

Article

Examining Factors Influencing Supply Chain Robustness and Supply Chain Velocity During Uncertainty with the Moderating Effect of Supportive HR Practices

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Abstract

The growing prevalence of severe and unpredictable disruptions has prompted logistics firms to restructure their supply chain strategies to ensure long-term sustainability. Therefore, this study developed a research framework with factors including supply chain innovation, supply chain empowerment, risk management capability, supply chain collaboration, and supply chain disruption, and investigated supply chain robustness. Moreover, this study conceptualized supportive HR practices as a moderating factor between supply chain robustness and supply chain velocity, highlighting their role in supporting sustainable supply chain performance. The study design is grounded in a quantitative research approach. Sample size was estimated using a priori power analysis. A research survey was administered using a purposive sampling approach. Overall, 253 valid responses were retrieved during the months of April and May 2024. These numerical responses were further analyzed with a structural equation modeling approach. The structural assessment indicated that supply chain innovation, risk management capability, supply chain disruption, supply chain empowerment, and supply chain collaboration explained 77.7% of the variance in supply chain robustness. Practically, this study proposes that supply chain innovation, risk management capability, supply chain disruption, and supply chain empowerment are key factors that boost supply chain robustness, contribute to sustainable operational performance, and hence need managerial attention. Similarly, this study suggests that managers could achieve supply chain velocity through supportive HR practices, which must be considered while developing sustainable supply chain strategies. This research is unique as it develops an integrated research model to investigate factors that impact supply chain robustness and supply chain velocity from a sustainability-oriented perspective.

Keywords: supply chain empowerment; disruption; innovation; supply chain velocity; supply chain robustness; supply chain sustainability; supportive HR practices



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1. Introduction

Globally, logistics operations are considered the backbone of any country's economy. Nevertheless, continuity of operations in the face of disruption is a key challenge for logistics firms [1]. For instance, during the recent pandemic, logistics firms experienced

a shortage of supply due to enforced lockdown, shutdown of transportation, and closure of borders. These disruptions badly affected supply chain operations and caused either a shortage or oversupply of products [2]. Moreover, the severity of catastrophic events has impelled policy makers to rethink and redesign resilient and robust strategies to ensure the continuity of logistics operations. The recent literature on supply chain management has revealed that resilience strategies rescued logistics firms during the recent pandemic [3–6]. Prior to this, the supply chain process had been widely studied to investigate supply chain agility, sustainability, lean management, and supply chain integration [7–9]. However, supply chain robustness and supply chain velocity have received less attention from academic researchers and policy makers [10]. The current study fills this research gap and develops a logistics model to investigate supply chain robustness and supply chain velocity in the face of catastrophic events.

Logistics operations in the post-pandemic world have changed drastically, and firms are now endeavoring to establish resilient strategies to boost supply chain robustness and supply chain velocity [11]. The authors of [11] have emphasized that achieving supply chain robustness and velocity in the face of disruption is a key challenge that needs to be addressed. Supply chain robustness is defined as a logistics firm's ability to maintain a predetermined performance level despite disruption or a series of disruptions. Therefore, supply chain velocity denotes the speed at which logistics operations are completed with products delivered to end customers on time [12,13]. In the context of Saudi Arabia, the market size of freight and logistics is estimated at USD 25.33 billion with a growth rate of 5.36% in 2024 [14]. Although logistics services have potential and significantly contributed to the Saudi economy, few studies have determined which factors impact supply chain robustness and supply chain velocity. Therefore, the current study develops a research model that comprises factors such as supply chain innovation, supply chain empowerment, supply chain collaboration, and supply chain disruption to investigate logistics firm's robustness. In addition, the moderating effect of supportive human resource practices is tested on supply chain robustness and supply chain velocity. More precisely, this study has the following objectives: to understand how supply chain innovation and empowerment impact supply chain robustness; to examine how risk management capability and supply chain collaboration impact supply chain robustness; to investigate how supply chain disruption increases supply chain robustness; to investigate how supportive HR practices strengthen the relationship between supply chain robustness and supply chain velocity. Notwithstanding prior logistics studies that have discussed supply chain agility, sustainability, lean management, and supply chain integration, this study opens a new avenue in the logistics literature by conceptualizing supply chain robustness and supply chain velocity, and hence broadens the scope and uniqueness of the current logistics research framework.

2. Literature Review

2.1. Theoretical Background

Drawing on dynamic capabilities theory, the resource-based view, and organizational information processing theory, this study develops a robust theoretical foundation to explain how key supply chain capabilities influence supply chain robustness and velocity in uncertain environments. Dynamic capabilities theory suggests that firms enhance performance by sensing, seizing, and reconfiguring resources in response to environmental turbulence, thereby positioning supply chain innovation, empowerment, risk management capability, and collaboration as critical mechanisms for strengthening adaptive capacity and operational responsiveness. Therefore, from a resource-based perspective, these capabilities represent valuable, rare, and difficult-to-imitate strategic resources that enable

firms to withstand disruptions while maintaining continuity and speed across supply chain operations. Additionally, the organizational information processing theory posits that effective supply chain performance under uncertainty depends on the organization's ability to process information efficiently; thus, collaboration, empowerment, and risk management capabilities reduce information asymmetry and improve coordination, enhancing both robustness and velocity. Moreover, supply chain disruption is conceptualized as an external shock that tests the effectiveness of these capabilities, reinforcing the need for dynamic and information-rich responses. Importantly, supportive HR practices serve as a critical moderating mechanism by facilitating employee skills development, decision autonomy, and cross-functional integration, thereby amplifying the effectiveness of supply chain capabilities in responding to uncertainty. Collectively, these theoretical lenses provide a coherent explanation for the proposed relationships and offer strong conceptual justification for the development of hypotheses. In the following section, the hypotheses are established by reviewing the latest studies on logistics, resilience, and supply chain velocity.

