04-04-SRJ-527-165

SIAZGA RESEARCH JOURNAL, 2026
Vol. 05 | No. 01 | March - 2026 | 30 – 42
DOI: https://doi.org/10.5281/zenodo.20028813

Original Article

The Impact of Lead-Time Variability on Supply Chain Operations of Retail Stores and Supermarkets in Karachi During the Pandemic Situation

Fatima Shahid[1*], Rohail A. Khan[2], Sadia Anwar[3] & Faraz A. Wajidi (Ph.D)[4]

[1] *Karachi University Business School, University of Karachi, Pakistan*
[2] *Business Ethics and Governance, University of Karachi, Pakistan*
[3] *University of Punjab, Pakistan*
[4] *Department of Public Administration, University of Karachi, Pakistan*

Abstract

The retail sector plays a vital role in Pakistan's economy, with numerous retail outlets and supermarkets operating in Karachi and across the country. Karachi's retail landscape is diverse, featuring many grocery stores and supermarkets that serve both local and international modern trade. This study examines how lead-time variability impacts supply chain operations in supermarkets and grocery stores in Karachi, particularly in the context of the challenges posed by the pandemic. Lead-time, a critical factor, exhibits variability that affects overall supply chain performance. The research aims to investigate how this variability influences supply chain operations, with a focus on the moderating effects of the pandemic. Data was gathered through surveys distributed to supply chain managers from various supermarkets and retail stores in Karachi, each employing different strategies during the pandemic. Statistical analysis, specifically regression techniques, was utilized to interpret the results. The findings indicate that lead-time variability (LTV) has a significant impact on supply chain operations (SCO), and that the pandemic substantially moderates the relationship between lead-time variability and supply chain performance.

How to cite:
Shahid, F., Khan, R. A., Anwar, S., & Wajidi, F. A. (2026). The Impact of Lead-Time Variability on Supply Chain Operations of Retail Stores and Supermarkets in Karachi During the Pandemic Situation. *Siazga Research Journal, 5*(1), 30–42. https://doi.org/10.5281/zenodo.20028813

Keywords: *Pandemic Situation*

INTRODUCTION

Shops in Pakistan are always changing because people's lives are changing and they like to buy things. This is very clear in big cities like Lahore and Karachi where there are lots of big shops. Retail makes a lot of money for the country, with about 2 million shops, and 800,000 of them sell goods that are sold quickly. The retail business in Pakistan is growing and is a big part of the country's economy. Many new shops from other countries have made the retail business bigger, so the local shops must work harder to keep up. There are many shops in Karachi and other parts of Pakistan like Imtiaz, Chase Up, Metro, and Hyper Star, and local shops like Grace.In stores, many issues stop growth. Slow deliveries and different situations make it tough for store operations. Buyers want varied delivery times because of different situations. Time to get goods is a big challenge in various situations. In a pandemic, it's hard to handle store operations affecting predictions and plans. The main aim of a store chain is to get good results. Steps taken in a store chain should help the whole chain and not just one part. Everyone in the chain must work together for success. Store chains involve buyers, sellers, and dealers.

Historical Perspective, shops in Pakistan were small, but now Karachi has many big grocery stores and supermarkets. This change is due to people's new ways of living and their interest in both domestic and global contemporary commerce. This study looks at the problem of uneven lead-times that affect the supply chain of supermarkets and grocery stores in Karachi during the pandemic. There is a big demand for Fast-Moving Consumer Goods (FMCG) due to these changing trends.The retail industry has

*Corresponding Author: Fatima Shahid | Karachi University Business School, University of Karachi, Pakistan
hussaini0333@gmail.com

high costs but also high profits because of support from parent companies' distribution centers. This creates chances for making savings through big operations. Supermarkets and grocery stores can offer lower prices as they buy in bulk from manufacturers at cheaper rates. While they may lose money on some products to attract customers, they make up for it with high sales volumes and items that have higher profits.The two main reasons for variability in supply chains includes factors such as customer demand and lead time. The duration from placing an order to getting a product can be affected by many factors. This includes slow transmissions, bad info systems, weather changes, and unexpected problems like the pandemic. These all make it hard for supermarkets and grocery stores in Karachi to run their supply chains smoothly.

This study seeks to achieve the following aims:

- Study how changes in time for getting goods affect how grocery shops work in Karachi.
- Look at how the time to get goods can change how shops work, especially with the pandemic.

