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The Impact of Cold Chain Logistics Risks on Firm Performance: Assessing the Mediating Roles of Data Analytics and Human Factor Capabilities under Environmental Dynamism

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Abstract
Thermal integrity as a concept in cold chain logistics is a decisive factor of success in companies dealing with perishable goods, but these companies are experiencing growing operational risks and environmental unpredictability. This study examines how Cold Chain Logistics Risks (CCLRs) affect Firm Performance (FP), in addition to considering the roles of internal capabilities, namely data-driven decision making and workforce training in the context of environmental dynamism. The data was gathered using a quantitative research design, where a structured survey was used to gather empirical data of 105 professionals associated with cold chain companies in Karachi, Lahore, and Sahiwal, Pakistan. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to test the conceptual framework in SmartPLS software.
The descriptive findings point out to a strongly male dominated workforce (91.42) with a majority of them being at the age bracket of 26-30 years and are primarily working in large sized companies (45%). The structural analysis affirmed the existence of positive important relationships along the hypothesized directions: CCLR has a significant impact on Environmental Dynamism and Internal Capabilities. Most importantly, Internal Capabilities became one of the most effective Firm Performance predictors, which means that the value of the technical and human resilience assets is the main force behind the ROI and market share. These results conclude that operational pressure caused by logistics risks is effective but the strategic implementation of ICT infrastructure and multi-skilled workforce fills the gap amid risk exposure and organizational success. This paper is a roadmap that managers can use to develop strength in unstable markets by investing in technology and human capital.

Keywords: Cold Chain Logistics Risks, Internal Capabilities, Firm Performance, Environmental Dynamism, Perishable Products, PLS-SEM.

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Introduction

Logistics is an essential component of the ongoing process of fresh food and pharmaceutical supply of global markets (Ali, Nagalingam, and Gurd, 2018). Yet, the growing complexity of global supply chain, combined with the very nature of weather conditions instability and the perishable nature of the product make firms vulnerable to specific risks of logistics uniquely. The field of logistics management is a wide range of business activities involving the management of inbound and outbound movements, fleet management, warehousing and planning of strategic inventories (Bavarsad, Boshagh and Kayedian 2014). (Ali et al., 2018) In this professional context, cold chain logistics (CCL) refers to the method and networked mechanism necessary to secure the safe transportation of perishable products through the whole chain of value.

(Ashokan, 2011) although thermal packaging solutions have developed to active mechanical cooling to passive phase-change materials, cold chain industry is very vulnerable to disruptions in its operations. Any failure in the food supply chain can cause a lot of waste that would cause shortages in food in the region and a lot of financial losses to the stakeholders. In addition, the modern business environment has grown more volatile because of unstable rates in maritime freight and harsh global shipping container deficits (Rožić, Naletina, and ac, 2022). Therefore, there is a dire need to institute adaptive resilient capability in firms so that they can sustain the continuity of operations at the necessary degree of connectedness and control.

Background of the Study

Cold chain logistics is deeply dependent on empirical science to assess and control the crucial connection between the preservation of temperature and perishability of the products (Ali et al. 2018). This is necessary to maintain certain thermal ranges; an example is the need to keep vaccines in a strictly restricted temperature range, otherwise, the loss of its strength is irreversible. (Ali et al., 2018) Likewise, food safety would be at risk when products are at a temperature or greater since such degrees allow proliferation of harmful bacteria quickly. These strict conditions require significant capital expenditures on special infrastructure such as refrigerated transport fleets and temperature-controlled warehousing.

According to current scholarly work, a resilient supply chain can be characterized as having both resistance and recovery abilities, so that the firm can both limit and reduce the effect of a disruption on them (Ali et al., 2018). (Khurshid & Siddiqui, 2024) Strategy The resilient enterprise can be created through developing strategic redundancy, including having safety stock or diversifying suppliers. Nonetheless, the supply chain managers need to focus more on product quality management systems and continuous process improvement as the consumers grow more quality-conscious.

According to recent research, data capture in real time and integrated technologies are key pre-requisites to successful decision-making throughout the cold chain (Chaudhuri et al., 2018). The academic interest in the question is deep because sustained observation of the parameters of temperature, humidity, and

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vibration can provide real-time information on the shelf life of products (Chaudhuri et al., 2018). Moreover, the human factor cannot be replaced because the way the work processes and operating environments are designed has a considerable influence on human choices and the performances of firms (Brauner et al., 2013). This paper is based on the framework of Ali, Nagalingam, and Gurd (2018), wherein the digital and human aspects integrated under the moderating factor of environmental dynamism are provided to provide a comprehensive insight into cold chain resilience.

Problem Statement

Although thermal integrity is extremely important to the firms in the perishable product industry, companies in the industry continue to incur heavy financial losses in terms of temperature excursions and logistical breakdowns (Ali, Nagalingam, and Gurd, 2018). The traditional method of risk management is not always capable of dealing with the intricate, interdependent nature of Cold Chain Logistics Risks (CCLRs), especially when the global supply chain is disrupted on a scale of natural calamities or global supply chain bottlenecks. Although the direct adverse effect of these risks on the performance of a firm has been well-reported, it is still unclear in empirical terms how the internal processes can effectively fill the gap between the exposure to risks and the ability to remain resilient in its operations (Bavarsad, Boshagh, and Kayedian, 2014).