2.2. Supply Chain Innovation and Empowerment

Logistics firms are facing disruption in supply chain operations due to rising global competition and a volatile business environment. Nevertheless, the robustness of their supply chain process enables logistics firms to deal with internal and external disruptive events. Therefore, a key challenge is to identify factors that impact supply chain robustness and improve supply chain velocity. The recent literature indicates that an innovative process can respond to changes quickly and efficiently [11–15]. The term supply chain innovation is defined as the conception of new ideas, the acceptance and implementation of new processes in logistics operations, the gathering of deep knowledge, and the continuous search for newness in products and services to satisfy customer needs [11]. Reference [16] stated that logistics firm innovation enhances responsiveness, increases quality, and allows a quick response to changes. Moreover, it has also been observed that during the COVID-19 pandemic, firms that were innovative and robust remained successful in managing supply chain operations [11–15]. In addition to innovation, the literature shows that supply chain empowerment boosts supply chain robustness, increasing supply chain velocity [17]. Supply chain empowerment refers to the efforts made by a logistics firm to empower employees and key stakeholders to improve transparency, decision making, and collaboration in the supply chain process, resulting in increased supply chain robustness. Studies have established that both supply chain innovation and empowerment are core antecedents of supply chain robustness [11–17]. Therefore, supply chain innovation and empowerment are hypothesized as follows:

H1: *Supply chain innovation is positively related to supply chain robustness.*

H2: *Supply chain empowerment is positively related to supply chain robustness.*

2.3. Risk Management and Collaboration

The risk management process enables firms to continually update their operational process—for example, by reviewing supply chain integration and information processing capability—to deal with unprecedented situations. More precisely, risk management is defined as a coordinated approach among supply chain stakeholders to identify and manage the potential to reduce disruption in the supply chain process [18]. Prior studies have shown that risk management strategies improve operational performance and thereby increase supply chain robustness [11–18]. Therefore, it is inferred that logistics firms with risk management capability are considered to be in a better position to respond to disruptive events. Similarly, collaboration has been shown to improve supply chain

robustness. The term collaboration in the context of supply chains is defined as the degree to which two or more autonomous firms work together, plan, and execute operations effectively to achieve common goals [19,20]. The process of collaboration involves activities such as information sharing, resource sharing, goal congruence, joint knowledge creation, and incentive alignment. Therefore, collaborations among stakeholders bring visibility to supply chain operations, reduce lead time, and boost supply chain robustness. Based on the above arguments, and consistent with [11–18], risk management and supply chain collaboration are hypothesized as follows:

H3: *Risk management capability is positively related to supply chain robustness.*

H4: *Supply chain collaboration is positively related to supply chain robustness.*

2.4. Supply Chain Disruption

Due to an increase in catastrophic events and a turbulent environment, logistics firms are expected to face unforeseen events. Therefore, organizations are striving to update their policies to cope with these challenges [21]. The term disruption has been studied in the context of economic, environmental, geographical, and technological disruptions. In the logistics literature, the term disruption is defined as operational failure in connecting either forward or backward nodes, resulting in failure to fulfill end customer demand. Studies have revealed that supply chain disruption is a trigger of current failure but also highlights other operational risks [11–21]. Similarly, disruptive events give logistics firms the opportunity to learn from current disruption and develop strategies that enhance supply chain robustness. In other words, disruption helps firms to understand loopholes in their strategies and hence improve supply chain robustness. Previous studies have established a link between supply chain disruption and supply chain robustness [3–22]. Therefore, supply chain disruption is hypothesized as follows:

H5: *Supply chain disruption is positively related to supply chain robustness.*

2.5. Supportive HR Practices

The uncertain and volatile business environment has forced organizations to introduce flexible and supportive human resource practices in the workplace to improve their performance. For instance, a recent study [23] has established a link between supportive human resource practices and organizational resilience. Supportive HR practices are identified as the extent to which employees receive recognition, emotional support, and instrumental support from managers. The role of supportive HR practices is to nurture a leadership mindset that favors employees, promotes their cultural norms, and encourages them to implement new initiatives in the workplace, which ultimately enhances supply chain robustness. Therefore, it is assumed that supportive HR practices will boost employees' confidence at work and motivate them to keep working during disruptive events. Studies have confirmed that supply chain robustness positively affects supply velocity [12–24]. The term supply chain velocity denotes the speed at which logistics operations are completed and could be achieved through supply chain robustness [12,13]. Previous studies have revealed that HR practices boost logistics firm resilience [25,26]. Nevertheless, the literature is limited with regard to supportive HR practices in logistics settings, except [23], which has established a conceptual link between supportive HR practices and supply chain velocity. Supporting the abovementioned literature, the present study fills the research gap and assumes that supportive HR practices strengthen the relationship between supply chain robustness and supply chain velocity, as shown in Figure 1. Therefore, the following relationships are theorized:

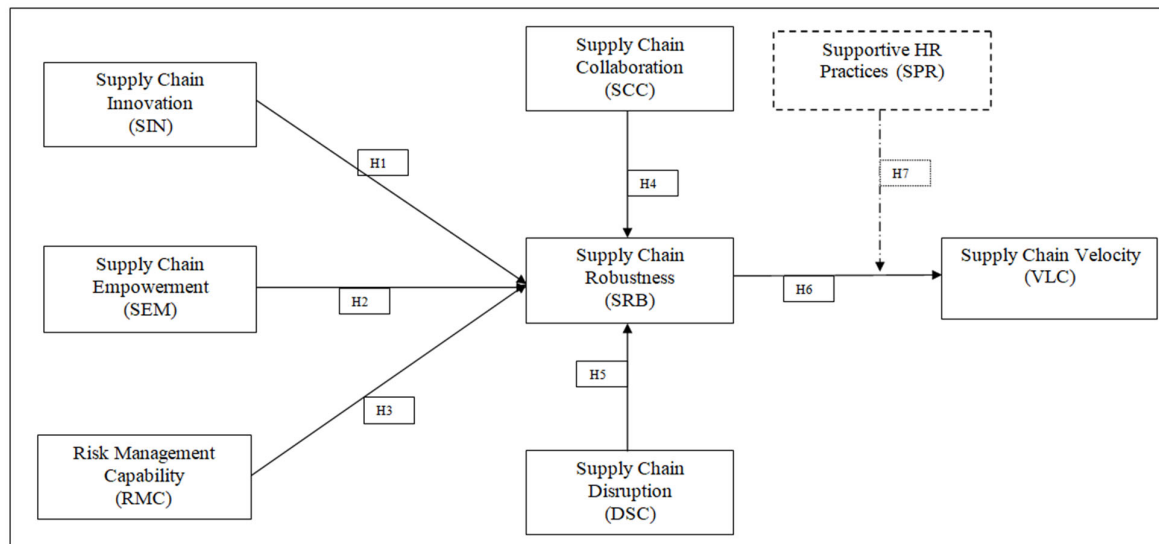


Figure 1. Research model.

H6: Supply chain robustness positively relates to supply chain velocity.

H7: Supportive HR practices moderate the relationship between supply chain robustness and supply chain velocity.