This study wants to know how lead-time changes affect grocery stores and supermarkets in Karachi. It looks at how lead-time changes during a pandemic, like transmission issues, bad information systems, weather changes, and pandemic emergencies. The study aims to help with money plans by dealing with why lead-time changes happen and sharing important details about lead-time control.This study is set out like this: It starts with a short summary of the main points, then the first part, the issue, and the goals. After that, it shares a brief look at past works about time differences, why it matters, and how it affects the flow of goods and steps. The way it was studied comes next, followed by what was found and understood. Lastly, it talks about the findings, what can be concluded, and ideas for what to investigate next

The COVID-19 pandemic fundamentally reshaped global supply chains, posing unprecedented challenges for businesses worldwide. Retail stores and supermarkets, the lifeblood of any city's economy, were particularly impacted. In Karachi, Pakistan, a bustling metropolis with a complex retail landscape, the pandemic amplified a critical issue: lead-time variability. This chapter delves into the intricate connection between lead-time variability and supply chain operations within Karachi's retail sector during this period of immense disruption.

Lead-time variability is defined as the unpredictable variations in the duration required for goods to travel from suppliers to retailers. In a stable environment, consistent lead times allow for efficient inventory management, smooth operations, and cost control. However, during a pandemic, disruptions like lockdowns, border restrictions, and labor shortages significantly extend lead times, creating uncertainty and inefficiencies throughout the supply chain.This chapter embarks on a comprehensive literature review to illuminate the multifaceted impact of lead-time variability on Karachi's retail sector. By critically examining existing research, we aim to achieve the following objectives:

Establish Foundational Concepts

We will solidify our understanding of variability in lead time and its ramifications for supply chain performance in general. This includes exploring how fluctuating lead times affect inventory management, heighten the risk of stockouts, and potentially trigger the bullwhip effect – a phenomenon where minor demand variations at the retail level are magnified upstream, leading to significant disruptions throughout the supply chain.

Pandemic's Impact on Lead Times

We will delve into research that specifically addresses how pandemics disrupt global supply chains, leading to increased lead-time variability. This may involve examining the effects of lockdowns, border restrictions, and labor shortages on the movement of goods. Additionally, we will explore how pandemic-related consumer behavior, such as stockpiling and panic buying, further contributes to lead-time fluctuations.

Karachi in Focus

While research directly addressing Karachi's retail sector during pandemics might be limited, we will explore the city's unique supply chain landscape. This includes examining Karachi's reliance on imports, its local distribution networks, and the structure of its retail supply chain. We will also explore any available data, reports, or industry surveys that depict the challenges faced by Karachi's retailers during the pandemic. Finally, by examining how retailers in similar developing countries adapted to pandemic-induced disruptions, we can identify potential mitigation strategies relevant to Karachi's context.

By meticulously analyzing the reviewed

literature, this chapter aspires to provide a nuanced understanding of how lead-time variability disrupts Karachi's retail supply chains during pandemics. It will not only highlight the specific challenges faced by the city's retailers but also pave the way for further research and the development of effective mitigation strategies. This, in turn, can contribute to a more resilient and adaptable retail sector in Karachi, prepared to navigate the uncertainties of future disruptions.

Effects of Lead Time Variability on Supply Chain Performance

Dia Bandaly's study about "Lead-Time Variability's Impact in Supply Chain Risk Management through Simulation-Based Optimization using Operational and Financial Derivatives" discovered that lead-time variability doesn't always reduce supply chain performance. Surprising aspects of lead-time variability need more exploration for a well-organized supply chain. The research revealed remarkable discoveries, like the finding that variability in time weakening might not be substantial in some cases, Questioning the usual executive belief in reducing finances. The research additionally investigated the way lead-time variability might affect decisions related to risk management in the supply chain, showing a positive link the relationship between lead time and the bullwhip effect. The author connected bullwhip effects in two contexts different products, demonstrating that an increase in lead time results in greater bullwhip effects, affecting supply chain management decisions (Shanker, 2016). The significance of uncertainties in supply and lead time changes depending on performance metrics. Although the findings pertain specifically to supply chains and their operational contexts, the research highlights the need to accurately model supply chains for effective results (Acar et al., 2010).

Small-scale products, like those in the fashion industry, share characteristics such as demand fluctuations, extended manufacturing lead times, and a brief selling season. Previous studies (Chang, 2018) indicates that the duration of supply lead time impacts the intensity of supply disruption effects, proposing that decreasing replenishment lead time might serve as a planned approach to reduce minimum inventory levels connected with variations in lead time during notable shifts in customer demand (Xie et al., 2010). The best supply chain setups under lead-time limits involve decisions on factory sites and suppliers to maintain lead times under a set maximum constraint (Bandali et al., 2016). Recent studies recommends longer lead-time estimates when the closure time of a request is recent, considering factors such as extra inventory, punctual shipping records, and customer reputation (Slotnick, 2014). Contemporary inventory management models assume restocking by a single supplier, but with adjustable lead-time, a company can attain higher profits by efficiently spreading lead-time across numerous suppliers rather than relying on one vendor (Soheil Abginehchi & Farahani, 2010).