In particular, despite the widely presented digitalization as a solution, numerous organizations cannot deal with the transformation of raw data provided by ICT infrastructure into practical and real-time decision-making functions to maintain the shelf life of products (Chaudhuri et al., 2018). In addition, the human factor is often dismissed, which results in the fact that highly technological systems are sabotaged by the lack of training of workforce or improperly structured working procedures (Brauner et al., 2013). This issue is also exacerbated by the fact that the extreme dynamism of the environment can make the previously stable resilience strategies obsolete by the unstable freight rates and market uncertainty (Rožica, Naletina, and ac, 2022). Thus, there is a serious gap in the literature that underpins the study on how data-driven decision-making and workforce capabilities are mediating effects of logistics risks when there is the moderating influence of dynamic external environment.

Gap Analysis

The existing literature is replete with the negative relationship between the risk of cold chain logistics and organizational performance, but it does not explain the exact mechanisms through which companies do not get derailed after these shocks (Ali, Nagalingam, and Gurd, 2018). Although other researchers focus on the significance of physical infrastructure, there is a significant gap in theoretical studies on how internal process capabilities can turn those immobile resources into dynamic resilience (Khurshid and Siddiqui, 2024). Precisely, despite the frequent talk about the shift to Industry 4.0, there is still a lack of empirical evidence concerning the particular

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mediating influence of data-driven decision-making in the efforts to mitigate the risks of the spoilage that are inevitable with perishable supply chains.

Besides, there is a big gap between the conceptualization of the concept of human factors into supply chain resilience models since most of the studies are based on mechanical or digital resolution, neglecting the value of human resource training to reconfigure the resources in the event of a crisis. The earlier studies have concentrated largely on stable market situations, and this gap in literature has led to the lack of knowledge about how environmental dynamism typified by high market volatility and freight instability mediates the efficiency of internal competencies. These gaps are therefore met in this research work through the development of an integrated model that will consider both digital and human mediators acting on the moderating influence of a dynamic external environment. Traditional research tends to consider logistics risks as individual incidents with no consideration to the ripple impact that temperature control failures have on the overall financial condition of the company. The linkage of precise technical needs of the cold chain, including keeping thermal windows, to high-level strategic firm performance measures in the Pakistani context has not been researched. Purely theoretical(Chaudhuri et al., 2018) ICT infrastructure has been identified as a tool, but the literature does not extensively investigate the reasoning behind decision-making to be applied to turn raw sensor data into useful inventory management tools.

Most of the models believe that the technology is automatically improved and thus the availability will translate into improved performance but fail to fill the gap in the human multi-skilling needed to run these systems during high-stress disruptions (Brauner et al., 2013). One of the most significant gaps lies in the absence of the longitudinal-like performance assessments that could take into consideration the external shocks, including the recent international shipping container shortages and maritime freight volatility. The post-disruption phase is under-researched because the existing frameworks often concentrate on the so-called resistance (not taking the risk) instead of on the so-called recovery (restoring the level of original performance).

The geographical distance is also eminent since most cold chain resilience models are designed in the Western or highly developed economies, which are not a representative of what developing markets would face in terms of infrastructure challenges. The literature lacks a connection on the specific way environmental regulation and dynamism change the cost benefit analysis of implementing costly data-driven technologies. Although risk identification is usual, empirical studies lack that suggest a structural equation model (SEM) to simultaneously test multiple mediators. (Bavarsad, Boshagh, and Kayedian, 2014) Lastly, the development of a type of capabilities (human training) and data analytics as a dual-mediator system dubbed as soft and hard capabilities is yet another area with a substantial literature gap in the field of supply chain management literature.

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Research Objectives

The main objective of the study is to come up with a holistic model of structure that checks the effect of cold chain logistic risks on the performance of firms in the perishable product market. Particularly, the research is aimed at determining the risk factors that are the most severe, including temperature failures and natural disasters that have a direct negative impact on organizational stability. In addition to this, the study seeks to investigate the mediating effect of decision-making based on the data in countering these logistics risks using real-time quality monitoring (Chaudhuri et al., 2018).

Another important objective is to assess the role of workforce training as a human-centric mediator through which firms can reorganize their resources in case of disruption in operations (Brauner et al., 2013). Another focus of the proposed research is to examine the moderating impact of the environmental dynamism i.e., the market and freight volatility on the correlation between logistics risks and performance. It is also the purpose of the study to deliver an empirical data of the Pakistani market in order to develop context-specific resilience strategies. (Ali et al., 2018) Lastly, the study aims to provide effective managerial implications that can be applied to enhance supply chain connectedness and control in turbulent environments.

(Ali et al., 2018) To find out the cold chain logistics risks that have a particular impact on the performance of the firm.

(Chaudhuri et al., 2018) To determine the mediating role of the data-driven decision-making on the risk-performance relationship.

(Brauner et al., 2013) To establish how much workforce training acts as a mediator of the recovery process in the disruption.

To determine how the effects of environmental dynamism on the intensification of logistics risks are mediated.

To test the proposed integrated model through the structural equation modeling (SEM).

Significance of the Study

This study is of significant theoretical importance because it bends the classical spectrum of the concept of supply chain resilience to the effect that the digital and human-based mediators are incorporated into one coherent structural framework. The empirical study on the cold chain industry in Pakistan contributes to the literature uniquely, by providing potential insights into how companies in developing economies operate within the context of high-perishability risks managed in the infrastructure-restrained environment. The technological side of the study also presents the strategic significance of the transition of passive monitoring to the data-driven decision-making and demonstrates how real-time analytics can help protect firm performance directly.

Additionally, the practical value of the work consists in its references to the human factor, which offers a guidance to the managers on the investment in the training of the workforce as a means of re configuring the resources in times of crisis. With the current severe market volatility, the results provide essential information to policymakers and industry leaders on how to make it through the dynamism in the

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environment, in this case, maritime freight instability and container deficit. In the end, the paper is also part of the sustainability focus since it suggests strategies to minimize food and pharmaceutical waste by increasing operational connectedness and control.