3. Methodology

3.1. Instrumental Development

In this study, instrument items are adopted from the literature. The process of scale development dictates either developing a completely new scale or adapting an existing one. Nevertheless, scale items were adapted for two strong reasons. First, scales already existed; second, all scale items had shown satisfactory loading and Cronbach's alpha values. These scale items were adopted and adapted to a supply chain robustness setting. Moreover, the scale items were measured on a 7-point Likert scale, where 1 is strongly disagree and 7 is strongly agree. The scale for the factor supply chain innovation was adapted from a previous study [11–27]. The scale items of supply chain empowerment were adapted from [11–28]. Moreover, measurement items for the factor risk management capability were adapted from [11–29]. The supply chain collaboration scale was adapted from previous research studies [30,31]. The scale for the factor supply chain disruption was adapted from [11]. Scale items for the factor supply chain robustness were adapted from [27–32]. Likewise, scale items for the factor supply chain velocity were adapted from [11–33]. Scale items for the factor of supportive HR practices were adopted from [23–34] and are shown in Appendix C.

3.2. Research Design, Methods, and Data Collection

As stated above, the research design of this study is grounded in the positivism research paradigm supplemented with quantitative research methods. This paradigm suggests that individuals' opinions are an objective reality and can be assessed through their observations. Therefore, quantitative data are collected through survey questionnaires. Moreover, hypotheses are tested with quantitative data retrieved through the survey questionnaire. Consistent with the research objectives, the survey questionnaire was designed to probe supply chain robustness and velocity. Nevertheless, prior to administering the survey, the population and sample size were used as guidelines, as provided by prior researchers in the same field [35,36]. The research population of this study is account managers working

in Saudi logistics firms. The reason for selecting managers is that they are assumed to have far-reaching information about production and supply chain operations compared to junior staff. Furthermore, the sample size of this study was selected through a priori power analysis with a medium effect size, as suggested by previous researchers [37,38]. This analysis suggests that at least 153 responses are required with seven predictors. The a priori power analysis chart is given in Appendix A.

In this study, empirical data were collected through the structured questionnaire. Therefore, before the field survey was administered, a pilot survey was conducted with five experts from the same field and twenty-five managers working in logistics firms. These experts were asked to review the questionnaire content and suggest whether items were clear and readable. They found that the content was clear and provided true definitions of supply chain robustness and supply chain velocity. The final survey questionnaire was distributed using a purposive sampling approach. Selecting this approach is appropriate because only senior-level managers participated. Thus, purposive sampling assisted the researchers in finding relevant respondents. Data were collected physically during April and May 2024. This study is cross-sectional and therefore data were collected at one point in time. Participation in the research survey was voluntary, with the promise that individual information would not be disclosed. Respondents were asked to fill in the survey questionnaire according to their understanding of how allocated factors influence supply chain robustness and enhance supply chain velocity. A total of 295 questionnaires were distributed among logistics managers. Among the 295 respondents, 18 refused to participate due to time constraints. Nevertheless, 277 managers showed interest and participated in the survey. After several reminders, 253 responses were retrieved with a response rate of 85%. Finally, these 253 responses were analyzed using structural equation modeling in Stata 17 (StataCorp LLC, College Station, TX, USA).

3.3. Addressing Missing Values and Common Method Bias

The initial step after data collection is to deal with missing values. According to [39], missing values appear during the data screening process and must be explained using Little's analysis. Little's missing values analysis suggested that data must be missing completely at random. In addition, missing values must be less than 10% [39]. Missing values analysis revealed that the highest missing value is 3% and substantially less than the threshold value [39]. Moreover, the results indicate that these values are missing completely at random and supported by Chi-Square, 673.132, DF = 67, Sig. = 0.987 [36]. The common method bias issue is tested with two kinds of remedies, namely, procedural and statistical. The procedural remedy suggests that a questionnaire should be mixed up prior to data collection. Therefore, it was adopted in this study and questionnaires were jumbled up prior to distribution. Nonetheless, for statistical testing, Harman's single factor analysis was incorporated. This analysis recommends that maximum variance revealed by single factors must be less than 40%. The results showed 25% variance explained by the first un-rotated single factor. Consequently, the results established that common method bias is not an issue in the current data set.

4. Data Analysis

4.1. Structural Equation Modeling

There are two types of structural equation modeling: variance-based and covariance-based. Both types have advantages and disadvantages [40]. As this study has developed a completely new research framework that comprises multiple factors, variance-based structural equation modeling is appropriate. Following structural equation modeling, data were assessed. The first stage of SEM ensures the factor reliability, indicator reliability,

and convergent and discriminant validity of each factor. However, the second stage tests the relationship among factors and effect sizes. In the first stage, also known as the measurement model, the factor reliability is confirmed following the criterion that alpha and composite values should be greater than 0.70. Moreover, indicator reliability is confirmed following loading values of 0.60. Likewise, convergent validity is tested following a threshold value of 0.50 of the average variance extracted [39–41]. The results confirm satisfactory factor reliability, indicator reliability, and convergent validity, and are shown in Table 1.

Table 1. Evaluating measurement model.

Scale Items	Loading	α	CR	AVE
DSC1: Logistic firm is capable to deliver service in the face of disruption.	0.855	0.802	0.884	0.720
DSC2: Logistic firm ensures quality and operates efficiently during disruption.	0.920			
DSC3: Firm ensures high level of inventory management during disruption.	0.763			
RMC1: This firm has multiple sources to manage stock during disruption.	0.835	0.815	0.890	0.730
RMC2: This firm has alternative of transportation during disruption.	0.879			
RMC3: This firm has ability to detect risk and maintain buffer stock.	0.850			
SCC1: This firm engages other supply chain partner to resolve issue.	0.867	0.807	0.886	0.722
SCC2: Logistic firm sets common goals with other stakeholder.	0.907			
SCC3: Logistic firm has strong collaborative communication to solve issues.	0.769			
SEM1: In our logistic firm employees are encouraged to take new initiative.	0.847	0.879	0.925	0.806
SEM2: Employees are equally involved into decision making process.	0.908			
SEM3: Logistic firm delegate authority to employee in the face of disruption.	0.935			
SIN1: Logistic firm seeks out new ways to complete operations.	0.823	0.822	0.894	0.739
SIN2: Logistic firm continuously try new things to complete operations.	0.903			
SIN3: Logistic firm solve problems through creative solutions.	0.851			
SPR1: Our firm allows me to participate in decisions regarding my job.	0.900	0.875	0.923	0.799
SPR2: Our firm will reward employees with fair appraisal system.	0.849			
SPR3: Our firm gives equal opportunity to learn new things through trainings.	0.931			
SRB1: Logistic firm is capable to meet customer demand.	0.897	0.939	0.956	0.845
SRB2: Logistic firm has ability to Perform well in the face of disruption.	0.949			
SRB3: Logistic firm can confront disruption without adaptation.	0.918			
SRB4: Logistic firm is able to continue operations even in complex scenarios.	0.914			
VLC1: Logistic firm is able to respond market changes quickly.	0.942	0.933	0.952	0.834
VLC2: Logistic firm is capable to confront environmental threats.	0.912			
VLC3: Logistic firm quickly responds to catastrophic events.	0.850			
VLC4: This logistic firm is able to respond disruption quickly.	0.945			

The results reveal satisfactory convergent validity of the factors. Nevertheless, the discriminant validity of the factors is established with cross-loading methods. The cross-loading analysis demonstrates that loadings of the indicator must be greater when compared with other indicators' loadings. Data are computed and the cross-loading analysis results reveal that all indicators exhibit higher loadings when compared to the corresponding construct loadings.