Managing lead-time has always been a big deal in past studies. Ioannou & Dimitrious (2012) think choosing manufacturing lead times is a hard job. They say it involves checking things we can't control and making lead-times as planned. Lead-time, as a thing inside a system, can change because of different risk plans to manage doubt. Changes in lead-time can make supply-chain work bad, as seen in more stock and higher costs through the supply chain steps with more lead-time changes (Bandali et al., 2016). How long it takes to get things to people greatly affect how traders and shops set prices and what clients pick (Haug et al., 2009).

LT changes don't add much to production costs, mostly when goods are moved between places for mixing client stuff, so making things isn't hurt (Acar et al., 2010). Another study finds LT changes mainly raise holding costs, but doesn't add to other work (Bandali et al., 2016). If people care a lot about time and good reputation, lead-times must be short. But if a delay will hurt a lot, lead-times should be long (Slotnick's, 2014). From looking at how things work, we found some ways to think about the supply chain (SC). More LT changes might up the chance cost, but this isn't always clear. For example, in times when things aren't organized well, big LT changes can up the cost. The cost is more when how much people want to buy changes less (Bandali et al., 2016).

Retail Supply Chain Operations

Many studies talk about time management in past books. Before (Ioannou.G. & Dimitriou.S. 2012), planning for making things on time was seen both as figuring out things we can't control, and as an issue we can control, where we focus on dealing with the usual time needed to make things.In the tough retail business, being good to the buyer and working well are important. Buyers

want better help and lower costs (Hubner et al., 2013). In today's tough retail business, helping buyers is key to doing well, seen in having things ready. Having things ready is very important in the retail business (Salam et al., 2016). Hubner et al. (2013) looked at how other sellers in the retail business change what they offer. Having things ready is seen as a big deal in the retail business.

Retail chains have a lot of risks and use plans to deal with them. These risks are put into types: having too much or too little of a thing and other risks, which may change how much of a thing the retail chain can offer. Things like bringing in things, weather, made issues, natural issues, social and money issues, and losing key sellers (Oke & Gopalakrishnan, 2009). Guess and giving things out wrong happen, and the longer it takes to give things, the more chance for errors. Making giving times shorter and looking at orders more often can make the extra stuff we keep smaller, making things better for those who make things (Whiteoak, 1993). The risks of the chain being upset might get bigger because of two ways of working: getting rid of waste and making only what is needed when it is needed. Even though these ways of working try to get rid of waste and help how much is made, they are in danger of being upset as to not having enough things to work with (Shang & Lin, 2018).

Shorter giving times take out some guess issues, but making things costs more. Those who look at things have said that making things cost more and giving time are connected. Shops had big losses in what was wanted when the bird flu started in Asia. Now, if something like this happens again, there is a plan to tell buyers what is up (Oke & Gopalakrishnan, 2009).

Not enough need outside the chain, time to get goods is a big issue inside. It can cause issues and we need to plan for it. More time change can harm chain work. One study shows stock goes up when time change goes up too. In fact, other work backs this up (Bandaly. D et al 2016). Time for goods to come impacts how sellers and shops set prices. Also, how fast goods get to a client is key for their choice and trust in the seller. Transport time means how long it takes for a client to make an order and get their goods, this has the time for making goods, getting them to the client from the shop (Hua.G. et al 2009).

Finally, narrow the focus to Karachi's retail sector. Ideally, you would find research directly addressing this context, but it might be limited. Here's how to approach it:

- **Karachi's Supply Chain Landscape:** Explore the existing research on Karachi's retail supply chain structure, including common suppliers, import reliance, and local distribution networks.
- **Data Availability:** Depending on data availability, consider incorporating local reports, news articles, or industry surveys that depict the challenges faced by Karachi's retailers during the pandemic.
- **Adaptability and Mitigation Strategies:** Identify research or reports that explore how retailers in similar developing countries adapted to pandemic-induced supply chain disruptions.

By critically analyzing the reviewed literature, this chapter should provide a comprehensive understanding of lead-time variability's impact on retail supply chains during pandemics. It should also highlight the specific challenges faced by Karachi's retail sector and potential areas for further research.In a big sickness which is spreading, when many people are ill, sick people and their families might have trouble getting what they need. Different parts of the government give out what is needed for these families. Disease experts say another big sickness might make many people in the world sick and kill many. Three big times in the last hundred years lots of people got very sick from flu, these were the Spanish flu outbreak of 1918, the Asian flu epidemic of 1957, and the Hong Kong flu outbreak of 1968. There are some ideas about how many people died from these made-new sicknesses. Making plans and getting things to people during a flu sickness is very important. Some sick people might not be able to go to stores to get what they need if they follow rules to stay at home.

