The Impact of Supply Chain Uncertainty on Performance: Exploring the Mediating Role of Visibility

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Abstract

This study explores the impact of supply chain uncertainties—economic, demand, and technological—on the performance of oil marketing companies (OMCs) in Pakistan's Petroleum Industry, while highlighting the critical mediating role of supply chain visibility (SCV). A quantitative research design was employed, gathering responses from industry professionals and analyzing the data through Smart PLS-4. Results demonstrate that uncertainties significantly disrupt supply chain performance. However, SCV effectively mitigates these challenges by enabling better decision-making, enhancing collaboration, and fostering operational agility. The study underscores the importance of adopting advanced technologies, such as IoT and blockchain, to strengthen SCV and build resilient supply chains. By addressing key challenges in the petroleum sector, this research provides actionable insights for OMCs to optimize their strategies, improve performance metrics, and navigate the complexities of an uncertain and volatile business environment.

Keywords: Supply Chain; Performance; Visibility

Introduction

According to HBR, "A supply chain is the full set of activities that are required to bring a product or service to market, including all the steps involved in obtaining raw materials, manufacturing products, and distributing them to consumers." It encompasses sourcing raw materials, manufacturing, logistics, distribution, and retail operations, creating value at each stage. Effective supply chain management (SCM) ensures that products and services reach customers efficiently, minimizing costs and maximizing satisfaction. Collaboration and technology play pivotal roles in streamlining operations and improving supply chain efficiency. SCM is crucial for businesses to maintain competitiveness, especially in dynamic and unpredictable markets. By aligning processes and sharing information, supply chains can respond to market demands with agility. However, managing supply chains is complex due to factors like

globalization, technological advancements, and evolving customer expectations. Consequently, organizations must adopt innovative strategies to optimize their supply chain performance while maintaining sustainability.

Supply chain uncertainty encompasses a range of unpredictable factors that disrupt the smooth functioning of supply chains, impacting their performance and resilience. Demand uncertainties arise from rapid changes in consumer preferences, inaccurate forecasts, or seasonal fluctuations, leading to overstocking or shortages. Economic uncertainties, such as inflation, currency fluctuations, and trade wars, further destabilize supply chains by affecting costs and market dynamics. Technological uncertainties, including the pace of innovation, cybersecurity threats, and integration challenges, complicate supply chain operations and decision-making. External shocks like pandemics, exemplified by COVID-19, magnify these challenges by disrupting production, delaying shipments, and straining global logistics networks. The pandemic exposed vulnerabilities such as labor shortages, restricted transportation, and supply-demand mismatches. Geopolitical tensions, climate events, and regulatory changes also exacerbate uncertainties. To maintain performance, businesses must adopt robust strategies, leveraging technology and collaboration to navigate these complexities.

Supply chain performance is a measure of how well supply chains meet objectives such as cost efficiency, responsiveness, and service quality. However, performance is often hindered by uncertainties, including demand fluctuations, supply disruptions, and external shocks like economic volatility or pandemics. Supply chain visibility (SCV) plays a critical role in mitigating these uncertainties and enhancing performance (Baah, Acquah, and Ofori, 2022). SCV enables real-time monitoring and tracking of goods, inventory, and information across the supply chain, fostering better demand forecasting, inventory control, and disruption management. For example, during the COVID-19 pandemic, companies with high SCV were able to quickly adapt to supply shortages and demand spikes. By improving transparency and collaboration among stakeholders, SCV reduces risks, improves decision-making, and ensures continuity even in uncertain conditions. Advanced technologies like IoT, AI, and blockchain further strengthen SCV, making it an indispensable tool for improving supply chain performance in a rapidly changing global environment (Baah, Acquah, and Ofori, 2022).

According to Pro Pakistani article on PSO's market performance (2023) the oil marketing sector in Pakistan is a pivotal component of the economy, with several companies playing a crucial role in the distribution and marketing of petroleum products such as motor gasoline (petrol), high-speed diesel, furnace oil, jet fuel, and lubricants (The Nation, 2024). The sector is regulated by the Oil and Gas Regulatory Authority (OGRA), which manages licensing, quality standards, pricing, and the overall regulatory environment (Pro Pakistani, 2023).

