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Using the Binary Matrices for Modeling the Supply Chain Issues of Virtual Shops: An Evidence from Pakistan

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Abstract

The study aims at developing a list of supply chain issues in virtual shops and construct a hierarchal model of those supply chain issues with the purpose to prioritize them. It is also geared towards unfolding the inter-relationships of those issues. The research design entails comprehensive review of literature and qualitative analysis following the collection of primary data from panel of experts utilizing Interpretive Structural Modeling (ISM) coupled with Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) as a methodology, this paper intends to probe into the supply chain issues creating bottlenecks in virtual shops' operations. ISM is conducive to find the influential supply chain issues whereas MICMAC classifies and analyzes the supply chain issues based on their driving and dependence powers. The results of ISM point out that the supply chain issue 'data centers affected by natural disasters' is the most influential issue since it occupies bottom level of ISM model whereas supply chain issues 'long lead time' and 'customer unavailability' occupy top of ISM model being least critical. Results of MICMAC disclosed that issues 'high delivery costs', 'long lead time' and 'customer unavailability' are categorized as dependent whereas 'network errors' and 'data centers affected by natural disaster' are classified as independent. All the other issues are contained into linkage cluster while no supply chain issue is autonomous depicting that all the issues are relevant. Over the past few years, the extent of research on e-commerce logistics and supply chain has been increased. Most of the researches have been conducted to create awareness on the importance of logistics and supply chain in e-commerce industry. But the supply chain issues faced by virtual shops have not been comprehensively identified in any research till date. This study attempt to find those issues and prioritize them. The findings of the study provide understanding of most influential and most influenced supply chain issues so that the practitioners can set their priority actions. This study has contributed theoretically and possess practical implications for the stakeholders of virtual shops as well. In view of the fact that the study is conducted without financial assistance and data is collected from medium-sized panel in a field setting, the study is limited to an extent.

Keywords: Supply Chain, Issues, Virtual Shops, MICMAC, Interpretive Structural Modelling

1. Introduction

The accelerated growth in virtual shopping has entailed an upsurge in supply chain complexities. In an attempt to run the business operations while keeping the customer contented, the virtual shopkeepers have to encounter a multitude of supply chain issues. The entire e-commerce supply chain is put into operations even when an ordinary item is ordered. The supply chain network of a requested product comprises the flow of that product from manufacturer, wholesalers and distributors towards the end-user. Following the delivery of product at customer's door-step, the reverse logistics comes into action (Lamba et al., 2020). The supply chain issues arisen during the forward flow as well as reverse flow of product have the potential to draw virtual businesses towards innumerable complications such as unsatisfied customer and lost sales (Chen, Ulmer and Thomas, 2022). The knotty issues in the forward and reverse logistics if not untangled might unfavorably influence the virtual shops' operations (Xia & Niu, 2020). As long as the virtual shops' supply chain issues are not figured out it is unfeasible to craft the solutions. The repeated occurrence of issues is counterproductive for the virtual businesses executing their operations with limited investments. For consistent growth of virtual shops, sensible management of supply chain has become indispensable. Owing to the fact that supply chains are the backbone of virtual shops and e-commerce businesses, it is imperative to identify the supply chain issues specifically in the developing countries. The supply chain issues seem more bewildered and convoluted in developing countries where there are noteworthy discrepancies in level of facilities available across the national boundaries (Lamba et al., 2020). Undeniably, there is an ample literature accentuating the significance of e-commerce supply chains but to the best of our knowledge, no research has been conducted specifically to identify and prioritize the virtual shops' supply chain issues (He et al., 2022; Risberg, 2022). The viability of virtual shops is still uncertain and dubious despite of the fact that online shopping has been significantly accelerated after the COVID-19 pandemic reason being their supply chain issues are not gotten into grips so far (Cuong & Tien, 2022; Ding et al, 2022; Seuring, 2022). The research questions are i) what are the major supply chain issues in virtual shops ii) How they are inter-connected iii) what is the key issue. Hence, the focus of the study is research gap as the scope of study is to explore the supply chain issues in virtual shops. The study is helpful for the stakeholders of virtual shops including suppliers, online customers, virtual shopkeepers, research community, government, regulators and society at large. Objectives of this research are: i) to identify and hierarchize the supply chain issues, ii) to develop an interpretive model and find inter-relationships of issues iii) to classify the issues and find key issue iv) to make discussions and interpret the results keeping reality in view. Since the importance of supply chain management as backbone of virtual shops is undeniable, valuable insights regarding the virtual shops' supply chain issues are provided by this study. It also highlights leading and influencing factors and presents an interpretive model as well.

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Numerous methodologies that could be used in this study include Multi Attribute Border Approximation Area Comparison (Stojanović & Puška, 2021), Weighted Aggregated Sum Product Assessment (Stojić et al., 2018), Interruptive Ranking Process (Shojaei, Jajarmizadeh, & Esfandyari Mahni, 2018), Total Interpretive Structural Modeling (Mathivathanan et al., 2021), Additive Ratio Assessment (Liao, Wen, & Liu, 2019) and Level Based Weight Assessment (Ögel, Ecer, & Özgöz, 2022).

Among the plethora of methodological choices available, Interpretive Structural Modeling (ISM) is considered to be best suited to achieve the objectives as it is convenient for analyzing the entangled inter-relationships of variables. It is one of the best tools for qualitative analysis as it articulates the complicated inter-relationships of variables into explicit models (Warfield, 1973). ISM technique is justified to use as a methodology because this study involves a complex phenomenon and ISM outperforms statistical techniques in the phenomena like that of in hand. Mental models are captured and transformed into binary models which ultimately modified into graphical model utilizing the ISM. MICMAC is coupled with ISM as well. MICMAC has potential to verify the results of ISM and categorize the supply chain issues in classification diagram based on their driving and dependence power. The study is arranged into five sections i.e. section one provides the introduction, section two is the review of literature, section three throws light on the methodology, section four comprises of analysis, results & discussion and section five contains concluding remarks.

2. Literature Review

The relevant contemporary literature has been explored to set out the outset of the study. The review of literature helps regarding important developments and it has been attempted to account for all important studies on the phenomenon under consideration. For this purpose, google search engine is utilized to explore databases such as Wiley-Blackwell, Taylor & Francis, Emerald, JStor and Science-Direct. Different keywords are used such as supply chain, issues, reverse logistics, suppliers, online customers, virtual shops, ISM and MICMAC. Approximately, two hundred papers were examined and the most relevant are reported herein. Plethora of studies conducted worldwide regarding importance of e-commerce in developed as well as emerging countries i.e., on supplier selection in online retail by Kaushik et al. (2022), supply chain models in e-commerce by Wang et al. (2018), on supplier encroachment by Xia & Niu (2020). Archetti & Bertazzi (2021) found out the challenges in inventory routing. Kaushta, Devi & Chauhan (2022) analyzed the barriers in adopting drones for delivery in e-commerce. Naseem, Yang & Xiang (2021) attempted to evaluate the criteria for the selection of logistics services provider in e-commerce industry. Dutta et al., (2019) evaluated e-commerce supply chain risk management. The studies are somehow directly or indirectly related to e-commerce supply chain problems but to the best of our knowledge, the issues of supply chain have not been identified, listed and prioritized previously.

The phenomenon of supply chain management takes its start from procurement, raw material buying, material storage, its conversion to final product and ultimately delivering it to the end-user (Beamon, 1998). Alshurideh et al. (2022) considered the forecasting, production and disposal to be included as parts of supply chain management. Virtual shopping is the buying of a service or a product via internet using any website, mobile applications or social networking site. Most of the businesses have moved from traditional physical stores to virtual businesses and COVID-19 pandemic majorly played a role in this transition. Virtual businesses are crafting their ways leaps and bounds in the business markets. The virtual shops' supply chains are more vulnerable than orthodox supply chains reason being the involvement of more uncertainty and entangled networks (Dutta et al., 2019). Emerging as well as developed nations are overwhelmed by the e-commerce success whereas the logistics management has suffered unfavorably (Yu et al., 2017). The goal of businesses traditionally was to offer highest quality product ever offered whereas provision of high quality service in the form of quick delivery at correct location has become indispensable (Naseem, Yang & Xiang, 2021). To keep their existence in market, virtual shopkeepers spare no effort to outbrave the challenges of changing customer demands and dynamic business environment (Alkahtani et al., 2019). Despite the augmentation of turbulent supply chain issues in virtual shops, the research on the potential issues has not been holistically conducted, therefore the study aims at identifying the influential issues and prioritize them. Pourhejazy (2020) argued that holding the inventory for a long time becomes an issue when high costs are incurred. The substandard products when rejected by the customers are returned back, curtailed the further orders consequently piled up in the warehouses. Oftentimes, virtual shopkeepers confront third party frauds as they are heavily reliant on their services. Lack of resources and time constraints coerce the virtual businesses to outsource services of third party logistics providers. Negligence of third party logistics providers in the form of operational inefficiency, long lead times, poor product return handling and wrong deliveries potentially cause ignominy to the online businesses (Naseem, Yang & Xiang, 2021). It takes one unpleasant experience for the customer to switch to another brand (Tjahjaningsih, Ningsih & Utomo, 2020). Reverse logistics becomes a back-breaking supply chain issue for the virtual shops when high costs incurred reason being it involved the entire phenomenon of recycling, repackaging and transportation (Wei, Ma & Liu, 2021). Liu, He & Max Shen (2021) brought a multitude of last mile problems to light acknowledging last mile to be pivotal as per the fact that it is the final step in order fulfillment. Lack of infrastructure, government regulations, overcrowd in urban areas contribute to failed attempts in order delivery to customer from the last mile distribution hub. In developing countries, the imbalance between roads infrastructure and ever-increasing vehicles contribute towards inflating last mile problems (Janjevic & Winkenbach, 2020). Data centers and offices as the back-end of virtual shops' supply chains getting affected by natural disasters is another issues that is being ignored (Dutta et al., 2019). Moreover, customer frauds are causing economic losses to virtual shopkeepers. As the virtual shopping is increasing on a rapid pace, reverse logistics services have become more prone to fraudulent activities (Shih et al., 2021). List of supply chain issues in virtual shops are extracted from literature (Table 1).

Table 1: List of Supply Chain Issues (Literature Based)

Sr. no.	Factors	Source
1.	High Holding costs	(Pourhejazy, 2020)
2.	Longer Lead Times	(Kaushik et al., 2022)
3.	Customer's unavailability	(Escudero-Santana et al., 2022)
4.	Third party fraud risk	(Dutta et al., 2019)
5.	Reverse Logistics complexities	(Lamba et al., 2020)
6.	Poor product return handling	(Lamba et al., 2020)
7.	Lack of information sharing	(Dutta et al., 2019)
8.	Non-automated fulfillment centers	(Dutta et al., 2019)
9.	Customer frauds	(Shih et al., 2021)
10.	Lack of quality checks	(Dutta et al., 2019)
11.	Data centers affected by natural disasters	(Dutta et al., 2019)
12.	Network errors	(Dutta et al., 2019)
13.	Software bugs and errors	(Dutta et al., 2019)
14.	Supply interruptions	(Rodrigues, 2020)
15.	Managing multiple suppliers	(Ishizaka et al., 2022)
16.	Poor route planning	(Chen, Umer & Thomas, 2022)
17.	Customers' demand of same-day delivery	(Chen, Umer & Thomas, 2022)
18.	Conventional delivery mechanisms	(Benarbia & Kyamakya, 2021)
19.	Lack of modern delivery methods & infrastructure	(Benarbia & Kyamakya, 2021)
20.	High delivery costs	(Lee, Ko & Moon, 2022)
21.	Last-mile logistics	(Escudero-Santana, 2022)
22.	Order fulfillment	(Kaushik et al., 2022)
23.	Communication issues	(Hua & Jing, 2015)
24.	Delivery tracking	(Wang, Dang & Hsu, 2021)
25.	Shipment errors	(Dutta et al., 2019)

The list of supply chain issues extracted from the literature is refined by panel of experts and verified list of twenty-two issues is generated (Table 2) which help to conduct this study in order to address the issue.

