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Driving Hotel Supply Chain Agility and Sustainability Through Intelligent Demand Forecasting and Waste Reduction

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Abstract

The fast development of the hospitality sector requires the innovative solution to the agile and sustainable hotel supply chains (SC). This paper will discuss how intelligent demand forecasting (IDF) and waste minimization practices can be used to improve agility of the supply chain, reduce operational waste and foster sustainability in the hotel industry. Based on the data gathered on 439 respondents and performed with the help of PLS-SEM, the results show that IDF has a strong positive impact on the accuracy of demand, overstocking, and shortage of services, as well as on the responsiveness of operations. Simultaneously, waste minimization measures are helping to reduce resource use and reduce environmental effects. Moreover, there is the mediating role of the reduction of operational waste, which enhances the association between the intelligent demand forecasting and the supply chain agility and sustainability. These findings can be of great use to hotel managers who want to use the benefits of high-level forecasting and waste management techniques and attain agile, efficient, and eco-friendly operations. The paper emphasizes the importance of smart technologies in enhancing the performance of operations and sustainability within the hospitality sector.

1. Introduction

The rate of technological change and uncertainty in the globe has only increased at a rapid pace, prompting supply chains to be digitalized especially in the hospitality sector [1]. This change is marked by the adoption of new sophisticated digital technologies and strategies that help to improve supply chain agility, operational efficiency, and sustainability. Since hotels exist in very dynamic markets characterized by changes in demand, seasonality, and unpredictable disturbances, the implementation of digital supply chain management practices has been mandatory [2]. These shocks, both on a global scale like pandemics, and more agile changes in the demand of tourism, highlight the necessity of a flexible supply chain that can adapt fast to new circumstances [3]. In this respect, supply chain agility has become an important capability, which is the capacity of the firms to react quickly and efficiently to the market changes, customer needs, and disruption of operations [4]. In this case agility is specifically relevant since the services provided by hotels are perishable, the occupancy rates vary and there is a necessity to balance the quality of the provided services with the efficiency of the resources. The fast-growing information technology (IT) has fundamentally altered the practices of supply chain management, with digital integration being a requirement of the contemporary hospitality operations [5]. This is often referred to as supply chain digitalization, which enhances the coordination, boosts the response and streamlines the functioning in the hotel areas. The current needs of the modern supply chain management include using data to make decisions that will enable the organization to perform well and be more efficient in the way they work [6]. All of these are extremely helpful in the hospitality industry where there is uncertainty about demand and thus the use of quality data is crucial for predictive analytics, real-time monitoring, and making informed decisions [7]. The key element of the hotel business in making a suitable capacity, staffing and inventory against the demand is the proper demand forecast so that the inefficiencies in the hotel business can be minimized and its responsiveness in service delivery can be maximized [8]. The introduction of smart technologies in the

supply chain not only increases the efficiency of the supply chain, but also brings a lot of organisational agility [9]. Agility enables the hotels to be responsive to the different tastes of the customers, market dynamics and external disruptions [10]. Advanced analytics and machine learning tools help the intelligent demand forecasting systems to forecast demand trends and optimize resource allocation to be able to respond better to these demands [11]. They are the ones that play an essential role in their competitiveness in an industry with high uncertainty and high level of competition [12].

Beyond the benefits of the operational aspects, Hotel Supply Chain Digitalization has potential environmental impacts that extend beyond the boundaries of the specific hotel. With the growing focus on sustainability in the world, the hospitality organizations are increasingly orienting their activities on environmental and social responsibility objectives [13]. The application of technology, such as artificial intelligence, Internet of Things (IoT), advance analytics etc., is transforming the hotel industry with respect to sustainability measures [14]. An example would be having real time monitoring systems keep track of energy and resource usage and intelligent analytics to find areas of inefficiencies and cut down on operation waste. With these technologies, the hotel can reduce their environmental footprint, and enhance operational performance [6]. Sustainable hotel supply chains do not only entail enhancing efficiency, but also consumption of resources and minimization of environmental effects [15]. Minimization of waste has now been a major focus in the operations of the hospitality industry and especially in food waste, energy consumption and inventory control. Through the power of smart demand forecasting and decision-making, hotels will be able to drastically decrease the amount of overstocking, resource underutilization, and waste generation that do not contribute to the company's revenue [16]. Furthermore, digital technologies allow increasing transparency and traceability and result in more responsible and sustainable supply chain practices [1, 7]. Regardless of the tremendous advantages linked to digital transformation, there are a number of challenges that impede the successful adoption of agile and sustainable supply chains in the hospitality industry [17]. These factors are complex technology, expensive implementation, resistance to change by the organization and the fact that the technology requires skilled staff [18]. Moreover, the high rate of technological innovations has rendered the continuous adaptation of organizations that involve incorporating emerging solutions in operations to be challenging [19]. The present research contributes to the body of knowledge by suggesting a comprehensive model that connects the intelligent demand forecasting to the sustainability consequences via the mediating effect of the operational waste reduction in the hotel environment. In contrast to previous literature, which considers digitalization, agility, and sustainability as independent variables, this study conceptualizes waste reduction as the main process by which intelligent forecasting practices can be converted into the outcomes of agility and sustainability. In particular, the paper operationalizes the concept of intelligent demand forecasting based on the practices, including demand sensing and predictive analytics, and data-driven resource planning, and analyses the ways in which the practices eliminate operational inefficiencies and improve environmental performance.

In addition, this paper presents a mechanism-based approach by differentiating direct and indirect impacts of intelligent demand forecasting to supply chain agility and sustainability. It also determines

the boundary conditions including data quality, demand variability, and technological preparedness that determine the success of these relationships. This study puts the analysis in the context of the hotel industry and is able to generalize the existing theories to a scenario with high demand uncertainty and resource sensitivity. How is agility of Hotel Supply Chains advanced by intelligent demand forecasting? How much the contribution of improved operational performance is to the reduction of the waste? How does waste reduction positively contribute to the sustainability of hotel supply chains? How does the operational waste reduction act as a mediator between intelligent demand forecasting and agility, and sustainability? By answering these questions, the study will fulfill a number of purposes such as exploring how intelligent demand forecasting affects agility, exploring the connection between operational efficiency and waste reduction, determining the contribution of waste reduction to sustainability and exploring the mediating effect of waste reduction. This work will expand the current knowledge about the hotel industry and the supply chain by providing a comprehensive framework that incorporates smart demand prediction, waste minimisation, responsiveness of the chain and sustainability. This study takes a holistic approach to these elements, as opposed to previous studies which individually studied these elements without their relation to the operational performance and environmental outcomes. The results make theoretical and practical contributions. The paper also puts forward the highest priority of waste minimization as a mediator that can link intelligent technologies and sustainability and agility results, hypothetically. In applications, it can be helpful information for hotel managers wishing to raise the performance of their hotel operations and achieve sustainability goals. The paper underlines that smart demand forecasting and waste management are not only tools of enhancing efficiency, but also strategic facilitators of responsive and sustainable hotel supply chains.

2. Theoretical Background and Literature Review

2.1. Theoretical Background

The disruptions brought about by globalization and their effects on supply chains (SC) have increased interest in research pertaining to supply chain agility (SCAG) in recent years [20]. It has been acknowledged by companies and researchers that the global supply chains have become more complicated than before due to unexpected disruptions, and novel ways of dealing with them are needed [21, 22]. To deal with these disruptions and improve supply chain agility, new insights and approaches are required, especially in the context of new challenges including the COVID-19 pandemic [23]. Since supply chains have always been vulnerable to disruption due to natural calamities, health crises, economic slowdowns, and other unpredictable situations, the literature has changed to highlight the significance of agility as a vital capability to respond to such disruptions [24]. The idea of agility traces back to the literature on organizational and operations management, specifically, to the capability of the system to react effectively and swiftly to change [25]. In the initial research, responsiveness and flexibility were highlighted as the critical attributes to environmental uncertainty coping. The notion over time became the capacity of organizations to detect changes, to respond fast and redesign operations in fluid environments [26]. In the context of the supply chain, agility means the ability of a supply chain to

adapt its operations effectively to changes in demand and external disturbances [27, 28]. This is not only in the capability of responding to disturbances but also in the capability of anticipating and adapting to the changing market environment in advance. Later studies broadened the understanding of supply chain agility to incorporate the capacity to record better performance results in the face of uncertainty, as opposed to being merely status quo [29]. This school of thought presents agility as a dynamic capability that facilitates organization reconfiguration of resources, enhancing responsiveness, and maintaining a competitive edge [30]. Based on the interdisciplinary approaches, supply chain agility is currently understood as a complex phenomenon that incorporates the technological, organizational, and operational levels [31]. It is very important in facilitating organizations especially those that deal with services, to effectively react to fluctuation in demand and operation environments.

