient transportation, and sustainable sourcing (Kumar et al., 2023b). Research indicates that supply chain management fosters cost minimization, risk reduction, and brand reputation. Empirical investigation is crucial for understanding the relationship between food security and environmentally friendly supply chain management (Das et al., 2023). Comprehensive analysis reveals that sustainable supply chain methods enhance food security. Kumar et al. (2023a) noted that sustainable procurement enhances product quality and safety, leading to improved food security for consumers. Lahane et al. (2023) observed that organic farming and water conservation contribute to better access to food in rural areas. Abbas et al. (2023) demonstrated that eco-friendly transportation reduces food waste, ensuring more precise distribution and enhancing food security. Drawing from empirical evidence, the hypothesis suggests a robust connection between food security and environmentally friendly supply chain management (Joshi et al., 2023). Research indicates that implementing sustainable supply chain methods can enhance food security (El Ayoubi et al., 2023). Sustainability measures encompassing food sourcing, transportation, and distribution are anticipated to augment the supply, affordability, and availability of nutritious food, consequently advancing nutritional security (Xiao et al., 2024). Thus, integrating sustainability principles into supply chain management strategies becomes imperative to address global food security challenges and foster sustainable development.

H1. *Sustainable supply chain management significantly influences the individuals' food security.*

Empirical studies, like Kumar et al. (2024), have linked environmentally conscious logistics management to operational and environmental outcomes. Research delves into various green logistics aspects, including sustainable packaging, energy-efficient warehousing, and eco-friendly shipping. Barbosa (2021) discovered that green logistics strategies lower carbon emissions, transportation costs, and enhance supply chain efficiency. Similarly, Yadav et

al. (2023) explored how green transportation regulations could curtail fuel use and greenhouse gas emissions. Bor (2021) demonstrated that green warehousing reduces resource usage and waste, consequently fostering more environmentally sustainable supply networks. Research has demonstrated that implementing green logistics management can enhance operational efficiency and promote environmental conservation (Kazancoglu et al., 2021). The concept links food security with green logistics management. A previous study provided empirical evidence supporting this notion. Green logistics could enhance food security (Iakovou et al., 2016). Programmes should enhance the availability, price, and accessibility of nutritious food. Sustainable storage minimises waste and maximises resource use, enhancing food supply networks (Alfasisi, 2022). Logistics management approaches should integrate environmental sustainability to tackle food security and advance sustainable development (Mahroof et al., 2022). Sustainable logistics can aid in the equitable distribution of food and safeguard vulnerable populations. Previous research has connected green logistics management with individual food security (Mastos et al., 2022). Thorough research indicates that green logistics can enhance food security by influencing supply chain operations and environmental sustainability (Kharola et al., 2022). Additional empirical research in various geographic and socioeconomic contexts is necessary to validate and enhance these findings (Gupta et al., 2024). Green logistics companies can enhance the sustainability and fairness of the food chain.

H2. *Green logistics management implementation significantly influences the individuals' food security.*

Prior empirical investigations have explored the impact of green logistics and sustainable supply chain management on the environmental and operational performance of supply networks (Alfasisi, 2022). Numerous studies have investigated the influence of environmentally sustainable logistics on environmental performance (Mastos et al., 2022). Sustainable packaging encompasses energy-efficient practices in warehousing, transportation, and packaging. Letunovska et al. (2023) analyses include carbon emissions, resource efficiency, and operating costs. Multiple studies by Xiao et al. (2024) examine the impact of sustainable supply chain management strategies on economic performance, social responsibility, and environmental sustainability, emphasizing waste reduction, ethical practices, and sustainable resource utilization. Kuwornu et al. (2023) demonstrate that sustainable supply chain management and green logistics management enhance supply chain efficiency and sustainability, while Abbas et al. (2023) reveal that green logistics management improves food security and supply chain sustainability. Mastos et al. (2022) advocate for eco-friendly transportation, route efficiency, and sustainable packaging to promote food security. Fernandez et al. (2021) recommend environmental mitigation, resource efficiency, and supply chain enhancement to achieve this goal. Lahane et al. (2023) suggest that sustainable supply chain management and logistics could address complex social and environmental issues like food insecurity. Mohseni et al. (2022) highlight the impact of green logistics management on food security and sustainable supply chain management, warranting further investigation. Alfasisi (2022) and Kumar et al. (2023b) propose researching how green supply chains and logistics influence food security across regions and socioeconomic categories. Yadav et al. (2023) argue that studying sustainable supply chain management, stakeholder coalitions, and market dynamics can enhance food security, green logistics, and sustainability, elucidating the intricate linkages in future sustainable food supply systems. An empirical study concludes that addressing global issues like food security necessitates long-term solutions.

H3. *Green logistics management implementation significantly moderates the relationship of sustainable supply chain management and individuals' food security.*

Empirical research has investigated the intricate connections among food safety knowledge, sustainable supply chain management, and food security (Haji et al., 2024). Gupta et al. (2024) conducted a study on the impact of food safety and sustainable supply chain management on food security in different settings. These variables encompass food availability, accessibility, and cost. Haji et al. (2024) emphasise the significance of educating people about food safety to prevent foodborne illnesses and maintain food quality. El Ayoubi et al. (2023) researched food security and sustainable supply chain management. Examples include ethical production, transparent labelling, and acquisition of renewable resources. Xiao et al. (2024) state that these methods improve socially and environmentally responsible food production and distribution. The study sheds light on the management of food security and food safety supply networks. Kumar et al. (2024) discovered that sustainable supply chain management can impact nutritional security, according to food safety data. Food safety awareness has been shown to impact the effectiveness of sustainable supply chain management in enhancing food security (Hoang et al., 2024). Implementing sustainable supply chain methods like as labelling, traceability, and quality control can be advantageous for employees that prioritise food safety. Being attentive decreases the incidence of food-borne diseases and enhances dietary decisions (Joshi et al., 2023). Paying attention to information can enable humans and skills to manage sustainable supply networks and uphold food security (Abbas et al., 2023) and educating customers on healthy, eco-friendly meal choices is essential (Kharola et al., 2022). An empirical investigation into the impact of food safety knowledge on sustainable supply chain management and personal food security is recommended to address this inquiry. This research may uncover insights into food security, the influence of food safety information on sustainable supply chain practices, and the socioeconomic and cultural factors shaping consumer behaviour. Mastos et al. (2022) assert that this approach enhances comprehension of fundamental concepts and procedures, revealing strong

connections between these qualities. Food security, sustainable supply chain management, and market dynamics are influenced by laws, regulations, and consumer preferences (Mohseni et al., 2022). Understanding the complex interactions among these variables is crucial to grasp their effects on sustainable food systems (Qin et al., 2021). Empirical research highlights the importance of considering people's knowledge and behaviour in food security and sustainability policies.