Table 2: List of Supply Chain Issues Verified by Panel of Experts

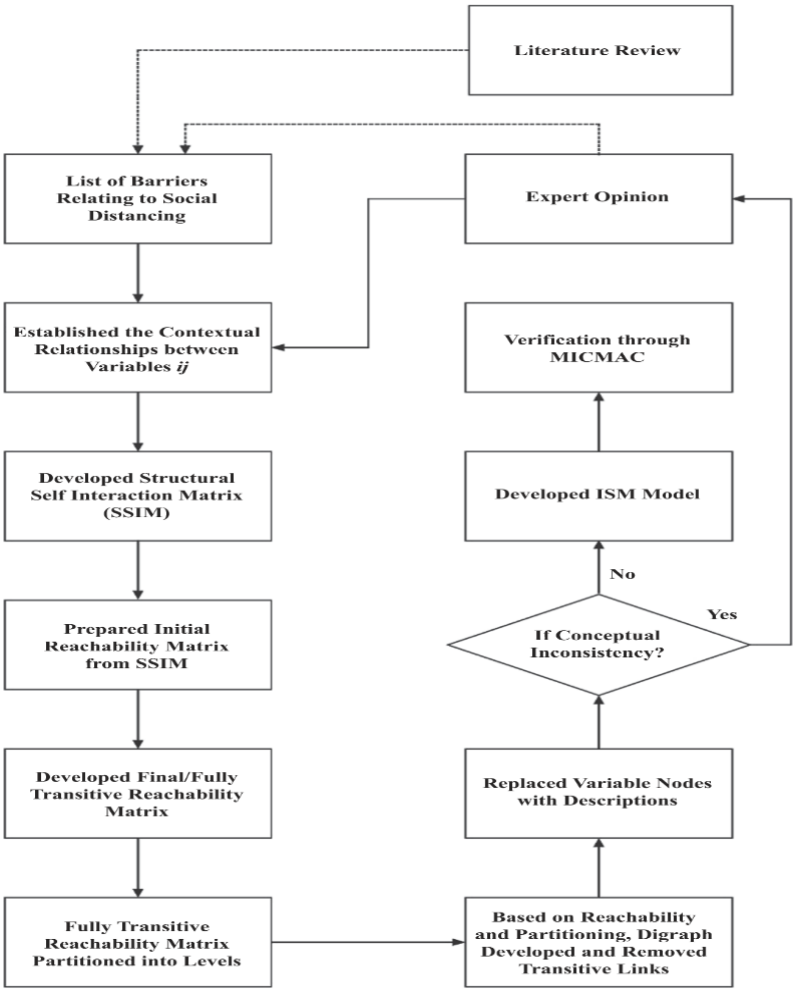
Sr. #	Issues	Experts												Sum
		1	2	3	4	5	6	7	8	9	10	11	12	
i.	High holding costs	√	x	√	√	√	√	√	x	√	√	x	√	9
ii.	Long lead time	√	√	x	√	√	√	√	x	√	√	√	x	9
iii.	Customer's unavailability	√	x	√	x	√	x	√	√	√	X	√	√	8
iv.	Third party fraud risk	x	√	√	√	√	√	√	√	√	√	√	x	10
v.	Reverse logistics complexities	√	√	√	√	√	√	x	x	x	√	√	√	9
vi.	Poor product return handling	√	√	√	√	√	√	√	√	√	√	√	√	12
vii.	*Lack of information sharing*	*x*	*x*	√	√	√	*x*	*x*	√	√	*X*	*x*	*x*	*5*
viii.	Non-automated fulfillment centers	√	√	√	x	x	√	√	x	√	√	√	√	9
ix.	*Customer frauds*	√	*x*	*x*	*x*	*x*	√	*x*	*x*	√	*X*	√	*x*	*4*
x.	Lack of quality checks	√	x	√	√	√	√	√	√	√	√	√	√	11
xi.	Data centers affected by natural disasters	√	x	x	√	√	√	√	√	√	√	x	√	9
xii.	Network errors	x	√	x	√	√	√	√	√	√	X	√	√	9
xiii.	Software bugs and errors	√	√	x	√	√	√	x	√	√	√	√	√	10
xiv.	Supply interruptions	√	√	√	√	√	x	√	√	√	√	x	√	10
xv.	Managing multiple suppliers	√	√	x	x	√	√	x	√	√	√	x	x	7
xvi.	Poor route planning	x	√	x	√	√	√	√	√	√	√	√	√	10
xvii.	*Customers' demand of same-day delivery*	*x*	*x*	*x*	√	√	*x*	√	√	√	*X*	*x*	*x*	*5*
xviii.	Conventional delivery mechanisms	√	√	x	√	√	√	√	√	√	√	√	x	10
xix.	Lack of modern delivery methods and infrastructure	√	√	x	x	√	√	√	√	√	X	x	√	8
xx.	High delivery costs	√	x	√	√	√	√	√	x	√	√	x	√	9
xxi.	Last-mile logistics	√	x	√	√	√	√	√	√	√	X	√	√	10
xxii.	Order fulfillment	√	√	x	√	√	x	√	√	√	√	√	√	10
xxiii.	Communication issues	x	√	√	√	√	√	√	√	√	√	√	x	10
xxiv.	Delivery Tracking	√	x	√	x	√	√	x	√	√	√	x	x	7
xxv.	Shipment errors	√	√	√	√	√	x	√	√	√	√	x	√	10

3. Methodology

Diverse multi-criteria decision-making (MCDM) techniques have been applied by numerous noteworthy studies in accordance with various decision criteria. Koshta, Devi and Chauhan (2022) utilized Grey-DEMATEL to analyze the barriers in adoption of drones for delivering healthcare items in rural areas. Lamba et al. (2020) ranked the hindrances of e-commerce reverse logistics supply chain deploying Fuzzy-AHP. BWM and VIKOR are deployed for the assessment of supplier selection criteria in virtual fashion industry (Kaushik et al., 2022). Bottlenecks to utilize block chain technology in logistics and supply chain are prioritized using TISM and MICMAC.

Since this study aims at bridging the gap by identifying the potential supply chain issues in virtual shops and analyzing their contextual relationships, none of the methodology is found appropriate except Interpretive Structural Modeling (ISM). The phenomenon under study entails variables having intricate inter-relationships. To develop comprehensive understanding regarding their direct and indirect relationships and describing them accurately, ISM is perceived to be best suited as researcher should make use of an appropriate methodology according to the nature and requirements of the study (Gay et al., 2006; Leedy & Ormrod, 2005; Issac & Michael, 1981). In this study, induction is used as an approach whereas interpretivism is the research philosophy. Based on primary data collected from a panel of experts, it is a qualitative study. The studies design comprises of identification of supply chain issues from literature review and collection of primary data for qualitative analysis (Fig 1)

Fig 1: Research design (Source: Abbass et al., 2021)



Population is the stake-holders of virtual shops i.e. the online customers, suppliers, virtual shop owners, researchers, international community, regulatory authorities and society at large. Non-probability based purposive sampling is used. Sample size is eighteen. The data is extracted on *VAXO* based matrix type questionnaire i.e. n(n-1)/2 from experts (Niazi, Qazi & Sandhu, 2019). The study uses approval voting combined with face-to-face, one-to-one, semi-structured, in-depth interviews for each pair of relations. Following steps are followed in this study as i) literature is reviewed for the identification of supply chain issues in virtual shops, ii) ISM is deployed for hierarchizing and structuring the relationships and iii) Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) is used for the graphical representation of issues into four quadrants as well as finding the key issue. To identify the factors, various methods are present such as Anecdotal Evidence from Literature (Azevedo, Carvalho & Cruz-Machado 2013), Interview Content Analysis (Xiao 2018), Presumed by Authors (Lohaus & Habermann 2019), Idea Engineering Workshops and Brainstorming Session (Kumar, Luthra & Haleem 2013)., Delphi Method (Bhosale & Kant 2016), Case Study (Li et al., 2019), Exploratory Factor Analysis (Li & Yang 2014), Meta-Analysis (Lohaus & Habermann 2019) and Experts' Opinion (Niazi, Qazi & Basit, 2019; Avinash, Sasikumar, & Murugesan 2018; Cai & Xia 2018) . Literature review is combined with experts' opinions to conduct this study. This research is built upon directed graph theory, set theory and Boolean algebra.

3.1. Panel of experts

A Panel of experts is constituted as it outperforms the statistical data gathered from masses. When data is either unreliable or limited, an experts' panel is constituted. 8-12 experts is an ideal size for the heterogeneous panel whereas 15-25 are ideally assigned to homogeneous panel following the ISM rules (Clayton, 1997; Jena et al., 2017). Heterogeneous panel of eighteen experts (Annexure A Table A1) is reckoned as optimum for this study as in-depth insights from academic experts and practitioners (having ten years of minimum experience) in the field of e-commerce and supply chain is essentially required. The panel consists of an associate professor and three assistant professors (holding Ph.D. degrees in supply chain) of sizable universities of Pakistan, a project director from National School of Public Policy, a team lead as well as a senior software engineer, e-commerce manager, digital marketing manager and a data scientist serving in an e-commerce platforms having a hands-on job for more than twelve years in industry, two suppliers, operations manager from a courier company, two virtual shop owners, an online customer, a respondent from international community and society at large. Approval voting is conducted with prospect respondents in a field setting in order to finalize the ISM questionnaire matrix and the supply chain issues. following the finalization of variables and matrix questionnaire, data is

elicited from experts in "one-to-one, face-to-face in-depth" interviews which took more than three months. *VAXO* symbols are used to take data on paired relations of supply chain issues at *ij* part of matrix questionnaire (Annexure C). Respondents were instructed i) to fill white cells leaving grey and the black, ii) leads to = contextual relationship, iii) column influences row, insert *A*, iv) row influences column, insert *V*, v) when column and row both influence each other simultaneously, insert *X*, vi) when no relation found to be existed between column and row, insert *O* (Niazi et al., 2020).

4. Analysis, Results and Discussion

4.1. Analysis

This section analyzes the supply chain issues in virtual shops using ISM with the purpose to build structural model and MICMAC diagram using MICMAC analysis.

4.2. Interpretive structural Modeling

Warfield (1973) devised the steps to develop ISM model. Data collected from experts is aggregated and SSIM is developed as shown in Table 3.