2.2. Literature Review and Hypothesis Development

2.2.1. Intelligent Demand Forecasting

Smart demand forecasting is a significant factor in improving the agility and sustainability of supply chains especially in the hospitality industry. Intelligent forecasting is a method that helps hotels predict demand trends of guests by using advanced analytics, machine learning methods, and predictive models and decreases chances of overstocking or service shortages [33]. This will have a direct impact in reducing operational waste since overstocking, wasted resources and service misfits can be reduced. Moreover, smart forecasting machines are self-learning systems that become increasingly accurate in the prediction as the real-time data is being processed and more responsive and adaptable supply chain processes are possible [17]. This ongoing enhancement enables organizations to be in a better position to match their operations with the dynamic market environment hence minimizing inefficiencies and waste production. The perishability of the service in the hospitality industry and its demand fluctuation are particularly related to demand forecasting and waste reduction, as very accurate forecasting and resource usage is needed in this sector [6]. Good forecasting helps manage inventory, staffing and resources – all which contribute to the outcomes of operational performance and sustainability..

H1a. Intelligent demand forecasting has a significant effect on operational waste reduction.

Many operations management (OM) researchers have studied the operational implications of demand forecasting practices and waste management. Other researchers have examined the role of forecasting systems in resource planning, operational efficiency, and minimization of waste in various industries [34]. These researches indicate that enhancing the quality of forecasting is not merely a matter of technological issue but a matter of managerial choice, organizational orientation, and coordination among the stakeholders [35]. In the same regard, scholars have also stressed that the efficiency of forecasting systems depends on the efficiency of organizations in incorporating these tools in their organizational processes and decision-making systems [36]. Besides that, the literature has also dealt with the operational issues that are involved in transforming the forecasting insights into efficient, sustainable practices [37–39]. In contrast to the previous analytical works, the study uses an empirical method in analyzing the effects of intelligent demand forecasting on the operational performance in the

hotel environment. In addition, it builds on the available literature by examining the role of forecasting-related gains to waste reduction and sustainability in service-based supply chains, which is a comparatively under-researched topic.

H1b. Intelligent demand forecasting has a significant effect on hotel supply chain sustainability.

2.2.2. Hotel Supply Chain Efficiency

The digital era of operations management (OM) has made supply chain efficiency more significant and especially in the hospitality industry. Hotel operations increasingly become more complex, which has led to a large number of studies aiming at optimizing efficiency and sustainability in service based supply chains [40–45]. Effective management of the hotel supply chain is very important in minimizing unnecessary inventory, energy, and wastage of materials. Earlier studies by Carrillo et al. [46] investigated the impact of customer behavior on the operations of a business to measure the level of waste produced and its management in service settings. More recently, research has also examined digital platforms and systems that can be used to facilitate the workings of a hospitality industry [38, 47–49], some of them modeling the idea of competitive dynamics and collaboration among service providers, providing information on how these services can be optimized to minimize operational wastes. These researches also look into the patterns of behavior and demand forces that have a direct effect on resource consumption and waste associated with inventory. They empirically test the effects of the variability in the demand and intensity of the services on customer purchasing and booking decisions that further impact inventory utilization and waste production. The same dynamics are studied by Zhang et al. [50], and Shen et al. [51] analyses the impact of operational channel decisions, including direct bookings and intermediary platforms, on the efficiency and waste reduction results.

H2a. Hotel supply chain efficiency has a significant effect on operational waste reduction.

On the same note, Yan et al. [52] discuss the impact of platform integration strategies on the operational efficiency and also connect models of service delivery in addition to waste management practices. The use of digital platforms in the larger supply chains strategies has been the subject of other studies [54, 55, 56, 57, 92], because of the advantages of their integration in facilitation of the supply chain operations and reduction of inefficiencies. Tian et al. [58] in their study of operational dynamics determine the impact of competition intensity and cost of service fulfillment on operational strategies. These are directly related to the waste management process since effective fulfillment will decrease unnecessary inventory and enhance the use of resources. As a result, the efficiency of supply chains is identified as a major contributor to sustainability in hotel management, which connects the achievement of the operational performance with the environment-friendliness.

H2b. Hotel supply chain efficiency has a significant effect on hotel supply chain sustainability.

2.2.3. Intelligent Waste Reduction

Smart waste management has become one of the revolutionary methods of making hotel supply chain sustainable through the use of modern technologies to overcome the lack of efficiency and reduce environmental devastation. With the help of predictive analytics, machine learning, and data-driven insights, intelligent systems can help to better predict demand and, in turn, minimize overstocking, underutilization of resources, and mismatched services [59, 60]. To illustrate, sophisticated analysis tools can be used to evaluate the demand trends of the guests so that procurement, inventory and service operations can be adjusted in accordance with the real demand. This feature will guarantee maximum use of resources, minimization of operational expenses, and improved efficiency [41, 61].

H3a. Intelligent waste reduction has a significant effect on operational waste reduction.

Also, smart technologies enhance the effectiveness of logistics and internal processes in hotels. Optimized resource distribution and planning of services minimizes energy usage and material wastage and maintains high quality of services [49, 56]. Moreover, intelligent inventory and resource management solutions contribute to a more efficient coordination of the activities of different departments, eliminating unnecessary consumption and the formation of waste. These systems are also known to help in sustainability through reuse, recycling and efficient use of resources. Intelligent analytics also help to improve strategic decision-making by showing areas to improve and inefficiencies. Hotels can raise their environmental and operational performance by a large degree by focusing on operational hotspots of waste [60, 61]. On the whole, smart waste minimization fills the gap between the sustainability goals and efficiency of operations in the hospitality sector.

H3b. Intelligent waste reduction has a significant effect on hotel supply chain sustainability.

2.2.4. Operational Waste Reduction

One of the fundamental steps in reducing waste in the operation processes is to identify the sources of waste. As such, it is important to determine the prevailing situation of operation in order to identify various forms of waste in the hotel supply chains [62]. The data analysis, observations, interviews, questionnaires, process mapping, and waste categorization are common practices of assessing operational waste. These strategies are typically undertaken with the employees in close cooperation to determine the inefficiencies accurately [62–64]. Awareness creation among employees regarding the waste in the operations, and educating them on how to identify inefficiencies is also an important measure towards enhancing the performance [37]. Process mapping is a useful tool after data collection to determine the bottlenecks and inefficiencies. Mapping methods are not very difficult to apply and they are also able to give clear information on weaknesses of operation [65]. Specifically, value stream mapping has been popularly applied to identify and analyze operations-based waste to enhance better efficiency and performance [66, 67]. The tools assist in creating a systematic outlook of how operations are run and contribute to the pursuit of constant enhancement.

H4. Operational waste reduction has a significant effect on hotel supply chain sustainability.

2.2.5. Hotel Supply Chain Sustainability

The concept of sustainability in hotel supply chain involves both environmental, social and economic aspects [68–70]. Balance between these dimensions is one of the goals of hospitality organizations [68, 69]. Digital transformation is also relevant to the sustainability efforts, as it helps to conduct operations more efficiently and transparently [71]. Also, sustainability has been gaining significance among customers to the hospitality industry, which offers a competitive edge to the hotels [72]. Smart technologies have highly contributed to the efficiency and sustainability of management of hotel supply chain. To illustrate, automated, and data-driven systems enable better utilization of resources, less waste, better service efficiency, and agility in demand response [73]. Predictive analytics helps the hotel to know the demand in advance preventing the issue of overstocking and the inefficient use of resources. In addition, intelligent systems improve the level of transparency and traceability throughout operations, compliance with environmental and ethical standards [74]. Hotels can also focus on collaborating with suppliers who are environmentally responsible by analyzing them through data-driven methods [75]. Smart systems are also involved in lessening the impact on the environment by way of streamlined logistics and resource planning, decreased energy use and operational waste [76]. Also, reverse logistics, including reuse and recycling, is facilitated by enhanced operational synergies, furthering principles of the circular economy [77]. Sustainable packages, procurement, and resource management are also being implemented by the use of intelligent analytics in hotels. As an example, evidence-based intelligence can streamline material usage, decrease unnecessary consumption, and coordinate the operations with sustainability targets [13, 78]. Besides, smart systems are used to improve customer interactions by offering sustainable services and fostering positive environmental habits. In general, the incorporation of intelligent technologies can be seen as a holistic approach to the attainment of sustainability in the hotel supply chains, striking a balance between the performance and the environmental responsibility of operations.

H5a. Operational waste reduction mediates the relationship between intelligent demand forecasting and hotel supply chain sustainability.

H5b. Operational waste reduction mediates the relationship between hotel supply chain efficiency and hotel supply chain sustainability.

H5c. Operational waste reduction mediates the relationship between intelligent waste reduction and hotel supply chain sustainability.