H4. *Food safety knowledge significantly moderates the relationship of sustainable supply chain management and individuals' food security.*

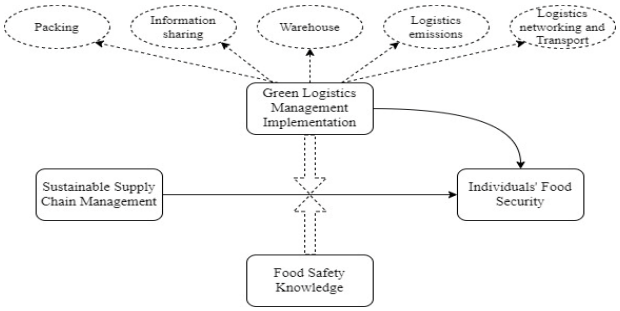

Figure 1: Proposed Model.

3. Methodology

This study was conducted within the food supply chain industry of the Eastern Province of Saudi Arabia, involving data collected from 169 farmers and employees across various departments. It employed a quantitative approach to investigate the relationships among sustainable supply chain management, green logistics management, food safety awareness, and food security. Data collection utilized a standardized questionnaire, allowing participants to express their views on the research constructs. The questionnaire scales were derived from established research studies to ensure reliability and validity of measurement equipment. Participants rated their responses on a Likert scale ranging from strongly disagree to strongly agree. Data collection methods included providing hard copies of the questionnaire or utilizing an online version based on participant convenience and preferences. This study used a ten-item scale to quantify sustainable supply chain management (Kot, 2018). Additionally, a sixteen-item scale was used to measure the application of green logistics management (Trivellas et al., 2020). The knowledge of food safety was assessed using a twelve-item scale (Aboaba et al., 2020). A scale of eight items was used to gauge each person's level of food security (Osaili et al., 2021).

Participants completed standardized questionnaires provided to them for data collection, utilizing Likert scales for responses. Their workplace perspectives and experiences determined agreement with each item. Stata SEM was employed to investigate variable correlations, estimating path coefficients, mediation and moderation effects, and assessing structural equation model fit. The study aimed to gather empirical data on proposed hypotheses in the food supply chain sector of Saudi Arabia's eastern province, advancing theoretical understanding and practical applications of project management approaches in the relevant sector through structural equation modelling.

4. Results

Table 1 demonstrates significant internal consistency for each variable. Sustainable supply chain management exhibits a Cronbach's Alpha coefficient of 0.855, indicating high reliability. Similarly, green logistics management shows a Cronbach's Alpha coefficient of 0.885, suggesting accurate assessments in supply chain management. The food safety knowledge test displays a Cronbach's Alpha coefficient of 0.817, indicating reliability. Additionally, the Cronbach's Alpha coefficient for food security among individuals is 0.846, accurately measuring the availability, accessibility, and cost of healthy food. These findings establish a robust foundation for data analysis and interpretation, showcasing the variables' internal consistency and dependability.

Table 1: Cronbach's Alpha.

Variable	Cronbach's Alpha
Sustainable supply chain management	0.855
Green logistics management implementation	0.885
Food safety knowledge	0.817
Individuals' food security	0.846

Table 2 confirms the validity of the measurement model through composite reliability and AVE scores for each variable. SSCM exhibits a composite reliability of 0.887, indicating high internal consistency. SSCM explains over 50% of observed variables' variance, with an average variance recovered of 0.510, surpassing the recommended threshold of 0.5. GLM demonstrates a composite reliability of 0.826, signifying strong internal consistency. The GLM AVE is 0.556, affirming convergent validity by attributing over 55% of observed variable variance to the GLM construct.

The food safety knowledge items demonstrate a composite reliability of 0.888, signifying high internal consistency. With an AVE of 0.538, the food safety knowledge surpasses the proposed threshold of 0.5, indicating convergence. Additionally, a composite dependability of 0.876 suggests strong internal consistency for food security items. The individual food security AVE, at 0.582, exceeds the acceptable level, affirming convergent validity. The measurement model effectively and consistently evaluates constructs, bolstering the study's findings and conclusions (Table 2).

Table 2: Validity and Reliability Confirmation.

Variable	Composite Reliability	Average Variance Extracted (AVE)
Sustainable supply chain management	0.887	0.510
Green logistics management implementation	0.826	0.556
Food safety knowledge	0.888	0.538
Individuals' food security	0.876	0.582

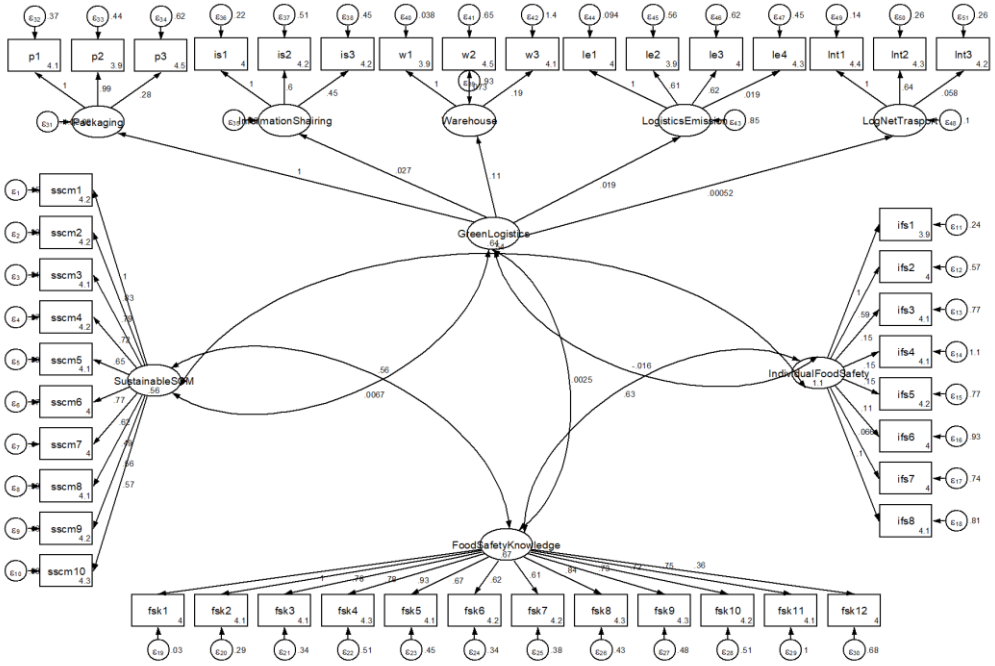

Figure 2: Estimated Model.