The total size of Pakistan's oil marketing industry is estimated to be around PKR 5-6 trillion

annually, driven by high consumption in the transport, power, and industrial sectors The market share of OMCs in Pakistan is heavily skewed towards a few dominant players

Table 1 Market Share

OMCs	Market Share (%)	Net Sales -FY 22/23
PSO	42.2	2.5 Trillion
Shell Pakistan Ltd	6-8	210 Billion
Attock Petroleum Ltd (APL)	10-12	180 Billion
Total Parco Pakistan Limited	8-10	170 Billion
Gas & Oil Pakistan Ltd (GO)	7-9	140 Billion
Hascol Petroleum Ltd (HPL)	3-4	70 Billion

The global petroleum industry operates through complex supply chains involving exploration, refining, transportation, and distribution (The News International, 2023). For oil-importing countries like Pakistan, the reliance on global markets creates significant vulnerabilities to external factors like price volatility and geopolitical tensions (Energy Update, 2023). Pakistan's petroleum industry is a critical sector, accounting for a substantial portion of energy needs and economic activity. The overall import share of petroleum products stood at about 29.76% of the total imports, emphasizing the importance of energy imports to Pakistan's economy (OCAC). Pakistan's petroleum import bill has significantly increased in recent years, reflecting the challenges faced by oil-importing nations due to rising global oil prices and economic factors. According to the State Bank of Pakistan's report, the petroleum import bill for November 2023 reached $1.32 billion, marking a 5.76% increase from previous year (November 2022).

The petroleum sector in Pakistan plays a critical role, contributing significantly to the country's energy needs, especially in transportation, power generation, and industrial processes Dawn (2023). However, it faces several supply chain challenges:

Global oil price fluctuations (25% variance in 2023) and domestic demand volatility (10% monthly swings) create unpredictability in supply planning and procurement processes (Trade Development Authority of Pakistan ,2023)

According to Trade Development Authority of Pakistan (2023), high inflation (30% in 2023) has compounded operational challenges for oil marketing companies (OMCs) and refineries, pushing up import costs and impacting profitability.

The Oil and Gas Regulatory Authority (OGRA) oversees pricing and supply but has faced criticism for delays and inefficiencies. The shift to fortnightly pricing mechanisms and efforts to phase deregulation highlight ongoing adjustments in the sector (Energy Update, 2023). Limited storage

capacity and outdated refinery technology hinder efficient distribution and compliance with international standards like Euro-V fuel (Energy Update, 2023). Cross-border smuggling of petroleum products remains a critical issue, resulting in significant revenue losses for the government and OMCs (McKinsey & Company. (2021).

Pakistan imports most of its petroleum products, with major sources being UAE, Saudi Arabia, and Qatar. In 2023, refined petroleum accounted for the majority (74%) of imports, highlighting the country's dependency on external source (Trade Development Authority of Pakistan ,2023). This study aims to analyze the impact of demand, economic, and technological uncertainties on the overall performance of the supply chain in the oil marketing sector specific to petroleum Industry of Pakistan. Also, the study intended to investigate the critical role of supply chain visibility (SCV) in managing the uncertainties that impact supply chain performance, with a specific focus on the petroleum industry in Pakistan.

Problem Statement

In Pakistan, Oil Marketing Companies (petroleum), the supply chain is exposed to a multitude of uncertainties, including economic fluctuations, demand variability, and rapid technological advancements. Simultaneously, unpredictable demand patterns and delays in technological adoption exacerbate operational inefficiencies, hindering the overall performance of OMCs in a highly competitive market.

Therefore, the research would evaluate the impact of Supply Chain Uncertainties (demand, economic and technological uncertainties) and mediating role of supply chain visibility on supply chain performance in Petroleum Industry of Pakistan OMCs.

Objectives

- To Examine the impact of supply chain uncertainties (demand, economic and technological uncertainties) on supply chain performance of OMCs -Petroleum Industry Only

- To Investigate the Mediating Role of Supply Chain Visibility:

    - Assess how supply chain visibility mediates the relationship between supply chain uncertainties (economic, demand, and technological) and supply chain performance.

    - Determine the extent to which improved visibility (e.g., real-time tracking, data sharing, transparency) can mitigate the adverse effects of supply chain uncertainties.

Research Question

What is the impact of supply chain uncertainties (economic, demand, and technological) on

the supply chain performance of Petroleum Industry in Pakistan, and does supply chain visibility mediate this relationship?

Scope of the Study

This research will focus on quantifying the impact of supply chain uncertainties, specifically economic, demand, and technological uncertainties—on the supply chain performance of Oil Marketing Companies (OMCs) in Pakistan, with particular emphasis on petroleum products. The study will also investigate the mediating role of supply chain visibility (SCV) in alleviating the adverse effects of these uncertainties and improving performance metrics such as cost efficiency, lead times, service quality, and overall responsiveness.

Identified Gaps

Limited Research on the Petroleum Sector in Pakistan

While many studies have explored supply chain uncertainties in various industries, there is limited research focusing specifically on the petroleum sector in Pakistan. The complexities of oil imports, government regulations, and market volatility create unique challenges that are not well addressed in existing literature (Iqbal, M ,2020). This study aims to fill this gap by providing a focused analysis of OMCs in Pakistan, specifically regarding petroleum products.

Lack of Focus on the Mediating Role of SCV

While the benefits of supply chain visibility have been recognized, there is insufficient research on how SCV specifically mediates the relationship between supply chain uncertainties and performance, especially in the petroleum sector (Iqbal, M ,2020). This research will address this gap by investigating how SCV can mitigate the impact of uncertainties, enhancing decision-making and improving operational resilience.