3. Data Collection and Instrumentation

To address the drawback of traditional CBSEM in our theoretical analysis, the research used PLS-SEM with bootstrapping (5000 replications) to estimate the proposed model [35–79]. A survey research design was used in this study which involved the use of a questionnaire. The target population will be operations managers, supply chain managers and revenue managers who work in 3–5 star hotels that are operational in Jordan. A structured questionnaire was used to gather the data by administering it to 439 managerial staff members who were chosen on the basis of a random sampling method. Data

screening led to the elimination of 39 responses after screening because of missing or incomplete data, leaving the final sample size of 400 valid responses. This sample size is beyond the minimum acceptable level of 150 recommended by other researchers [80].

In determining the required sample size for the survey, a standard formula for estimating a population proportion was employed (Formula (1)):

$n = z^2 \times p \times q / d^2$ (1)

$n = (1.96)^2 \times (p) \times (q) / d^2$

$n = (1.96)^2 \times 0.50 \times 0.50 / (0.075)^2$

$n = 3.8416 \times 0.25 / 0.005625$

$n = 0.9604 / 0.005625$

n = 150 (2)

The parameters used in this calculation have been chosen in such a way that it give a strong and conservative estimate. The Z-value of 1.96 represents a 95 percent confidence interval using the normal distribution. The maximum variance assumption is indicated by p = 0.50 and q = 1- p = 0.50. This assumption maximizes the product (p × q), and hence creates the greatest required sample size and a conservative estimation method. The margin of error d was set at 0.075, derived from a 15% allowable relative error applied to p (i.e., 0.15 × 0.50) [81]. This arrangement will guarantee that the computed sample size will be adequate to define the actual population proportion with a high degree of confidence and precision. The sample size (439) is adequate in terms of statistical analysis and hypothesis testing as the actual sample size (439) is above the required minimum (150). A pilot test and few bias tests were carried out before the actual survey was carried out to check the validity and reliability of the data. Academic researchers and industry practitioners were used in the pilot test to test the content validity, clarity, and reliability of the measurement instrument [82]. Five hotel managers and seven academic experts pretested the questionnaire to make sure that the items were clear, relevant, and in the context of the hospitality. The participants were managers of various hierarchical levels and this ensured that the instrument was evaluated comprehensively. The second pilot test was performed in a group of 40 respondents to determine the reliability and clarity of the measurement items further [83]. According to the received feedback, some minor changes have been implemented to enhance wording and get rid of ambiguous points. The construct validity and reliability were then evaluated through PLS-SEM and the findings were observed to be within reasonable limits. This made the survey tool sound and capable of collecting full scale data. The respondents were to rate the practices of their organizations regarding the processes of hotel supply chains on a five-point Likert scale with the range of strongly disagree (1) to strongly agree (5). This type of measurement contributed to a solid and valid foundation of the measurement of all the constructs presented in the research model. Moreover, the respondents who participated in data collection were representing various levels of managers in order to reduce the

chances of bias in the data collection process through self-reported measures. High-level managers constitute 12.6% of the sample, middle level managers constitute 49.1% and lower level managers constitute 38.3% of the sample. The demographic data of the 439 respondents in the form of gender, managerial position, work experience, and hotel size is provided in Table 1.

Table 1
Demographic information.

Particular	Description	Value	Percentage
Gender	Male	254	57.9%
	Female	185	42.1%
Experience	5–10 Years	167	38.0%
	11–15 Years	216	49.2%
	16–20 Years	56	12.8%
Position	High-Level Manager	56	12.6%
	Middle-Level Manager	215	49.1%
	Lower-Level Manager	168	38.3%
Size of Organization	Large Hotels	80	18.2%
	Medium Hotels	127	28.9%
	Small Hotels	232	52.9%

The representativeness of the sample is also supported by Table 1 because it involves comparing the distribution of the sample to the general structure of managerial positions within the hospitality industry. The respondent distribution by the level of management and the size of the hotel is closely related to the reality of the industry, where the majority of managers are middle-level and small to medium-sized hotels. This congruence increases the validity and generalizability of the study results.

4. Data Analysis and Results

Structural equation modeling (SEM) was employed in this study to analyze the data and test the proposed hypotheses. SEM is a statistical method applied to test the validity of the theoretical models based on empirical data [84]. This is a multivariate approach, which analyzes the structural correlations among the latent variables and their respective constructs. SEM allows establishing and confirming the relationships between more than two variables at once. Its main strength is that it can examine the intricate association among multiple latent constructs with a minimum of model estimation error [85]. There are two common SEM methods (a) covariance-based and (b) variance-based. The paper followed a variance-based method through partial least squares (PLS-SEM) which is aimed at maximizing the explained variance of endogenous constructs. The smartPLS 4 software was used to carry out the

analysis [84]. Besides, a bootstrapping process was done with 5000 subsamples to evaluate the importance of the model paths [86, 87]. PLS-SEM is said to be suitable in complex models and in case of exploratory research. The analysis was done in two steps according to the accepted methodological guidelines [88]. Measurement model was first tested to determine reliability and validity then structural model and research hypotheses were tested.

4.1. Measurement Model

As the initial step in the analysis, the measurement model, the evaluation of the relationships between the latent constructs and their observed indicators was assessed. The present research has performed multiple tests according to the accepted standards of validity and reliability test [86, 89]. Two primary elements were incorporated in the evaluation of the measurement model, including convergent and discriminant validity, which were measured with SmartPLS 4. Cronbachs alpha, composite reliability (CR), and average variance extracted (AVE) were used to determine convergent validity as in Table 2. The internal consistency of the measurement items was estimated using Cronbach alpha. Hair et al. [79] state that above 0.7 values mean acceptable reliability. The outcomes demonstrate that, all constructs in this research surpass the suggested threshold, and it validates high internal consistency. Composite reliability was also used to assess construct reliability. Values above 0.7 are acceptable as proposed by Fornell et al. [90]. Composite reliability of all constructs in this study was more than 0.7 which is satisfactory. Additionally, the proportion of variance which was captured by each construct over measurement error was measured using average variance extracted (AVE). Hair et al. [91] point out that the AVE values need to be above 0.5. According to the results, all constructs satisfy this requirement, which proves the satisfactory convergent validity. Moreover, the items of the measurement loading were also analyzed in terms of their factor loadings on their constructs. The acceptable item reliability has a minimum of 0.5 [91]. Each of the measurement items (see Appendix A) surpassed this value, which means that the indicators are valid and reflect their respective constructs in an adequate manner. The cross-loadings and the Fornell-Larcker criterion [32] were used in evaluating discriminant validity [90]. Discriminant validity is the degree to which a construct is differentiated in relation to any other construct in the model. Based on this criterion, the square root of the AVE of each construct (diagonal values) must be more than its correlations with other constructs (off-diagonal values). According to Table 3, all the diagonal values are higher than the corresponding off-diagonal values, which proves that the discriminant validity is achieved and satisfies the thresholds.

Table 2
Measurement Model Result

Constructs	Items	Loadings	Cronbach's Alpha	C/R (rho_a)	C/R (rho_c)	AVE
Intelligent Demand Forecasting (IDF)	IDF1	0.81	0.86	0.87	0.90	0.64
	IDF2	0.78				
	IDF3	0.82				
	IDF4	0.80				
	IDF5	0.79				
Intelligent Waste Reduction (IWR)	IWR1	0.71	0.85	0.85	0.89	0.63
	IWR2	0.74				
	IWR3	0.82				
	IWR4	0.82				
	IWR5	0.84				
Hotel Supply Chain Efficiency (HSCE)	HSCE1	0.81	0.84	0.85	0.89	0.62
	HSCE2	0.79				
	HSCE3	0.83				
	HSCE4	0.78				
	HSCE5	0.71				
Hotel Supply Chain Sustainability (HSCS)	HSCS1	0.82	0.88	0.88	0.91	0.67
	HSCS2	0.80				
	HSCS3	0.80				
	HSCS4	0.81				
	HSCS5	0.86				
Operational Waste Reduction (OWR)	OWR1	0.76	0.83	0.83	0.88	0.59
	OWR2	0.82				
	OWR3	0.77				

Constructs	Items	Loadings	Cronbach's Alpha	C/R (rho_a)	C/R (rho_c)	AVE
Intelligent Demand Forecasting (IDF)	**IDF1**	**0.81**	**0.86**	**0.87**	**0.90**	**0.64**
	IDF2	**0.78**				
	OWR4	**0.75**				
	OWR5	**0.74**				

Table 3
Discriminant Validity (Fornell–Larcker Criterion)

Constructs	IDF	IWR	HSCS	HSCE	OWR
Intelligent Demand Forecasting (IDF)	**0.80**				
Intelligent Waste Reduction (IWR)	**0.13**	**0.79**			
Hotel Supply Chain Sustainability (HSCS)	**0.39**	**0.57**	**0.78**		
Hotel Supply Chain Efficiency (HSCE)	**0.33**	**0.47**	**0.72**	**0.82**	
Operational Waste Reduction (OWR)	**0.31**	**0.59**	**0.72**	**0.52**	**0.77**

Table 4 has the cross-loadings. By the suggestions of Hair et al. [93], the loading of the indicator variables on their corresponding latent constructs should be higher than the loading of the indicator variables on the other constructs so as to attain discriminant validity. In order to make the table easier to read and interpret, Table 4 only reports the factor loadings above 0.50 since these are the most significant contributions. The items with the loadings of above 0.70, which show strong item reliability, are emphasized by bold. Two aspects are concerned with the interpretation: (1) whether the items load strongly on their intended constructs, thus validating the intended measurement structure, and (2) whether any items have reasonably high cross-loadings on multiple constructs, which are scrutinized with care in order to have adequate discriminant validity. Altogether, the findings affirm that the indicators load on their corresponding constructs the most.