The results of the cross-loading analysis are shown in Table 2, demonstrating adequate discriminant validity of the factors.

Table 2. Factors' cross loadings.

Indicator	DSC	RMC	SCC	SEM	SIN	SPR	SRB	VLC
DSC1	0.855	0.589	0.571	0.666	0.509	0.521	0.600	0.618
DSC2	0.920	0.711	0.655	0.800	0.630	0.569	0.739	0.752
DSC3	0.763	0.678	0.682	0.542	0.554	0.652	0.641	0.593
RMC1	0.637	0.835	0.519	0.701	0.583	0.556	0.647	0.641
RMC2	0.686	0.879	0.621	0.664	0.665	0.643	0.731	0.684
RMC3	0.678	0.850	0.723	0.611	0.611	0.670	0.686	0.671
SCC1	0.643	0.646	0.867	0.579	0.579	0.546	0.671	0.627
SCC2	0.650	0.678	0.907	0.618	0.728	0.661	0.728	0.713
SCC3	0.633	0.518	0.769	0.515	0.512	0.491	0.520	0.538
SEM1	0.695	0.698	0.546	0.847	0.549	0.546	0.642	0.646
SEM2	0.716	0.631	0.631	0.908	0.717	0.581	0.728	0.711
SEM3	0.733	0.746	0.633	0.935	0.713	0.616	0.766	0.743
SIN1	0.570	0.609	0.527	0.637	0.823	0.610	0.713	0.663
SIN2	0.550	0.619	0.622	0.577	0.903	0.559	0.701	0.661
SIN3	0.603	0.643	0.710	0.688	0.851	0.699	0.708	0.627
SPR1	0.650	0.687	0.642	0.586	0.593	0.900	0.671	0.650
SPR2	0.488	0.547	0.435	0.492	0.613	0.849	0.610	0.522
SPR3	0.674	0.707	0.692	0.643	0.732	0.931	0.724	0.710
SRB1	0.674	0.697	0.632	0.713	0.722	0.674	0.897	0.721
SRB2	0.729	0.745	0.700	0.758	0.780	0.672	0.949	0.782
SRB3	0.741	0.792	0.741	0.723	0.769	0.729	0.918	0.830
SRB4	0.731	0.728	0.721	0.732	0.757	0.687	0.914	0.881
VLC1	0.758	0.723	0.708	0.746	0.746	0.707	0.870	0.942
VLC2	0.751	0.734	0.701	0.682	0.674	0.687	0.773	0.912
VLC3	0.628	0.649	0.623	0.694	0.607	0.508	0.724	0.850
VLC4	0.695	0.737	0.678	0.731	0.730	0.676	0.826	0.945

Note: Bold values indicate statistical significance, while italicized values represent threshold values.

The factors' discriminant validity is established with the Fornell–Larcker analysis [42]. The Fornell–Larcker method is widely used in scientific research. It suggests that the square root of the average variance extracted must be greater when compared with corresponding factors in a correlation matrix [39–43]. The results show that the square root values of the average variance extracted are higher in rows and columns, demonstrating that factors are discriminant. The results of the discriminant analysis are shown in Table 3.

Table 3. Fornell–Larcker analysis.

Factors	DSC	RMC	SCC	SEM	SIN	SPR	SRB	VLC
DSC	0.848							
RMC	0.781	0.855						
SCC	0.751	0.728	0.850					
SEM	0.796	0.769	0.674	0.898				
SIN	0.669	0.726	0.721	0.739	0.859			
SPR	0.684	0.731	0.672	0.648	0.725	0.894		
SRB	0.783	0.806	0.762	0.796	0.824	0.751	0.919	
VLC	0.777	0.779	0.743	0.781	0.758	0.710	0.877	0.913

4.2. Hypotheses Testing and Multicollinearity Assessment

The multi-collinearity issue is addressed prior to hypothesis testing. To ensure data validity, this study selected variance inflation factor analysis. Based on a threshold value of 3.3, this study established that multi-collinearity is unlikely to be a concern as VIF values are less than the threshold value. The results indicate the maximum VIF value is 2.675 in measuring supply chain robustness. Similarly, the largest value of VIF is 2.322 in determining supply chain velocity. The results of the VIF analysis can be seen in Table 4.

Table 4. Variance inflation factor analysis.

Factors	Supply Chain Robustness	Supply Chain Velocity
Supply chain disruption	1.888	
Risk management capability	2.499	
Supply chain collaboration	1.978	
Supply chain empowerment	2.675	
Supply chain innovation	1.904	
Supportive HR practices		1.266
Supply chain robustness		2.322

Next, this study proceeds with testing the hypotheses using the bootstrapping method, following the approach recommended by previous researchers [37,38]. The bootstrapping procedure was performed using 5000 subsamples, a commonly accepted standard in PLS-SEM analysis to ensure robust estimation of path coefficients [36–41]. This non-parametric resampling technique enhances the statistical power of the analysis by providing more accurate confidence intervals and standard errors. Moreover, the bootstrapping procedure also mitigates the issue of data normality. In evaluating the hypothesized relationships, key statistical metrics such as beta coefficients, *t*-values, standard errors, and *p*-values were examined. These metrics provide insights into the strength, direction, and significance of the relationships between latent constructs, hence testing the research model. Table 5 presents the hypothesis analysis results.