Quantification of Impact of Uncertainties on Supply Chain Performance

Existing literature often discusses the qualitative aspects of supply chain disruptions, but there is a lack of quantitative studies that measure the exact impact of demand, economic, and technological uncertainties on supply chain performance in the petroleum sector. This study will provide empirical data and statistical analysis to quantify these impacts.

Technological Uncertainty in Oil Marketing

The rapid pace of technological change, including digital transformation, automation, and data analytics, presents challenges in supply chain management (Aslam, 2021). However, there is a gap in understanding how technological uncertainties such as infrastructure limitations and varying technological adoption affect OMCs' ability to manage supply chains efficiently (Aslam, 2021). This research will focus on identifying these technological barriers and how SCV can mitigate their impact.

Data Integration and Digitalization Challenges

Despite the potential of SCV to improve performance, many OMCs in Pakistan face challenges related to fragmented supply chains and lack of integration across stakeholders. There is a need for studies that explore how OMCs can overcome these challenges through better data-sharing practices and technological adoption **(**Tarei, P. K, 2020). This research will contribute to understanding how improving SCV through digital tools can lead to greater efficiency and stability in petroleum supply chains.

How This Study Will Address the Gaps

This study will provide valuable insights into how SCV can improve the resilience of Pakistan's petroleum supply chains by examining the relationship between uncertainties and performance. By focusing on empirical data from OMCs and utilizing statistical methods to quantify the impact of uncertainties, this research will add to the body of knowledge on petroleum supply chains in Pakistan. It will also highlight the practical ways in which SCV can help mitigate disruptions and improve operational performance, particularly by exploring how technologies such as real-time tracking and data sharing can help OMCs adapt to market and environmental fluctuations. The findings will not only fill existing research gaps but also offer actionable recommendations for OMCs to enhance their supply chain strategies in the face of increasing uncertainties.

This research will help individual players like PSO, GO, and PARCO by providing actionable insights into how supply chain visibility (SCV) can mitigate the negative impacts of uncertainties, such as fluctuating demand, economic volatility, and technological disruptions. It will offer strategies to enhance real-time tracking, improve data-sharing practices, and streamline decision-making processes. By adopting these findings, OMCs can optimize inventory management, reduce supply disruptions, and achieve better cost efficiency, giving them a competitive edge in the dynamic petroleum market.

Literature Review

Supply Chain Uncertainty: (Independent Variable)

Supply chain uncertainty refers to the unpredictability and lack of reliability in various elements of the supply chain, which can disrupt operations and impact overall performance. This uncertainty can stem from a range of sources, including demand fluctuations, supply variability, process inefficiencies, and external factors such as economic or geopolitical changes. For example:

Demand Uncertainty

Difficulty in accurately predicting customer preferences or order volumes can lead to overstocking or stockouts. According to B. M. Beamon (2015) when it comes to supply planning,

it is the quality of demand forecasts at the lower levels of product hierarchies that is most impactful to forecasting performance or lower down the uncertainties that has been forecasted. As T. S. Chan and H. J. Qi (2013) found this to be true, especially when product demands are negatively correlated. This arises from unpredictable customer demand patterns, inaccuracies in forecasting, or volatile market conditions. Fisher (1997) highlights that mismatched supply chain strategies with demand characteristics can exacerbate uncertainty.

Supply Uncertainty

Factors such as unreliable suppliers, variable lead times, and quality issues contribute to supply-side challenges. Zsidisin (2003) emphasizes that understanding supplier risk is critical in managing supply uncertainty.

Technological Uncertainty

According to Sara Sarir, Mohamed El Oumami and Zitouni Beidouri (2024), petroleum sector requires a vital and complexed segmentation of energy sector globally. The supply chain sector of any industry is so much exposed to various risks from both sides: externally and internally. These risks significantly impact the performance of supply chain in petroleum industry. Technological uncertainty, economic uncertainty, social changes can be significantly impacts the performance of supply chain. Technological risks can disrupt operations, increase costs, and affect supply chain reliability. Understanding these risks is crucial for enhancing supply chain resilience, improving performance, and mitigating vulnerabilities. (sara, Oumami and Beidouri, 2024). To mitigate these uncertainties, companies often focus on enhancing supply chain visibility, which involves real-time tracking and sharing of information across the supply chain. This improved transparency helps in better forecasting, planning, and decision-making, ultimately reducing the impact of uncertainties. Supply chain uncertainty refers to the unpredictability and variability that businesses face within their supply chains, which can significantly disrupt operations and hinder performance. Researchers have explored various dimensions and sources of uncertainty to understand its implications better.

Sources of Supply Chain Uncertainty

Information Gaps

Inadequate or inaccurate data sharing between supply chain partners can lead to decision-making errors. Lee et al. (1997) in his study discussed the "bullwhip effect," where distorted information amplifies uncertainty along the supply chain.