Table 4
Cross-loadings

Constructs	Items	IDF	IWR	HSCS	HSCE	OWR
Intelligent Demand Forecasting (IDF)	IDF1	0.813	0.174	0.396	0.322	0.263
	IDF2	0.785	0.121	0.298	0.257	0.228
	IDF3	0.828	0.083	0.277	0.258	0.282
	IDF4	0.809	0.058	0.247	0.234	0.231
	IDF5	0.794	0.099	0.347	0.269	0.259
Intelligent Waste Reduction (IWR)	IWR1	0.198	0.718	0.488	0.614	0.354
	IWR2	0.197	0.745	0.468	0.584	0.367
	IWR3	0.023	0.822	0.432	0.226	0.551
	IWR4	0.066	0.827	0.459	0.251	0.562
	IWR5	0.095	0.848	0.448	0.291	0.515
Hotel Supply Chain Efficiency (HSCE)	HSCE1	0.353	0.442	0.811	0.458	0.618
	HSCE2	0.299	0.398	0.793	0.503	0.499
	HSCE3	0.359	0.514	0.834	0.575	0.667
	HSCE4	0.326	0.457	0.789	0.455	0.634
	HSCE5	0.236	0.448	0.718	0.629	0.443
Hotel Supply Chain Sustainability (HSCS)	HSCS1	0.368	0.408	0.669	0.822	0.555
	HSCS2	0.288	0.335	0.582	0.809	0.386
	HSCS3	0.245	0.294	0.509	0.808	0.345
	HSCS4	0.229	0.474	0.565	0.816	0.416
	HSCS5	0.239	0.437	0.637	0.868	0.449
Operational Waste Reduction (OWR)	OWR1	0.094	0.548	0.463	0.287	0.768
	OWR2	0.179	0.518	0.525	0.408	0.825
	OWR3	0.154	0.502	0.468	0.316	0.772
	OWR4	0.399	0.392	0.648	0.496	0.752
	OWR5	0.341	0.382	0.655	0.495	0.749

Table 5 shows the analysis of HTMT. Another approach that is applied to measure discriminant validity among constructs is the heterotraitmonotrait ratio (HTMT) as suggested by [94]. Such a method measures the level of correlation of various constructs or make sure that they are empirically different. Based on the rules, the values of HTMT should not exceed 0.85 or 0.90 to ensure a sufficient level of discriminant validity [95, 96]. The findings reveal that the entire HTMT values in this research are below the recommended level of 0.90, which shows that the discriminant validity has been achieved satisfactorily in all the constructs.

Table 5
Heterotrait–Monotrait (HTMT) ratio.

Constructs	IDF	IWR	HSCS	HSCE	OWR
Intelligent Demand Forecasting (IDF)	1				
Intelligent Waste Reduction (IWR)	0.169	1			
Hotel Supply Chain Sustainability (HSCS)	0.455	0.677	1		
Hotel Supply Chain Efficiency (HSCE)	0.375	0.566	0.818	1	
Operational Waste Reduction (OWR)	0.353	0.708	0.849	0.593	1

4.2. Structural Model

The structural or inner model [97] is another part of SEM defining the relationship between the latent variables. It establishes the structural paths of the constructs of the proposed conceptual framework [98,99]. The structural model was estimated through the PLS-SEM bootstrapping process and the hypothesis relationships were evaluated with respect to significance. Table 6 shows that the model fit was assessed based on the standardized root mean square residual (SRMR) and normed fit index (NFI). The SRMR is used to determine the divergence between the observed and expected correlation matrices, values of 0.09 or lower denote a good fit of the model [79]. The SRMR used in this research was 0.076, which shows a fit to accept. The NFI was 0.952, which is greater than the recommended value of 0.90, which again proves the sufficiency of the model fit.

Table 6
Model fit

Fit Measurement	SRMR	NFI
Measurement index	0.076	0.952
Recommendation index	< 0.09	> 0.90

Table 7 shows the value of R2 and adjusted R2 of the endogenous constructs, i.e. the hotel supply chain sustainability (HSCS) and the operational waste reduction (OWR). The R^2 value for HSCS is 0.706, while the adjusted R^2 is 0.70. In a similar manner, R 2 of OWR is 0.46 with an adjusted R 2 of 0.45. These findings show that the model accounts a significant percentage of variation in hotel supply chain

sustainability and moderate amount of operational reduction of waste. The HSCS of 0.70 indicates that the model has a strong explanatory power, meaning that the HSCS of intelligent demand forecasting, hotel supply chain efficiency, and intelligent waste reduction explain a large part of sustainability results. The value of OWR 0.46 indicates a moderate but significant degree of explanatory power. The low value of R 2 and adjusted R 2 shows there is no instability in the model and it is not likely to be overfitted.

Table 7
R^2 and adjusted R^2

HSCS	R-Square	Adjusted R-Square
	0.706	**0.705**
OWR	0.460	0.458

Path coefficients of PLS-SEM are standardized regression coefficients ( ) that show the direction and strength of relationships among constructs. A statistically significant path is one whose p-value is below 0.05 and T-value is above 1.97. As demonstrated in Table 8, intelligent demand forecasting positively and significantly impacts on operational waste reduction as well as positively on the sustainability of the hotel supply chain. Such findings indicate that better forecasting accuracy leads to improved operational efficiency and leads to sustainability outcomes. In addition, the efficiency of hotel supply chain is a very important and significant factor in minimizing operational waste and sustainability. This means that effective supply chain operations are important in ensuring that waste is minimized and environmental performance enhanced in the hospitality industry. The findings also reveal that the positive influence of intelligent waste reduction on operational waste reduction as well as the direct impact on the sustainability of hotel supply chain cannot be underestimated. These results imply the necessity to incorporate intelligent technologies into the operational processes to improve the efficiency and sustainability. Moreover, the impact of operational waste reduction on hotel supply chain sustainability is strong and significant, which proves the fact that this is a critical factor of environmental performance. In general, the results have shown that intelligent demand forecasting, supply chain effectiveness, and intelligent waste minimization have both direct and indirect impacts on sustainability, where operational waste reduction is a significant mediator.

Table 8
Results of path analysis

Hypothesis	Regression Path	Standard β	Effect Type	T Value	p Value	Remarks
H1a	IDF → OWR	0.167	Direct	3.889	0.000	accepted
H1b	IDF → HSCS	0.115	Direct	3.954	0.000	accepted
H2a	HSCE → OWR	0.259	Direct	3.537	0.000	accepted
H2b	HSCE → HSCS	0.418	Direct	8.211	0.000	accepted
H3a	IWR → OWR	0.454	Direct	7.808	0.000	accepted
H3b	IWR → HSCS	0.126	Direct	3.028	0.002	accepted
H4	OWR → HSCS	0.394	Direct	6.809	0.000	accepted
Note: $p < 0.05$; $T > 1.97$.						

The relationship between intelligent demand forecasting and hotel supply chain sustainability through operational waste reduction is mediated by intelligent waste reduction, as shown in Table 9 and Fig. 1. The results reveal that all mediation paths are substantial, which proves that operational waste reduction is one of the crucial mechanisms by which the independent variables affect the results in terms of sustainability. The findings also indicate the existence of both direct and indirect effects meaning that there is partial mediation in all relationships. Such results agree with the existing studies [13, 74], which highlight the need to incorporate intelligent technology in supply chain activities to deal with environmental issues. The smartness of systems in the hospitality industry promotes coordination in the operations of the hospitality industry, better use of resources, and sustainability programmes. In turn, smart technologies serve as an essential facilitator of operational efficiency and environmental sustainability in hotel supply chains.