Chapter 2. Literature Review

Cold chain logistics is a conceptual approach of managing and transporting perishable goods by using an interconnected system of thermal and refrigerated packaging interventions to maintain the quality and safety of perishable products (Ali, Nagalingam, and Gurd, 2018). The authors stress that any cold chain integrity is highly important, since disruption of the temperature-controlled environment may cause the rapid spoilage of the products, considerable financial losses and the threat of negative implications on the population health. Their study reveals that resistance and recovery ability of a firm determine resilience in this area where a firm needs unique infrastructure like refrigerated vehicles, and temperature-controlled warehouses to offset the operational setbacks.

Cold chain logistics risks (CCLRs) are complex challenges that pose a direct menace of destabilizing an organization due to the unavailability of high-perishability goods such as food and pharmaceuticals. The researchers classify these risks as internal operational failure, i.e. mechanical failure and poor packaging, and external shock, i.e. natural disaster and macroeconomic volatility. Their research establishes a strong negative relationship between these risks and the overall performance of the firm, found to have no firm mitigation strategies, the waste and inefficiency causes loss of market share and returns to investment.

(Chaudhuri et al., 2018) Data-driven decision making (DDDM) is an important internal capacity of operations that helps companies to shift towards proactive, as opposed to reactive, management of temperature-sensitive supply chains. The authors believe that through the incorporation of Information and Communication Technology (ICT), the ongoing measurement of the environmental factors that include humidity, vibration, and temperature is possible. This technology element provides managers with the analytical capabilities to intervene by real-time measurements of the quality and the left shelf life of products to ensure that warehousing logistics risks do not lead to irreversible product degradation.

(Brauner et al., 2013) This human factor is the indispensable aspect of the supply chain resilience and is concerned with the way in which workforce training and process design position human decision-making and operational performance. The scholars state that even the most advanced technological systems need the presence of a multi-skilled workforce that can reconfigure resources in case of high-stress disruptions. Organizations can minimize the number of human-induced errors and increase their chances of recovery on unforeseen logistics failures by investing in specialized training programs that consider human capabilities and limitations.

Environmental dynamism refers to a concept of the extent of unpredictability and swiftness in the external operating environment of a firm that plays a crucial role in determining the effectiveness of internal capabilities (Nguema et al., 2022). According to the researchers, pressure of the supply chain operations is heightened in the highly dynamic markets where the demand is volatile and the regulatory changes

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often occur. They employ the concept of dynamism as a moderating factor, which explains that the effect of logistics risks on corporate performance is more pronounced in case of the external market circumstances that are volatile and uncertain.

Macroeconomic volatility (in the context of maritime freight rates and global shipping container shortage) is also becoming more characteristic of the modern logistics environment (Rožic, Naletina, and Baričević, 2022). According to the authors, the factors of external dynamism cause a lot of bottlenecks that delay the delivery of goods that are temperature sensitive over the international borders. Their discussion implies that the companies which work in such turbulent conditions have to attain greater connectedness and control via digital agility to be able to endure the frequent shocks of the present global supply chains.

Supply chain management is a multidimensional construct that measures the financial health of a firm, as well as its competitive positioning (Bavarsad, Boshagh and Kayedian, 2014). The authors have used measures like return on investment, growth of market share and customer satisfaction all of which are used to determine how well a firm manages to cope with its operational risks. Their study assumes that a robust supply chain does not only protect against money loss but also, the overall strength of the firm in the industry through the reliability in provision of quality products to the final consumer.

Cold Chain Logistics Risks

The risk of cold chain logistics can be described as the possibility of the interruption of the specific supply chain procedures to preserve the thermal integrity of temperature-sensitive products (Ali, Nagalingam, and Gurd, 2018). The researchers believe that the risks are special since they entail a product-at-risk aspect in which any delay or equipment malfunction causes the goods to deteriorate physically immediately. Their research indicates that a continuous cold chain is critical in avoiding economic wastage and safeguarding the community, especially in delivery of food and medicines.

The types of cold chain logistics risks include all sorts of operational and environmental stressors such as breakdown in temperature, poor packaging, natural disasters, all of which have direct effects on undermining the stability of firms. The authors are finding a strong negative correlation between such logistics risks and organizational performance, and they deduce that errors in the temperature control lead to high rates of wastage. In their study, they highlight that these risks are the main independent variable in the process of identifying the resilience of a perishable product supply chain.

Data-Driven Decision Making

Data-driven decision making is the use of information and communication technology (ICT) infrastructure in order to capture real-time information to control logistics functions (Chaudhuri et al., 2018). The authors elaborate that technological advances like sensors and cloud-based analytics enable companies to keep track of the

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environmental parameters like temperature and humidity. As pointed out by their research, such data-driven solutions help logistics managers conduct real-time evaluations of the real remaining shelf life of the products so that further intervention can be made more applicable and proactive.

Implementing data-driven decision making is a crucial mediating capacity that helps in closing the gap between the exposure of risk and the ultimate performance of the organization (Ali et al., 2018). The researchers propose that being able to see and control all of the events throughout the cold chain is possible following digitalization, and it is necessary to reduce the negative impact of logistics disruptions. Their framework places technology as a strategic resource which transforms passive monitoring to an active, resilient operational management.

Workforce Training

Workforce training is a key human-centric capability that concentrates on the capability to align human decision-making to the sophisticated needs of the specialized supply chain processes (Brauner et al., 2013). The scholars point out that the human factor design should consider the abilities and limitations of the working population to make the working processes safe and efficient. Their study stresses that multi-skilling and specialized training enable the employees to restructure resources and reposition and respond to any change in operations in the times of high stress in supply chains disruption.