Complexity and Globalization

As supply chains become more global and interconnected, the complexity increases, making them more susceptible to disruptions (Christopher & Peck, 2004).

Variability in Processes

Inconsistent production schedules, fluctuating raw material availability, and logistical delays add to operational unpredictability (Chopra & Sodhi, 2004).

Impacts of Supply Chain Uncertainty

Supply chain uncertainty can affect various performance metrics, including cost efficiency, service levels, and responsiveness. For instance:

Operational Performance

Uncertainty often leads to higher inventory levels, increased lead times, and reduced capacity utilization (Simangunsong et al., 2012).

Strategic Impact

It undermines a firm's ability to respond to market demands effectively, thereby impacting competitive advantage (Wagner & Bode, 2008).

Approaches to Manage Uncertainty

Supply Chain Visibility

Improved transparency and real-time data access are crucial for mitigating uncertainty. Barratt and Oke (2007) argue that supply chain visibility enhances collaboration and reduces risks.

Risk Management

Employing robust risk assessment frameworks can help identify and prepare for potential uncertainties (Tang, 2006).

Flexibility and Agility

Building an agile supply chain capable of adapting to changes quickly can offset the adverse effects of uncertainty (Christopher, 2000).

Supply chain uncertainty is an inherent challenge that requires proactive strategies, including technological integration, process optimization, and strong partnerships, to minimize its impact on performance. Continuous research and the adoption of adaptive frameworks are essential for managing the dynamic nature of uncertainty effectively.

Supply Chain Performance (SCP)

Supply chain performance refers to the effectiveness and efficiency of a supply chain in achieving its goals, such as cost reduction, service enhancement, and improved responsiveness to market demands. Researchers have extensively studied various dimensions, metrics, and factors influencing supply chain performance to enhance business competitiveness (Gunasekaran ,2004).

Supply Chain Performance and its Dimensions

Supply chain performance measures how well the supply chain delivers value to

customers and stakeholders. Gunasekaran et al. (2004) categorize supply chain performance into key dimensions

Efficiency: The ability to minimize costs while maintaining service levels.

Flexibility: The capability to respond to changes in demand or disruptions.

Responsiveness: Speed in meeting customer needs and adapting to market fluctuations.

Quality: Consistency and reliability in meeting customer expectations.

Key Metrics for Measuring Supply Chain Performance

Cost Metrics. Total logistics costs, inventory carrying costs, and operational expenses (Beamon, 1999).

Time Metrics: *Lead times, order cycle times, and delivery speed (Chopra & Meindl, 2007).*

Customer Service Metrics: Order fill rates, on-time deliveries, and customer satisfaction scores (Lambert & Pohlen, 2001).

Asset Utilization Metrics: Inventory turnover ratios and capacity utilization (Kaplan & Norton, 1996).

Factors Influencing Supply Chain Performance

Supply Chain Integration.   *Close collaboration and coordination among supply chain partners lead to improved performance. Frohlich and Westbrook (2001) found that higher levels of integration positively impact efficiency and responsiveness.*

Technology Adoption.   Advanced technologies like IoT, blockchain, and AI enhance data visibility, decision-making, and real-time monitoring, which significantly improve performance (Barua et al., 2004).

Supply Chain Agility. *An agile supply chain is better equipped to manage disruptions and variability, thus maintaining high performance (Christopher, 2000).*

Supply Chain Visibility. Transparency in operations enables better forecasting, reduced bullwhip effects, and faster response times, as highlighted by Barratt and Oke (2007).

Challenges to Supply Chain Performance

Globalization: Increased complexity and longer lead times in global supply chains can hinder performance (Christopher & Peck, 2004).

Supply Chain Disruptions*: Events like natural disasters, geopolitical tensions, or pandemics disrupt operations and reduce efficiency (Sheffi, 2005).*

Sustainability Pressures: *Balancing economic, social, and environmental goals often complicates supply chain operations (Seuring & Müller, 2008).*

Strategies for Enhancing Supply Chain Performance

Lean Practices: Eliminating waste and optimizing processes to improve efficiency and reduce costs (Womack & Jones, 1996).

Agile Frameworks*: Adopting flexible and adaptive practices to manage variability and respond to customer needs promptly (Christopher, 2000).*

Collaborative Planning*: Enhancing joint forecasting, planning, and replenishment among supply chain partners (Simatupang & Sridharan, 2005).*

Digital Transformation: *Leveraging advanced technologies to enhance visibility, coordination, and decision-making capabilities (Ivanov et al., 2019).*

Supply chain performance is a multifaceted construct that influences organizational success. Effective performance measurement and management strategies, coupled with integration, visibility, and agility, are critical to achieving competitive advantage in dynamic markets.