Table 9
Results of Mediation Analysis

Hypothesis	Regression Path	Standard β	Effect Type	T Value	p Value	Remarks
H5a	**IDF → OWR → HSCS**	**0.066**	**Indirect**	**3.082**	**0.003**	**Moderate Mediation**
H5b	**HSCE → OWR → HSCS**	**0.102**	**Indirect**	**3.571**	**0.000**	**Moderate Mediation**
H5c	**IWR → OWR → HSCS**	**0.179**	**Indirect**	**4.781**	**0.000**	**Moderate Mediation**

5. Discussion

The findings of the study provide useful information about the potential of intelligent technologies to enhance the sustainability, agility and efficiency of supply chains in hotels – with a very different nature from traditional manufacturing and retail. The characteristics of the hospitality environment are variability of demand, seasonality, perishability of services, changing occupancy rates and customer expectations. All these details add up to the need of smart systems not only being desirable, but necessary as well. The contribution of the study will be more precise and applicable when the findings are presented in the context of the challenges encountered in the Hospitality Industry. The first is an intelligent forecasting system has a significant impact on the competency of the supply chain and this is particularly true in the hotel environment. As opposed to traditional industries, the hospitality system processes are highly responsive and show extreme sensitivity against real time changes in customer bookings, seasonality changes and customer preferences. The findings validate the benefits and effectiveness of the intelligent forecasting systems that harness advanced analytics and data-driven insights to better forecast hotel demand. This leads to improved resource allocation, improved staffing, reduced overstocking and improved staffing capacity–customer demand fit. The previous studies show that proper information-processing skills are key to reduce uncertainty in dynamic environment [17] which explains why efficient management of hotel operations is impossible if the proper forecasting is not properly done. The prevention of underutilization and shortage of resources is particularly important in the context of the hospitality industry, as the quality of the services offered directly affects the customer satisfaction and competitiveness. Second, the research draws a lot of attention to the critical role of smart waste minimization in ensuring sustainability in hotel supply chains. Hospitality waste has many forms, such as food waste, energy waste, excessive inventory, and unutilized resources. The intelligent systems assist in detecting the inefficiencies like demand mismatch, over procurement, and inefficient use of resources. Studying the operational trends will help hotels improve the procurement decision, minimize food waste, maximize energy usage and general resource utilization. This is in line with sustainability literature that suggests that intelligent technologies enhance decision-making and decimate resource utilization [34]. Moreover, sustainable practices help to enhance brand image and customer confidence that become more significant in the hospitality business [6]. Third, the supply chain efficiency as a waste reduction driver is especially applicable in the hotel environment. The outcomes indicate that there is a direct reduction in operational waste as a result of the improvement in operational efficiency through better coordination, streamlined processes and data-driven decision making. This reinforces the notion that efficiency and sustainability are not mutually exclusive objectives, but are two sides of the same coin. However, hospitalities are special because smaller inefficiencies can quickly compound into a significant loss of resources, and it's critical to ensure that efficiency and sustainability can be delivered as a single package. The intelligent systems can contribute this alignment, by enhancing the coordination among various departments, such as procurement, inventory management and service delivery. Moreover, the study confirms that smart practices are having a huge effect on increasing the agility of hotel supply chains. Hotels face a world of uncertainty in terms of the variability of the demand, its cancellations and external factors like economic changes or world crisis. The results show that in the context of smart demand forecasting and waste management, the hotel supply chains are able to react efficiently and promptly to these changes. It is consistent with the previous studies

which have revealed that agility and sustainability are complementary variables and can be supported by better technologies [13, 74, 76, 78]. Predictive analytics and other smart tools assist in faster decision-making, flexible resource allocation, and market dynamics response. Notably, this paper focuses on the hospitality industry but the results are applicable to other data intensive and service based industries such as tourism services, logistics operations and smart service systems. The application of smart structures may be incorporated in industries where they have the same challenge of dealing with the variability in demand and environmental sustainability. The research is relevant to the overall literature since it demonstrates the positive impact of smart technologies on decision-making under uncertainty, in line with information processing theory. Finally, the study is a contribution to the body of work on intelligent supply chain management in an empirical context for hospitality industry. The findings show that there is significant positive potential for smart demand forecasting and waste management in supply chain agility, effiency and sustainability. Possible further research topics are industry-specific dynamics such as fluctuations in demand, the customization of services, and making optimal use of resources. Furthermore, researchers can discuss potential problems with intelligent technologies, such as data privacy, system complexity, and implementation problems, and make industry comparisons to support their theory.

5.1. Practical Implications

The outcomes are translated into suggestions that can be applied by hotel practitioners. Hotels are encouraged to build a smart demand forecasting system specific to their operational data and with an ability to evolve models continuously because of the volatility of the demand. Waste reduction should be through food services, energy management, inventory systems and supported by real-time monitoring dashboards to identify inefficiencies and opportunities for intervention. It is crucial to be interoperable with existing operating systems. Cloud-based, modular solutions can be used in smaller hotels and intelligent systems are supposed to be integrated with enterprise solutions such as ERP, property management systems in larger hotel chains. Data verification, tracking, and reporting are strong data governance practices that are necessary to promote reliability and transparency. Moreover, employees' training and human supervision systems must be implemented to help them make decisions and to not rely too heavily on the automated systems. Key indicators that should be used to monitor performance should include accuracy in forecasting, inventory turnover, resource use, waste reduction rate, energy usage, and the environmental impact indicators.

5.2. Managerial Implications

From a managerial perspective, intelligent technologies can be seen as strategic enablers to make companies more agile and sustainable, not as a cost reduction. Hotel managers ought to set up governance structures that will guarantee the safety of data, transparency, and responsibility in utilising the intelligent systems. Invest in building internal capacity, including adopting data management infrastructure, gaining analytics expertise, and aligning the operation team with the IT team and sustainability team. The incentive systems are designed to align the objectives of sustainability and

efficiency to the work of the employees. Hotels that don't depend on a single technology shouldn't be concerned with flexibility, interoperability and scalability of technology solutions. The operational strategies should be incorporated with risk management practices, such as monitoring model performance and addressing possible biases. A slow and steady rollout with pilot projects and phased implementation can be adopted to ensure a smooth and successful process of adoption and value creation in the long-term..

5.3. Theoretical Implications

Although past literature points to the possible threats posed by intelligent technologies, including the issue of data privacy and algorithmic obscurity, the results of the current research show that such threats do not always negatively affect the supply chain agility and sustainability in case the right governance mechanisms are established. The findings indicate that there are a number of prerequisites in which intelligent technologies are most efficient: (1) high-quality and well-structured data, (2) proper data governance and monitoring systems, (3) the presence of human control over the decision-making process, (4) the integration and readiness of the organization, and (5) the compliance with ethical and regulatory standards. In such circumstances, intelligent systems will increase the accuracy of forecasts, minimize operational waste, and overall enhance the supply chain performance. This research offers a more detailed theoretical insight into the role of intelligent technologies in the contemporary supply chain management by explaining the circumstances in which they can be helpful in terms of agility and sustainability. It emphasizes the role of governance, transparency, and human participation in ensuring maximum benefits of intelligent systems and reduction of risks involved.

6. Conclusions

This paper explored the significance of smart demand management and minimizing waste to improve agility and sustainability of hotel supply chains. Intelligent technologies have the potential to transform the existence of the modern supply chain industry where agility, sustainability, and efficiency are not only desirable but necessary to remain competitive in a fast-evolving environment. Using the smart systems to make the right choice in the demand forecast, hotels can optimize the resources to allocate them, minimize the cost of operations, and minimize wastes, thus having more efficient and sustainable operations. Another highlight of the study is that smart practices are also useful in enhancing the agility of the supply chain and minimizing operational waste, which helps hotels to react positively to demand variability and other external disruptions. The findings indicate that there is a high degree of synergy between efficiency and sustainability which implies that the two can be reached at the same time by implementing smart technologies through the use of strategic approaches. This disputes the conventional perception of efficiency and sustainability being opposing objectives. Further, this research context is in the hospitality industry, although the findings could be relevant in other service-driven and data-driven sectors where the importance of sustainability and efficiency in operations are paramount. The insights shared are valuable tips for organizations that want to leverage smart technology solutions for performance and sustainability in more complicated and volatile environments.

6.1. Limitations

There are a few limitations of this study that need to be mentioned. To begin with, cross-sectional research design restricts the possibility to make causal relationships and does not exclude the reverse causality in its entirety. Second, common method variance and perceptual bias could be a part of the single wave of data collection and self-reported measures. Despite the implementation of procedural and statistical solutions, there might be a certain level of bias. Third, the fact that the study is centered on hotels in a particular geographical setting is a limiting factor in generalizing the results to other parts of the world with differing economic, regulatory, and operational conditions. Fourth, constructs are operationalized in a way that could streamline complex practices in an organization, and this could lead to measurement error. Moreover, the model specification options can be not comprehensive enough to capture all the relevant variables, which can leave residual confounding factors. Lastly, operational indicators were used to measure the sustainability outcomes as opposed to overall environmental assessment of the systems, including the lifecycle analysis, which can restrict the accuracy of assessing the level of environmental impact on a wider picture.