The hypothesis analysis revealed that supply chain innovation is positively related to supply chain robustness and confirmed by $\beta = 0.358$, *t*-statistic of 5.598, and significance at $p < 0.000$; therefore, H1 is accepted. Supply chain empowerment has shown a positive impact on supply chain robustness and is supported by $\beta = 0.160$, *t*-statistics 2.453, and significance at $p < 0.007$, confirming H2. The risk management capability is positively related to supply chain robustness and reinforced by $\beta = 0.207$, *t*-statistics 3.876, and significance at $p < 0.000$;

therefore, H3 is accepted. Supply chain collaboration has a positive impact on supply chain robustness backed by $\beta = 0.124$, t -statistics 2.350, and significance at p 0.009; hence, H4 is accepted. The relationship between supply chain disruption and supply chain robustness is found to be significant and confirmed by $\beta = 0.161$, t -statistics 2.763, and significance at p 0.003, confirming H5. Moreover, this study confirms that supply chain robustness is significantly related to supply chain velocity and confirmed by $\beta = 0.797$, t -statistics 21.722, and significance at p 0.000, and H5 is therefore accepted. Finally, the moderating effect of supportive HR practices is tested with the product indicator approach. The results show that the relationship between supply chain robustness and supply chain velocity is positively moderated and confirmed by $\beta = 0.043$, t -statistics 1.849, and significance p 0.032, and H7 is therefore confirmed. The findings for direct and moderating hypotheses are presented in Appendix B. Although supportive HR practices are statistically confirmed to moderate the impact of the relationship between supply chain robustness and supply chain velocity, the actual strength of the relationship is tested with simple slope analysis. The results of the simple slope graph demonstrate that SPR at +1 SD reveals an uphill trend, and hence, it is assumed that a higher moderating impact of supporting HR practices will strengthen the relationship between supply chain robustness and supply chain velocity. Figure 2 explains the trend of a moderating relationship between SPR at +1 SD and SPR at −1 SD gradients.

Table 5. Analysis of hypotheses.

Hypothesis	Path Coefficient	β	STDEV	t -Statistics	Significance
H1	SIN $\rightarrow$ SRB	0.358	0.064	5.598	0.000
H2	SEM $\rightarrow$ SRB	0.160	0.065	2.453	0.007
H3	RMC $\rightarrow$ SRB	0.207	0.054	3.876	0.000
H4	SCC $\rightarrow$ SRB	0.124	0.053	2.350	0.009
H5	DSC $\rightarrow$ SRB	0.161	0.058	2.763	0.003
H6	SRB $\rightarrow$ VLC	0.797	0.037	21.722	0.000
H7	SPR $\times$ SRB $\rightarrow$ VLC	0.043	0.023	1.849	0.032



Figure 2. Simple slope analysis.

4.3. Importance/Performance Matrix

The hypothesis analysis confirms the significant impact of the outlined factors on measuring outcome factor. Nevertheless, the importance of the factors remains to be examined with importance/performance map analysis. The first step in this analysis is to select an outcome factor. Supply chain velocity is taken as an outcome factor in the IPMA. Data were computed and the results revealed that supply chain robustness is the most important factor in measuring supply chain velocity. Supply chain innovativeness is identified as the second-most important factor in measuring the velocity. Furthermore, the importance of risk management capability, supply chain disruption, supply chain empowerment, and supportive HR practices was found to be sizeable. The importance/performance level was also measured. Supportive HR practices have shown the highest performance level in measuring supply chain velocity. Factors' importance and performance are shown in Table 6.

Table 6. Importance/performance analysis.

Supply Chain Velocity Importance and Performance Level		
Factors	Factors Effects	Factors Performance
Supply chain disruption	0.128	68.120
Risk management capability	0.165	65.838
Supply chain collaboration	0.099	68.669
Supply chain empowerment	0.128	68.992
Supply chain innovation	0.285	69.355
Supportive HR practices	0.149	74.434
Supply chain robustness	0.797	69.517

The importance and performance level of the factors is assessed with an importance/performance map. The importance of the factors can be found on the x -axis horizontally in the IPMA map. Therefore, performance indicators can be seen vertically on the y -axis. The importance/performance map clearly indicates that supply chain robustness is the most influential factor in measuring supply chain velocity. Supply chain collaboration is found to be the least important when compared with the other corresponding factors. Nevertheless, for policy makers, these results suggest that supply chain innovation, risk management capability, supply chain disruption, supply chain empowerment, and supportive HR practices are key factors for boosting supply chain velocity. Figure 3 shows the importance and performance of the factors in relation to supply chain velocity.

4.4. Coefficient of Determination and Effect Size Analysis

To establish the research framework, validity factor variance was examined through the R^2 coefficient of determination. The results revealed that collectively, supply chain innovation, risk management capability, supply chain disruption, supply chain empowerment, and supply chain collaboration explained 77.7% of the variance in supply chain robustness. Therefore, supportive human resource practices and supply chain robustness explained R^2 81% of the variance in supply chain velocity. These findings confirm that the research model has substantial theoretical and statistical power to measure supply chain velocity. Moreover, the factors' effect sizes f^2 were estimated based on threshold values of 0.02 small, 0.15 medium, and 0.35 large [39]. The results demonstrate that supply chain innovation has a medium effect size in measuring supply chain robustness. Nevertheless, factors such as risk management capability, supply chain disruption, supply chain empowerment, and

supply chain collaboration show a small effect size in measuring supply chain robustness. In the extended model, supply chain robustness demonstrates a large effect in measuring supply chain velocity. Nevertheless, supportive HR practices show a small effect size in measuring supply chain velocity. The results of the coefficient of determination and effect sizes are shown in Table 7.