Table 3: Confirmatory Factor Analysis.

Measurement	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
SSCM1	1.000	(constrained)				
SSCM2	0.652	0.050	12.610	0.000	0.573	0.776
SSCM3	0.683	0.054	12.223	0.000	0.597	0.816
SSCM4	0.761	0.056	13.238	0.000	0.674	0.899
SSCM5	4.036	0.045	86.276	0.000	0.817	0.265
SSCM6	1.036	0.097	10.279	0.000	0.874	0.269
SSCM7	0.952	0.094	9.805	0.000	0.794	0.174
SSCM8	0.992	0.094	10.231	0.000	0.836	0.216
SSCM9	0.940	0.093	9.718	0.000	0.782	0.161
SSCM10	1.123	0.101	10.753	0.000	0.957	0.366
FSK1	1.000	(constrained)				
FSK2	0.820	0.085	9.283	0.000	0.675	0.021
FSK3	0.952	0.095	9.718	0.000	0.793	0.177
FSK4	0.988	0.109	8.800	0.000	0.802	0.242
FSK5	3.982	0.048	80.454	0.000	0.206	0.215
FSK6	0.728	0.082	8.539	0.000	0.586	0.920
FSK7	0.991	0.100	9.564	0.000	0.822	0.227
FSK8	1.035	0.096	10.424	0.000	0.876	0.265
FSK9	1.083	0.086	12.117	0.000	0.944	0.295
FSK10	1.073	0.088	11.749	0.000	0.930	0.288
FSK11	1.067	0.090	11.420	0.000	0.920	0.287
FSK12	0.282	0.077	3.559	0.000	0.136	0.447
P1	1.000	(constrained)				
P2	1.022	0.078	12.668	0.000	0.899	0.215
P3	1.219	0.094	12.484	0.000	0.696	0.452
IS1	1.000	(constrained)				
IS2	0.816	0.070	11.304	0.000	0.702	0.985
IS3	0.860	0.073	11.459	0.000	0.742	0.036
W1	1	(constrained)				
W2	3.889	0.047	79.632	0.000	0.093	0.117
W3	3.769	0.050	72.293	0.000	0.080	0.260
LE1	1	(constrained)				
LE2	4.096	0.045	87.968	0.000	0.144	0.327
LE3	3.991	0.044	88.568	0.000	0.039	0.215
LE4	3.970	0.043	90.124	0.000	0.019	0.192
LNT1	1	(constrained)				
LNT2	3.895	0.045	83.549	0.000	0.036	0.119
LNT3	3.892	0.042	89.834	0.000	0.040	0.110
IFS1	1	(constrained)				
IFS2	4.018	0.043	90.801	0.000	0.068	0.242
IFS3	4.179	0.050	80.890	0.000	0.221	0.423
IFS4	4.125	0.056	71.113	0.000	0.153	0.380
IFS5	4.012	0.039	99.717	0.000	0.070	0.227
IFS6	4.102	0.044	91.169	0.000	0.153	0.330
IFS7	3.844	0.052	71.239	0.000	0.087	0.081
IFS8	0.942	0.085	10.763	0.000	0.803	0.145

Table 3 presents the results of the measurement model CFA. It includes standardized factor loadings (OIM Coef.), standard errors, z-values, p-values, and 95% confidence intervals for each observable variable on its latent

construct. All items demonstrate significant construct factor loadings, affirming the convergent validity of the measurement model. Factor loadings for SSCM categories 2, 3, and 4 (0.652-0.761, z-values > 0.05, p < 0.001) are significant. Food Safety Knowledge (FSK) items (FSK2, FSK3, and FSK4) exhibit substantial factor loadings (0.820-0.988) with z-values (p < 0.001). Additionally, significant factor loadings for other latent constructs like Perceived Benefits (P), Information Sufficiency (IS), Working Conditions (W), Leadership Effectiveness (LE), Learning and Training (LNT), and Information Flow and Sharing (IFS) confirm the validity and reliability of the measurement model. CFA results indicate that the measuring model **accurately captures study constructs.**

Table 4 displays the fitness statistics of the measuring items, indicating the variance each indicator explains in its latent construct. SSCM elements SSCM1–SSCM10 show moderate to high fitness coefficients ranging from 0.526 to 0.934, with SSCM5 exhibiting the highest value of 0.934. FSK components range from 0.511 to 0.766. GLM indicators P1–P3, IS1–IS3, W1–W3, LE1–LE4, and LNT1–LNT3 have fitness values of 0.541–0.772. IFS components demonstrate moderate to high fitness coefficients, ranging from 0.512 to 0.870. These statistics illustrate the contribution of each indicator to its latent construct, enhancing the validity and reliability of the measurement model.

Table 4: Measurement Items Fitness Statistics.

Variable	Indicator	Original Sample
Sustainable supply chain management	SSCM1	0.693
	SSCM2	0.746
	SSCM3	0.769
	SSCM4	0.791
	SSCM5	0.934
	SSCM6	0.782
	SSCM7	0.526
	SSCM8	0.642
	SSCM9	0.829
	SSCM10	0.810
Food safety knowledge	FSK1	0.766
	FSK2	0.737
	FSK3	0.609
	FSK4	0.555
	FSK5	0.662
	FSK6	0.711
	FSK7	0.749
	FSK8	0.697
	FSK9	0.595
	FSK10	0.588
	FSK11	0.522
	FSK12	0.511
Green logistics management implementation	P1	0.541
	P2	0.794
	P3	0.694
	IS1	0.723
	IS2	0.739
	IS3	0.584
	W1	0.577
	W2	0.716
	W3	0.705
	LE1	0.537
	LE2	0.680
	LE3	0.772
	LE4	0.698
	LNT1	0.724
	LNT2	0.634
	LNT3	0.660
Individuals' food security	IFS1	0.674
	IFS2	0.533
	IFS3	0.577
	IFS4	0.512
	IFS5	0.845
	IFS6	0.830
	IFS7	0.870
	IFS8	0.699

Table 5 presents the Chi-square fit data for assessing the goodness of fit of the measurement model. The likelihood ratio of 1846.3329 significantly differs from that of a saturated model, with a p-value of 0.000,

indicating a substantial difference between the proposed and saturated models. Similarly, the comparison chi-square value between the baseline and saturated models was 713.81122, with a p-value of 0.000, highlighting significant differences between them. These fit statistics indicate that while the measurement model approximates the relationships between observed variables and latent constructs, it may not precisely match the data.