6.2. Future Research

The utilization of smart technologies in supply chains also presents some valuable research opportunities. The ethical issues that the future research should explore include data privacy, algorithm bias, and decision-making transparency. Intelligent systems should be implemented responsibly and accountably to be sustainable. Further research is also needed to explore the medium- to long-term impact of intelligent technologies on the nature of the workforce, particularly on the process of automation, job change, and future skill requirements. The use of intelligent systems to boost the efficiency of operations has impact, but the broader potential of intelligent systems on labour markets should be explored further. Besides, longitudinal studies are recommended to improve the assessment of the sustainability of the adoption of intelligent technology in the long-term, and its effects in the resource preservation, in the waste minimisation and in the environmental performance.. Future studies can also focus on the way smart systems can be used to improve supply chain transparency and traceability to allow organizations to fulfill the growing stakeholder demands of ethical and sustainable practices. Interindustrial and international comparisons would help to better understand the opportunities of effective application of intelligent technologies in various settings, especially those ones, where the variability of demand and the complexity of operations are high.

Declarations

Consent to Publish declaration: not applicable.

Consent to Participate declaration: not applicable.

Ethics declaration: not applicable.

Funding Declaration: This research received no external funding.

Clinical trial number: not applicable.

Ethical approval

The protocol was approved by the Ethics Committee of Al-Ahliyya Amman University (Reference: Al Dhaid U -EC-2024-253) and was conducted in accordance with the principles outlined in the Declaration of Helsinki and the Guidelines for Ethical Research by the institution.

Consent to participate

Informed consent was obtained from all participants involved in the study. All respondents were informed of the purpose of the research, the nature of their participation, and their right to withdraw at any time without penalty. Participation was entirely voluntary.

Consent to publish

Not applicable. The manuscript does not contain any identifiable personal information or images of identifiable individuals.

Data availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

References

1. Abhishek V, Jerath K, Zhang ZJ. Agency selling or reselling? Channel structures in electronic retailing. Manage Sci. 2016;62:2259–80. https://doi.org/10.1287/mnsc.2015.2222.
2. Abou Kamar M. Transforming hotel supply chain using intelligent decision support system: Prospects and challenges. J Arab Universities Tourism Hospitality. 2021. https://doi.org/10.21608/JAAUTH.2021.63136.1136.
3. Al-Husain RA, Elshaer AM, Alzuman A. & others. (2024). Toward sustainable performance in the hotel food supply chain: Influences of quality management practices and digital integration. *Administrative Sciences, 14*, Article xx. https://doi.org/10.3390/admsci14
4. Alqudah AZ, Alshar MM, Mahmoud MM, Sheyab A, Radwan SN, S., Ali A. E-marketing and creativity as drivers of organizational performance in the packaging and food processing industry in Jordan: The mediating role of customer satisfaction. PaperASIA. 2026;42(1b):57–68.

5. Alqudah A, Ryad Momani H, Odeh Alshawabkeh R, Al-Abbadi L, Al-Kassem H, A., Zaqeeba N. (2025). The impact of cognitive computing on sustainable logistics systems: The role of forecasting analytics as a mediator in enhancing environmental performance. *EDPACS*, 1–10. 10.1080/07366981.2025.2596449
6. Alqudah A, Ryad Momani H, Odeh Alshawabkeh R, Al-Abbadi L, Al-Kassem H, A., Dalbouh A. M. (2025). The impact of smart technologies on logistics sustainability: The role of predictive analytics as a mediator in improving environmental performance. *EDPACS*, 1–10. 10.1080/07366981.2025.2596464
7. Alqudah A, Ryad Momani H, Alshawabkeh O, Al-Abbadi R, Al-Kassem LH, Ananzeh A, H., Alqudah H. The impact of cyber-physical systems on logistics sustainability: The role of smart energy monitoring as a mediator in improving energy efficiency. EDPACS. 2025;1–9. 10.1080/07366981.2025.2596460.
8. Alqudah A, Ryad Momani H, Alshawabkeh O, Al-Abbadi R, Al-Kassem LH, A., Qawqzeh H. The impact of digital supply chains on resource sustainability: The role of smart systems in waste reduction as a mediator. EDPACS. 2025;1–9. 10.1080/07366981.2025.2596451.
9. Alreahi M, Bujdosó Z, Dávid LD, Gyenge B. Green supply chain management in hotel industry: A systematic review. Sustainability. 2023;15. https://doi.org/10.3390/su15. Article xx.
10. Anderson JC, Gerbing DW. The effect of sampling error on convergence, improper solutions, and goodness-of-fit indices for maximum likelihood confirmatory factor analysis. Psychometrika. 1984;49:155–73. https://doi.org/10.1007/BF02294170.
11. Anderson JC, Gerbing DW. Structural equation modeling in practice: A review and recommended two-step approach. Psychol Bull. 1988;103:411–23. https://doi.org/10.1037/0033-2909.103.3.411.
12. Annarelli A, Nonino F. Strategic and operational management of organizational resilience: Current state of research and future directions. Omega. 2016;62:1–18. https://doi.org/10.1016/j.omega.2015.08.004.
13. Atasu A, Van Wassenhove LN. An operations perspective on product take-back legislation for e-waste: Theory, practice, and research needs. Prod Oper Manage. 2012;21(3):407–22. https://doi.org/10.1111/j.1937-5956.2011.01264.x.
14. Avendaño L. (2026). Assessing the degree of contribution of IoT integration in the hotel supply chain: 4Rs. In *Information systems for intelligent systems: Proceedings of ISBM 2025* (Vol. 5, p. 290).
15. Bag S, Rahman MS, Srivastava G, Shore A, Ram P. Examining the role of virtue ethics and big data in enhancing viable, sustainable, and digital supply chain performance. Technol Forecast Soc Chang. 2023;186:122154. https://doi.org/10.1016/j.techfore.2022.122154.
16. Banihani T, Siam I, Salah A, Alrgaibat M, AlQudah A. The impact of industry 4.0 technologies and information integration on logistics performance: Exploring the moderating role of digital transformation. J Project Manage. 2026;11(2):467–82.
17. Batista L, Bourlakis M, Smart P, Maull R. In search of a circular supply chain archetype: A content-analysis-based literature review. Prod Plann Control. 2018;29:438–51.

https://doi.org/10.1080/09537287.2017.1343502.

18. Birkmaier A, Imeri A, Riester M, Reiner G. Preventing waste in food supply networks—A platform architecture for AI-driven forecasting based on heterogeneous big data. Procedia CIRP. 2023;120:708–13. https://doi.org/10.1016/j.procir.2023.10.123.
19. Bokrantz J, Skoogh A, Berlin C, Stahre J. Smart maintenance: Instrument development, content validation and an empirical pilot. Int J Oper Prod Manage. 2020;40:481–506. https://doi.org/10.1108/IJOPM-11-2018-0674.
20. Buhalis D, O'Connor P, Leung R. Smart hospitality: From smart cities and smart tourism towards agile business ecosystems in networked destinations. Int J Contemp Hospitality Manage. 2023. https://doi.org/10.1108/IJCH.
21. Carrillo JE, Vakharia AJ, Wang R. Environmental implications for online retailing. Eur J Oper Res. 2014;239:744–55. https://doi.org/10.1016/j.ejor.2014.05.034.
22. Christopher M, Holweg M. Supply chain 2.0: Managing supply chains in the era of turbulence. Int J Phys Distribution Logistics Manage. 2011;41(1):63–82. https://doi.org/10.1108/09600031111101439.
23. Christopher M, Peck H. Building the resilient supply chain. Int J Logistics Manage. 2004;15(2):1–14. https://doi.org/10.1108/09574090410700275.
24. de Jesus Pacheco DA, Clausen DM, Bumann J. A multi-method approach for reducing operational wastes in distribution warehouses. Int J Prod Econ. 2023;256:108705. https://doi.org/10.1016/j.ijpe.2022.108705.
25. Dhanorkar S, Muthulingam S. Do e-waste laws create behavioral spillovers? Quasi-experimental evidence from California. Prod Oper Manage. 2020;29:1738–66. https://doi.org/10.1111/poms.13173.
26. Dong H, Wang D, Bashar S. E-commerce supply chain resilience and sustainability through AI-driven demand forecasting and waste reduction. Sustainability. 2025;18(1):360. https://doi.org/10.3390/su18010360.
27. Dutta P, Mishra A, Khandelwal S, Katthawala I. A multiobjective optimization model for sustainable reverse logistics in Indian e-commerce market. J Clean Prod. 2020;249:119348.
28. Ekren BY, Stylos N, Zwiegelaar J, Turhanlar EE, Kumar V. Additive manufacturing integration in e-commerce supply chain network to improve resilience and competitiveness. Simul Model Pract Theory. 2023;122:102676. https://doi.org/10.1016/j.simpat.2023.102676.
29. El Hilali W, El Manouar A, Idrissi MAJ. Reaching sustainability during a digital transformation: A PLS approach. Int J Innov Sci. 2020;12:52–79. https://doi.org/10.1016/j.jclepro.2019.119348.
30. Elshaer IA, Azazz AM, Aljoghaiman A, Mansor M, Salama MA, Fayyad S. Artificial intelligence-driven supply chain agility and resilience: Pathways to competitive advantage in the hotel industry. Logistics. 2025;10(1):5. https://doi.org/10.3390/logistics10010005.
31. Ferguson ME, Toktay LB. The effect of competition on recovery strategies. Prod Oper Manage. 2006;15(3):351–68. https://doi.org/10.1111/j.1937-5956.2006.tb00251.x.