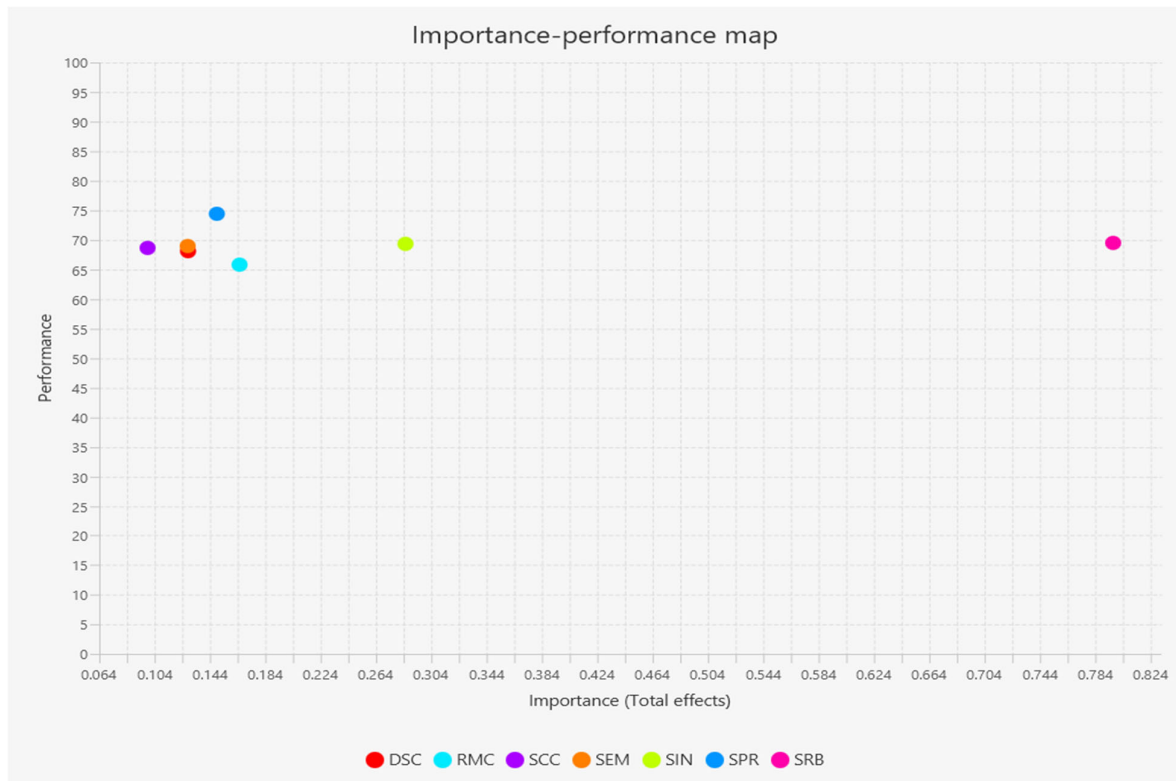


Figure 3. Importance/performance map.

Table 7. Coefficient of determination R^2 and effect sizes f^2 .

Coefficient of Determination R^2		
Factors	R^2	Variance impact
Supply chain robustness	81.0%	Substantial
Supply chain velocity	77.7%	Substantial
Supply chain robustness		
Factors	f^2	Effect size
Supply chain disruption	0.035	Small effect
Risk management capability	0.065	Small effect
Supply chain collaboration	0.027	Small effect
Supply chain empowerment	0.037	Small effect
Supply chain innovation	0.232	Medium effect
Supply chain velocity		
Factors	f^2	Effect size
Supportive HR practices	0.036	Small effect
Supply chain robustness	1.227	Large effect

5. Discussion

The surge in catastrophic events such as the recent pandemic, earthquakes, terrorism, tsunamis, and floods has forced policy makers to create robust supply chain strategies, which in turn boost supply chain velocity and overall performance of logistics firms. For instance, during the pandemic, logistics firms experienced a shortage of supply due to interruptions in transportation and the closure of borders. These disruptions badly affected supply chain operations and caused either a shortage or oversupply of products. In the face of these disruptions, the continuity of logistics operations is a key challenge for logistics firms. The current study developed a research model that reveals core antecedents of supply chain robustness and supply chain velocity. These antecedents were further tested with structural equation modeling. The statistical results show that supply chain innovation is positively related to supply chain robustness and is consistent with previous studies [11–16]. Similarly, supply chain empowerment has been shown to positively impact supply chain robustness, and this finding is in line with previous studies [11–17]. Concerning the risk management capability of logistics firms, the results show it is positively related to supply chain robustness and supports arguments developed in a previous study [18]. Likewise, supply chain collaboration has been shown to positively impact supply chain robustness and confirms arguments developed in previous studies [11–18]. The relationship between supply chain disruption and supply chain robustness is confirmed, and this finding is consistent with a previous study [11–22].

In the extended model, supply chain robustness has a positive impact in determining supply chain velocity, consistent with previous studies [11–32]. Similarly, this study tested the role of supportive HR practices in the relationship between supply chain robustness and supply chain velocity. The findings confirm that supporting HR practices will strengthen the relationship between supply chain robustness and supply chain velocity and confirm arguments established in past studies [23–26]. Although this study confirms the significant impact of exogenous factors on outcome factors, the results show substantial variance in measuring supply chain robustness and velocity. Taken together, supply chain innovation, risk management capability, supply chain disruption, supply chain empowerment, and supply chain collaboration explain 77.7% of the variance in supply chain robustness. Similarly, supportive human resource practices and supply chain robustness explain R^2 81% of the variance in supply chain velocity. However, the individual impact of the factors was assessed with effect size analysis. The effect size f^2 analysis demonstrates that supply chain innovation is the most influential factor in measuring supply chain robustness, with a medium effect size. Although logistics operations have potential and significantly contribute to the Saudi economy, there is little discussion of the importance of supply chain robustness and supply chain velocity. Therefore, the findings of this research will help managers to understand the importance of the outlined factors in nurturing supply chain robustness and velocity in the face of disruption.

5.1. Contributions to Theory

The overarching goal of this study is to shed light on factors that boost supply chain robustness and supply chain velocity. Consequently, it develops an amalgamated research model and extensively contributes to theoretical knowledge, especially in logistics settings. This study conceptualizes the relationship between supply chain innovation and supply chain robustness, and hence enriches the logistics literature in the context of innovation in logistics operations. Similarly, examining the impact of supply chain empowerment and risk management capability on supply chain robustness significantly contributes to the logistics literature. Although supply chain risk management capability has been studied in terms of logistics firm performance, conceptualizing the relationship between risk management

capability and supply chain robustness has revealed a new dimension in logistics research. Furthermore, establishing a relationship between supply chain collaboration and supply chain robustness significantly contributes to theoretical knowledge. The importance of reactive supply chain strategies cannot be ignored, and therefore, the relationship between supply chain disruption and supply chain robustness is established, and hence enriches the literature. Another useful theoretical contribution of this study is that it tests the moderating effect of supportive HR practices in the relationship between supply chain robustness and supply chain velocity. Although the literature has revealed a significant positive impact of HR practices in determining logistics operation performance, the moderating effect of supportive HR practices has rarely been studied. Therefore, current research has revealed that high-impact supportive human resource practices will strengthen the relationship between supply chain robustness and supply chain velocity, and hence enrich logistics literature with supportive human resource practices.