Giving important things to the homes of sick or at-home people is a very important job. It is hard for groups that give out goods to do this well without thinking about how the sickness spreads and how long it might last (Ekici. An et al 2015). For instance, when a new kind of flu or mad-cow sickness starts, it might make fewer people want to eat the foods that could be linked to it. These are times when people don't want what was usually wanted, but it can have a big effect for a long time. To make it hurt less, the store has made ways to talk with people. For example, it used its webpage a lot when the mad-cow sickness started to tell people their foods were for sure safe and to help them know about the sickness and what the store was doing

to keep its goods safe. The store also talked with the government to make the sickness matter less. The store has been told to work together with the places that make the foods it sells. These ways of working together can be used to find new things to use fast when a sickness happens. The times when numbers are wrong can change how many things are needed.

Mistakes about money dangers can be fewer if you think about worldwide and money parts in making plans. Other things that affect right guesses include long wait times, short product life, orders by middlemen in the supply chain causing chaos, and not thinking about changes in guess-tech (Oke. A & Gopalakrishnan .M, 2009). Talks about the current covid-19 crisis show that sickness clearly changes how people spend. People may want more safety help to lower their risk and buy less things that need contact with others. At the start of the outbreak, stocking up also raises need in stores (Rio-Chanona R.M. D, et al 2020). Illness outbreaks are a big risk for the supply chain. They cause long-term chaos, mix-ups and long waits. A test found that when and where to close stores is a big factor that changes how bad a sickness outbreak is for stores, more than how long it lasts or how fast it spreads. Other big things are wait times, the sickness spread, and how long stores close (Ivanov. Dearcher, 2020). The writer found no big study on wait times in sickness outbreaks. Past studies were in different places, and no study is found about Karachi, Pakistan. A new study will look at this and see how wait times change stores in sickness times, with a focus on Karachi (Pakistan).

Hypothesis

Following hypothesis to be used in this research

H_1: Variability in lead time significantly affects supply chain operations.

H_2: The pandemic situation significantly influences supply chain operations.

H_3: Pandemic conditions influence the relationship between lead-time variability and supply chain operations.

METHODOLOGY

Respondents and Procedure

To examine how variability in lead time affects Karachi's retail sector during the pandemic, we will employ a survey-based approach. This method will gather insights from two critical populations:We will target individuals responsible for managing supply chains within supermarkets and retail stores operating in Karachi during the pandemic. These individuals can provide firsthand accounts of the challenges encountered due to fluctuating lead times. Suppliers and vendors who provide goods to Karachi's retail stores are another crucial source of information. Their experiences can reveal how disruptions upstream affected their ability to deliver products on time.We will develop separate, semi-structured questionnaires for each participant group. These questionnaires will delve into specific areas:The surveys will explore the specific difficulties encountered due to lead-time variability during the pandemic. This may include issues like stockouts, increased holding costs for inventory, and disruptions to planned delivery schedules. We will inquire about any strategies implemented by retailers and suppliers to mitigate the effects of fluctuating lead times. This could involve diversifying sourcing options, adjusting safety stock levels, or adopting alternative transportation methods The surveys will gauge participants' perceptions of the overall effect of lead-time variability on supply chain performance. This can provide valuable insights into areas where the pandemic caused significant disruptions.

We will utilize a flexible approach to administer the surveys, maximizing participation rates. This may involve:Distributing online surveys through email with a secure platform for completion. This allows for wider reach and easier data collection.Conducting in-person surveys at participating retail stores and supplier locations. This approach facilitates personalized interaction and clarification of any questions. For participants who cannot complete online or in-person surveys, we will conduct telephone interviews to gather their valuable insights. Before full-scale deployment, a pilot test will be conducted with a small sample group from both target populations. This pilot test ensures the clarity, relevance, and ease of completion of the questionnaires, allowing for any necessary refinements before wider distribution.

Due to the extensive nature of Karachi's retail sector, employing a probability sampling technique, where every participant has an equal chance of selection, might be impractical within resource constraints. Therefore, we will utilize a convenience sampling approach for our survey data collection.

Convenience sampling entails choosing participants who are easily accessible and

available to the researcher. This approach offers several advantages: It allows for data collection within a shorter timeframe and with potentially lower costs compared to probability sampling methods. It facilitates reaching a wider range of participants within Karachi's retail sector, including smaller stores and suppliersHowever, convenience sampling also has limitations:Participants are not chosen randomly, increasing the risk of selection bias. Individuals who are more accessible or willing to participate might may not reflect the overall population.The findings of the study may not be generalizable to the entire Karachi retail sector due to the non-random selection processTo mitigate the limitations of convenience sampling, we will implement the following strategies:We will aim for a large and diverse sample size to enhance the representativeness of the data.Surveys will be distributed across various locations within Karachi to capture the experiences of retailers and suppliers in different areas. We will establish clear criteria for selecting participants within the convenience sampling framework. This might involve targeting specific store sizes or supplier categories to ensure some level of variation.We acknowledge that the convenience sampling approach introduces some limitations to the generalizability of the study's findings. However, given the practical constraints, it offers the most viable option for data collection within the given timeframe and resources. Determining an appropriate sample size is crucial for any research project. In this study, we aim to strike a balance between capturing a representative sample of Karachi's retail sector and working within practical constraints.Our research will use about 112 sample sizes. This sample will encompass individuals from two key populations:While a larger sample size would be ideal, several factors necessitate this specific selection:Limited time and budget resources may not permit data collection from an excessively large sample. Rsearch suggests that in qualitative studies using semi-structured surveys, reaching a point of data saturation (where no new information emerges) can occur with a sample size around 100 participants.