Relationship Between Supply Chain Uncertainty and Supply Chain Visibility

According to Charles, Dalian, Senyo and Daniel (2021) Supply chain uncertainty creates information asymmetry, leading to poor decision-making and inefficiencies. SCV alleviates this by providing timely and accurate information across the supp SCV mediates the relationship between SCU and SCP by translating uncertainty management into performance improvements. It does so in several ways:

Improved Decision-Making

Greater visibility allows for more informed decisions, reducing the inefficiencies caused by SCU. For instance, firms can optimize inventory levels and production schedules, as demonstrated by Tukamuhabwa (2017).

Enhanced Responsiveness and Agility

SCV enables firms to quickly adapt to demand and supply disruptions, thereby mitigating the negative impact of SCU on SCP. Christopher and Lee (2004) link visibility to supply chain agility, showing its importance in dynamic environments.

Collaboration and Coordination

SCV fosters better collaboration among supply chain partners, leading to enhanced performance metrics like on-time delivery and cost efficiency. Flynn et al. (2010) show that information sharing improves SCP by fostering stronger partnerships.

Empirical Evidence Supporting SCV as a Mediator

Several studies empirically confirm the mediating role of SCV in linking SCU and SCP.

Barratt and Barratt (2011). Their study highlights that firms with higher visibility can mitigate SCU's adverse effects more effectively, resulting in improved service levels and cost reductions.

Schoenherr and Swink (2012)

Their research shows that SCV positively impacts operational performance by reducing uncertainties in global supply chains.

Dubey et al. (2018). Examining SCV in the context of emerging markets, they found it significantly enhances SCP by reducing uncertainty in demand forecasting and supplier reliability.

Practical Implications for Supply Chain Management

Invest in Technology: Organizations should adopt technologies that enhance SCV, such as advanced analytics, blockchain, and real-time tracking systems, to manage SCU effectively and improve SCP.

Promote Collaboration*: Firms must build strategic alliances and share information transparently across supply chain networks to maximize the benefits of SCV.*

Focus on Proactive Risk Management: *Leveraging SCV for predictive insights helps in identifying and mitigating risks before they escalate into performance issues.*

Role of SCV in Reducing Uncertainty

Barratt and Oke (2007) argue that visibility minimizes demand and supply variability by fostering better forecasting, scheduling, and communication among partners. This reduces the bullwhip effect where distorted information amplifies uncertainty along the supply chain (Lee et al, 1997).

Technology as an Enabler

Technologies like IoT, blockchain, and cloud computing are pivotal in enhancing SCV. Zhang et al. (2011) highlight how real-time information sharing reduces uncertainty by improving transparency and operational coordination. Supply chain visibility acts as a critical enabler in transforming the challenges posed by uncertainty into opportunities for performance improvement. It bridges the gap between the unpredictability inherent in supply chains and the need for efficiency, responsiveness, and flexibility. Investing in SCV is no longer optional but essential for firms seeking to thrive in uncertain and competitive environments.

Hypothesis Development

The volatile nature of global oil prices, coupled with economic fluctuations, creates significant economic uncertainties that directly affect the procurement, pricing, and inventory management practices of oil marketing companies (OMCs) in Pakistan. Demand uncertainties further complicate supply chain operations, stemming from unpredictable consumer demand patterns, regulatory changes, and external shocks such as geopolitical tensions and global pandemics. Additionally, technological uncertainties, driven by the rapid

pace of digital transformation, infrastructure limitations, and varying degrees of technological adoption, present considerable obstacles for the companies to achieve efficient and resilient supply chains. These uncertainties impact supply chain performance metrics such as cost efficiency, lead time, service quality, and overall responsiveness. In this context, supply chain visibility emerges as a crucial factor that can mediate the relationship between supply chain uncertainties and performance outcomes. Enhanced visibility allows for better real-time decision-making, risk mitigation, and adaptive strategies to manage disruptions, ensuring more agile and robust supply chains. However, achieving such visibility in Pakistan's OMC sector is challenging due to fragmented supply chain networks, lack of digital integration, and insufficient data-sharing practices among stakeholders.

Under the consideration of previous literature review following are the hypotheses which we have to test to acquire our desired results of the research.

H1: Supply chain uncertainty has a negative impact on supply chain performance. _Rationale:_ Higher uncertainty in supply and demand reduces efficiency, increases costs, and negatively affects responsiveness (Christopher & Lee, 2004).