5.2. Contributions to Practice

This study has produced several interesting findings that could assist policy makers in understanding how to boost supply chain robustness and supply chain velocity during disruption. The results show that the factors outlined in the research model represent concrete solutions to boost supply chain robustness. For instance, this study confirms that innovation and supply chain empowerment increase supply chain robustness and therefore need managerial attention. Similarly, factors such as risk management capability and supply chain collaboration influence supply chain robustness and thereby improve supply chain velocity. Moreover, supply chain disruption highlights logistics firms' weaknesses and helps them understand loopholes in their strategies, and hence improve supply chain robustness. Likewise, another important dimension in this study is the testing of the moderating effect of supportive human resource practices in the relationship between supply chain robustness and supply chain velocity. This study confirms that implementation of supportive human resource practices will boost logistics firms' robustness and supply chain velocity. Another challenge for logistics managers is to achieve maximum efficiency with minimum resources in supply chain operation. Therefore, with the help of f^2 analysis, this study recommends that among all exogenous factors, supply chain innovation is the most influential in measuring supply chain robustness. Therefore, with the single factor of supply chain innovation, managers can achieve robustness and velocity in their logistics operations. Nevertheless, importance/performance analysis reveals the broader context and indicates that factors such as supply chain innovation, risk management capability, supply chain disruption, supply chain empowerment, and supportive HR practices are key factors that boost supply chain velocity. Therefore, managers and policy makers should consider these factors while developing new supply chain strategies, which in turn boost supply robustness and supply chain velocity in the face of disruption.

6. Conclusions

The prevalence of catastrophic events has forced logistics firms to introduce robust supply chain strategies. Therefore, the current study develops a comprehensive research framework that integrates supply chain innovation, supply chain empowerment, risk management capability, supply chain collaboration, and supply chain disruption to examine their combined and individual effects on supply chain robustness and supply chain velocity during disruptive events. The importance of this framework lies in its holistic treatment of both proactive capabilities and external shocks, offering a more nuanced understanding of how supply chains can not only withstand disruptions but also maintain operational speed under uncertainty. The key innovation of this study is the simultaneous investigation of

robustness and velocity, two critical yet often separately examined dimensions of supply chain resilience, within a single integrated model. Furthermore, by incorporating supportive HR practices as a moderating mechanism, this study introduces a novel human-centric perspective that explains how organizational practices enhance the effective deployment of supply chain capabilities during crises. This integrative and theory-driven approach advances the existing supply chain literature by moving beyond isolated capability analyses and providing a dynamic, multi-dimensional explanation of supply chain performance in highly disruptive environments. From a sustainability perspective, strengthening supply chain robustness and velocity enables logistics firms to ensure operational continuity, reduce disruption-related inefficiencies, and support sustainable supply chain performance under uncertainty. Moreover, the statistical results indicate that factors such as supply chain innovation, risk management capability, supply chain disruption, supply chain empowerment, and supply chain collaboration have a positive impact on supply chain robustness and explain 77.7% of its variance. This study has also conceptualized the moderating effect of supportive HR practices on the relationship between supply chain robustness and supply chain velocity. The results have confirmed this moderating effect. Moreover, both supply chain robustness and supportive HR practices have explained R^2 81% of the variance in supply chain velocity. Similarly, effect size f^2 analysis has demonstrated that supply chain innovation is the most influential factor in measuring supply chain robustness, with a medium effect size. This study has developed an amalgamated model to investigate supply chain robustness and supply chain velocity and substantially contributes to the logistics literature. For policy makers, this research has suggested that factors such as supply chain innovation, risk management capability, supply chain disruption, and supply chain empowerment are key factors that boost supply chain robustness. Furthermore, this study has revealed that managers can achieve supply chain velocity through supportive HR practices, which must be considered while developing new supply chain strategies. This study also concludes that logistics managers can achieve maximum efficiency with supply chain innovation, and innovation factors therefore demand policy makers' attention. In summary, this research shows that key factors such as supply chain innovation, risk management capability, supply chain disruption, supply chain empowerment, and supportive HR practices boost supply chain robustness and supply chain velocity during catastrophic events.

Research Limitations and Future Directions

Despite making several contributions to theory and practice, this study has some limitations, and therefore, future research directions must be acknowledged. First, the research model used in this study has indicated proactive and reactive factors to boost supply chain robustness. Nevertheless, there are still other factors that could enhance supply chain robustness such as digitalization, big data analytics, and artificial intelligence. Therefore, future researchers should extend the existing framework with the suggested factors that could produce interesting findings. Similarly, the research model has conceptualized direct and moderating hypotheses to investigate supply chain robustness and supply chain velocity. Nevertheless, future researchers should test the mediating role of supply chain robustness between exogenous and endogenous factors. Regarding methodology, this study is based on a cross-sectional design. However, a longitudinal research design could produce more authentic findings and is recommended for further research. Similarly, the data collection process was limited to logistics managers. Nevertheless, the participation of other logistics stakeholders in the current logistics survey could enhance the scope of this research. Moreover, as it was conducted in the Saudi region, the results are only reliable for

the Saudi manufacturing industry. Future researchers may conduct cross-cultural research to obtain deeper insight into how logistics operations differ from region to region.

Author Contributions: M.A.Y.Y. and I.E. conceived and designed the study. I.E. conducted the experiments and collected the data. M.A.Y.Y. analyzed and interpreted the data. N.T.M.A.A. contributed to refining the theoretical framework, strengthening the interpretation of the results, and supporting the revision process in response to reviewers' comments. All authors have read and agreed to the published version of the manuscript.