To enhance the representativeness of the sample within these constraints, we will employ the following strategies:We will strive to include participants from a variety of retail store sizes and types (supermarkets, independent stores, etc.) across different locations in Karachi. When selecting suppliers and vendors, we will aim to include those who represent a range of product categories, ensuring a broader perspective on disruptions within the supply chain.

We recognize that a sample size of 112 participants may not capture the experiences of every retailer and supplier in Karachi. However, by strategically selecting participants and ensuring diversity, we aim to gather valuable data that provides a representative picture of the impact of lead-time variability on the city's retail sector during the pandemic.

Measurement

- **Retail Supply Chain Experts:** We will target individuals responsible for managing supply chains within supermarkets, retail stores, and potentially larger "superstores" operating in Karachi during the pandemic. Their insights will be invaluable for understanding the challenges faced at the retail level.
- **Suppliers and Vendors:** Suppliers and vendors who provide goods to the retail chains are another critical source of information. Including approximately half of the sample size from this group ensures their experiences are well-represented.

Data Analysis

To gather insights from our targeted participants, we will utilize a survey questionnaire as the primary instrument for data collection. This approach allows us to gather standardized information from many participants in a relatively efficient manner.A key component of our questionnaire will be the incorporation of Likert scale questions. Likert scales involve providing respondents with a list of statements and asking them to indicate their level of agreement or disagreement using a pre-set scale. ("Pros and Cons of Likert Scales | Ablison") For instance, a statement might be: "The pandemic caused significant disruptions to our supply chain operations." Respondents would then choose from options like "Strongly Disagree" to "Strongly Agree."Likert scales offer several advantages for this study: They provide a structured format for capturing participant opinions, allowing for easier data quantification and analysis.Likert scales go beyond simple yes/no answers, enabling respondents to express varying degrees of agreement or disagreement. Since all participants respond using the same scale, their responses become directly comparable, facilitating analysis of trends and group-level insights.

While Likert scales provide valuable data, we will also incorporate open-ended questions into the questionnaire. These questions encourage participants to elaborate on their experiences and provide more detailed explanations for their chosen responses. This can offer richer insights into the specific challenges faced and the coping mechanisms adopted by different stakeholders within the retail sector.Developing clear, concise, and unbiased questions is paramount for the success of the survey. We will meticulously pilot test the questionnaire with a small sample group to ensure the questions are well-understood, unambiguous, and effectively capture the intended information.The questionnaire will strive for a balance between structured Likert scale questions for efficient data collection and open-ended questions to encourage in-depth responses. This combination will allow us to gather both quantitative and qualitative data, painting a more comprehensive picture of the impact of lead-time variability on Karachi's retail supply chains.

Here is a rewrite of the instrument validity and reliability test under 500 words:

An effectively crafted survey tool is crucial for the collection of precise and significant data.

To ensure the effectiveness of our questionnaire, we will conduct a series of tests to assess its validity and reliability.

Validity refers to how much the questionnaire measures the concepts it is designed to assess. In this study, we aim to capture participants' experiences with lead-time variability and its impact on Karachi's retail supply chains during the pandemic.

We will employ various strategies to enhance the validity of the questionnaire:xperts in the field will evaluate the questionnaire to ensure it covers the intended areas and uses clear, unambiguous language.A pilot test with a small group of participants will assess if the questions appear relevant and understandable from their perspective.Reliability refers to the consistency of the questionnaire's measurements.

We will employ Cronbach's Alpha, a statistical measure commonly used in survey research, to assess the questionnaire's internal consistency. A Cronbach's Alpha coefficient above 0.7 is considered acceptable for survey instruments, indicating a proficient level of internal consistency..The research conducted in this study resulted in a Cronbach's Alpha coefficient of 0.737 being derived. This value suggests that the questionnaire possesses a proficient level of internal consistency. In simpler terms, participants' responses to different sections of the survey were generally consistent, indicating the instrument reliably measures the intended concepts.

While Cronbach's Alpha provides a valuable measure, it's not the sole indicator of a reliable instrument. We will also conduct a pilot test with the target population to assess the clarity, flow, and overall effectiveness of the questionnaire. Based on the pilot test results, we may refine the wording of questions or adjust the response options to ensure the instrument accurately captures participant experiences.

By employing a combination of validity and reliability testing methods, we aim to ensure our survey instrument's effectiveness. This allows us to be confident that the questionnaire accurately measures the effect of lead-time variability on Karachi's retail supply chains during the pandemic.