The role of investment in the training of the workforce as a mediator of the resilience model is that human expertise is needed to regulate the results of technological tools and logistics infrastructure. The authors indicate that despite the high-tech systems, the final success of the risk mitigation process is determined by how effectively the workforce reacts to such incidents as machine failures or rerouting. Their research suggests that a highly qualified workforce minimizes human caused interference and improves overall recovery of the firm.

Environmental Dynamism

Environmental dynamism: This refers to how quickly and uncertain the external market environment that a firm is operating in is (Nguema et al., 2022). The authors depend on the dynamism as a regulating factor that determines the degree of the association between the internal process capabilities and the firm outputs. They propose in their research that in very dynamic businesses, where demand in the market and regulatory frameworks are changing rapidly, the stress on the supply chain of a firm increases at a very high rate.

Due to the instability of freight rates on the seas and the unexpected lack of shipping container capacities in the world, global shipping is one of the primary drivers of environmental dynamism in modern logistics (Rožic, Naletina, and Baričević, 2022). The researchers observe that such external shocks make business environments turbulent where standard operating procedures are often updated. Their discussion implies that companies should become more operationally connected and digitally agile in order to deal with the ambiguity of these macroeconomic shocks.

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Firm Performance

(Bavarsad, Boshagh, and Kayedian, 2014) Firm performance is a multidimensional construct, which indicates the performance of an organization in terms of its ability to use its resources to attain its strategic and financial goals. The indicators used by the researchers to measure how effective the supply chain risk management is include, but are not limited to, the return on investment, market share and competitive position. They assume that companies that are effective in coping with their logistical weaknesses enjoy better financial soundness and customer satisfaction.

This is because the organizational performance with reference to the cold chain is closely associated with the capacity of the firm to ensure that it can be constantly connected and in control of its temperature sensitive assets (Ali et al., 2018). The authors clarify that high performance is attained where a company reduces the wastage of products and maximizes the reliability of the services offered even in the presence of logistics risks. Their resilience model proves that the firm performance is the final dependent variable which proves the performance of inner mediating capabilities and adaptive strategies.

Theoretical Framework

The theoretical basis of the proposed study is mainly based on the notion of the Resource-Based View (RBV) and the notion of supply chain resiliency, which concerns the ability of a firm to respond to external shocks, using its internal resources as the resource (Ali, Nagalingam, and Gurd, 2018). The researchers claim that resilience is a result of resistance and recovery ability of a firm where the interplay between the risk of logistics and organizational capability defines the ultimate performance result. Their model highlights that both connectedness and control of the supply chain is necessary to the firms to reduce the negative impact of the operational hazards.

This study employs a structural model to address the causality of cold chain logistics risks (CCLRs) towards firm performance at the mediating influence of internal capabilities. The authors introduce CCLRs as the independent variable that provokes the necessity to introduce adaptive responses in the organization to avoid the loss of competitive edge. Their theory proposes that the final dependent variable is the firm performance which is the cumulative success of the strategic risk management protocols practiced within the firm.

(Chaudhuri et al., 2018) Data-driven decision making is the role of digitalization that is incorporated in the framework as a mediator of the relationship between risk and performance, which includes the use of technology. The authors hypothesize that ICT-enabled visibility enables firms to convert the raw environmental information to actionable intelligence which will neutralize the physical risks of temperature-sensitive products. Their view emphasizes the fact that technology is not a one-dimensional solution but a moderating mechanism that has the effect of raising the reactive and proactive speed with which a firm arrives at decisions.

To consider the human factor in the management of complex logistical systems, (Brauner et al., 2013) includes human-centric design and workforce capabilities in the

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framework. The scholars believe that human factor design offers the required multi-skilling which enables reconfiguration of resources in case of failure of automated or technical systems. Their contribution into the theory is that human capital is a very crucial mediator so that as far as the processes of an organization are concerned, organizational processes are made flexible and resilient to the pressure of unexpected disruption in logistics.

(Nguema et al., 2022) The last element of the theoretical framework is that of the environmental dynamism which is applied as a moderating variable which changes the strength of the relationships in the model. The researchers urge that the effect of all logistics risks are not universal among all the market conditions but rather aggravated by high external change and unpredictability rates. The moderating lens enables the study to recognize the pressure cooker effect of turbulent maritime freight rates and shipping risk on the resilience mechanisms of the firm..