Table 3: Structural-Self Interaction Matrix (SSIM)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1		V	V	O	V	V	O	O	A	O	A	A	V	O	V	A	A	O	O	A	O	O
2			O	O	O	A	A	O	O	A	A	A	A	A	A	A	O	A	A	A	A	A
3				O	O	A	O	O	O	A	A	A	O	A	A	A	A	O	O	A	A	O
4					O	O	O	O	O	O	O	O	A	O	A	V	X	O	O	O	O	A
5						X	A	A	A	O	A	V	A	X	A	O	O	A	O	A	O	V
6							X	X	X	O	O	O	O	A	X	A	O	V	O	O	O	O
7								V	O	X	O	X	O	V	O	X	O	O	O	O	V	V
8									O	O	O	O	O	O	O	O	O	O	O	O	O	O
9										O	O	V	V	O	O	O	V	O	O	V	V	V
10											X	X	O	O	O	X	O	O	O	X	V	X
11												X	X	O	O	X	O	O	O	V	V	X
12													X	X	X	A	V	A	V	X	X	X
13														O	O	O	O	A	O	X	X	X
14															X	X	V	O	A	O	O	V
15																X	V	V	V	O	V	O
16																	V	V	V	V	X	X
17																		O	O	O	O	O
18																			X	O	O	O
19																				X	X	O
20																					V	X
21																						O
22																						

SSIM is transformed into initial reachability matrix in Table 4 by converting *VAXO* into binary digits i.e. 0 and 1.

Table 4: Initial Reachability Matrix

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1
6	0	1	1	0	1	1	1	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0
7	0	1	0	0	1	1	1	1	0	1	0	1	0	1	0	1	0	0	0	0	1	1
8	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	1	1	0	0	1	0	0	1	1	0	0	0	1	0	0	1	1	1
10	0	1	1	0	0	0	1	0	0	1	1	1	0	0	0	1	0	0	0	1	1	1
11	1	1	1	0	1	0	0	0	0	1	1	1	1	0	0	1	0	0	0	1	1	1
12	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	1	1	1	1
13	0	1	0	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1
14	0	1	1	0	1	1	0	0	0	0	0	1	0	1	1	1	1	0	0	0	0	1
15	0	1	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	0	1	0
16	1	1	1	0	0	1	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1
17	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
18	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0
19	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	0
20	1	1	1	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	1	1	1	1
21	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	1	0
22	0	1	0	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	1	0	1

Table 5: Final Reachability Matrix (Transitive Matrix)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Driving
1	1	1	1	1*	1	1	1*	1*	1*	0	1*	1*	1	1*	1	1*	1*	1*	1*	1*	1*	1*	**21**
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
4	1*	1*	1*	1	0	1*	1*	0	0	1*	1*	1*	0	1*	1*	1	1	1*	1*	1*	1*	1*	**18**
5	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1	**22**
6	1*	1	1	1*	1	1	1	1	1	1*	0	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1*	**21**
7	1*	1	1*	1*	1	1	1	1	1*	1	1*	1	1*	1	1*	1	1*	1*	1*	1*	1	1	**22**
8	0	1*	1*	0	1	1	1*	1	1*	0	0	1*	0	1*	1*	0	0	1*	0	0	0	1*	**12**
9	1	1*	1*	1*	1	1	1*	1*	1	1*	1*	1	1	1*	1*	1*	1	1*	1*	1	1	1	**22**
10	1*	1	1	1*	1*	1*	1	1*	0	1	1	1	1*	1*	1*	1	1*	1*	1*	1	1	1	**21**
11	1	1	1	1*	1	1*	1*	0	0	1	1	1	1	1*	1*	1	1*	1*	1*	1	1	1	**20**
12	1	1	1	1*	1*	1*	1	1*	0	1	1	1	1	1	1	1*	1	1*	1	1	1	1	**21**
13	1*	1	1*	1	1	1*	1*	0	0	1*	1	1	1	1*	1*	1*	1*	0	1*	1	1	1	**19**
14	1*	1	1	1*	1	1	1*	1*	1*	1*	1*	1	1*	1	1	1	1	1*	1*	1*	1	1	**22**
15	1*	1	1	1	1	1	1*	1*	1*	1*	1*	1	1*	1	1	1	1	1	1	1*	1	1*	**22**
16	1	1	1	1*	1*	1	1	1*	1*	1	1	1	1*	1	1	1	1	1	1	1	1	1	**22**
17	1	1*	1	1	1*	1*	0	0	0	0	0	0	1*	0	1*	1*	1	0	0	0	0	0	**10**
18	1*	1	1*	1*	1	1*	1*	0	0	1*	1*	1	1	1*	1*	0	1*	1	1	1*	1*	1*	**19**
19	1*	1	1*	0	1*	1*	0	0	0	1*	0	1*	1*	1	1*	1*	1*	1	1	1	1	1*	**17**
20	1	1	1	1*	1	1*	1*	0	0	1	1*	1	1	1*	1*	1*	1*	1	1	1	1	1	**20**
21	1*	1	1	1*	1*	1*	1*	0	0	1*	1*	1	1	1*	1*	1	1*	1*	1	1*	1	1*	**20**
22	1*	1	1*	1	1*	1*	1*	0	0	1	1	1	1	1*	1*	1	1*	1*	1*	1	1*	1	**20**
Dependence	**19**	**21**	**21**	**18**	**19**	**20**	**18**	**11**	**9**	**17**	**16**	**19**	**18**	**19**	**20**	**18**	**19**	**18**	**18**	**18**	**18**	**19**	**393**

Transitive relations in initial reachability matrix are checked scientifically using MS Excel Software. 0's are replaced by 1* where transitive relations existed. As a result, final reachability matrix is developed in Table 5.

As formulated by Warfield (1973), standard iteration method is followed to partition transitive matrix into levels which are represented in (Annexure D Table D1-D10). Conical matrix is prepared using permutation method. ISM model is deduced on diagonals of conical matrix in grey cells. For brevity, a concise depiction of ISM is represented in Table 6. The Table 6 shows the supply chain issues at their respective levels along with their driving-dependence powers. The issues with high driving power are at the bottom whereas ones with high dependence power are at the top.

Table 6: Abridged Representation of ISM

			Reachability																						
	Level	Code	2	3	6	15	17	12	14	19	20	21	22	4	7	5	13	18	8	11	1	16	10	9	
	Level I	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Level II	6	1	1	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1*	1	1	0	1*	1*	1*	1	21
		15	1	1	1	1	1	1	1	1	1*	1	1*	1	1*	1	1*	1	1*	1*	1*	1	1*	1*	22
		17	1*	1	1*	1*	1	0	0	0	0	0	0	1	0	1*	1*	0	0	0	1	1*	0	0	10
	Level III	12	1	1	1*	1	1	1	1	1	1	1	1	1*	1	1*	1	1*	1*	1	1	1*	1	0	21
		14	1	1	1	1	1	1	1	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1*	1*	1	1*	1*	22
		19	1	1*	1*	1*	1*	1*	1	1	1	1	1*	0	0	1*	1*	1	0	0	1*	1*	1*	0	17
		20	1	1	1*	1*	1*	1	1*	1	1	1	1	1*	1*	1	1	1*	0	1*	1	1*	1	0	20
Antecedent		21	1	1	1*	1*	1*	1	1*	1	1*	1	1*	1*	1*	1*	1	1*	0	1*	1*	1	1*	0	20
		22	1	1*	1*	1*	1*	1	1*	1*	1	1*	1	1	1*	1*	1	1*	0	1	1*	1	1	0	20
	Level IV	4	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1	1*	0	0	1*	0	1*	1*	1	1*	0	18
		7	1	1*	1	1*	1*	1	1	1*	1*	1	1	1*	1	1	1*	1*	1	1*	1*	1	1	1*	22
	Level V	5	1*	1*	1	1*	1*	1	1	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	22
		13	1	1*	1*	1*	1*	1	1*	1*	1	1	1	1	1*	1	1	0	0	1	1*	1*	1*	0	19
	Level VI	18	1	1*	1*	1*	1*	1	1*	1	1*	1*	1*	1*	1*	1	1	1	0	1*	1*	0	1*	0	19
	Level VII	8	1*	1*	1	1*	0	1*	1*	0	0	0	1*	0	1*	1	0	1*	1	0	0	0	0	1*	12
		11	1	1	1*	1*	1*	1	1*	1*	1	1	1	1*	1*	1	1	1*	0	1	1	1	1	0	20
	Level VIII	1	1	1	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1*	1*	1*	1	1*	0	1*	21
		16	1	1	1	1	1	1	1	1	1	1	1	1*	1	1*	1*	1	1*	1	1	1	1	1*	22
	Level IX	10	1	1	1*	1*	1*	1	1*	1*	1	1	1	1*	1	1*	1*	1*	1*	1	1*	1	1	0	21
	Level X	9	1*	1*	1	1*	1	1	1*	1*	1	1	1	1*	1*	1	1	1*	1*	1*	1	1*	1*	1	22
		Dependence	21	21	20	20	19	19	19	18	18	18	19	18	18	19	18	18	11	16	19	18	17	9	393

Dependence

Driving

ISM Model commonly known as directed graph is constructed in accordance with the results of level partitioning (fig 2). ISM model shows that supply chain issue coded as 2 and 3 occupy top-level i.e. *level I*. Issue 6, 15 and 17 occupy *level II*. Issue 12, 14, 19, 20, 21 and 22 occupy *level III*. Issue 4 and 7 occupy *level IV*. Issue 5 and 13 occupy middle level i.e. *level V*. Issue 18 occupy *level VI*. Issue 8 and 11 occupy *level VII*. The issue 1 and 16 occupy lower middle level i.e. *level VIII*. Finally, the issue 10 and 9 are positioned at *level IX* and *level X* respectively.

4.3. MICMAC Analysis

With the application of classical MICMAC analysis, driving-depending diagram (Fig. 3) is developed from transitive matrix using a scale-centric approach (Godet 1986).

MICMAC graph show that issues (1, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21 and 22) are represented in linkage cluster, issues (2, 3 and 17) are classified in dependent, issues (8 and 9) fall in independent cluster whereas none of the issues is categorized in autonomous cluster depicting the relevance of supply chain issues to the phenomenon under while most of the issues are agile as evident from their presence in linkage cluster.

With the admittance of heavy traffic on e-commerce websites, existence of virtual shops has become indispensable to keep businesses alive. The problem under examination is the identification, analysis and categorization of mystified issues that have been branched into the supply chains of virtual shops. Therefore, the study is designed with the objective to identify those issues using literature review in combination with experts' approval voting, hierarchize them using ISM and classify them deploying MICMAC method. Databases such as Wiley-Blackwell, Taylor & Francis, Emerald, JStor and Science-Direct are explored using Google as search engine to review the literature and resultantly twenty-five issues that have been penetrated into virtual shops' supply chains were identified (Table 1). Out of twenty-five issues, twenty-two retained after taking experts' opinion (Table 2). Conforming to the rules of ISM, the least critical issues fell at the top of the model whereas those having high driving power occupied bottom of ISM model being most critical. Customer's unavailability (3) and long lead time (2) having low driving power occupy *level I* of ISM hierarchy. The bottom of ISM i.e. *level X* is occupied by issue 'data centers affected by natural disasters (9)' having high driving power in fact. Conventional delivery mechanisms (15), poor product return handling (6) and high delivery costs (17) are the issues settled at *level II*. The upper middle level i.e. *level III* is occupied by five supply chain issues namely 'supply interruptions (12), 'poor route planning (14), 'order fulfillment (19)', 'communication issues (20), delivery tracking problem (21) and 'shipment errors (22). At *level IV*, two supply chain issues are positioned i.e. 'non-automated fulfillment centers (7) and 'third-party fraud risk (4). 'Reverse logistics complexities (5)' and 'managing multiple suppliers (13)' are placed at the

middle i.e. *level V*. 'Last mile logistics (18)' is at *level VI*, 'lack of quality checks (8)', 'software bugs & errors (11)' at *level VII*. 'High holding costs (1)' and 'lack of modern delivery methods & infrastructure (16)' occupy *level VIII*.