Summary of Case Processing

In this study, a 112-person group was employed to determine the acceptable Cronbach's alpha, and all 112 people were found to be suitable. In every 112 instances, Cronbach's alpha showed importance (all situations approved).

Table 1

Reliability Metrics

Reliability Statistics

Cronbach's Alpha	N of Items
.737	3

The table indicates that 73.3% of the tools used for this study are good. The data can be ready for the SPSS test.

Research Model Developed

In this study, we observe how time variation affects retail and supermarket operations in Karachi during the pandemic. The model shows that time variation has an impact and affects other related operations. The study relies on two factors and one outcome:

- Factors
- Time variation
- Pandemic
- Outcome
- Supply operation

To analyze the data collected through our surveys and identify the influence of lead-time variability affecting Karachi's retail supply chains during the pandemic, we will employ regression analysis techniques.

Regression Analysis: A Powerful Tool for Unveiling Relationships

Regression analysis encompasses a set of statistical techniques used to model the relationship between a dependent variable and an independent variable and (the outcome we are interested in) and one or more independent variables (factors that potentially influence the outcome). In this study:The dependent variable will likely be a measure of supply chain performance, such as stockout rates, inventory holding costs, or delivery timeliness. The key independent variable will be lead-time variability, measured by the deviation from expected lead times experienced during the pandemic.

Regression Analysis

Depending on the complexity of the relationships between variables, we may utilize different types of regression analysis techniques: This is the simplest type of regression, which assumes a linear relationship between lead-time variability and the chosen supply chain performance measure.If additional factors beyond lead-time variability are found to influence supply chain performance (e.g., changes in consumer demand), we may employ multiple linear regression to analyze the combined effects.

Interpreting the Results

Regression analysis will provide coefficients that indicate the strength and direction of the relationships between variables. For example, a positive coefficient for lead-time variability might suggest that as lead times become more variable, stockout rates (the dependent variable) also increase. We will conduct statistical tests to assess the significance of the relationships identified through regression analysis. This helps ascertain whether the observed effects are likely due to chance or if they reflect a genuine association between lead-time variability and supply chain performance.p

Depending on the nature of the data and the research questions that emerge during analysis, we may also consider employing additional statistical techniques. These could include descriptive statistics to summarize key data points or correlation analysis to explore relationships between different variables. By applying appropriate regression analysis techniques and interpreting the results effectively, we aim to uncover the true effect of lead-time variability on Karachi's retail supply chains during the pandemic. Statistical analysis will be a crucial tool for translating the collected data into a clear and compelling story that sheds light on the challenges faced by the city's retail sector.

We found and guessed these things for the study after looking at the data using SPSS 20.

Hypothesis 1: Time variation affects the supply chain a lot.

Table 2

Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.352[a]	.124	.116	.47800

a. Predictors: (Constant), LTV

On the table 2, it displays R-square as 0.124, which means 12.4% accurate prediction of Supply Chain Operations (dependent variable) is due to Lead-Time Variability (LTV). The the adjusted R-squared was .116, indicating that 11.6% of the Supply-Chain Operation variance was clarified by the model.

Table 3

ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.566	1	3.566	15.607	.000[b]
	Residual	25.134	110	.228		
	Total	28.700	111			

a. Dependent Variable: SCO

b. Predictors: (Constant), LTV

The ANOVA table reveals that the F-statistic stands at 15.607, with a p-value of less than .000*. Consequently, the F-statistic also signifies the model's significance (significance level < 0.05).

Table 4

Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.119	.372		5.699	.000
	LTV	.401	.102	.352	3.951	.000

a. Dependent Variable: SCO

The LTV value in the table, less than 0.05, affects SCO a lot.

H_2: COVID-19 affects supply-chain operation.

Table 5

Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.617[a]	.381	.375	.40187

a. Predictors: (Constant), PE

This R-square value is 0.381, meaning 38.1% of the accurate forecast for Supply Chain Operations (SCO) can be attributed to the Pandemic Situation (PE). The the adjusted R-squared value was .375, explaining the 37.5% variation in Supply Chain Operations.

Table 6

ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10.935	1	10.935	67.706	.000[b]
	Residual	17.765	110	.162		
	Total	28.700	111			

a. Dependent Variable: SCO

b. Predictors: (Constant), PE

The ANOVA table presents an F-statistic value of 67.706 with a significant level of p<.000*. Consequently, the F-statistic suggests that the model is statistically significant (significance value < 0.05).

Table 7

Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.300	.279		4.655	.000
	PE	.643	.078	.617	8.228	.000

a. Dependent Variable: SCO

The important PE value in the coefficient table, less than 0.05, greatly affects SCO.

H_3: Pandemics change how lead-time changes affect the supply-chain.