Table 5: Chi-square Fit statistics.

Fit statistic	Value	Description
Likelihood ratio	1846.3329	model vs. saturated
p > chi2	0.000	
chi2_bs (2728)	713.81122	baseline vs. saturated
p > chi2	0.000	

Table 6 provides goodness of fit statistics for both the saturated and estimated models. The Estimated Model's SRMR is 0.067, while the Saturated Model's SRMR is 0.057. A lower SRMR signifies a better fit between the model and the data. Although the Estimated Model's SRMR is slightly higher than that of the Saturated Model, both values fall within acceptable limits, demonstrating accurate representation of variable-latent construct relationships. In conclusion, these goodness of fit statistics affirm the structural description of the estimated model's data.

Table 6: Model Goodness of Fit Statistics.

	Saturated Model	Estimated Model
SRMR	0.057	0.067

Table 7 presents R-square statistics for each latent construct in the measurement model. R-square quantifies the proportion of endogenous latent variable variance explained by exogenous influences. SSCM has an R-square value of 0.467, indicating that its observed variables account for 46.7% of its variation. Similarly, GLM has an R-square value of 0.399, indicating that observed factors explain 39.9% of its variation. FSK demonstrates the highest R-square score of 0.523, indicating that 52.3% of its variance stems from the model's observed variables. These R-square statistics elucidate the extent to which observable factors influence latent construct variability, highlighting the indicators' efficacy in capturing the underlying concepts.

Table 7: R-square statistics.

Variable	R Square
Sustainable supply chain management	0.467
Green logistics management implementation	0.399
Food safety knowledge	0.523

Table 8 depicts path analysis results, revealing that sustainable supply chain management, green logistics management implementation, and food safety knowledge have direct and moderate effects on food security. The research demonstrates a significant positive correlation between SSCM and food security, with a path coefficient of 0.713 ($p < 0.001$). This underscores the importance of ethical sourcing, waste reduction, and transparent labelling in ensuring access to nutritious and safe food for households. GLM significantly enhances food security ($p < 0.001$), with an r square value of 0.596, indicating that environmentally friendly transportation, streamlined logistics, and sustainable packaging improve food supply chains and food security.

Path analysis reveals that GLM implementation and food safety awareness moderate the relationship between SSCM and individuals' food security. GLM implementation moderates the SSCM-food security relation ($p < 0.001$) with a path coefficient of 0.208. Together, SSCM and GLM enhance food security more effectively, underscoring the importance of integrating sustainability principles throughout the supply chain to enhance resilience and sustainability. Additionally, the path coefficient of 0.614 ($p < 0.001$) indicates that food safety knowledge moderates the relationship between SSCM and food security. This highlights the influence of food safety knowledge and food choices on SSCM techniques' ability to provide safe and nutritious food, emphasizing the significance of consumer education and awareness.

Table 8: Path Analysis.

	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Sustainable supply chain management significantly influences the individuals' food security.	0.713	0.252	4.856	0.000	0.423	0.565
Green logistics management implementation significantly influences the individuals' food security.	0.596	0.147	4.074	0.000	0.309	0.883
Green logistics management implementation significantly moderates the relationship of sustainable supply chain management and individuals' food security.	0.208	0.066	2.905	0.000	0.080	0.337
Food safety knowledge significantly moderates the relationship of sustainable supply chain management and individuals' food security.	0.614	0.151	4.196	0.000	0.318	0.910

Path analysis elucidates the intricate connection between food security and supply chain management. Exploring the direct and indirect impacts of sustainable supply chain management, green logistics management, and food safety knowledge can enhance our comprehension of food security's resilience and sustainability within food systems.