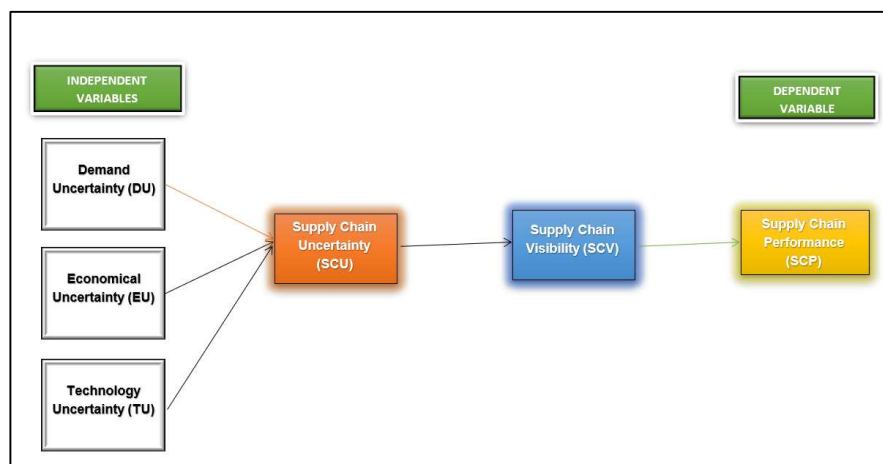**H2:** Supply chain uncertainty has a negative impact on supply chain visibility. _Rationale:_ Uncertainty disrupts information flow and creates barriers to achieving transparency and coordination (Barratt & Oke, 2007).

H3: Supply chain visibility has a positive impact on supply chain performance. _Rationale:_ Improved visibility enhances decision-making, reduces lead times, and improves customer service levels (Schoenherr & Swink, 2012).

H4: Supply chain visibility mediates the relationship between supply chain uncertainty and supply chain performance.

Rationale: Visibility mitigates the adverse effects of uncertainty by improving data availability and decision-making, thereby enhancing performance (Dubey et al., 2018).

Figure 1 Conceptual Frame Work

Methodology

Research Approach

The proposed research is an exploratory study and quantitative in nature. The proposed empirical study will determine the impact of supply chain uncertainties on supply chain visibility which ultimately determines the supply chain performance of Petroleum Industry in Pakistan. The study was carried out through questionnaire shared with supply chain professionals working in OMCs. The responses received from professionals were used to find out the impact of supply chain uncertainties due to demand, technology and economic uncertainties on supply chain performance of their respective organization. The responses were also used to understand the mediatory role of supply chain visibility between supply chain uncertainties and supply chain performance. Responses received through questionnaire were analyzed through Smart PLS-4.

Research Method

The proposed research follows the empirical study depends on data collection from OMC's (petroleum sector) of Pakistan. we have chosen the online questioners as a tool of data collection so that it would be convenient for researcher to send the questionnaire easily and the respondent to fill it online on google chrome. The online google form is more cost effective as compared to the former method of data collection. The collected data has been analysed through Smart PLS-4, to attain the result of different tests as regression and correlation to study the dependency of variables on each other and existence of significant relationship between variables.

Research Design

The proposed research followed the purposive sampling technique which was convenient for the researchers to collect data from different companies of OMC sector and sample size was set to be approximately 150. Responses were collected within a month from November 2024 to December 2024 from individuals who were working in Supply Chain of Petroleum Industry of Pakistan.

Table 2 Mapping Table

Research Question/Objective	Variable(s)	Hypothesis	Theoretical Framework	Methodology (Data Collection)	Data Analysis Technique
Impact of SCU on SCP of Petroleum Industry in Pakistan, and does SCV mediate this relationship?	SCU (EU, DU, TU - Indep) SCP (Dependent) SCV(Mediating)	**H1:** SCU has a negative impact on SCP **H2:** SCU has a negative impact on SCV. **H3:** SCV has a positive impact on SCP. **H4: SCV** mediates the relationship between SCU and SCP.	Resource-Based View (RBV), Contingency Theory, and Supply Chain Risk Management Theory: Together, these explain how SCV as a valuable resource mitigates SCU and enhances SCP	Online Survey (Questionnaire)	Smart PLS 4

Construct Measurement

The collected data was processed in Smart PLS-4 and questionnaire had been designed on Likert scale to acquire better responses from respondents. The online google form link is here: https://forms.gle/ob9QasqE45x2cAH48

Data Analysis

Purposive sampling technique was used for data collection, in which online questionnaire was floated to the concerned individuals associated with the supply chain of petroleum Industry of Pakistan in different OMCs. Upon receipt of approximately 150 responses, data was analyzed using Smart PLS-4.

Table 3 Demographic characteristics of the sample

Sample Size=166		Frequency	Percentage
Designation	HOD	21	12.7
	Manager	91	54.8
	Asst Manager	34	20.5
	Executive	20	12
Education	Masters & above	58	34.9
	Graduate	108	65.1
Department	Supply Chain	69	41.6
	Operations	73	44
	Procurement	16	9.6
	Finance	8	4.8
Company Age (Yrs)	4 - 6	33	19.9
	7 - 9	24	14.5
	10 - 12	45	27.1
	13 or above	64	38.6
Company Size (No of Employees)	51 - 100	4	2.4
	101 - 200	15	9
	201 - 400	41	24.7
	401 and above	106	63.9
Gender	Male	156	94
	Female	10	6