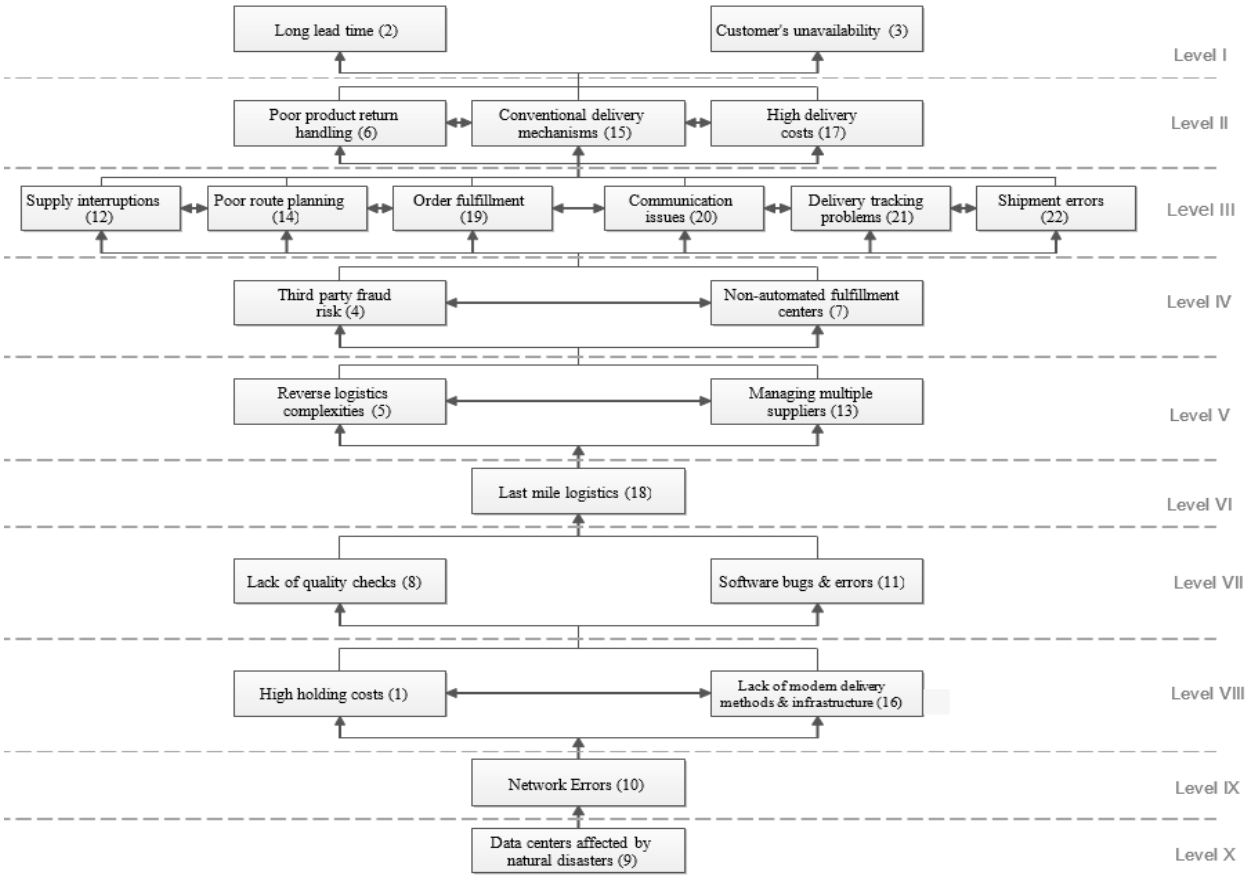


Fig 2: ISM Model (Source: Constructed by Authors)

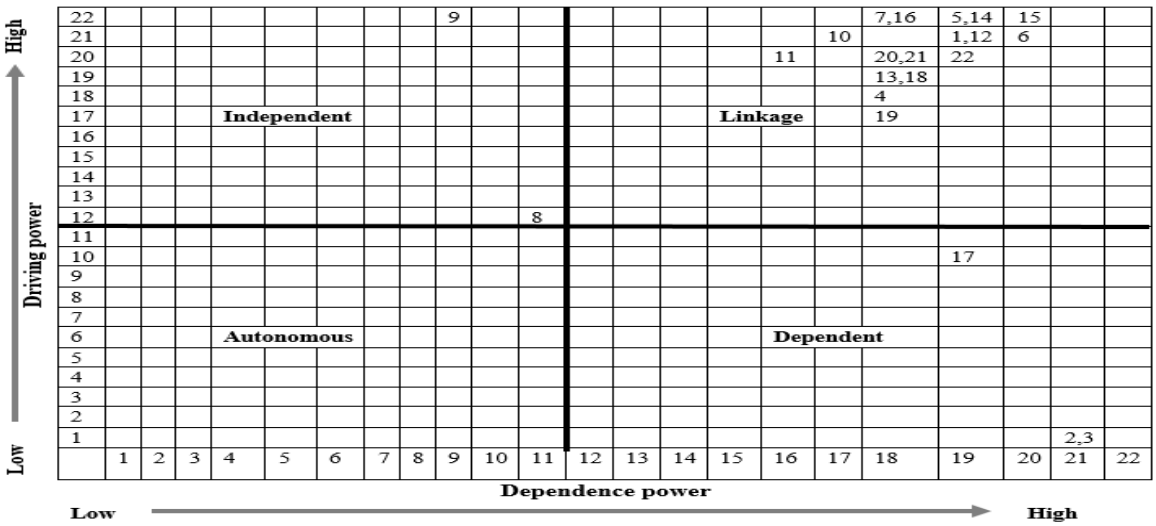


Fig 3: MICMAC Analysis

Network errors (10) is positioned at *level IX* whilst at the bottom of ISM model, the most critical issue having power to drive the system i.e. 'data centers affected by natural disasters (9)' is present. The results of MICMAC analysis deliver a driving-dependence diagram illustrating the relationship and relative importance of supply chain issues. There exists no supply chain issue that is to be categorized into autonomous quadrant according to MICMAC analysis. Issues 'long lead time (2)', 'customer unavailability' (3) and 'high delivery costs (17)' fall into dependent cluster which means that these are not the core supply chain issues but indirectly affect the supply chains of virtual shops and the intensity of effect is dependent on numerous other issues in fact. 'Lack of quality check (8)' and 'data centers affected by natural disasters' pose less dependence and high driving power which is the reason for their representation in dependent quadrant. Supply chain issues 'poor route planning (14)', 'non-automated fulfillment centers (7), 'conventional delivery mechanisms (15)', 'communication issues (20)', 'software bugs and errors (11)', 'reverse logistics complexities (5), 'high holding costs (1)',

'network errors (10)', 'third party fraud risk (4)', 'supply interruptions (12)', 'poor product return handling (6)', 'managing multiple suppliers (13)', 'lack of modern delivery methods and infrastructure (16)', 'order fulfillment (19)', 'delivery tracking (21)', 'shipment errors (22)', and 'last mile logistics (18)' being agile and ambivalent fall in linkage quadrant. The summary of results is represented in Table 7.

Table 7: Summary Results of Literature, MICMAC and ISM

	Results of Literature Review Ratified by Experts	Results of MICMAC Analysis				ISM Results	
No.	**Issue**	**Driving**	**Dependence**	**Effectiveness**	**Cluster**	**Level**	**Comments**
1	High holding costs	21	19	2	Linkage	VIII	
2	Long lead time	1	21	-20	Dependent	I	
3	Customer's unavailability	1	21	-20	Dependent	I	
4	Third party fraud risk	18	18	0	Linkage	IV	
5	Reverse logistics complexities	22	19	3	Linkage	V	
6	Poor product return handling	21	20	1	Linkage	II	
7	Non-automated fulfillment centers	22	18	4	Linkage	IV	
8	***Lack of quality checks***	***12***	***11***	***1***	***Independent***	***VII***	***Key Factor***
9	***Data centers affected by natural disasters***	***22***	***9***	***13***	***Independent***	***X***	***Key Factor***
10	Network errors	21	17	4	Linkage	IX	
11	Software bugs and errors	20	16	4	Linkage	VII	
12	Supply interruptions	21	19	2	Linkage	III	
13	Managing multiple suppliers	19	18	1	Linkage	V	
14	Poor route planning	22	19	3	Linkage	III	
15	Conventional delivery mechanisms	22	20	2	Linkage	II	
16	Lack of modern delivery methods & infrastructure	22	18	4	Linkage	VIII	
17	High delivery costs	10	19	-9	Dependent	II	
18	Last-mile logistics	19	18	1	Linkage	VI	
19	Order fulfillment	17	18	-1	Linkage	III	
20	Communication issues	20	18	2	Linkage	III	
21	Delivery Tracking	20	18	2	Linkage	III	
22	Shipment errors	20	19	1	Linkage	III	

Results of literature review, ISM analysis and MICMAC are summarized in Table 7. The issues coded as 8 and 9 i.e. 'lack of quality checks' and 'data centers affected by natural disasters' respectively, are identified as key factors. Both are independent and can potentially affect other factors. 'customer's unavailability (3)' and 'long lead time (2)' are least affective and are dependent as well.

5. Discussion

The study aims to explore and explain the pivotal issues that have become bottlenecks virtual shops' supply chain and build an interpretive relationship-based structural model. A hierarchal model and driving-dependence diagram come to the fore resultantly. Into six parts, discussion is divided i.e. discussion regarding i) study results, ii) comparison of study with existing contemporary literature iii) practical implication of the study iv) theoretical contributions, v) limitations and vi) future recommendations.