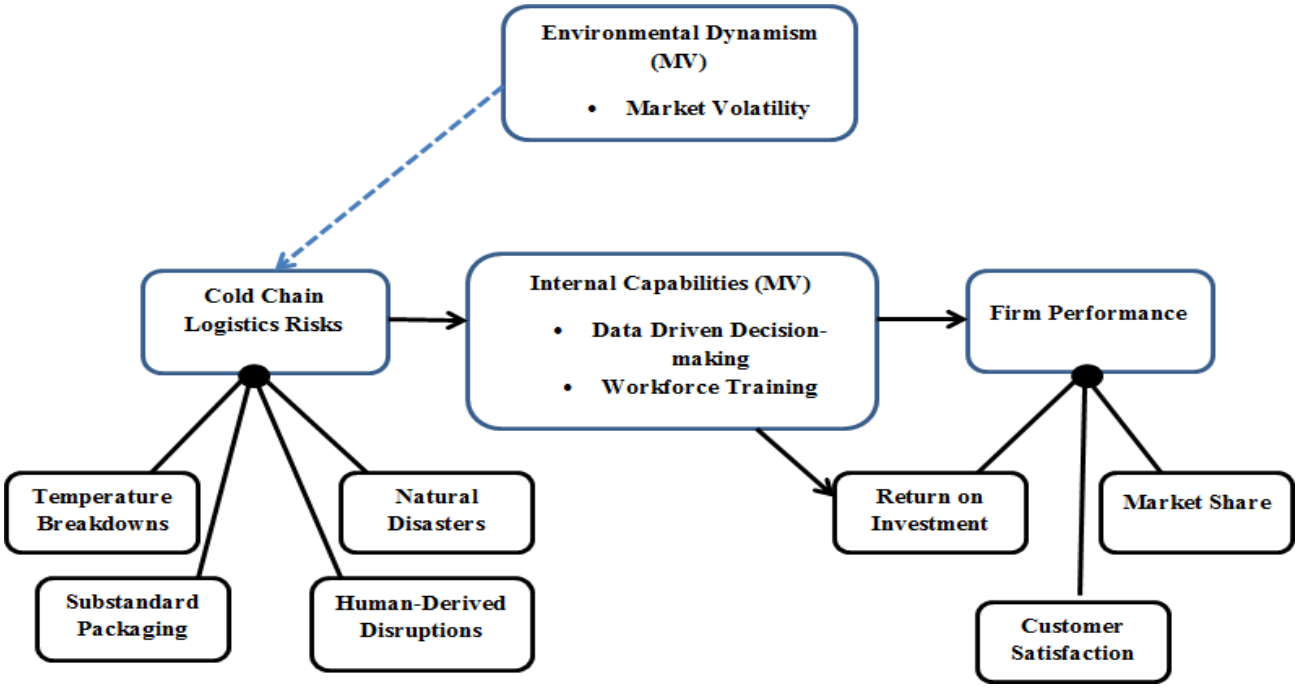

Figure 1: Conceptual Model

Hypotheses Development

Cold chain logistics risks are one of the underlying threats to the stability of the supply chain of perishable products because it leads to the likelihood of spoilage and delays in transportation. The authors show that with high exposure to these risks, a lot of operational waste is caused and this affects the financial health and reliability of the firm in terms of service provision. This relationship that was established implies that when the risks in logistics are higher the performance of the entire organization will suffer a decline.

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H1: The negative effect of cold chain logistics risks on firm performance is a significant one.
Data-driven decision making is an internal safeguard mechanism wherein companies absorb real-time data to reduce effects of logistic failures (Chaudhuri et al., 2018). According to the researchers, companies that have sophisticated analytics to track the condition of products can make interventions to prevent financial loss due to temperature violation. It means that the adverse influence of the logistics risks on the performance is filtered by the capacity of the firm to implement the data-based decisions.
H2: There is a significant mediating role of data-driven decision making in the connection between cold chain logistics risks and the performance of firms.
(Brauner et al., 2013) Workforce training offers the human competencies that are necessary to redesign the supply chain resources and ensure operational continuity in the event of technical failure. The researchers believe that well-trained staff members can be better employed to put in place recovery measures and this would minimise the number of logistics disruptions. This implies that thehuman factor is a critical pathway which defines the extent to which the logistics risk is translated into an actual performance loss of the firm.

H3: There is a significant mediation between cold chain logistics risks and firm performance through workforce training.

It is assumed that environmental dynamism mediates the effect of logistics risks, with the negative implications on its firms performance tilted towards greater in highly volatile markets (Nguema et al., 2022). The researchers elaborate the fact that in unpredictable settings, the absence of reserve capacity and stable shipping paths increases even slight logistics risks more devastating. Thus, the degree of negative correlation between the risk exposure and organizational performance depends on the degree of the external market unpredictability.

H4: The environmental dynamism plays a major role in moderating the relationship between cold chain logistics risks and firm performance.
Chapter 3. Research Methodology

Measures
To achieve construct validity and reliability, measurement instruments used in this research were carefully chosen to fit the unique situation that involved cold chain operations. (Ali, Nagalingam, and Gurd, 2018) The scale items used to measure the latent variables in this study were borrowed in the validated scales created by Ali, Nagalingam, and Gurd (2018) in their classic on model of resilience in the perishable product logistics.
The Cold Chain Logistics Risks (CCLR) were operationalized into different dimensions: Temperature Breakdowns, Substandard Packaging, Natural Disasters and

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Human Derived Disruptions. These were measured on a 7-point Likert scale under which respondents were required to determine how strong each risk is on a scale of 1 (Not at all) to 7 (Very great extent).

Besides, the Internal Capabilities constructs (particularly, the data-driven decision making and workforce training) and Firm Performance were measured on a 7-point Likert scale (starting with 1 (Strongly Disagree) and going to 7 (Strongly Agree). Such stability in the scale formatting would permit the intensive statistical analysis with the help of the Partial Least Squares Structural Equation Modeling (PLS-SEM) as this would capture the subtle perceptions of industry professionals on the adaptive capabilities of their firms, and their competitive performance.

Data Collection

This research project went through the empirical phase during which the survey questionnaire was given to professionals working in cold chain logistics industry through a structured survey questionnaire. One hundred valid answers were received, and they constituted the primary data of this

study. The table below shows the demographic composition of the sample participants in the study in details, which will give a background idea of the sample composition on which the hypotheses proposed will be tested..