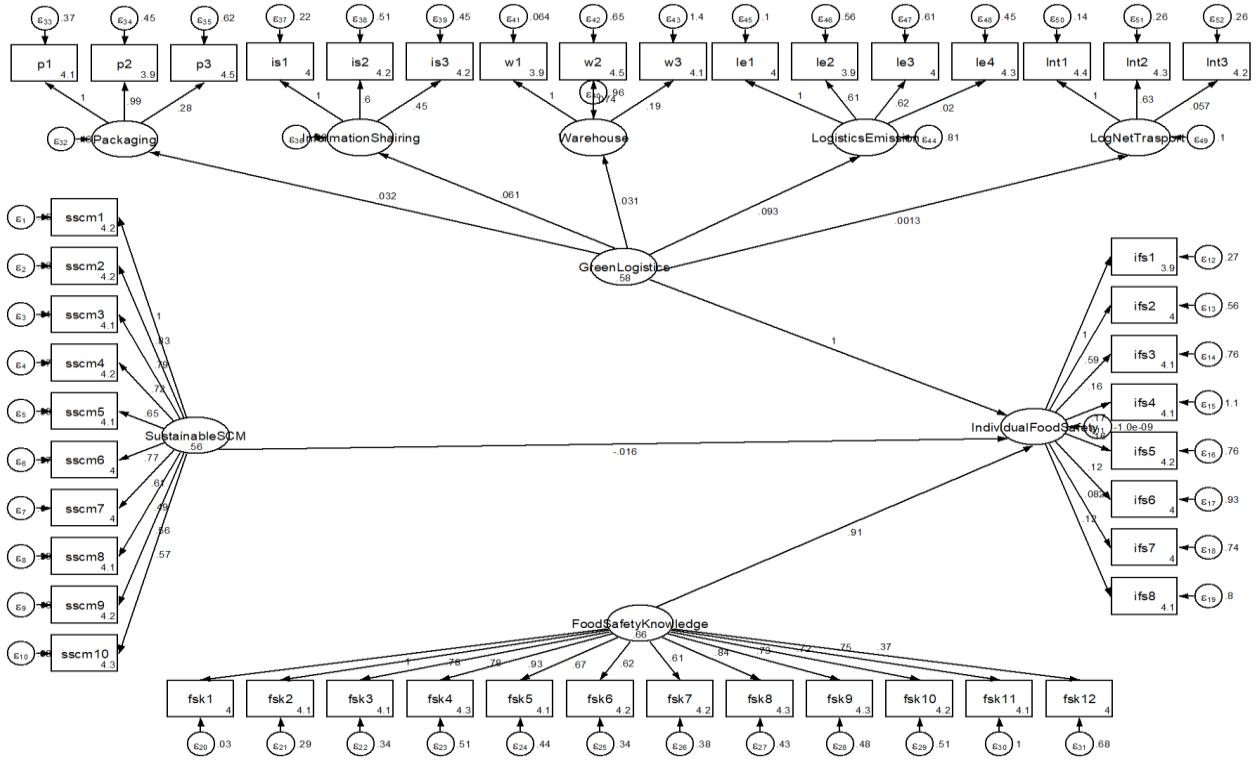

Figure 3: Structural Model for Direct Paths Analysis.

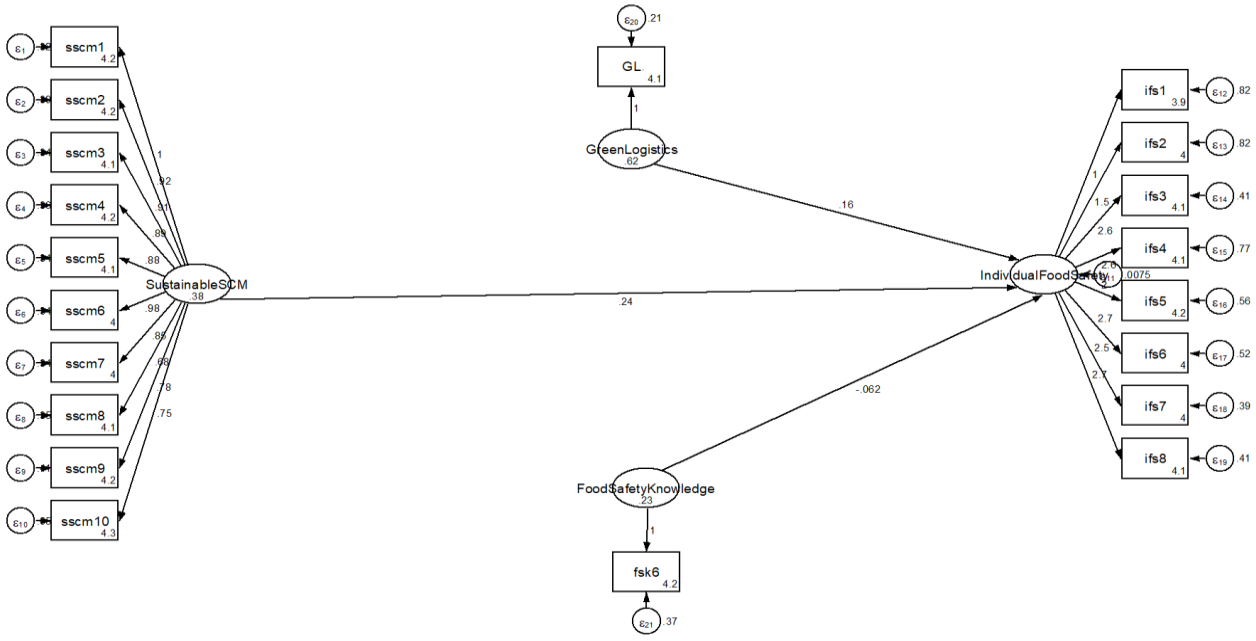

Figure 4: Structural Model for Moderating Paths Analysis.

5. Discussion

Green logistics, sustainable supply chain management, and food safety awareness are essential components for addressing the complexities of the global supply chain network. The increasing importance of sustainable supply chains arises as communities strive to provide affordable and nutritious food. This study investigates the intricate relationship among food safety knowledge, green logistics management, sustainable supply chain management, and individual food security to showcase robust food system development strategies. It analyses the impact of green logistics management and food safety knowledge on food security and Sustainable Supply Chain Management behaviours.

The study confirms that SSCM & GLM enhance food availability, supporting the first and second hypotheses. Sustainable supply chains are vital for stabilizing domestic food supplies, as ethical sourcing and waste reduction promote the availability, affordability, and accessibility of nutrient-dense food. These initiatives enhance food supply

networks, mitigating food poverty and fostering sustainable development. Additionally, GLM enhances food security judgments by prioritizing environmentally sustainable practices such as optimal routing and eco-friendly transportation. When combined, SSCM and GLM improve food security more effectively than individually, offering businesses a comprehensive approach to address sustainable development and food security challenges in their supply chains (Mahroof et al., 2022). Sustainable purchasing ensures nutrient-rich food and supports nearby farmers and communities, enhancing food security and socioeconomic conditions. Implementing eco-friendly logistical solutions like route optimization and carbon reduction enhances food supply network safety, improving efficiency and sustainability. Research findings corroborate stakeholder, resource-based, and institutional theories, highlighting supply chain management's impact on the economy, society, and environment. Environmentally friendly supply chains and logistics enhance a company's longevity, profitability, and competitiveness. Integrating sustainability into supply chain management promotes sustainable development and food security. SSCM and GLM aid firms in expanding and sustaining food supply networks, contributing to global food security. Addressing complex socio-environmental concerns like food security necessitates a holistic approach to sustainability.

This study aims to elucidate how food safety awareness and green logistics management moderate the relationship between sustainable supply chain management and food security. Confirmation of the third and fourth hypotheses provides crucial insights, indicating that sustainable supply chain food security benefits should be assessed individually and contextually. The third hypothesis demonstrates that food safety awareness influences SSCM actions and food security outcomes, emphasizing the importance of maintaining high standards for food quality and safety, preventing foodborne illnesses, and promoting healthy eating habits. Food safety specialists benefit from SSCM methods integrating quality assurance, traceability, and clear labelling, which aim to enhance food security. Conversely, the fourth hypothesis suggests that GLM adoption exacerbates SSCM behaviours and personal food security. Green logistics enhances food security by enhancing the sustainability and effectiveness of food distribution networks, with strategies including greener transportation, routing, and packing. The study concludes that both SSCM and GLM contribute positively to food security, and adherence to food supply chain sustainability criteria can enhance resilience, efficiency, and sustainability for businesses (Kazancoglu et al., 2021). Individual and community food security improves, sparking theoretical and practical discussions. Empirical support for institutional theory complements the resource-based and stakeholder approaches. Assessing theoretical frameworks involves contextual factors, human behaviour, and supply chain sustainability activities. Lu et al. (2021) emphasize the need for a coordinated sustainable approach to address food security challenges. Integrating food safety and environmental consciousness into supply chain management can enhance food security and sustainable development. Contextual and human elements are crucial for improving food security and food supply network sustainability.