32. Fornell C, Larcker DF. Evaluating structural equation models with unobservable variables and measurement error. J Mark Res. 1981;18:39–50. https://doi.org/10.1177/002224378101800104.
33. Ghaderi Z, Shakori H, Bagheri F, Hall CM, Rather RA, Moaven Z. Green supply chain management, environmental costs and supply chain performance in the hotel industry: The mediating role of supply chain agility and resilience. Curr Issues Tourism. 2024;27(13):2101–17. https://doi.org/10.1080/13683500.2023.2268424.
34. Gokhale AA. Enterprise-wide networking for manufacturing. Comput Ind Eng. 1998;35(1–2):259–62. https://doi.org/10.1016/S0360-8352(98)00086-1.
35. Gold AH, Malhotra A, Segars AH. Knowledge management: An organizational capabilities perspective. J Manage Inform Syst. 2001;18:185–214. https://doi.org/10.1080/07421222.2001.11045669.
36. Guillet BV. Variations of the resilience of industrial alloys of copper according to temperature. Comptes Rendus de l'Académie des Sci. 1913;157:548–50.
37. Gupta S, Drave VA, Bag S, Luo Z. Leveraging smart supply chain and information system agility for supply chain flexibility. Inform Syst Front. 2019;21:xxx–xxx. https://doi.org/10.1007/s10796-019-09916-1.
38. Hagiu A, Wright J. Marketplace or reseller? Manage Sci. 2015;61:184–203. https://doi.org/10.1287/mnsc.2014.1903.
39. Hair JF, Ringle CM, Sarstedt M. PLS-SEM: Indeed a silver bullet. J Mark Theory Pract. 2011;19:139–52. https://doi.org/10.2753/MTP1069-6679190202.
40. Hair JF, Ringle CM, Sarstedt M. Partial least squares: The better approach to structural equation modeling? Long Range Plann. 2012;45:312–9. https://doi.org/10.1016/j.lrp.2012.09.011.
41. Hair JF, Ringle CM, Sarstedt M. Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance. Long Range Plann. 2013;46:1–12. https://doi.org/10.1016/j.lrp.2013.01.001.
42. Hair JF, Risher JJ, Sarstedt M, Ringle CM. When to use and how to report the results of PLS-SEM. Eur Bus Rev. 2019. https://doi.org/10.1108/EBR-11-2018-0203.
43. Hair JF, Sarstedt M, Hopkins L, Kuppelwieser VG. Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. Eur Bus Rev. 2014;26:106–21. https://doi.org/10.1108/EBR-10-2013-0128.
44. Hao L, Fan M. An analysis of pricing models in the electronic book market. MIS Q. 2014;38:1017–32. https://doi.org/10.25300/MISQ/2014/38.4.02.
45. Hasanein AM, Khairy HA, Aljoghaiman A, Al-Romeedy BS. Tackling supply chain disruptions through digital agility: Evidence from the hotel industry. Logistics. 2026;10(2):34. https://doi.org/10.3390/logistics10020034.
46. Hastig GM, Sodhi MS. Blockchain for supply chain traceability: Business requirements and critical success factors. Prod Oper Manage. 2020;29:935–54. https://doi.org/10.1111/poms.13147.

47. Henseler J, Ringle CM, Sarstedt M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. J Acad Mark Sci. 2015;43:115–35. https://doi.org/10.1007/s11747-014-0403-8.
48. Holling CS. Resilience and stability of ecological systems. Annu Rev Ecol Syst. 1973;4:1–23. https://doi.org/10.1146/annurev.es.04.110173.000245.
49. Hossain MS, Sikdar MSH, Chowdhury A. & others. (2025). AI-driven aggregate planning for sustainable supply chains: A systematic literature review of models, applications, and industry impacts. *American Journal of Applied Sciences*. https://doi.org/10.63125/3jdpkd14
50. Hride FT, Ferdousi F, Jasimuddin SM. Linking perceived price fairness, customer satisfaction, trust, and loyalty: A structural equation modeling of Facebook-based e-commerce in Bangladesh. Global Bus Organizational Excellence. 2022;41:41–54. https://doi.org/10.1002/joe.22153.
51. Ignat B, Chankov S. Do e-commerce customers change their preferred last-mile delivery based on its sustainability impact? Int J Logistics Manage. 2020;31:521–48. https://doi.org/10.1108/IJLM-11-2019-0305.
52. Julies M, Bhuiyan S, McMurtrey M. Hotel supply chain: Enhancing operational efficiency, sustainability, and resilience. J Strategic Innov Sustain. 2025;20(4):1–13.
53. Kock N. Common method bias in PLS-SEM: A full collinearity assessment approach. Int J e-Collaboration. 2015;11:1–10. https://doi.org/10.4018/ijec.2015100101.
54. Kuruzovich J, Etzion H. Online auctions and multichannel retailing. Manage Sci. 2018;64:2734–53. https://doi.org/10.1287/mnsc.2016.2666.
55. Kwark Y, Chen J, Raghunathan S. Platform or wholesale? A strategic tool for online retailers to benefit from third-party information. MIS Q. 2017;41:763–85. https://doi.org/10.25300/MISQ/2017/41.3.05.
56. Li G, Yang H, Sun L, Sohal AS. The impact of IT implementation on supply chain integration and performance. Int J Prod Econ. 2009;120:125–38. https://doi.org/10.1016/j.ijpe.2008.07.017.
57. Liang R, Wang J, Huang M, Jiang Z-Z. Truthful auctions for e-market logistics services procurement with quantity discounts. Transp Res Part B: Methodological. 2020;133:165–80. https://doi.org/10.1016/j.trb.2019.04.010.
58. Lim SFWT, Srai JS. Examining the anatomy of last-mile distribution in e-commerce omnichannel retailing. Int J Oper Prod Manage. 2018;38:1735–64. https://doi.org/10.1108/IJOPM-09-2017-0558.
59. Loehlin JC. New50. Latent variable models: An introduction to factor, path, and structural analysis. Erlbaum; 1987. pp. 87–91.
60. Loehlin JC. (2004). *Latent variable models*. Taylor & Francis. https://doi.org/10.4324/9781410609823
61. Mangiaracina R, Marchet G, Perotti S, Tumino A. A review of the environmental implications of B2C e-commerce: A logistics perspective. Int J Phys Distribution Logistics Manage. 2015;45:565–91. https://doi.org/10.1108/IJPDLM-06-2014-0133.

62. Mazahir S, Verter V, Boyaci T, Van Wassenhove LN. Did Europe move in the right direction on e-waste legislation? Prod Oper Manage. 2019;28(1):121–39. https://doi.org/10.1111/poms.12900.
63. Mehrotra A, Agarwal R, Awan U, Walsh ST. & others. (2025). Zero waste solutions in hospitality: Technology alignment and agile management practices for responsible consumption and production of food. *Journal of Sustainable Tourism*. https://doi.org/10.1080/09669582.2025
64. Mishra D, Vijayvargy L. Smart tourism supply chains: Integrating AI, advanced analytics, and robotics for enhanced customer experiences. Handbook of business analytics. Taylor & Francis; 2025.
65. Nikolaou IE, Evangelinos KI, Allan S. A reverse logistics social responsibility evaluation framework based on the triple bottom line approach. J Clean Prod. 2013;56:173–84. https://doi.org/10.1016/j.jclepro.2011.12.009.
66. Niu B, Xie F, Chen L, Xu X. Join logistics sharing alliance or not? Incentive analysis of competing e-commerce firms with promised-delivery-time. Int J Prod Econ. 2020;224:107553. https://doi.org/10.1016/j.ijpe.2019.107553.
67. Oláh J, Kitukutha N, Haddad H, Pakurár M, Máté D, Popp J. Achieving sustainable e-commerce in environmental, social and economic dimensions by taking possible trade-offs. Sustainability. 2018;11:89. https://doi.org/10.3390/su11010089.
68. Olufemi-Phillips AQ, Ofodile OC, Toromade AS, Igwe AN, Eyo-Udo NL. Utilizing predictive analytics to manage food supply and demand in adaptive supply chains. Int J Eng Res Dev. 2024;20(11):1041–59.
69. Pettit TJ, Croxton KL, Fiksel J. Ensuring supply chain resilience: Development and implementation of an assessment tool. J Bus Logistics. 2013;34(1):46–76. https://doi.org/10.1111/jbl.12009.
70. Ponomarov SY, Holcomb MC. Understanding the concept of supply chain resilience. Int J Logistics Manage. 2009;20(1):124–43. https://doi.org/10.1108/09574090910954873.
71. Pu W, Ma S, Yan X. Consumer service level-oriented resilience optimisation for e-commerce supply chain considering hybrid strategies with blockchain adoption. Int J Prod Res. 2024;62:7226–60. https://doi.org/10.1080/00207543.2023.2245678.
72. Pu W, Ma S, Yan X. Geographical relevance-based multi-period optimization for e-commerce supply chain resilience strategies under disruption risks. Int J Prod Res. 2024;62:2455–82. https://doi.org/10.1080/00207543.2023.2238910.
73. Qi Y, Wang X, Zhang M, Wang Q. Developing supply chain resilience through integration: An empirical study on an e-commerce platform. J Oper Manag. 2023;69:477–96. https://doi.org/10.1016/j.jom.2023.01.004.
74. Rasool M, Murtza MH, Rasheed MI. & others. (2025). Information technology competency and supply chain performance: Role of risk management orientation and supply chain agility. *Journal of Hospitality and Tourism Technology*. https://doi.org/10.1108/JHT
75. Raza SA, Qazi W, Umer A. Facebook is a source of social capital building among university students. J Educational Comput Res. 2017;55:295–322. ttps://doi.org/10.1177/0735633116667357.