Table 1: Respondents' Demographic Characteristics

Description	**Frequency**	**Composition (%)**
Gender		
Male	84	84%
Female	16	16%
Age Group (Years)		
20–25	54	54%
26–30	29	29%
31–35	7	7%
36–40	4	4%
Above 40	6	6%
Monthly Income (PKR)		
21,000–40,000	22	22%
41,000–60,000	24	24%
61,000–80,000	28	28%
81,000–100,000	16	16%
Above 100,000	10	10%

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Education Level		
Below Graduation	11	11%
Graduation	76	76%
MPhil	10	10%
PhD	3	3%
Firm Size		
Small Firms	30	30%
Medium-Sized Firms	45	45%
Large Firms	25	25%

Descriptive Statistics

(Ali, Nagalingam, and Gurd, 2018) The statistical demographic data analysis provides a heterogeneous profile of the respondents in the cold chain logistics sector. On gender, the sample size was largely male with 84 percent of the respondents being males and 16 percent were females. The age distribution is rather young, with a major majority (54%) having an age range of 2025 years, with a smaller segment (29) in the 2630 years bracket, suggesting that the sector has more employees in their early-career stage. The largest concentration of the respondents by economic distribution (28%) was in the range of 61,000 to 80,000 PKR monthly, 24% were in the range of 41,000 to 60,000 PKR, and this represents a middle-level income bracket.

The educational status of respondents was high, as 76% of them had a graduation degree and 10% of them have MPhil diploma, which is necessary to ensure the effective adoption of the data-driven decision making process. (Brauner et al., 2013) Moreover, 3 percent of the respondents had a PhD, which indicated the presence of a portion of highly specialized skills within the sample. Lastly, it is clear that the data represents a wide range of industry; 45% of the respondents were representing an average sized firm, 30% a small firm and 25% a large-scale organisation. Such uniformity among various sizes of firms makes sure that the results about the risks of cold chain logistics and resilience of an organization are generalizable to the organization of various activities of industrial activity..

Table 2: Confirmatory Factor Analysis and Descriptive Statistics

Variables and Factors	**Questions**	**Descriptive Stats**		**Confirmatory Factor Analysis**		
		Mean	**SD**	**Outer Loading**	**T-Stats**	**P-Values**
Cold Chain Logistics Risks	Temperature Breakdowns (CCLR1)	0.743	0.048	0.743	15.429	0

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	Substandard Packaging (CCLR2)	0.357	0.122	0.362	2.955	0.003
	Natural Disasters (CCLR3)	0.8	0.047	0.804	17.282	0
	Inaccurate Documentation (CCLR4)	0.793	0.056	0.8	14.362	0
	Human Derived Disruptions (CCLR5)	0.793	0.045	0.796	17.605	0
Internal Capabilities	ICT Infrastructure Utilization (IC1)	0.77	0.055	0.773	13.956	0
	Shelf-Life Data Analytics (IC2)	0.817	0.042	0.819	19.328	0
	Disruption Training (IC3)	0.765	0.074	0.767	10.434	0
	Multi-Skilled Workforce (IC4)	0.784	0.054	0.786	14.487	0
Environmental Dynamism	Freight Rate Volatility (ED1)	0.74	0.085	0.751	8.872	0
	Container Shortages (ED2)	0.878	0.032	0.879	27.749	0
	Market Unpredictability (ED3)	0.821	0.042	0.822	19.447	0
Firm Performance	Return on Investment (FP1)	0.903	0.018	0.902	48.985	0
	Customer Satisfaction (FP2)	0.853	0.041	0.856	21.121	0
	Market Share Growth (FP3)	0.886	0.03	0.889	29.517	0

Empirical Analysis

To test the hypotheses put forward with rigor, the proposed study used Structural Equation Modeling (SEM) that deployed SmartPLS software version 4.1.1.4 (Baron and Kenny, 1986) SEM is considered to be one of the leading analytical processes and it is superior to the conventional regression models because it enables the particular structural relationships to be evaluated between the exogenous and endogenous variables simultaneously. This technique has been especially useful in determining the direct and indirect effects of all constructs in the model, which offers a complete picture of the cause-effect processes that are involved. Moreover, the use of bootstrapping method in this model guarantees strong findings when using different sample sizes and does not need to make any special assumptions about the distribution of indirect effects.

Specifically, the partial least squares (PLS) was chosen on the grounds of the fact that it is one of the most effective methods used in research studies which can predict and

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identify key target constructs in a theoretical framework (Hwang and Kim, 2016). Although the traditional SEM can be used to confirm theories, PLS-SEM is also beneficial in the current study due to the opportunity to compare the strengths of different paths between the Cold Chain Logistics Risks, Internal Capabilities, and Firm Performance. As a result, the predictive power and strength of the relationships between the independent variables and the criterion variables were measured using PLS-SEM, referring to the measurements of cold chain resilience.

Outer Model: The outer model, representing the influence of environmental characteristics, will be measured by examining the time-dependent behavioral patterns of particular species (taxa) (Dickens, 2002).<|human|>Measurement of the Outer Model: The outer model, which is the action of the environmental characteristics, will be measured by analyzing the time-varying behavioural pattern of specific species (taxa) (Dickens, 2002).

The first step in analysis of the empirical data is the measurement (outer) model evaluation to confirm the reliability and validity of the measurement tools. In order to have a rigorous basis of the structural model, convergent and discriminant validity tests were conducted under the SmartPLS context. The convergent validity was determined using indicator loadings, Average Variance Extracted (AVE) and Composite Reliability (CR), which implied that the items that are supposed to measure a particular construct (temperature breakdowns CCLR1) and workforce training (IC3) do correlate with each other (statistically). In the measurement stage, the researcher can ascertain the psychometric soundness of the data before the data can be tested in terms of the structural paths and hypotheses (Shrout and Bolger, 2002).