Construct Reliability and Validity

Evaluation of the measurement model adopts a confirmatory assessment of the convergent and discriminant validity (Campbell & Fiske, 1959). Convergent validity (CV) is adequate in the given study because the Average Variance Extracted (AVE) is over 0.500. Composite Reliability is also established since each construct's values are above 0.70 (Figure 2). The results for Reliability and validity and outer loadings for the items are given in Figure 2 Measurement Model with Composite Reliability (Construct Validity)

Table 4. Discriminant validity is evaluated through the forell-larcker criterion (

Table **5**). The table shows that the Average Variance Extracted (AVE) square root for the construct is greater than the inter-construct correlation. Discriminant validity is also assessed by the Heterotrait-Monotrait (HT-MT) ratio of correlations (Henseler et al., 2015) having values below 0.90. Hence, discriminant validity for the model is also established (
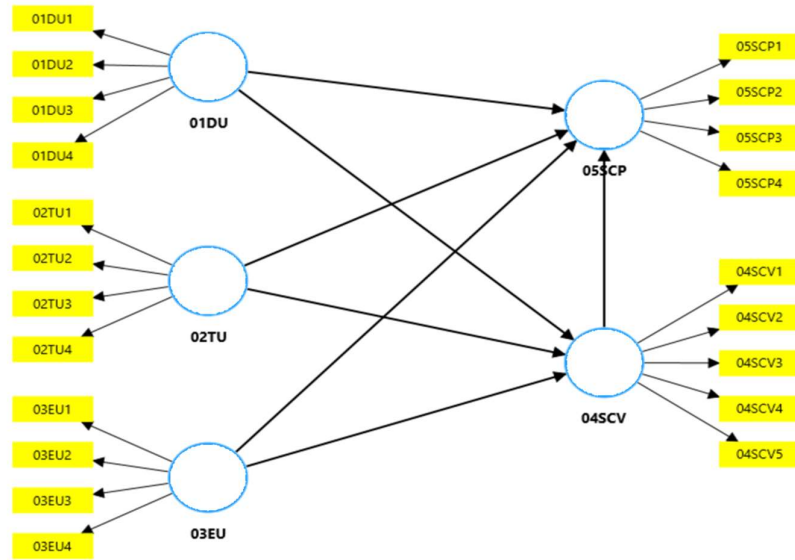
Table **5**)

Figure 2 Measurement Model with Composite Reliability (Construct Validity)

Table 4 First Order Reflective Measurement Model Results

Construct	Item	Loading	CR	Avg Var Extracted
Demand Uncertainty	DU1	0.819	0.829	0.548
	DU2	0.734		
	DU3	0.733		
	DU4	0.701		
Tech Uncertainty	TU1	0.822	0.887	0.663
	TU2	0.835		
	TU3	0.822		
	TU4	0.777		
Eco Uncertainty	EU1	0.734	0.818	0.529
	EU2	0.702		
	EU3	0.762		
	EU4	0.713		
Supply Chain Vis	SCV1	0.747	0.87	0.574
	SCV2	0.773		
	SCV3	0.791		
	SCV4	0.801		
	SCV5	0.761		
	SCP1	0.762	0.83	0.55

Supply Chain Performance	SCP2	0.765		
	SCP3	0.762		
	SCP4	0.747		

Table 5 Value for Fornell-Larcker Criterion and Heterotrait-Monotrait Ratio (HTMT)

	DU	*TU*	*EU*	*SCV*	*SCP*
DU	*0.741*	0.751	0.682	0.537	0.778
TU	0.548	*0.814*	0.582	0.45	0.673
EU	0.509	0.462	*0.727*	0.843	0.741
SCV	0.448	0.384	0.644	*0.758*	0.623
SCP	0.595	0.541	0.646	0.703	*0.742*

Hypotheses Testing

The study examined the dimensions of Supply Chain Uncertainty (SCU) on Supply Chain Performance (SCP) and Supply Chain Visibility (SCV) for H_1 and H_2 along with Supply Chain Visibility (SCV) on Supply Chain Performance (SCP) for H_3. Results of these hypotheses are given in the below Table 6.

Table 6 Values for Hypotheses Testing

| Relationships	β	STDDEV	T Stats	P Values	5%	95%	Results
H_1: SCU -> SCP	0.468	0.073	6.444	0.000	0.342	0.583	Supported
H_2: SCU -> SCV	0.653	0.072	9.084	0.000	0.515	0.754	Supported
H_3: SCV -> SCP	0.398	0.079	5.012	0.000	0.256	0.522	Supported
R^2 SCV = 0.621	Q^2 SCV = 0.389						
R^2 SCP = 0.427	Q^2 SCP = 0.505						

Mediation analysis

Mediation analysis was performed to assess the mediating role of SCV. The results (Table 7) revealed that SCV found to be a significant mediator (H4: β=0.26, t=4.299, p=0.000).