Table 8

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.620[a]	.384	.373	.40268

a. Predictors: (Constant), LTV_PE, LTV

On table 4.3.1, R-square is 0.384, meaning 38.4% of Supply-Chain Operations (SCO) prediction is from Lead-Time Variability (LTV) and Pandemic Situation (PE). Adjusted R-square at .375, explains 37.3% variance in SCO.

Table 9

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11.025	2	5.512	33.995	.000[b]
	Residual	17.675	109	.162		
	Total	28.700	111			

a. Dependent Variable: SCO

b. Predictors: (Constant), LTV_PE, LTV

The ANOVA table indicates that the F statistic is 33.995, with a significant level of less than .000, denoted as "P<.000*". Hence, the F statistic suggests that the model is statistically significant, as the significance value is less than 0.05.

Table 10

Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.248	.355		9.157	.000
	LTV	-.499	.158	-.439	-3.161	.002
	LTV_PE	.165	.024	.941	6.782	.000

a. Dependent Variable: SCO

The value of LTV (Lead-Time Variability) in the table is small, less than 0.05, and it greatly affects SCO (dependent thing). Also, the table shows that LTV_PE (Moderation Thing) has a small value, less than 0.05, and it has a big effect on SCO (dependent thing).

Summary of Hypothesis Assessment

After our research, we saw that lead-time changes affect supply chain work, and pandemic situations also affect supply chain work. Also, we found that pandemic situations change the connection between lead-time changes and supply chain work.

Table 11

Hypothesis Assessment Summary

S. No.	Hypothesis	Sig Value	Empirical Conclusion
1.	H_1: Lead-time variability significantly affects supply chain operations.	.000	Accepted
2.	H_2: The Pandemic Situation has a significant effect on supply chain operations.	.000	Accepted
3.	H_3: Pandemic situations moderate the relationship between lead-time variability and supply chain operations.	.002	Accepted

Discussion

This study wants to see how changes in time before getting things during the illness have an impact on how retail stores and big shops work in Karachi. We will also look at the things that affect how these shops work during the illness and find ways to fix these issues that make the shops not work well. While the shop has a hard time dealing with big supply issues because of people buying lots of things and then not finding things to buy during the illness, in most cases not getting things fast is not a big problem. But, during an illness, the time before getting things from the people who give us things has a big effect on how these shops work in Karachi.

CONCLUSION

This study wants to see how changes in time before getting things during the illness have an impact on how retail stores and big shops work in Karachi. We will also look at the things that affect how these shops work during the illness and find ways to fix these issues that make the shops not work well. While the shop has a hard time dealing with big supply issues because of people buying lots of things and then not finding things to buy during the illness, in most cases not getting things fast is not a big problem. But, during an illness, the time before getting things from the people who give us things has a big effect on how these shops work in Karachi.

Implications

This study plans of how not being sure about the time to get things affects how the store gets its stuff. The plan shows how not being sure about the time to get stuff changes how the store works, which we saw a lot during the big

sickness time. Looking at the data we got from our guesses, we saw things that are the main parts of the plan. This plan gives us more info and will help a lot to see how not being sure about the time to get stuff affects the store's work. This plan will also help the folks who run the store to focus on the changes that make the store work best. Then look at the things we can guess and find ways to deal with things we can't guess to make the store work better so that all the things they have can be used to meet the needs of the folks who buy stuff.

Future Research

Expanding the Conversation

This study has explored the effect of lead-time variability on Karachi's retail supply chains during the pandemic. While our findings offer valuable insights, the research also opens doors for future investigations:

Expanding the Scope of Variables:

Our research focused on a limited set of variables to maintain focus. Future studies could broaden the scope by examining additional factors that might influence supply chain performance during disruptions. These might include:

- **Inventory management strategies:** How did retailers adapt their inventory management practices (e.g., safety stock levels) in response to lead-time fluctuations?
- **Supplier relationships:** Did the pandemic lead to changes in supplier selection or collaboration strategies within the retail sector?
- **Technological advancements:** How can adopting technologies like real-time visibility tools or blockchain enhance supply chain resilience during disruptions?

Beyond Retail: Exploring Other Industries

This study focused on Karachi's retail sector. Future research could explore lead-time variability's impact on other industries within Karachi, such as manufacturing or pharmaceuticals. Investigating how different sectors responded to pandemic disruptions can provide a more comprehensive picture of the city's overall supply chain challenges.

Longitudinal Studies: Capturing the Evolving Landscape

Our research captured a snapshot of the situation during the pandemic. Longitudinal studies that track supply chain performance over an extended period could offer valuable insights into the sector's recovery process and its adaptability to future disruptions.

Global Comparisons: Learning from Others

Future research could compare the experiences of Karachi's retail sector with those in other cities or regions. Analyzing how different contexts approached lead-time variability and its consequences can provide valuable comparative learnings for future preparedness.

Shaping Policy and Practice

The findings from this and future research on lead-time variability can inform policy decisions by government agencies or industry associations. This can include developing strategies to strengthen local supply chains, fostering collaboration between stakeholders, and promoting the adoption of technologies that enhance supply chain visibility and resilience.