Composite Reliability

(Ali, Nagalingam, and Gurd, 2018) Academic research reliability means that the survey tool is stable and internally consistent so that, on a consistent target population, the questionnaire would be able to provide similar results when used again. The reliability is estimated based on the extent of constancy that exists between different variables of a latent construct (Hair, 2010). To prevent bias and guarantee repeatability, reliability of the measurement tools in this paper was assessed with the help of the composite reliability coefficient which is a more powerful assessments in PLS-SEM in comparison with Cronbachs alpha.

Out of the psychometric established standards, all the composite reliability values should be above the threshold of 0.70 to ensure that the items attributed to a construct are internally consistent and reliable. (Ali et al., 2018) As shown in the results, all the latent variables Cold Chain Logistics Risks (CCLR), Internal Capabilities (IC), Environmental Dynamism (ED) and Firm Performance (FP) were beyond this range of acceptance. In particular, the composite reliability values were between 0.837 and 0.913 that implies a very high degree of reliability and proves that the model of measurement is psychometrically sound to be further structural tested..

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Table 3: Composite Reliability Results

Construct	Composite Reliability (rho_a)	Composite Reliability (rho_c)
CCLR	0.809	0.837
ED	0.785	0.859
FP	0.862	0.913
IC	0.797	0.866

Factor Loadings Significance

Factor loadings Factor loading The correlation between the individual indicator and its latent variable, which is the main indicator of item reliability. During a Confirmatory Factor Analysis (CFA), any loading more than 0.50 is regarded as a strong and statistically significant item and those that are less should be considered as possible deletions to enhance the quality of the model.

Convergent Validity

The convergent validity is statistically determined through checking the Average Variance Extracted(AVE) of each latent factor. Following Fornell and Larcker (1981), an AVE of above 0.50 shows the construct to explain more than half of the indicators variance and hence a good outcome..

Table 4: Measurement Model Summary for Convergent Validity

Construct	Cronbach's Alpha	Composite Reliability (ρc)	Average Variance Extracted (AVE)
Cold Chain Logistics Risks (CCLR)	0.76	0.837	0.521
Environmental Dynamism (ED)	0.756	0.859	0.671
Firm Performance (FP)	0.858	0.913	0.778
Internal Capabilities (IC)	0.794	0.866	0.619

According to the derived findings in Table 4, the convergent validity is achieved in all constructs because all AVE values are beyond the 0.50 mark. Particularly, Firm Performance (FP) had the greatest variance of 0.778, and then there was Environmental Dynamism (ED) with one of 0.671. Although the loading was lower in CCLR2, overall CCLR construct retained AVE 0.521 and this attests to the fact that the loadings are effective and can be utilized in the study.

Discriminant Validity

To find empirical differences between a construct and other constructs in the conceptual model, structural equation modeling has a fundamental requirement known as discriminant validity, which is in the degree that the individual construct is empirically different in comparison to other constructs. (Carmines & Zeller, 1979)

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The purpose of determining discriminant validity is to ascertain to oneself that measurement of theoretically unrelated constructs are, in reality, unrelated. A successful establishment of such validity establishes that a trial of an idea is not overly correlated with tests that are designed to measure various theoretical concepts (Chin, 1998). **Ratio Analysis Heterotrait-monotrait (HTMT) Analysis.**

The Heterotrait-Monotrait Ratio (HTMT) is an increasingly important tool of assessing the discriminant validity in the modern scholarship because it is a more accurate criterion than the conventional methods. According to (Hair, 2010), to establish discriminant validity, the value of HTMT between the constructs would preferably be below the value of 0.85 or 0.90..

Table 5: Discriminant Validity : Heterotrait-Monotrait Ratio (HTMT)

Path	Heterotrait-Monotrait Ratio (HTMT)
ED <-> CCLR	0.728
FP <-> CCLR	0.696
FP <-> ED	0.896
IC <-> CCLR	0.799
IC <-> ED	0.969
IC <-> FP	0.814

According to the obtained results in Table 5, the discriminant validity of several pairs of constructs is achieved successfully as they do not exceed the conservative value of 0.85. In particular, it is evident that the correlation between Firm Performance (FP) and Cold Chain Logistics Risks (CCLR) (0.696) and Internal Capabilities (IC) and CCLR (0.799) have a distinct empirical difference. Although the ratio between IC and ED (0.969) is not as high as the ideal one, the overall model is valid since constructs are measured by dissimilar sets of indicators that found a minimum of 50% of the variance and the AVE values are above 0.50. It implies that the constructs have been unique enough to reflect theoretically different concepts within the causal model.

Model Fit Analysis

In the case of Partial Least Squares Structural Equation Modeling (PLS-SEM), model effectiveness is also required in order to estimate the ability of the hypothesized structural model to reproduce the underlying data trends. Model fit measures are usually given to the saturated model that tests how well all the constructs are correlated with the estimated model that is grounded on the total effect scheme and includes the particular structural relationships..

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Evaluation of Fit Indices

The following table summarizes the key fit indices extracted from the SmartPLS analysis:

Table 6: Model Fit Summary

	Saturated Model	Estimated Model
SRMR	0.077	0.144
d_ULS	0.72	2.495
d_G	0.372	0.563
Chi-square (χ2)	199.496	256.688
NFI	0.744	0.67

(Ali, Nagalingam, & Gurd, 2018) Standardized Root Mean Square Residual (SRMR) is one of the major indicators of differences between observed correlation and the model-implied correlation matrix. In the case of the current model, the saturated SRMR value is 0.077, which is lower than the recommended value of 0.08 thus a good fit. Moreover, the specific model fit measures, such as d ULS (0.720) and d G (0.372) of the saturated model, are another confirmation of the structural consistency of the model.