Sustainable supply chain management, eco-friendly logistics, and food safety are crucial for human food security, as confirmed by all four hypotheses. Supply chain activities should prioritize sustainability and be assessed contextually. Comprehensive efforts to address food supply chain sustainability can enhance system resilience, efficiency, and continuity, benefiting global food security. Academics, professionals, and policymakers must devise innovative sustainable development and food security strategies to tackle the world's increasing interconnectedness and unpredictability. The study reveals the intricate relationship among sustainable supply chain management, green logistics management, food safety awareness, and individual food security. It underscores the significant advantages of sustainable methods for food security programs. Integrating environmental, social, and economic sustainability into supply chain decision-making is crucial. The moderating effects highlight the need for targeted interventions considering individual and contextual aspects. However, acknowledging study limitations and exploring future research directions are essential. The analysis sheds light on fundamental interconnections and mechanisms vital for sustaining food systems. Collaboration among stakeholders is crucial in addressing food security challenges within sustainable development frameworks.

Implications of the Study

This research enhances understanding and has significant theoretical implications, particularly in linking sustainable supply chain management, green logistics management, food safety knowledge, and individual food security. It strengthens stakeholder, resource-based, and institutional theories, shedding light on supply chain dynamics and food security. The identification of moderating variables emphasizes contextual and human factors in sustainability project evaluation, expanding theoretical understanding of food security factors. The research underscores sustainability's environmental, social, and economic interdependence, offering theoretical insights into sustainable development's breadth and food security effects. Overall, it improves comprehension of sustainable food system mechanisms, providing a theoretical foundation for future research and comprehensive frameworks to address food security within sustainable development agendas.

This research is crucial for stakeholders in the food supply chain, policy-making, and sustainable development sectors. It highlights the importance of integrating sustainability into supply chain management strategies to enhance food security. Ethical sourcing, waste reduction, and green transportation can be prioritized by food companies based on the study's findings, improving both food security and environmental sustainability. Policymakers can use empirical data from this research to formulate and enforce supply chain sustainability policies to tackle systemic food security issues. The study, conducted by the EPA, emphasizes the need for tailored approaches considering factors like food safety awareness

and consumer behaviour in sustainability evaluations. Targeted education and awareness initiatives are essential for empowering consumers to make informed and environmentally sustainable food choices. The research underscores the necessity of collaborative efforts to build sustainable and resilient food systems, aligning with goals of food security, environmental conservation, and economic growth.

Limitations and Future Research Directions

This study highlights the connections between food security, GLM, SSCM, and understanding of food safety; yet, it has several shortcomings that should be investigated in further studies. The cross-sectional nature of the study's data makes determining causality difficult. The causal and chronological relationships between food security and sustainability may be demonstrated through experimental or longitudinal research. The study places a high priority on quantitative analysis, which could ignore contextual and qualitative sustainability intervention efficacy factors. A mixed-method study could clarify the sustainability of the food supply chain.

The study overlooks societal-level institutional frameworks, market dynamics, and policy contexts, concentrating solely on individual outcomes. Future research should explore how macro-level factors influence the relationship between sustainability programs and food security. It neglects intermediary mechanisms and contextual factors, focusing solely on the direct and moderating effects of SSCM, GLM, and food safety knowledge on food security outcomes. Analysing supply chain resilience, community empowerment, and governance systems could shed light on how sustainability measures impact food security. While the research clarifies the sustainability-food security relationship, addressing these limitations and exploring future avenues could enhance food system sustainability initiatives.

Acknowledgment

This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Grant 6114]'.

References

Abbas, H., Zhao, L., Gong, X., & Faiz, N. (2023). The perishable products case to achieve sustainable food quality and safety goals implementing on-field sustainable supply chain model. *Socio-Economic Planning Sciences*, *87*, 101562. doi: https://doi.org/10.1016/j.seps.2023.101562

Aboaba, K. O., Fadiji, D. M., & Hussayn, J. A. (2020). Determinants of food security among rural households in Southwestern Nigeria: USDA food security questionnaire core module approach. *Journal of Agribusiness and Rural Development*, *2*(56), 113–124. doi: http://dx.doi.org/10.17306/J.JARD.2020.01295

Alfasisi, M. R. (2022). *Exploring the roles and practices of international retailers in implementing sustainable supply chains to attain food security in Jordan* (Doctoral dissertation, University of Petra (Jordan)). Retrieved from https://www.proquest.com/openview/d11e08546392b7419900ec1c052acb15

Barbosa, M. W. (2021). Uncovering research streams on agri-food supply chain management: A bibliometric study. *Global Food Security*, *28*, 100517. doi: https://doi.org/10.1016/j.gfs.2021.100517

Bor, J. K. M. (2021). *Green supply chain management practices and performance of food and beverage processing sector in Kenya* (Doctoral dissertation, JKUAT-COHRED). Retrieved from http://localhost/xmlui/handle/123456789/5498

Das, S., Barve, A., Sahu, N. C., Muduli, K., Kumar, A., & Luthra, S. (2023). Analysing the challenges to sustainable food grain storage management: a path to food security in emerging nations. *International Journal of Food Science & Technology*, *58*(10), 5501-5509. doi: https://doi.org/10.1111/ijfs.16437

El Ayoubi, M. S., & Radmehr, M. (2023). Green food supply chain management as a solution for the mitigation of food supply chain management risk for improving the environmental health level. *Heliyon*, *9*(2), e13264. doi: https://doi.org/10.1016/j.heliyon.2023.e13264

Ersoy, P., Börühan, G., Kumar Mangla, S., Hormazabal, J. H., Kazancoglu, Y., & Lafcı, Ç. (2022). Impact of information technology and knowledge sharing on circular food supply chains for green business growth. *Business Strategy and the Environment*, *31*(5), 1875-1904. doi: https://doi.org/10.1002/bse.2988