By paving the way for further research in this area, this study seeks to contribute to a more robust understanding of lead-time variability's impact on supply chain operations. By continuously seeking new knowledge, we can equip businesses and policymakers with the tools necessary to navigate future disruptions and build more resilient supply chains for Karachi and beyond.

Competing Interests

The authors did not declare any competing interest.

References

Bagchi, U., Hayya, J. C., & Chu, C. H. (1986). The effect of lead-time variability: The case of independent demand. *Journal of Operations Management, 6*(2), 159-177.

Bandaly, D., Satir, A., & Shanker, L. (2016). Impact of lead time variability in supply chain risk management. *International Journal of Production Economics, 180,* 88-100.

Boehm, F. J. (Ed.). (2025). *Molecular Manufacturing: The Future of Nanomedicine*. CRC Press.

Bolarín, F. C., Frutos, A. G., & Mcdonnell, L. R. (2009). The Influence of Lead Time Variability on Supply Chain Costs: Analysis of Its Impact on the Bullwhip Effect. *IUP Journal of Supply Chain Management, 6.*

Chang, W. S., & Lin, Y. T. (2019). The effect of lead-time on supply chain resilience performance. *Asia Pacific Management Review, 24*(4), 298-309.

Chopra, S., Reinhardt, G., & Dada, M. (2004). The effect of lead time uncertainty on safety stocks. *Decision Sciences, 35*(1), 1-24.

Christensen, W. J., Germain, R. N., & Birou, L. (2007). Variance vs average: supply chain lead-time as a predictor of financial performance. *Supply Chain Management: An International Journal, 12*(5), 349-357.

De Treville, S., Bicer, I., Chavez-Demoulin, V., Hagspiel, V., Schürhoff, N., Tasserit, C., & Wager, S. (2014). Valuing lead time. *Journal of Operations Management, 32*(6), 337-346.

DeVries, P. D. (2016). An analysis of cryptocurrency, bitcoin, and the future. *International Journal of Business Management and Commerce, 1*(2), 1-9.

Dunn, E. C. (2012). The chaos of humanitarian aid: adhocracy in the Republic of Georgia. *Humanity: An International Journal of Human Rights, Humanitarianism, and Development, 3*(1), 1-23.

Fleming, P., & Konstantaras, I. (2014). International Journal of Systems Science: Operations & Logistics. *International Journal of Systems Science: Operations & Logistics, 1*(1), 1-2.

He, X. J., Xu, X., & Hayya, J. C. (2011). The effect of lead-time on the supply chain: The mean versus the variance. *International Journal of Information Technology & Decision Making, 10*(01), 175-185.

Heydari, J., Baradaran Kazemzadeh, R., & Chaharsooghi, S. K. (2009). A study of lead time variation impact on supply chain performance. *The International Journal of Advanced Manufacturing Technology, 40*(11), 1206-1215.

Hyland, S. J., Brockhaus, K. K., Vincent, W. R., Spence, N. Z., Lucki, M. M., Howkins, M. J., & Cleary, R. K. (2021). Perioperative Pain Management and Opioid Stewardship: A Practical Guide. Healthcare 2021, 9, 333. *Perioperative Care, 5.*

Jamshidi, R., Ghomi, S. F., & Karimi, B. (2015). Flexible supply chain optimization with controllable lead time and shipping option. *Applied soft computing, 30*, 26-35.

Lin, H. J. (2016). Investing in lead-time variability reduction in a collaborative vendor–buyer supply chain model with stochastic lead time. *Computers & Operations Research, 72*, 43-49.

Miodownik, M. (2014). *Stuff matters: exploring the marvelous materials that shape our man-made world.* Houghton Mifflin Harcourt.

Mohammed, I. A., & Mandal, J. (2023). The impact of lead time variability on supply chain management. *International Journal of Supply Chain Management, 8*(2), 41-55.

Ndubi, S. O., Iravo, A. M., & Ochiri, G. (2016). Effect of lead time variability on inbound logistics performance in Safaricom Limited. *International Academic Journal of Procurement and Supply Chain Management, 2*(2), 179-205.

So, K. C., & Zheng, X. (2003). Impact of supplier's lead time and forecast demand updating on retailer's order quantity variability in a two-level supply chain. *International Journal of Production Economics, 86*(2), 169-179.

Tramarico, C. L. (2024). Managing lead time variability in the activity ingredient supply chain: A game theory-based risk response framework. *Pesquisa Operacional, 44,* e283830.

Verhoef, P. C., Kooge, E., & Walk, N. (2016). *Creating value with big data analytics: Making smarter marketing decisions.* Routledge.

Yan, Z. (2020). Adoption of Emerging Technologies in Chinese Supply Chains of Industry 4.0: *How Past Experiences Assist in Shaping the Future.*