5.1. Discussion on Results of the study

Literature is reviewed in order to dig out list of issues prevailing in supply chains of virtual shops and consequently multifold of them were identified, verified by the experts later on (Table 2). The list backed the structural formation of a model underlying the phenomenon. ISM is used as a modeling technique. In ISM model, the most influential and the most influenced issues lie at the bottom-level and top-level respectively. A ten-level ISM model is obtained. Supply chain issue 'long lead time (2)' and 'customer's unavailability (3)' are found at *level I* reason being they are most influenced. It can be inferred from the result that these two supply chain issues are not the pivotal ones and are not at level inter-related. They may indirectly impact the system as they might be influenced by other critical issues. *Level II* consists of three issues i.e. 'conventional delivery mechanisms (15)', 'poor product return handling (6)' and 'high delivery costs (17)'. These are somehow influential comparative to the *level I* issues. Using conventional methods i.e. delivering products by roads incur high costs and the returned product might not be handled with much care as well. Moving towards *level III* which is occupied by five supply chain issues i.e. 'shipment errors (22)', 'delivery tracking problems (21)', 'communication issues (20)', 'poor product return handling (14)', 'order fulfillment (19)', 'poor route planning (14)' and 'supply interruptions (12)'. As these reside at one of the upper middle levels of ISM, their potential to impact the system increases as we move from top to bottom. 'Non-automated fulfillment centers (7)' and 'third party fraud risk (4)' are at *level IV* moderately affecting the system. 'Managing multiple suppliers (13)' and 'reverse logistics complexities (5)' settled at *level V* considered to be middle level issues, possessing the power to drive and driven by other issues. 'Last mile logistics (18)' is solely placed at *level VI*. The substandard products returned to virtual shops might be the reason of lack in quality checks (Dutta et al., 2019). Thereof, 'lack of quality checks (8)' and 'software bugs & errors (11)' are at *level VII* as software errors pose difficulties in order placement and its order delivery. The influencing power starts to shoot up while moving down in ISM model. 'Lack of modern deliver methods & infrastructure (16)' and 'high holding costs (1)' occupy *level VIII*. 'Network errors (10)' and 'data centers affected by natural disaster (9)' being at *level IX* and *level X* respectively should be gotten into grips on immediate bases in order to get rid of hindrances in virtual shops' supply chains. The e-commerce is still evolving and data centers being the backend of virtual shops and their supply chains must not be at the risk of being damaged by natural disasters (Dutta et al., 2019).

In addition, MICMAC analysis put forth a driving-dependence diagram illustrating relationship and importance of issues comparative to each other. The issues which do not affect the supply chain positively or negatively are represented in autonomous quadrant. Issues 'long lead time (2)', 'high delivery costs (17)' and 'customer unavailability (3)' fall into dependent cluster which means that these are not the core supply chain issues and having negligible driving power to individually disrupt the system. The cluster i.e. linkage is having the ambivalent issues, simultaneously having high driving and dependence power. Those categorized as linkage are 'poor route planning (14)', 'non-automated fulfillment

centers (7)', 'conventional delivery mechanisms (15)', 'communication issues (20)', 'software bugs and errors (11)', 'reverse logistics complexities (5)', 'high holding costs (1)', 'network errors (10)', 'third party fraud risk (4)', 'supply interruptions (12)', 'poor product return handling (6)', 'managing multiple suppliers (13)', 'lack of modern delivery methods and infrastructure (16)', 'order fulfillment (19)', 'delivery tracking (21)', 'shipment errors (22)', and 'last mile logistics (18). The most influential issues, possibly the root cause of virtual shops' supply chain problems are 'lack of quality check (8)' and 'data centers affected by natural disasters (9)' classified as dependent. 'Lack of quality checks (8) and 'data centers affected by natural disasters (9)' possess high effectiveness and are key issues.

5.2. Discussion on Comparison of the study with contemporary literature

This research study can be compared to the contemporary literature. Some of the studies are given in Table 8

Table 8: Comparison of results of the present study with prior studies in the literature

Study	Focus	Country	Factors	Results	Method
In hand	Supply chain issues in virtual shops	Pakistan	22	Data centers affected by natural disasters is the key factor	ISM
Koshta, Devi & Chauhan (2022)	Barriers to adoption of delivery drones	India	13	Lack of government regulations is the most critical factor	Grey-DEMATEL
Kaushik et al. (2022)	Criteria for supplier selection in e-commerce fashion industry	India	38	Just in time (JIT) capabilities, billing flexibility, order flexibility, technical soundness, return policies are the most preferred criteria	BWM and VIKOR
Kaur et al. (2018)	Barriers in managing green supply chain	Canada	36	Knowledge, product design and commitment related barriers are the most critical	DEMATEL
Lamba et al. (2020)	Ranking the barriers in reverse logistics e-commerce supply chain	India	16	Lack of investment in reverse logistics topmost barrier	Fuzzy-AHP
Mathivathanan et al. (2021)	Hindrances to the adoption of block chain technologies in supply chain	India	9	Unfamiliarity with technology and unclear benefits are most influential barriers	TISM and MICMAC

Results of this study are unique and different from others like it uses different data collection and data analysis methods. It is discrete on the basis of context and variables involved. Kaushik et al. (2022) evaluated criteria for a suitable supplier selection in context of e-commerce fashion industry, study being conducted in India using BWM and VIKOR as methodology. They found five criteria to be most critical (Table 8). Mathivathanan et al. (2021) deployed modified form of ISM i.e. TISM plus MICMAC to uncover bottlenecks of block chain adoption in supply chain with nine variables in Indian context. Non-clarity of benefits and lack of familiarity with technology are found top barriers analogous to results. Lack of investment emerged as pivotal barrier when Fuzzy-AHP is brought into use to prioritize barriers in e-commerce reverse logistics with sixteen variables by (Lamba et al., 2020). Koshta, Devi & Chauhan (2022) conducted research to dig out barriers in the way of adopting drones for delivery and used Grey-DEMATEL. They found lack of government regulations as key factor. Kaur et al. (2018) identified knowledge, product design and commitment related barriers to be most pivotal hindrances in implementation of green supply chain with the help of DEMATEL method. This study is different as it is conducted with twenty-two variables (supply chain issues). A different data collection and data analysis method is used. Moreover, it has contributed differently in practical and theoretical domains. The study is conducted in Pakistan.

5.3. Discussion on practical implications

The virtual shopkeepers, supply chain managers can prioritize their actions while attempting to get rid of supply chain issues as the highly significant and least important of those are identified and listed here in this study. The research in particular shows the key issue, therefore, to keep the backend of supply chain and virtual shops strong, data centers must be made resistant to the natural disasters. Prior research must be conducted by regulatory authorities on geographical locations while setting up data centers. Since, Lack of quality checks is another key issue, hence the virtual shopkeepers should communicate their concerns to the suppliers and manufacturers in order to avoid recurring returns. Network errors, software bugs & errors being two bottom level issues must be looked upon. In this regard, training sessions can be arranged to make employees develop skill sets required to tackle these issues. Managers can incorporate prioritized practices by assessing issues individually based on their position in hierarchy. It develops understanding about issues in online buyers, international community and society at large. The study is helpful in tactical eradication of supply chain issues on the road to gain competitive advantage in virtual businesses.

5.4. Discussion on theoretical contributions

This study provides myriad of theoretical contributions. First of all, this study gives a logical order to the supply chain issues valuable for both virtual shop owners and supply chain managers. Neither of the existing studies have yet explored and hierarchized the virtual shops' supply chain issues nor build their contextual relationships using an interpretive approach ISM and MICMAC. The categorization of issues into different cluster help researchers recognize their nature. Another theoretical contribution is the use of novel and accepted methodologies i.e. ISM and MICMAC.

5.5. Discussion on limitations

The study has some limitations like it is conducted with twenty-two variables. There might be other more critical issues. The data is collected from eighteen experts in Pakistan. Therefore, the generalizability is limited. It is methodologically limited as well. Weights are not assigned to the issues in order to represent their importance comparative to each other. The model developed as a result of ISM analysis is not tested afterwards. Additionally, the respondents are not provided with any financial assistance which can cause biased opinions.

5.6. Discussion on future recommendations

It is recommended to incorporate a more comprehensive list of supply chain issues. The study also recommends to use Wavelet analysis, Delphi methods and modified forms of ISM i.e. TISM. SEM can be used to validate the results in future studies. It is suggested to constitute a panel of experts from all over the world in order to increase generalizability. The experience of researchers and practitioners can be included with the incorporation of Grey weights-based MICMAC analysis. The future studies are recommended to be funded by some institution.

5.7. Contributions of the study

The study contributed an ISM model on issues related to virtual shops' supply chains. A MICMAC graph and novel information about the issues is also contributed along with the discussion on inter-relationships of issues.

6. Conclusion

By admitting the inflating growth of virtual business and their increasing supply chain issues, the study holds great significance for the virtual shopkeepers, suppliers and third party logistics service providers craving to eliminate the issues in their supply chains. The problem under study is to explore, analyze, hierarchize and categorize the mystified issues undesirably affecting the supply chains. Therefore, taking the problem into consideration, this study attempts to identify, organize the issues, construct a relationship based interpretive model, develop understanding and make careful discussions regarding its implications keeping reality in view. Literature review is conducted in combination with experts' approval voting to identify the potential issues. Interpretive Structural Modeling (ISM) is deployed to place the issues at respective levels, give them priority ranking, generate hierarchy and MICMAC is utilized for the partitioning of supply chain issues into four quadrants corresponding to their driving-dependence potential. According to results of literature review, twenty-two supply chain issues contribute to the unsatisfactory performance of virtual shops.

Results of ISM shows Customer's unavailability (3) and long lead time (2) occupy *level I* of ISM hierarchy. The bottom of ISM i.e. *level X* is occupied by issue 'data centers affected by natural disasters (9)'. Conventional delivery mechanisms (15), poor product return handling (6) and high delivery costs (17) are the issues positioned at *level II*. The upper middle level i.e. *level III* is occupied by five supply chain issues i.e. 'supply interruptions (12), 'poor route planning (14), 'order fulfillment (19)', 'communication issues (20), delivery tracking problem (21) and 'shipment errors (22). At *level IV*, two supply chain issues are ranked i.e. 'non-automated fulfillment centers (7) and 'third-party fraud risk (4). 'Reverse logistics complexities (5)' and 'managing multiple suppliers (13) are placed at the middle i.e. *level V*. 'Last mile logistics (18) occupy *level VI*, 'lack of quality checks (8)', 'software bugs & errors' at level *VII*. 'High holding costs (1) and 'lack of modern delivery methods & infrastructure (16) occupy *level VIII*. 'Network errors (10)' lies at *level IX* whereas *level X* is occupied by the most pivotal supply chain issue i.e. 'data centers affected by natural disasters (9) which possesses the power to drive the system.

According to MICMAC results, issues 'long lead time (2)', 'high delivery costs (17)' and 'customer unavailability (3)' fall into dependent cluster. Those categorized as linkage are 'poor route planning (14)', 'non-automated fulfillment centers (7), 'conventional delivery mechanisms (15)', communication issues (20)', 'software bugs and errors (11)', 'reverse logistics complexities (5), 'high holding costs (1)', 'network errors (10)', 'third party fraud risk (4)', 'supply interruptions (12)', 'poor product return handling (6)', 'managing multiple suppliers (13)', 'lack of modern delivery methods and infrastructure (16)', 'order fulfillment (19)', 'delivery tracking (21)', 'shipment errors (22)', and 'last mile logistics (18). These are having disruption potential along with stability provision potential. The most influential issues, possibly the root cause of virtual shops' supply chain problems are 'lack of quality check (8)' and 'data centers affected by natural disasters (9)' classified as dependent. 'Lack of quality checks (8) and 'data centers affected by natural disasters (9)' possess high effectiveness and are key issues. The autonomous cluster is unoccupied. The overall analysis indicates that all of the issues under investigation are relevant and the system as a whole is unbalanced, requiring attention on immediate basis.