Fernandez, C. M., Alves, J., Gaspar, P. D., & Lima, T. M. (2021). Fostering awareness on environmentally sustainable technological solutions for the post-harvest food supply chain. *Processes*, *9*(9), 1611. doi: https://doi.org/10.3390/pr9091611

Gupta, R., & Shankar, R. (2024). Managing food security using blockchain-enabled traceability system. *Benchmarking: An International Journal*, *31*(1), 53-74. doi: https://doi.org/10.1108/BIJ-01-2022-0029

Haji, M., & Himpel, F. (2024). Building Resilience in Food Security: Sustainable Strategies Post-COVID-19. *Sustainability*, *16*(3), 995. doi: https://doi.org/10.3390/su16030995

Heydari, M. (2024). Cultivating sustainable global food supply chains: A multifaceted approach to mitigating food loss and waste for climate resilience. *Journal of Cleaner Production*, *442*, 141037. doi: https://doi.org/10.1016/j.jclepro.2024.141037

Hoang, T., Bell, J., Hiep, P. H., & Autry, C. W. (2024). The sustainable development of rural-to-urban food supply chains in developing nations. *The International Journal of Logistics Management*, *35*(1), 158-186. doi: https://doi.org/10.1108/IJLM-02-2022-0072

Hoang, V. (2021). Modern short food supply chain, good agricultural practices, and sustainability: A conceptual framework and case study in Vietnam. *Agronomy*, *11*(12), 2408. doi: https://doi.org/10.3390/agronomy11122408

Iakovou, E., Bochtis, D., Vlachos, D., & Aidonis, D. (2016). *Supply chain management for sustainable food networks*. John Wiley & Sons. doi: https://doi.org/10.1002/9781118937495

Islam, M. M., Murad, M. W., McMurray, A. J., & Abalala, T. S. (2017). Aspects of sustainable procurement practices by public and private organisations in Saudi Arabia: an empirical study. *International Journal of Sustainable Development & World Ecology*, *24*(4), 289-303. doi: https://doi.org/10.1080/13504509.2016.1209794

Joshi, S., & Sharma, M. (2022). Digital technologies (DT) adoption in agri-food supply chains amidst COVID-19: an approach towards food security concerns in developing countries. *Journal of Global Operations and Strategic Sourcing*, *15*(2), 262-282. doi: https://doi.org/10.1108/JGOSS-02-2021-0014

Joshi, S., Singh, R. K., & Sharma, M. (2023). Sustainable agri-food supply chain practices: Few empirical evidences from a developing economy. *Global Business Review*, *24*(3), 451-474. doi: https://doi.org/10.1177/0972150920907014

Kazancoglu, Y., Ozbiltekin-Pala, M., Sezer, M. D., Ekren, B. Y., & Kumar, V. (2021). Assessing the impact of COVID-19 on sustainable food supply chains. *Sustainability*, *14*(1), 143. doi: https://doi.org/10.3390/su14010143

Kharola, S., Ram, M., Mangla, S. K., Goyal, N., Nautiyal, O., Pant, D., et al. (2022). Exploring the green waste management problem in food supply chains: A circular economy context. *Journal of Cleaner Production*, *351*, 131355. doi: https://doi.org/10.1016/j.jclepro.2022.131355

Kot, S. (2018). Sustainable supply chain management in small and medium enterprises. *Sustainability*, *10*(4), 1143. doi: https://doi.org/10.3390/su10041143

Kumar, A., Mangla, S. K., & Kumar, P. (2024). Barriers for adoption of Industry 4.0 in sustainable food supply chain: a circular economy perspective. *International Journal of Productivity and Performance Management*, *73*(2), 385-411. doi: https://doi.org/10.1108/IJPPM-12-2020-0695

Kumar, M., Choubey, V. K., Raut, R. D., & Jagtap, S. (2023a). Enablers to achieve zero hunger through IoT and blockchain technology and transform the green food supply chain systems. *Journal of Cleaner Production*, *405*, 136894. doi: https://doi.org/10.1016/j.jclepro.2023.136894

Kumar, M., Raut, R. D., Jagtap, S., & Choubey, V. K. (2023b). Circular economy adoption challenges in the food supply chain for sustainable development. *Business Strategy and the Environment*, *32*(4), 1334-1356. doi: https://doi.org/10.1002/bse.3191

Kuwornu, J. K., Khaipetch, J., Gunawan, E., Bannor, R. K., & Ho, T. D. (2023). The adoption of sustainable supply chain management practices on performance and quality assurance of food companies. *Sustainable Futures*, *5*, 100103. doi: https://doi.org/10.1016/j.sftr.2022.100103

Lahane, S., Paliwal, V., & Kant, R. (2023). Evaluation and ranking of solutions to overcome the barriers of Industry 4.0 enabled sustainable food supply chain adoption. *Cleaner Logistics and Supply Chain*, *8*, 100116. doi: https://doi.org/10.1016/j.clscn.2023.100116

Letunovska, N., Offei, F. A., Junior, P. A., Lyulyov, O., Pimonenko, T., & Kwilinski, A. (2023). Green Supply Chain Management: The Effect of Procurement Sustainability on Reverse Logistics. *Logistics*, *7*(3), 47. doi: https://doi.org/10.3390/logistics7030047

López-Gálvez, F., Gómez, P. A., Artés, F., Artés-Hernández, F., & Aguayo, E. (2021). Interactions between microbial food safety and environmental sustainability in the fresh produce supply chain. *Foods*, *10*(7), 1655. doi: https://doi.org/10.3390/foods10071655

Lu, H., Mangla, S. K., Hernandez, J. E., Elgueta, S., Zhao, G., Liu, S., et al. (2021). Key operational and institutional factors for improving food safety: a case study from Chile. *Production Planning & Control*, *32*(14), 1248-1264. doi: https://doi.org/10.1080/09537287.2020.1796137

Mahroof, K., Omar, A., & Kucukaltan, B. (2022). Sustainable food supply chains: overcoming key challenges through digital technologies. *International Journal of Productivity and Performance Management*, *71*(3), 981-1003. doi: https://doi.org/10.1108/IJPPM-12-2020-0687

Mastos, T., & Gotzamani, K. (2022). Sustainable supply chain management in the food industry: A conceptual model from a literature review and a case study. *Foods*, *11*(15), 2295. doi: https://doi.org/10.3390/foods11152295