76. Rice JB, Caniato F. Building a secure and resilient supply network. Supply Chain Manage Rev. 2003;7(5):22–30.
77. Salah OH, Ayyash MM. E-commerce adoption by SMEs and its effect on marketing performance: An extended TOE framework with AI integration, innovation culture, and customer tech-savviness. J Open Innovation: Technol Market Complex. 2024;10:100183. https://doi.org/10.3390/joitmc10020183.
78. Sarstedt M, Ringle CM, Smith D, Reams R, Hair JF. Partial least squares structural equation modeling (PLS-SEM): A useful tool for family business researchers. J Family Bus Strategy. 2014;5:105–15. https://doi.org/10.1016/j.jfbs.2014.01.002.
79. Sheffi Y, Rice JB. A supply chain view of the resilient enterprise. MIT Sloan Manage Rev. 2005;47(1):41–8.
80. Shen Y, Willems SP, Dai Y. Channel selection and contracting in the presence of a retail platform. Prod Oper Manage. 2019;28:1173–85. https://doi.org/10.1111/poms.12972.
81. Shishodia A, Sharma R, Rajesh R, Munim ZH. Supply chain resilience: A review, conceptual framework and future research. Int J Logistics Manage. 2023;34(3):879–908. https://doi.org/10.1108/IJLM-03-2021-0141.
82. Shukla S, KC S. Leveraging blockchain for sustainability and supply chain resilience in e-commerce channels for additive manufacturing: A cognitive analytics management framework-based assessment. Comput Ind Eng. 2023;176. https://doi.org/10.1016/j.cie.2023.108931.
83. Siddiqi MTH, Rasel MAB, Ahmed H, Rahman R, Khan MS. The role of technology in optimizing customer-centric supply chains for hospitality and retail. Strategic Data Manage Innov. 2025;2(1):41–61.
84. Srinivasan R, Lohith CP. (2017). Pilot study—Assessment of validity and reliability. In *Strategic marketing and innovation for Indian MSMEs* (pp. 43–49). Springer. https://doi.org/10.1007/978-981-10-3598-0_4
85. Su T, Tao Y, Wang J. FinTech adoption and the clustered development of rural e-commerce: Evidence from Taobao Village. Pac-Basin Financ J. 2024;85:102315. https://doi.org/10.1016/j.pacfin.2024.102315.
86. Tan Y, Carrillo JE. Strategic analysis of the agency model for digital goods. Prod Oper Manage. 2017;26:724–41. https://doi.org/10.1111/poms.12660.
87. Taseen M, Yongli W, Ali E. (2023). Integration of artificial intelligence for demand forecasting and resource allocation in renewable energy supply chains. In *Proceedings of the 25th International Multi Topic Conference (INMIC 2023)*.
88. Tenenhaus M, Vinzi VE, Chatelin Y-M, Lauro C. PLS path modeling. Comput Stat Data Anal. 2005;48:159–205. https://doi.org/10.1016/j.csda.2004.03.005.
89. Teo TSH, Srivastava SC, Jiang L. Trust and electronic government success: An empirical study. J Manage Inform Syst. 2008;25:99–132. https://doi.org/10.2753/MIS0742-1222250303.

90. Thornton RV, Ferrone R. The environment, e-commerce, and sustainability. Environ Qual Manage. 2001;10:85–91. https://doi.org/10.1002/tqem.1308.
91. Tsang YP, Fan Y, Lee CKM, Lau HCW. Blockchain sharding for e-commerce supply chain performance analytics towards Industry 5.0. Enterp Inform Syst. 2024;18:2311807. https://doi.org/10.1080/17517575.2023.2311807.
92. Tsay AA, Agrawal N. Channel conflict and coordination in the e-commerce age. Prod Oper Manage. 2004;13:93–110. https://doi.org/10.1111/j.1937-5956.2004.tb00146.
93. Wu H, Cai G, Chen J, Sheu C. Online manufacturer referral to heterogeneous retailers. Prod Oper Manage. 2015;24:1768–82. https://doi.org/10.1111/poms.12351.
94. Yan Y, Zhao R, Xing T. Strategic introduction of the marketplace channel under dual upstream disadvantages in sales efficiency and demand information. Eur J Oper Res. 2019;273:968–82. https://doi.org/10.1016/j.ejor.2018.08.044.
95. Zawaideh FH, Abu-Ulbeh W, Majdalawi YI, Zakaria MD, Jusoh JA, Das S. (2023). E-commerce supply chains with considerations of cyber-security. In *Proceedings of the International Conference on Computer Science and Emerging Technologies (CSET 2023)*.
96. Zhang T, Choi T. Optimal consumer sales tax policies for online-offline retail operations with consumer returns. Nav Res Logist. 2021;68:701–20. https://doi.org/10.1002/nav.21966.
97. Zhang X, Yao Y. How much is too much? The effect of offline call intensity on online purchase of digital services. Prod Oper Manage. 2020;29:509–25. https://doi.org/10.1111/poms.13120.

Figures

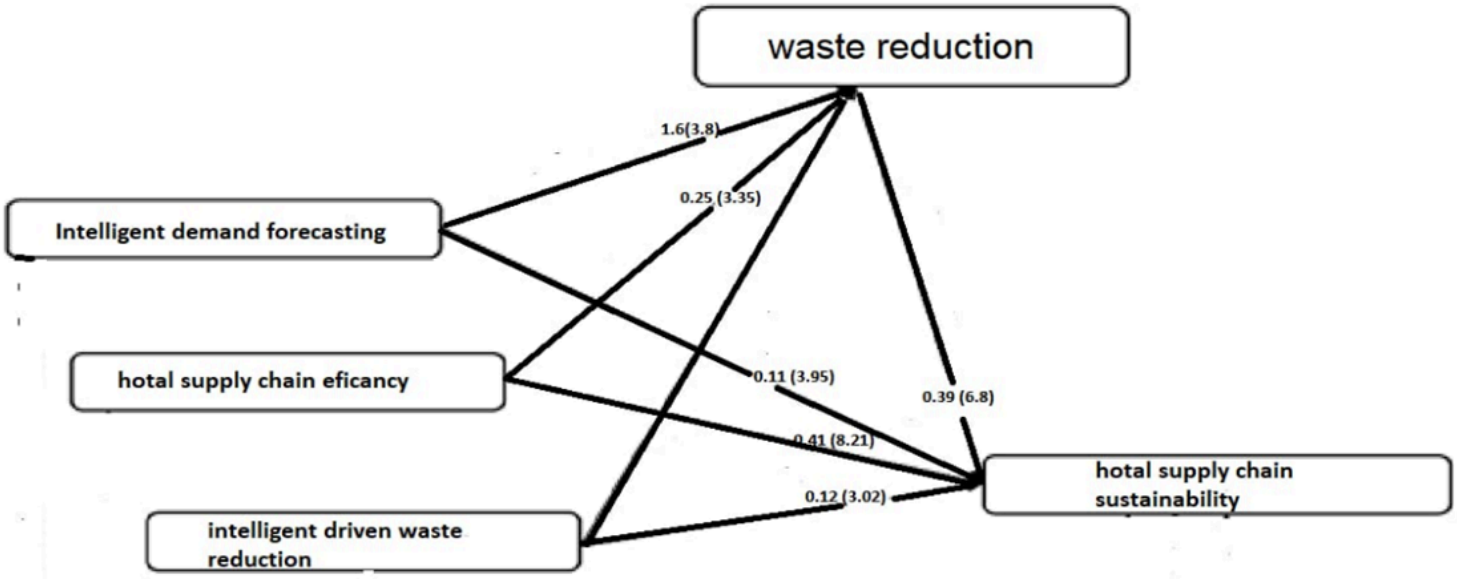


Figure 1

Results of direct hypothesis analysis.