The study theoretically contributed as it explored cardinal supply chain issues affecting virtual shops operations. It contributed an ISM model, simplified representation of complicated inter-relationships of issues, comparative discussions and MICMAC diagram. It is significant for the practitioners as well who desire to prioritize their actions while making strategies to brush off those supply chain issues. The study is beneficial for the e-commerce platforms and virtual shop owners in need of setting priorities to embark on the roads of unmatched superior quality service providers.

ISM techniques does not quantify the relative importance of factors, therefore, the study provides a future direction to apply TOPSIS, AHP, Fuzzy-AHP, GRA and SEM etc. The future studies can use PCA technique in order to explore more potential issue that might have been overlooked in this study. The generalizability of the study is limited to some extent reason being the collection of data from virtual shops' stakeholders in Pakistan. To broaden the generalizability, the opinions of both virtual shops and supply chain stakeholders can be taken from all over the world in future.

References

Abbass, K., Niazi, A. A. K., Qazi, T. F., Basit, A., & Song, H. (2021). The aftermath of COVID-19 pandemic period: barriers in implementation of social distancing at workplace. *Library Hi Tech*.

AlKahtani, M., Rehman, A. U., Al-Zabidi, A., & Choudhary, A. (2019). Agile supply chain assessment: an empirical study on concepts, research and issues. *Arabian Journal for Science and Engineering*, *44*(3), 2551-2565.

Alshurideh, M. T., Al Kurdi, B., Alzoubi, H. M., Ghazal, T. M., Said, R. A., AlHamad, A. Q., ... & Al-kassem, A. H. (2022). Fuzzy assisted human resource management for supply chain management issues. *Annals of Operations Research*, 1-19

Archetti, C., & Bertazzi, L. (2021). Recent challenges in Routing and Inventory Routing: E-commerce and last-mile delivery. *Networks*, *77*(2), 255-268.

Avinash A., Sasikumar P., & Murugesan A. (2018). Understanding the interaction among the barriers of biodiesel production from waste cooking oil in India-an interpretive structural modeling approach. Renewable energy, 127, 678–684.

Azevedo, S., Carvalho, H., & Cruz-Machado, V. (2013). Using interpretive structural modelling to identify and rank performance measures: an application in the automotive supply chain. *Baltic Journal of Management*.

Beamon, B. M. (1998). Supply chain design and analysis:: Models and methods. *International journal of production economics*, *55*(3), 281-294**.**

Benarbia, T., & Kyamakya, K. (2021). A literature review of drone-based package delivery logistics systems and their implementation feasibility. *Sustainability*, *14*(1), 360

Bhosale, V. A., & Kant, R. (2016). An integrated ISM fuzzy MICMAC approach for modelling the supply chain knowledge flow enablers. *International Journal of Production Research*, *54*(24), 7374-7399.

Cai Y., & Xia C. (2018). Interpretive Structural Analysis of Interrelationships among the Elements of Characteristic Agriculture Development in Chinese Rural Poverty Alleviation. Sustainability, 10(3), 786.

Chen, X., Ulmer, M. W., & Thomas, B. W. (2022). Deep Q-learning for same-day delivery with vehicles and drones. *European Journal of Operational Research*, *298*(3), 939-952.

Clayton, M. J. (1997). Delphi: a technique to harness expert opinion for critical decision-making tasks in education. *Educational psychology*, *17*(4), 373-386.

Cuong, T. H., & Tien, N. H. (2022). Application of ICT in Logistics and Supply Chain in post-Covid-19 economy in Vietnam. *International Journal of Multidisciplinary Research and Growth Evaluation*, *3*(1), 493-451.

Ding, C., Liu, L., Zheng, Y., Liao, J., & Huang, W. (2022). Role of Distribution Centers Disruptions in New Retail Supply Chain: An Analysis Experiment. *Sustainability*, *14(*11), 6529.

Dutta, P., Suryawanshi, P., Gujarathi, P., & Dutta, A. (2019). Managing risk for e-commerce supply chains: an empirical study. *IFAC-PapersOnLine*, *52*(13), 349-354.

Escudero-Santana, A., Muñuzuri, J., Lorenzo-Espejo, A., & Muñoz-Díaz, M. L. (2022). Improving E-Commerce Distribution through Last-Mile Logistics with Multiple Possibilities of Deliveries Based on Time and Location. *Journal of Theoretical and Applied Electronic Commerce Research*, *17*(2), 507-521

Gay, L. R., Mills, G. E., & Airasian, P. (2006). edition 8. *Educational research: Competencies for analysis and analysis and applications. Upper Saddle River, NJ. Pearson Education*.

Godet, M. (1986). Introduction to la prospective: seven key ideas and one scenario method. *futures*, *18*(2), 134-157.

He, P., He, Y., Tang, X., Ma, S., & Xu, H. (2022). Channel encroachment and logistics integration strategies in an e-commerce platform service supply chain. *International Journal of Production Economics*, *244*, 108368.

Hua, W., & Jing, Z. (2015). An empirical study on e-commerce logistics service quality and customer satisfaction. *WHICEB Proceeding*, 269-275.

Isaac, S., & Michael, W. B. (1981). Handbook in research and evaluation: For education and the behavioral sciences.

Ishizaka, A., Khan, S. A., Kheybari, S., & Zaman, S. I. (2022). Supplier selection in closed loop pharma supply chain: a novel BWM–GAIA framework. *Annals of Operations Research*, 1-24.

Janjevic, M., & Winkenbach, M. (2020). Characterizing urban last-mile distribution strategies in mature and emerging e-commerce markets. *Transportation Research Part A: Policy and Practice*, *133*, 164-196.

Jena, J., Sidharth, S., Thakur, L. S., Pathak, D. K., & Pandey, V. C. (2017). Total interpretive structural modeling (TISM): approach and application. *Journal of Advances in Management Research*.

Kaur, J., Sidhu, R., Awasthi, A., Chauhan, S., & Goyal, S. (2018). A DEMATEL based approach for investigating barriers in green supply chain management in Canadian manufacturing firms. *International Journal of Production Research*, *56*(1-2), 312-332.

Kaushik, V., Kumar, A., Gupta, H., & Dixit, G. (2022). A hybrid decision model for supplier selection in Online Fashion Retail (OFR). *International Journal of Logistics Research and Applications*, *25*(1), 27-51.

Koshta, N., Devi, Y., & Chauhan, C. (2022). Evaluating Barriers to the Adoption of Delivery Drones in Rural Healthcare Supply Chains: Preparing the Healthcare System for the Future. *IEEE Transactions on Engineering Management*.

Kumar, S., Luthra, S., & Haleem, A. (2013). Customer involvement in greening the supply chain: an interpretive structural modeling methodology. *Journal of Industrial Engineering International*, *9*(1), 1-13.

Lamba, D., Yadav, D. K., Barve, A., & Panda, G. (2020). Prioritizing barriers in reverse logistics of E-commerce supply chain using fuzzy-analytic hierarchy process. *Electronic Commerce Research*, *20*(2), 381-403.

Lee, J., Ko, C., & Moon, I. (2022). E-commerce supply chain network design using on-demand warehousing system under uncertainty. *International Journal of Production Research*, 1-27.

Leedy, P. D., & Ormrod, J. P. (2005). Practical research–planning and design 8th Edn Pearson. *Upper Saddle River, NJ*.

Li, G., Huang, D., Sun, C., & Li, Y. (2019). Developing interpretive structural modeling based on factor analysis for the water-energy-food nexus conundrum. *Science of The Total Environment*, *651*, 309-322.

Li, M., & Yang, J. (2014). Analysis of interrelationships between critical waste factors in office building retrofit projects using interpretive structural modelling. *International Journal of Construction Management*, *14*(1), 15-27.

Liao, H., Wen, Z., & Liu, L. (2019). Integrating BWM and ARAS under hesitant linguistic environment for digital supply chain finance supplier section. *Technological and Economic Development of Economy*, *25*(6), 1188-1212.

Liu, S., He, L., & Max Shen, Z. J. (2021). On-time last-mile delivery: Order assignment with travel-time predictors. *Management Science*, *67*(7), 4095-4119.

Lohaus, D., & Habermann, W. (2019). Presenteeism: A review and research directions. *Human Resource Management Review*, *29*(1), 43-58.

Mathivathanan, D., Mathiyazhagan, K., Rana, N. P., Khorana, S., & Dwivedi, Y. K. (2021). Barriers to the adoption of blockchain technology in business supply chains: a total interpretive structural modelling (TISM) approach. *International Journal of Production Research*, *59*(11), 3338-3359.

Naseem, M. H., Yang, J., & Xiang, Z. (2021). Selection of Logistics Service Provider for the E-Commerce Companies in Pakistan Based on Integrated GRA-TOPSIS Approach. *Axioms*, *10*(3), 208.

Niazi A. A. K., Qazi T. F., & Basit A. (2019). An Interpretive Structural Model of Barriers in Implementing Corporate Governance (CG) in Pakistan. Global Regional Review, 4(1) 359–375.

Niazi, A. A. K., Qazi, T. F., & Sandhu, K. Y. (2019). Uncovering the Myths of TQM in Readymade Garment Sector of Pakistan: An Interpretive Structural Modeling Approach. *Review of Economics and Development Studies*, *5*(3), 531-540.

Niazi, A. A. K., Qazi, T. F., Ali, I., & Ahmad, R. (2020). Prioritizing determinants of effective whistle blowing (WB): Interpretative structural modeling approach. *International Journal of Law and Management*, *62*(3), 213-230.

Ögel, İ. Y., Ecer, F., & Özgöz, A. A. (2022). Identifying the leading retailer-based food waste causes in different perishable fast-moving consumer goods' categories: application of the F-LBWA methodology. *Environmental Science and Pollution Research*, 1-17.

Pourhejazy, P. (2020). Destruction decisions for managing excess inventory in e-commerce logistics. *Sustainability*, *12*(20), 8365.

Risberg, A. (2022). A systematic literature review on e-commerce logistics: Towards an e-commerce and omni-channel decision framework. *The International Review of Retail, Distribution and Consumer Research*, 1-25.

Seuring, S., Brandenburg, M., Sauer, P. C., Schünemann, D. S., Warasthe, R., Aman, S., ... & Khalid, R. U. (2022). Comparing regions globally: impacts of COVID-19 on supply chains–a Delphi study. *International Journal of Operations & Production Managemen*t.

Shih, D. H., Huang, F. C., Chieh, C. Y., Shih, M. H., & Wu, T. W. (2021). Preventing return fraud in reverse logistics—A case study of ESPRES solution by Ethereum. *Journal of Theoretical and Applied Electronic Commerce Research*, *16*(6), 2170-2191.

Shojaei, P., Jajarmizadeh, M., & Esfandyari Mahni, M. (2018). Evaluating and Prioritizing Barriers of Implementation Green Supply Chain by Using Interpretive Ranking Process (IRP) Case: South Electric Power Generation Company). *Journal of Executive Management*, *9*(18), 63-88.

Stojanović, I., & Puška, A. (2021). Logistics performances of gulf cooperation council's countries in global supply chains. *Decision Making: Applications in Management and Engineering*, *4*(1), 174-193.

Stojić, G., Stević, Ž., Antuchevičienė, J., Pamučar, D., & Vasiljević, M. (2018). A novel rough WASPAS approach for supplier selection in a company manufacturing PVC carpentry products. *Information*, *9*(5), 121.