Mohseni, S., Baghizadeh, K., & Pahl, J. (2022). Evaluating barriers and drivers to sustainable food supply chains. *Mathematical problems in engineering*, *2022*, 4486132. doi: https://doi.org/10.1155/2022/4486132

Osaili, T. M., Al-Nabulsi, A. A., & Taybeh, A. O. (2021). Food safety knowledge, attitudes, and practices among Jordan universities students during the COVID-19 pandemic. *Frontiers in public health*, *9*, 729816. doi: https://doi.org/10.3389/fpubh.2021.729816

Oyedijo, A., Kusi-Sarpong, S., Mubarik, M. S., Khan, S. A., & Utulu, K. (2024). Multi-tier sustainable supply chain management: a case study of a global food retailer. *Supply Chain Management: An International Journal*, *29*(1), 68-97. doi: https://doi.org/10.1108/SCM-05-2022-0205

Qin, X., Godil, D. I., Sarwat, S., Yu, Z., Khan, S. A. R., & Shujaat, S. (2021). Green practices in food supply chains: evidence from emerging economies. *Operations Management Research*, 1-14. doi: https://doi.org/10.1007/s12063-021-00187-y

Trivellas, P., Malindretos, G., & Reklitis, P. (2020). Implications of green logistics management on sustainable business and supply chain performance: evidence from a survey in the greek agri-food sector. *Sustainability*, *12*(24), 10515. doi: https://doi.org/10.3390/su122410515

Xiao, G., Samian, N., Faizal, M. F. M., As'ad, M. A. Z. M., Fadzil, M. F. M., Abdullah, A., et al. (2024). A Framework for Blockchain and Internet of Things Integration in Improving Food Security in the Food Supply Chain. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *34*(1), 24-37. doi: https://doi.org/10.37934/araset.34.1.2437

Yadav, V. S., Singh, A. R., Raut, R. D., & Cheikhrouhou, N. (2023). Blockchain drivers to achieve sustainable food security in the Indian context. *Annals of Operations Research*, *327*(1), 211-249. doi: https://doi.org/10.1007/s10479-021-04308-5

Appendix 1

Sustainable Supply Chain Management Scale

1. To what extent does your organization prioritize the reduction of environmental impact in its supply chain activities?
2. How effectively does your organization manage waste and minimize resource consumption throughout the supply chain?
3. To what degree does your organization collaborate with suppliers to ensure ethical and sustainable sourcing practices?
4. How well does your organization integrate social responsibility initiatives into its supply chain operations?
5. To what extent does your organization consider long-term sustainability goals in decision-making processes within the supply chain?
6. How effectively does your organization communicate sustainability policies and practices to stakeholders involved in the supply chain?
7. How well does your organization assess and manage risks related to sustainability issues in the supply chain?
8. To what extent does your organization invest in innovation and technology to enhance sustainability within the supply chain?
9. How well does your organization measure and track key performance indicators related to sustainability in the supply chain?
10. How effectively does your organization collaborate with regulatory bodies and industry associations to ensure compliance with sustainability standards?

Green Logistics Management Implementation Scale:

1. To what extent does your organization utilize eco-friendly transportation modes (e.g., electric vehicles, hybrid trucks) in its logistics operations?
2. How effectively does your organization optimize transportation routes to minimize fuel consumption and reduce carbon emissions?
3. To what degree does your organization implement sustainable packaging practices (e.g., reusable packaging, biodegradable materials) in its logistics operations?
4. How well does your organization utilize technology (e.g., GPS tracking, RFID) to improve efficiency and reduce environmental impact in logistics operations?
5. To what extent does your organization collaborate with logistics partners to implement green initiatives throughout the supply chain?
6. How effectively does your organization manage inventory to reduce overstocking and minimize waste in logistics operations?
7. How well does your organization implement reverse logistics practices to reduce waste and maximize resource recovery?
8. To what degree does your organization invest in employee training and awareness programs to promote green practices in logistics operations?
9. How effectively does your organization monitor and evaluate the environmental performance of logistics operations?
10. To what extent does your organization collaborate with governmental agencies and environmental organizations to promote sustainable logistics practices?
11. How well does your organization integrate sustainability criteria into the selection and evaluation of logistics service providers?
12. How effectively does your organization implement green warehousing practices to minimize energy consumption and reduce environmental impact?
13. To what degree does your organization utilize data analytics and optimization techniques to improve efficiency and sustainability in logistics operations?
14. How well does your organization engage with customers and suppliers to promote sustainability initiatives in logistics operations?
15. To what extent does your organization invest in renewable energy sources (e.g., solar panels, wind turbines) to power logistics facilities?
16. How effectively does your organization communicate its commitment to sustainability to stakeholders involved in logistics operations?

Food Safety Knowledge Scale:

1. How confident are you in your understanding of safe food handling practices?
2. To what extent are you familiar with the potential health risks associated with consuming contaminated food?
3. How well do you understand the principles of proper food storage to prevent spoilage and contamination?
4. How knowledgeable are you about the proper cooking temperatures for different types of food to ensure food safety?
5. To what extent are you aware of the importance of washing hands and surfaces to prevent cross-contamination during food preparation?
6. How well do you understand food labeling and expiration dates to identify safe and fresh food products?
7. How familiar are you with common foodborne pathogens and their symptoms?
8. To what extent do you understand the importance of separating raw and cooked foods to prevent foodborne illnesses?
9. How knowledgeable are you about potential allergens and how to avoid cross-contact during food preparation?
10. How confident are you in your ability to recognize signs of food spoilage or contamination?
11. To what extent are you familiar with food safety

regulations and guidelines set forth by regulatory authorities?
12. How well do you understand the risks associated with consuming raw or undercooked foods?

Individuals' Food Security Scale:

1. How often do you worry about having enough food to meet your household's needs?
2. To what extent do you feel confident in your ability to afford a balanced and nutritious diet for yourself and your family?
3. How often do you experience uncertainty about where your next meal will come from?
4. How well do you feel your household's food supply meets your dietary preferences and nutritional needs?
5. To what extent do you feel your household has reliable access to a variety of foods to maintain a healthy diet?
6. How often do you have to make difficult choices between buying food and paying for other essential expenses (e.g., rent, utilities)?
7. How well do you feel your household is prepared to cope with unexpected financial setbacks that could affect access to food?
8. To what extent do you feel your household has access to community resources (e.g., food banks, soup kitchens) in times of need?