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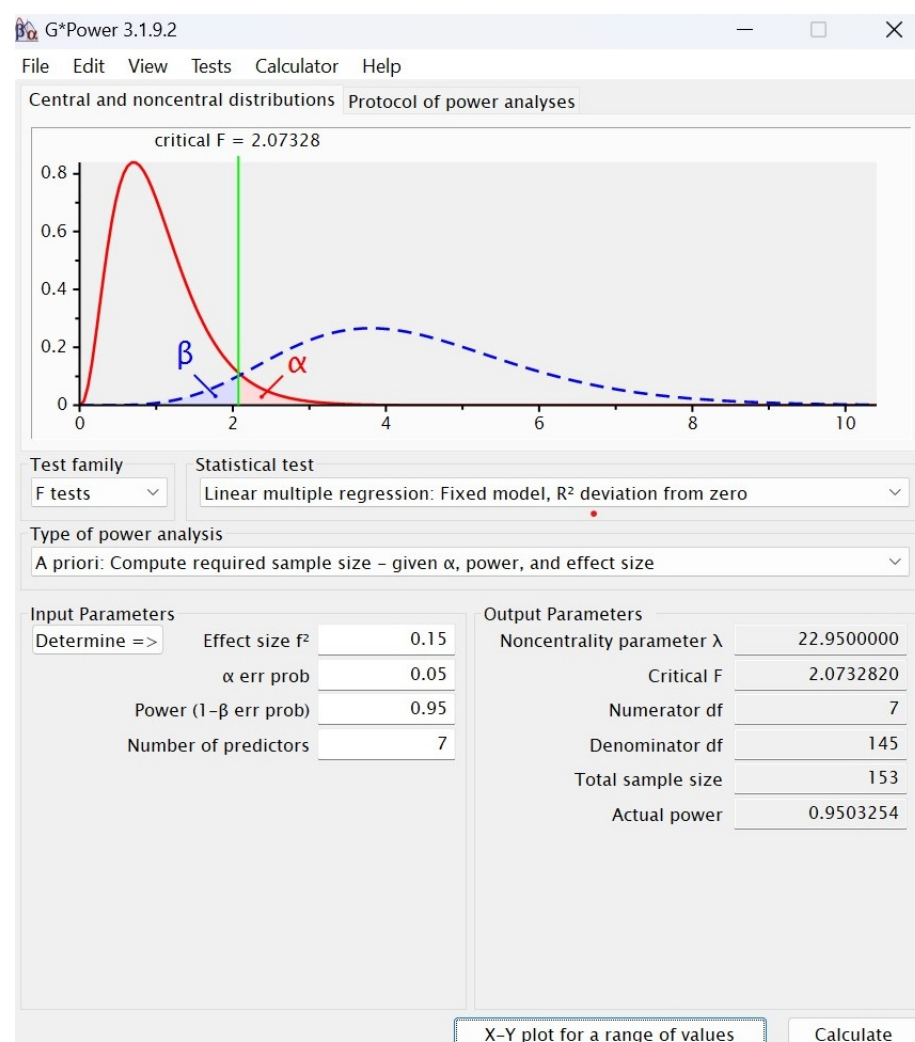
Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by bioethics committee of scientific and medical research, university of Jeddah (Project identification UJ-REC-283 and 29 October 2024 of approval).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

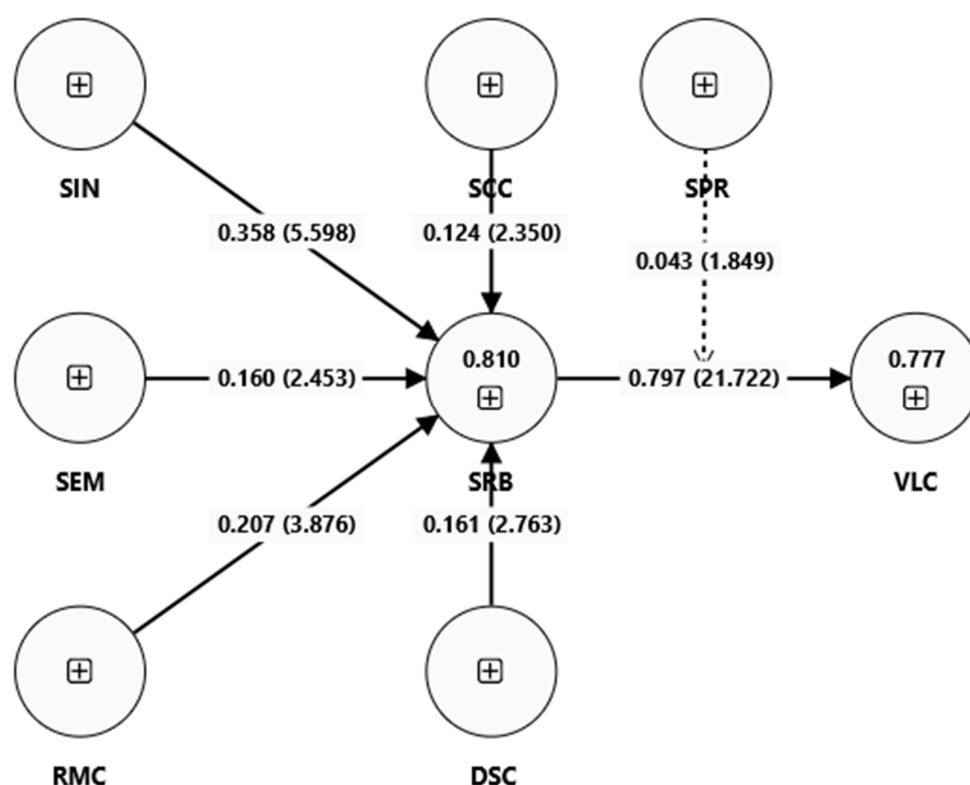
Data Availability Statement: The original data presented in the study are openly available in Zenodo at <https://zenodo.org/uploads/15229095> (accessed on 19 January 2026).

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Sample Size Computation



Appendix B. Results of the Hypotheses



Appendix C. Survey Questionnaire

Questionnaire Items

Supply chain disruption (DSC)

DSC1: Logistic firm is capable to deliver service in the face of disruption.

DSC2: Logistic firm ensures quality and operates efficiently during disruption.

DSC3: Firm ensures high level of inventory management during disruption.

Risk management capability (RMC)

RMC1: This firm has multiple sources to manage stock during disruption.

RMC2: This firm has alternative of transportation during disruption.

RMC3: This firm has ability to detect risk and maintain buffer stock.

Supply chain collaboration (SCC)

SCC1: This firm engages other supply chain partner to resolve issue.

SCC2: Logistic firm sets common goals with other stakeholder.

SCC3: Logistic firm has strong collaborative communication to solve issues.

Supply chain empowerment (SEM)

SEM1: In our logistic firm employees are encouraged to take new initiative.

SEM2: Employees are equally involved into decision making process.

SEM3: Logistic firm delegate authority to employee in the face of disruption.

Supply chain innovation (SIN)

SIN1: Logistic firm seeks out new ways to complete operations.

SIN2: Logistic firm continuously try new things to complete operations.

SIN3: Logistic firm solve problems through creative solutions.

Supportive HR practices (SPR)

SPR1: Our firm allows me to participate in decisions regarding my job.

SPR2: Our firm will reward employees with fair appraisal system.

SPR3: Our firm gives equal opportunity to learn new things through trainings.

Supply chain robustness (SRB)

SRB1: Logistic firm is capable to meet customer demand.

SRB2: Logistic firm has ability to Perform well in the face of disruption.

SRB3: Logistic firm can confront disruption without adaptation.

SRB4: Logistic firm is able to continue operations even in complex scenarios.

Supply chain velocity (VLC)

VLC1: Logistic firm is able to respond market changes quickly.

VLC2: Logistic firm is capable to confront environmental threats.

VLC3: Logistic firm quickly responds to catastrophic events.

VLC4: This logistic firm is able to respond disruption quickly.

Note: Bold and italicized headings represent latent constructs, while the listed items (e.g., DSC1–DSC3) represent the corresponding measurement items.

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