Tjahjaningsih, E., Ningsih, D. H. U., & Utomo, A. P. (2020). The effect of service quality and product diversity on customer loyalty: The role of customer satisfaction and word of mouth. *The Journal of Asian Finance, Economics and Business*, *7*(12), 481-490.

Wang, C. N., Dang, T. T., & Hsu, H. P. (2021). Evaluating sustainable last-mile delivery (LMD) in B2C E-commerce using two-stage fuzzy MCDM approach: A case study from Vietnam. *IEEE Access*, *9*, 146050-146067.

Wang, Y., Jia, F., Schoenherr, T., & Gong, Y. (2018). Supply chain-based business model innovation: the case of a cross-border E-commerce company. *Sustainability*, *10*(12), 4362.

Warfield, J. N. (1973). Binary matrices in system modeling. *IEEE Transactions on Systems, Man, and Cybernetics*, (5), 441-449.

Wei, L., Ma, Z., & Liu, N. (2021). Design of reverse logistics system for B2C e-commerce based on management logic of internet of things. *International Journal of Shipping and Transport Logistics*, *13*(5), 484-497.

Xia, J., & Niu, W. (2020). A perspective on supplier encroachment in the era of e-commerce. *Electronic Commerce Research and Applications*, *40* 100924.

Xiao, L. (2018). Analyzing consumer online group buying motivations: An interpretive structural modeling approach. *Telematics and Informatics*, *35*(4), 629-642.

Yu, Y., Wang, X., Zhong, R. Y., & Huang, G. Q. (2017). E-commerce logistics in supply chain management: Implementations and future perspective in furniture industry. *Industrial Management & Data Systems*, *117*(10), 2263-2286.

Annexure A: Profile of Panel of Experts

Table A1: Profile of Panel of Experts

Sr.	Designation	Organization	Education	Experience
1	Associate Professor	Punjab University Lahore	PhD	16 years
2	Assistant Professor	UET Lahore	PhD	10 years
3	Assistant professor	UMT Lahore	PhD	14 years
4	Assistant professor	LCWU	PhD	10 years
5	Project Director	National School of Public Policy	Masters	11 years
6	Team Lead	Daraz.pk	Masters	12 years
7	E-commerce Manager	Daraz.pk	Graduation	10 years
8	Senior Software Engineer	Daraz.pk	Graduation	10 years
9	Data Engineer	OLX	Graduation	10 years
10	CEO	BGT Mobile Accessories	Graduation	11 years
11	CEO	IT Zone Electronics	Graduation	13 years
12	Manager Digital Marketing	TEKHQS	Masters	12 years
13	Manager Operations	TCS	Masters	10 years
14	Online customer	-	Graduation	10 years
15	International community(Canadian national)	-	Graduation	10 years
16	One of the citizens of Pakistan (senior citizen) Doctor	Indus Hospital	MBBS, FCPS	11 years
17	Proprietor Virtual Shop	D Mart (using platform of daraz.pk)	Graduation	5 years
18	Proprietor Virtual Shop	Pak Accessories (using platform of daraz.pk)	Graduation	5 years

Annex B: Survey for the Verification of Supply Chain Issues

Respected respondent, I am the student of MBA at Institute of Business and Management (IB&M) University of Engineering and Technology, Lahore. I am doing my research thesis on above mentioned topic, using interpretive structural modeling. From initial literature review I prepared a list of possible supply chain issues of virtual shops for that I need a confirmation by experts. I seek you considered opinion as expert in this behalf.

If you agree to participate, please fill the following table. You are requested to evaluate as to whether the issue is relevant, important and necessary to be studied. If your answer is yes, please write "Y" otherwise write "N" in blank column. You may suggest to add, delete, alter, merge or change any factor at the space provided under table.

Sr.	Issues	Description	Yes/No
1	High holding costs	High costs incurred when inventory not sold for long time includes depreciation, obsolete inventory, rental and personnel cost etc.	
2	Longer lead time	When the order is placed relatively longer time is taken by the order fulfillment center to deliver the product.	
3	Customer's unavailability	Customer not available (temporarily or permanent) at the locations specified in the shipping address.	
4	Third party fraud risk	The third party can commit fraud by supplying low quality, fake or used products to the customers that untimely affects the repute of the virtual shop being run with all good intentions.	
5	Reverse logistics complexities	Reverse logistics becomes complex when different parties are involved in handling the products returned by the customers.	
6	Poor product return handling	When the product is returned by the customer, it is handled carelessly, unwillingly or unfriendly by the third party or supplier.	
7	Lack of information sharing	There is clearly lack of real time information sharing that how the events are happening or things rolling out in exact.	
8	Non-automated fulfillment centers	It reflects on virtual shops if the supplier or third party lacks access to modern technologies' based systems like Enterprise Resource Planning (ERP) or Electronic Data Interchange (EDI).	
9	Customer frauds	Customers' also have faking aptitudes and can make frauds in different forms say by returning stolen or damaged goods etc.	
10	Lack of quality checks	Poor quality of product by the supplier results in more product returns any resultantly damage image of virtual shops.	
11	Data centers affected by natural disasters	The data centers/stores providing 24/7 connectivity with the customers may be affected by natural disasters such as earth quacks or floods and do not attain priority in rehabilitation activities.	
12	Network errors	Supply is directly affected by network errors include the slow network, weak signals, VLAN or VPN issues but customers and other stakeholders do not appreciate.	
13	Software bugs and errors	Supply is affected by software bugs and errors, unexplained coding errors resulting in mismanaged inventory, delivery and payment etc. that could not be appreciated by stakeholders particularly by customers of virtual shops.	
14	Supply interruptions	The interruption of supply due to any reason even beyond the control of virtual vendors is not accepted/admitted by the customers.	
15	Managing multiple suppliers	The issue of complexity arises, when products are made available to the customer through different and multiple suppliers.	
16	Poor route planning	Poor route planning that causes delay in delivery due to assignment of one vehicle to multiple locations.	
17	Customer's demand of same-day-delivery	Delivering orders same day to every customer is not possible whereas the customers are always desirous of same-day-delivery.	
18	Conventional delivery mechanisms	Conventional method (i.e. by road delivery method is used by the delivery service providers) that obviously takes time and raises complexity.	
19	Lack of modern delivery methods and infrastructure	Modern delivery infrastructure such as drone charging stations and drone landing stations are absent.	
20	High delivery costs	Due the current price hike production, packaging, storage and delivery involve high costs that virtual shops being at primitive stage may be unable to afford.	
21	Last-mile logistics	This refers to transporting the merchandize to its final destination from nearest center of distribution that involves full fledge infrastructure that presently virtual shops lack, in fact.	
22	Order fulfillment	Order fulfilment becomes an issue when more orders are placed than the forecasted.	
23	Communication issues	Lack of proper communication between supplier, customer, virtual seller and courier services is an issue.	
24	Delivery tracking	Complexity arises while keeping track of different delivery services used by different suppliers	
25	Shipment errors	Errors that occur while packaging the product and/or when picking up by the delivery services providers.	

Suggestions (to add, delete, alter, merge or change any factor/issue**):**

_____

_____

Personal information (Optional)
Name: _____ Designation: _____
Organization: _____
Experience: _____ Contact number: _____

Thank you for your participation and contribution in research study.

Maryam Aziz
Research Scholar
Institute of Business and Management,
University of Engineering and Technology, G. T, Road, Lahore

Annexure C: Survey for the Determination of Relationships
Using the Binary Matrices for Modeling the Supply Chain Issues of Virtual Shops; An Evidence from Pakistan

Approximately 30 minutes required to fill

Questionnaire

- We are conducting research regarding "supply chain issues in virtual shops"
- Your input will be a great contribution in our research work and this information will be used for research purpose only.
- The data will be used in combined statistical statements.

Section 1: Personal information
Name: _____
Designation: _____
Organization: _____
Address: _____
Phone: _____

Demographics: (Please tick the relevant box)

Gender	**Male** ☐ **Female** ☐	**Marital status**	**Married** ☐ **Single** ☐
Age group	21-30 ☐ 31-40 ☐ 41-50 ☐ Above 50 ☐	**Qualification**	Less than 14 years ☐ -years ☐ Above 16 years ☐ 16years ☐
Income (in thousands)	< 40 ☐ 40-80 ☐ 81-100 ☐ 101-200 ☐ 201-300 ☐ Above 300 ☐	**Experience**	Up to 5 years ☐ 5-10 years ☐ 10-15 years ☐ above 15 ☐

Section 2: Research Questionnaire

1. Fill only white cell.
2. Contextual relationship "leads to"
3. What to enter in the white cells?

- Enter V when the row influences the column
- Enter A when the column influences the row
- Enter O when there is no relation between the row and the column
- Enter X when row and column influence each other

4. Definition/description of each determinant is given in annexure for ready reference of respondents.

Code	Issues	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	High holding costs																						
2	Long lead time																						
3	Customer's unavailability																						
4	Third party fraud risk																						
5	Reverse logistics complexities																						
6	Poor product return handling																						
7	Non-automated fulfillment centers																						
8	Lack of quality checks																						
9	Data centers affected by natural disasters																						
10	Network errors																						
11	Software bugs and errors																						
12	Supply interruptions																						
13	Managing multiple suppliers																						
14	Poor route planning																						
15	Conventional delivery mechanisms																						
16	Lack of modern delivery methods and infrastructure																						
17	High delivery costs																						
18	Last-mile logistics																						
19	Order fulfillment																						
20	Communication issues																						
21	Delivery Tracking																						
22	Shipment errors																						

Annexure D: Level Partitions

Table D1: Level-I Partitioning

Code	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,9,11,12,13,14,15,16,17,18,19,20,21	
2	2	1,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22	2	**I**
3	3	1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22	3	**I**
4	1,2,3,4,6,7,10,11,12,14,15,16,17,18,19,20,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,17,18,20,21,22	1,4,6,7,10,11,12,14,15,16,17,18,20,21,22	
5	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,21,22	1,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22	1,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22	
6	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18,19,20 ,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,8,9,10,12,13,14,15,16,17,18,19,20,21,22	
7	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,20,21,22	
8	2,3,5,6,7,8,9,12,14,15,18,22	1,5,6,7,8,9,10,12,14,15,16	5,6,7,8,9,12,14,15	
9	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,21,22	1,5,6,7,8,9,14,15,16	1,5,6,7,8,9,14,15,16	
10	1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19,20,21,22	4,5,6,7,9,10,11,12,13,14,15,16,18,19,20,21,22	4,5,6,7,10,11,12,13,14,15,16,18,19,20,21,22	
11	1,2,3,4,5,6,7,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,7,9,10,11,12,13,14,15,16,18,20,21,22	1,4,5,7,10,11,12,13,14,15,16,18,20,21,22	
12	1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22	1,4,5,6,7,8,10,11,12,13,14,15,16,18,19,20,21,22	
13	1,2,3,4,5,6,7,10,11,12,13,14,15,16,17,19,20,21,22	1,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20,21,22	1,5,6,7,10,11,12,13,14,15,16,17,19,20,21,22	
14	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22	
15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21, 22	
16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,17,19,20,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,17,19,20,21,22	
17	1,2,3,4,5,6,13,15,16,17	1,4,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,13,15,16,17	
18	1,2,3,4,5,6,7,10,11,12,13,14,15,17,18,19,20,21,22	1,4,5,6,7,8,9,10,11,12,14,15,16,18,19,20,21,22	1,4,5,6,7,10,11,12,14,15, 18,19,20,21,22	
19	1,2,3,5,6,10,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,18,19,20,21,22	1,5,6,10,12,13,14,15,16, 18,19,20,21,22	
20	1,2,3,4,5,6,7,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,18,19,20,21,22	1,4,5,6,7,10,11,12,13,14, 15,16,18,19,20,21,22	
21	1,2,3,4,5,6,7,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,18,19,20,21,22	1,4,5,6,7,10,11,12,13,14, 15,16,18,19,20,21,22	
22	1,2,3,4,5,6,7,10,11,12,13,14,15,16,17,18,19,20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22	1,4,5,6,7,10,11,12,13,14, 15,16,18,19,20,21,22	