Table 7 Values of Hypotheses Testing (Moderation Analysis)

	β	STDDEV	T Stats	P Values	Results
H_4: SCU -> SCV -> SCP	0.26	0.061	4.299	0.000	Supported

Figure 3 Structural Model
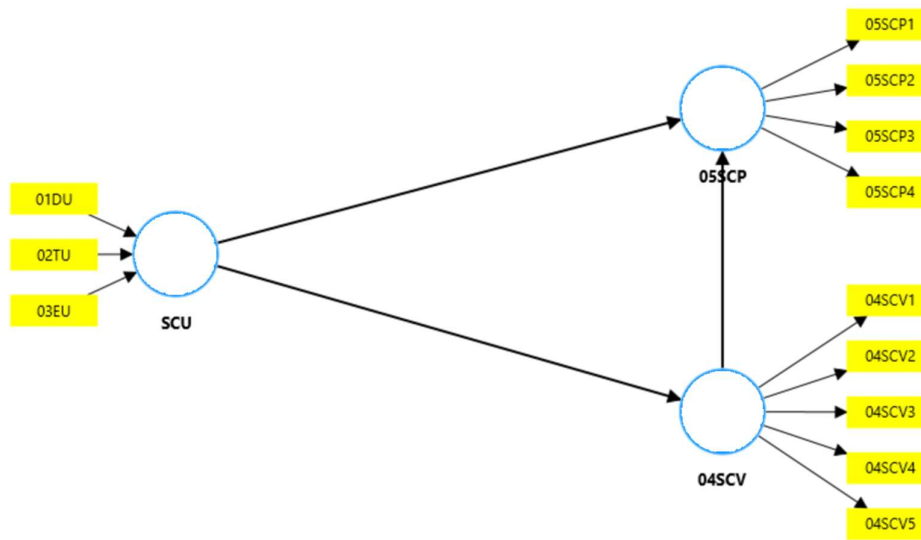
Hypotheses Testing Results

As given in Table 6, Hypotheses results revealed that SCU has a significant impact on SCP (β= 0.468, t=6.444, p=.000). Hence, H_1 was supported. The results also revealed that SCU has a significant impact on SCV (β=9.084, t=6.444, p=0.000) supporting H_2. Finally, the results revealed a significant impact of SCV of SCP (β=5.012, t=0.398, p=0.000) supporting H_3. Similarly, Table 5 revealed that SCV found itself to be a significant mediator (H4: β=0.26, t=4.299, p=0.000) supporting H_4.

Discussion

The study investigated the impact of supply chain uncertainties (SCU) on supply chain performance (SCP), with supply chain visibility (SCV) as a mediating factor. The evaluation of the measurement model confirmed the reliability and validity of the constructs, with all metrics—Average Variance Extracted (AVE), Composite Reliability (CR), and discriminant validity (Fornell-Larcker and HTMT)—meeting established thresholds.

The structural model results provide significant insights:

- SCU has a direct and significant impact on SCP suggesting that uncertainties in demand, technology, and economics pose challenges to supply chain performance.

- SCU significantly influences SCV indicating that as uncertainties rise, greater supply chain visibility is required to mitigate risks.

- SCV positively impacts SCP emphasizing the importance of visibility in enhancing performance.

- Mediation analysis revealed that SCV significantly mediates the relationship between SCU

and SCP and acts as a key mechanism in mitigating the adverse effects of uncertainties on performance.

The model's predictive **capability** was validated through R^2 and Q^2 values:

- **R^2** for SCV (0.621) and SCP (0.427) indicates that the model explains 62.1% of the variance in SCV and 42.7% in SCP, reflecting moderate explanatory power.

- **Q^2** for SCV (0.389) and SCP (0.505) demonstrates strong predictive relevance, confirming that the model reliably predicts the constructs in unseen scenarios.

Overall, the findings highlight the robustness of the model in explaining and predicting the relationships among supply chain uncertainties, visibility, and performance.

Conclusion, Limitations and Recommendations

Conclusion

This study demonstrates that supply chain uncertainties significantly influence supply chain performance and that visibility serves as a critical mediator in mitigating these effects. The strong predictive relevance of the model (Q^2) underscores its practical applicability, making it a valuable tool for decision-makers aiming to improve performance in uncertain environments. Organizations should prioritize strategies that enhance visibility and predictive capabilities to build resilient supply chains and achieve superior outcomes.

Limitations and Recommendations

The study is focused on a specific context, which limits its generalizability to other industries or regions. It also relies on cross-sectional data, capturing only a snapshot of the supply chain environment and not accounting for long-term dynamics. Additionally, the study excludes potential mediators and moderators, such as supply chain agility or resilience, which could offer deeper insights into performance. The research's narrow industry scope and lack of geographic diversity further restrict its applicability to broader contexts.

Future research should broaden the scope to include multiple industries and regions to validate the relationships between supply chain uncertainty, visibility, and performance across different contexts. Incorporating additional mediators like supply chain resilience and adopting a longitudinal study design will provide a more comprehensive understanding of these relationships. Additionally, exploring technological advancements and regional/cultural differences could enhance the model's applicability and effectiveness in diverse global supply chains.

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