Table D2: Level-II Partitioning

Code	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19, 20,21, 22	1,4,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20,21, 22	1,4,5,6,7,9,11,12,13, 14,15,16,17,18,19,20,21	
4	1,4,6,7,10,11,12,14,15,16,17,18,19,20,21, 22	1,4,5,6,7,9,10,11,12,13,14,15,16,17,18,20,21,22	1,4,6,7,10,11,12,14, 15,16,17,18,20,21,22	
5	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20, 21,22	1,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21, 22	1,5,6,7,8,9,10,11,12, 13,14,15,16,17,18,19,20,21,22	
6	1,4,5,6,7,8,9,10,12,13,14,15,16,17,18,19, 20,21, 22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 21,22	1,4,5,6,7,8,9,10,12,13,14,15,16,17,18,19,20, 21,22	**II**
7	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20, 21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,20,21, 22	
8	5,6,7,8,9,12,14,15,18,22	1,5,6,7,8,9,10,12,14,15,16	5,6,7,8,9,12,14,15	
9	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20, 21,22	1,5,6,7,8,9,14,15,16	1,5,6,7,8,9,14,15,16	
10	1,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19 ,20,21,22	4,5,6,7,9,10,11,12,13,14,15,16,18,19,20,21,22	4,5,6,7,10,11,12,13, 14,15,16,18,19,20,21,22	
11	1,4,5,6,7,10,11,12,13,14,15,16,17,18,19,2 0,21,22	1,4,5,7,9,10,11,12,13,14,15,16,18,20,21,22	1,4,5,7,10,11,12,13, 14,15,16,18,20,21,22	
12	1,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19 ,20,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21, 22	1,4,5,6,7,8,10,11,12, 13,14,15,16,18,19,20,21,22	
13	1,4,5,6,7,10,11,12,13,14,15,16,17,19,20,2 1,22	1,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20,21, 22	1,5,6,7,10,11,12,13, 14,15,16,17,19,20,21,22	
14	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20, 21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21, 22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20, 21,22	
15	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20, 21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20, 21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,21,22	**II**
16	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20, 21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,17,19,20,21,2 2	1,4,5,6,7,9,10,11,12, 13,14,15,16,17,19,20,21, 22	
17	1,4,5,6,13,15,16,17	1,4,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20,2 1, 22	1,4,5,6,13,15,16,17	**II**
18	1,4,5,6,7,10,11,12,13,14,15,17,18,19,20,2 1,22	1,4,5,6,7,8,9,10,11,12,14,15,16,18,19,20,21,22	1,4,5,6,7,10,11,12,14, 15,18,19,20,21,22	
19	1,5,6,10,12,13,14,15,16,17,18,19,20,21,2 2	1,4,5,6,7,9,10,11,12,13,14,15,16,18,19,20,21,2 2	1,5,6,10,12,13,14,15,16,18,19,20,21,22	
20	1,4,5,6,7,10,11,12,13,14,15,16,17,18,19,2 0,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,18,19,20,21,2 2	1,4,5,6,7,10,11,12,13,14,15,16,18,19,20,21,2 2	
21	1,4,5,6,7,10,11,12,13,14,15,16,17,18,19,2 0,21,22	1,4,5,6,7,9,10,11,12,13,14,15,16,18,19,20,21,2 2	1,4,5,6,7,10,11,12,13,14,15,16,18,19,20,21,2 2	
22	1,4,5,6,7,10,11,12,13,14,15,16,17,18,19,2 0,21,22	1,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21, 22	1,4,5,6,7,10,11,12,13,14,15,16,18,19,20,21,2 2	

Table D3: Level-III Partitioning

Code	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,4,5,7,8,9,11,12,13,14,16,18,19,20,21,22	1,4,5,7,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,9,11,12,13,14,16,18,19,20,21	
4	1,4,7,10,11,12,14,16,18,19,20,21,22	1,4,5,7,9,10,11,12,13,14,16,18,20,21,22	1,4,7,10,11,12,14,16,18,20,21,22	
5	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	
7	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,8,9,10,11,12,13,14,16,18,20,21,22	1,4,5,7,8,9,10,11,12,13,14,16,18,20,21, 22	
8	5,7,8,9,12,14,18,22	1,5,7,8,9,10,12,14,16	5,7,8,9,12,14	
9	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,5,7,8,9,14,16	1,5,7,8,9,14,16	
10	1,4,5,7,8,10,11,12,13,14,16,18,19,20,21,22	4,5,7,9,10,11,12,13,14,16,18,19,20,21,22	4,5,7,10,11,12,13,14,16,18,19,20,21,22	
11	1,4,5,7,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,9,10,11,12,13,14,16,18,20,21,22	1,4,5,7,10,11,12,13,14,16,18,20,21,22	
12	1,4,5,7,8,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,8,10,11,12,13,14,16,18,19,20,21,22	**III**
13	1,4,5,7,10,11,12,13,14,16,19,20,21,22	1,5,7,9,10,11,12,13,14,16,18,19,20,21,22	1,5,7,10,11,12,13,14,16,19,20,21,22	
14	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20, 21,22	**III**
16	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,9,10,11,12,13,14,16,19,20,21,22	1,4,5,7,9,10,11,12,13,14,16,19,20,21,22	
18	1,4,5,7,10,11,12,13,14,18,19,20,21,22	1,4,5,7,8,9,10,11,12,14,16,18,19,20,21,22	1,4,5,7,10,11,12,14,18,19,20,21,22	
19	1,5,10,12,13,14,16,18,19,20,21,22	1,4,5,7,9,10,11,12,13,14,16,18,19,20,21,22	1,5,10,12,13,14,16,18,19,20,21,22	**III**
20	1,4,5,7,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,10,11,12,13,14,16,18,19,20,21,22	**III**
21	1,4,5,7,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,10,11,12,13,14,16,18,19,20,21,22	**III**
22	1,4,5,7,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,8,9,10,11,12,13,14,16,18,19,20,21,22	1,4,5,7,10,11,12,13,14,16,18,19,20,21,22	**III**

Table D4: Level-IV Partitioning

Code	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,4,5,7,8,9,11,13,16,18	1,4,5,7,9,10,11,13,16,18	1,4,5,7,9,11,13,16,18	
4	1,4,7,10,11,16,18	1,4,5,7,9,10,11,13,16,18	1,4,7,10,11,16,18	**IV**
5	1,4,5,7,8,9,10,11,13,16,18	1,5,7,8,9,10,11,13,16,18	1,5,7,8,9,10,11,13,16,18	
7	1,4,5,7,8,9,10,11,13,16,18	1,4,5,7,8,9,10,11,13,16,18	1,4,5,7,8,9,10,11,13,16,18	**IV**
8	5,7,8,9,18	1,5,7,8,9,10,16	5,7,8,9	
9	1,4,5,7,8,9,10,11,13,16,18	1,5,7,8,9,16	1,5,7,8,9,16	
10	1,4,5,7,8,10,11,13,16,18	4,5,7,9,10,11,13,16,18	4,5,7,10,11,13,16,18	
11	1,4,5,7,10,11,13,16,18	1,4,5,7,9,10,11,13,16,18	1,4,5,7,10,11,13,16	
13	1,4,5,7,10,11,13,16	1,5,7,9,10,11,13,16,18	1,5,7,10,11,13,16,	
16	1,4,5,7,8,9,10,11,13,16,18	1,4,5,7,9,10,11,13,16	1,4,5,7,9,10,11,13,16	
18	1,4,5,7,10,11,13,18	1,4,5,7,8,9,10,11,16,18	1,4,5,7,10,11,18	

Table D5: Level-V Partitioning

Code	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,5,8,9,11,13,16,18	1,5,9,10,11,13,16,18	1,5,9,11,13,16,18	
5	1,5,8,9,10,11,13,16,18	1,5,8,9,10,11,13,16,18	1,5,8,9,10,11,13,16,18	**V**
8	5,8,9,18	1,5,8,9,10,16	5,8,9	
9	1,5,8,9,10,11,13,16,18	1,5,8,9,16	1,5,8,9,16	
10	1,5,8,10,11,13,16,18	5,9,10,11,13,16,18	5,10,11,13,16,18	
11	1,5,10,11,13,16,18	1,5,9,10,11,13,16,18	1,5,10,11,13,16	
13	1,5,10,11,13,16	1,5,9,10,11,13,16,18	1,5,10,11,13,16,	**V**
16	1,5,8,9,10,11,13,16,18	1,5,9,10,11,13,16	1,5,9,10,11,13,16	
18	1,5,10,11,13,18	1,5,8,9,10,11,16,18	1,5,10,11,18	

Table D6: Level-VI Partitioning

Code	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,8,9,11,16,18	1,9,10,11,16,18	1,9,11,16,18	
8	8,9,18	1,8,9,10,16	8,9	
9	1,8,9,10,11,16,18	1,8,9,16	1,8,9,16	
10	1,8,10,11,16,18	9,10,11,16,18	10,11,16,18	
11	1,10,11,16,18	1,9,10,11,16,18	1,10,11,16	
16	1,8,9,10,11,16,18	1,9,10,11,16	1,9,10,11,16	
18	1,10,11,18	1,8,9,10,11,16,18	1,10,11,18	**VI**

Table D7: Level-VII Partitioning

Code	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,8,9,11,16	1,9,10,11,16	1,9,11,16	
8	8,9	1,8,9,10,16	8,9	**VII**
9	1,8,9,10,11,16	1,8,9,16	1,8,9,16	
10	1,8,10,11,16	9,10,11,16	10,11,16	
11	1,10,11,16	1,9,10,11,16	1,10,11,16	**VII**
16	1,8,9,10,11,16	1,9,10,11,16	1,9,10,11,16	

Table D8: Level-VIII Partitioning

Code	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,9,16	1,9,10,16	1,9,16	**VIII**
9	1,9,10,16	1,9,16	1,9,16	
10	1,10,16	9,10,16	10,16	
16	1,9,10,16	1,9,10,16	1,9,10,16	**VIII**

Table D9: Level-IX Partitioning

Issue	Reachability Set	Antecedent Set	Intersection Set	Level
9	9,10	9	9	
10	10	9,10	10	**IX**

Table D10: Level-X Partitioning

Issue	Reachability Set	Antecedent Set	Intersection Set	Level
9	9	9	9	**X**