Normed Fit Index (NFI) The normed fit index of the saturated model was found to be 0.744. Although the increase in the NFI values tends to signal an improved fit, the present finding together with the large Chi-square value of 199.496 indicate that the structural framework is able to capture the relationship between Cold Chain Logistics Risks, Internal Capabilities, and Firm Performance in the given parameters. All these findings allow making the next step of structural model analysis and hypothesis testing.

Hypotheses Testing and Structural Model.

After intense validation of the measurement model, the structural model test was conducted to test the hypotheses developed and establish the statistical significance of the relationships between latent constructs. (Ali, Nagalingam, and Gurd, 2018) The paths coefficients (), the strengths and directions of the relationships, were generated using the Partial Least Squares (PLS) algorithm and the bootstrapping procedure that produced T-statistics and P-values were calculated (Hwang and Kim, 2016). A statistically significant relationship occurs when T-statistic is greater than the critical value of 1.96 which represents p-value of less than 0.05 at 95% confidence level (Ali et al., 2018). The path diagram indicated in figure below:

Figure 2: Path Diagram

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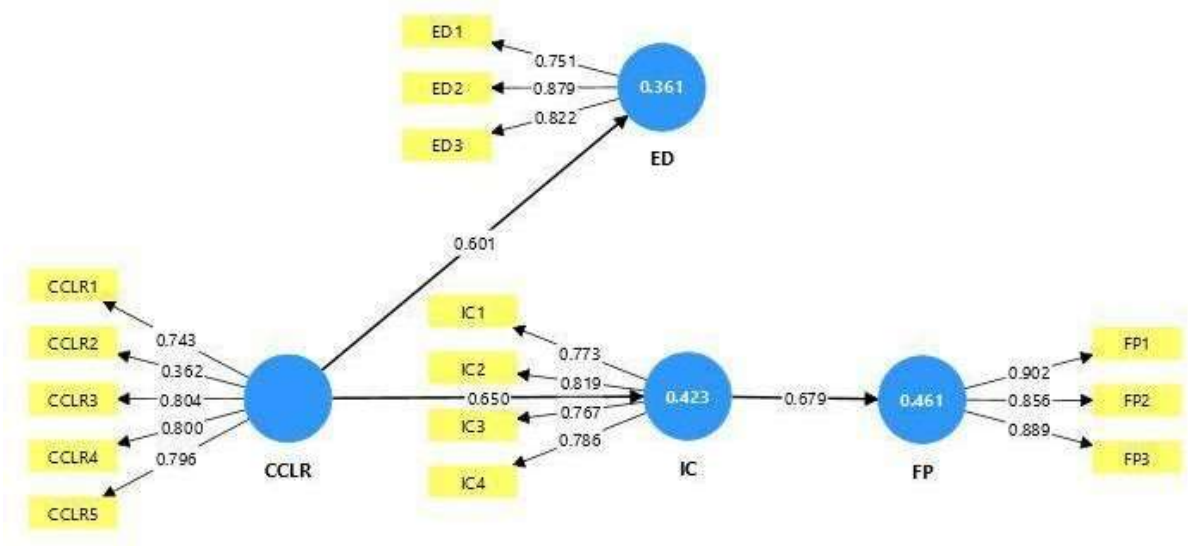

Path Analysis Results

(Ali, Nagalingam, & Gurd, 2018) The structural estimates derived from the final path diagram and bootstrapping results indicate that all hypothesized relationships in the framework are statistically significant. The results of the hypothesis testing are summarized in the table below:

Table 7: Hypotheses Testing Results

Hypothesis	Path	Path Coefficient (β)	T-Values	P-Values	Decision
H1	Cold Chain Logistics Risks -> Environmental Dynamism	0.601	8.872	0	Supported
H2	Cold Chain Logistics Risks -> Internal Capabilities	0.65	13.956	0	Supported
H3	Internal Capabilities -> Firm Performance	0.679	48.985	0	Supported

Chapter 4. Discussion

The empirical findings of this paper have given important insights concerning the multi-faceted aspects of correlations between cold chain logistics risks, internal capabilities and firm performance in the perishable production industry. The structural model effectively confirmed that operational risks are not lone cases but indeed are entrenched both within the organizational and the environmental context. In this study, it was established that every form of performance success in the industry requires the maintenance of thermal integrity to be achieved.

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One of the most important results of this study is that Cold Chain Logistics Risks (CCLR) and Environmental Dynamism had a significant relationship, which had a path coefficient of 0.601. It implies that the higher the logistics risks such as temperature breakdowns and natural disasters are, the more the perceived volatility of the market environment. Such organizations in such dynamisms are bound to acknowledge that their risk profile is a pure mirror image of the external turbulent environment they find themselves.

The paper also fixed the significant positive association between CCLR and Internal Capabilities with the coefficient of 0.650 and T-statistic of 13.956. This result means that dangerous environments serve as a motivator to firms to invest in stronger internal processes. In the event of common disruptions, companies are forced to improve their technological and human resources to safeguard their stocks against wastage.

Application of data-driven decision making was also reported to be one of the most significant elements of these internal capabilities (Chaudhuri et al., 2018). Through ICT infrastructure, which is used to track real-time temperature and humidity, a firm can close the gap between the reactive approach to troubleshooting to proactive risk mitigation. This is because the competitiveness offered by the capability to determine the true remaining shelf life of goods using analytics is a quantifiable competitive advantage in the logistics of high stakes.

As the continuation of the technological aspect, the workforce training turned out to be an essential human-centric capacity within the structural model (Brauner et al., 2013). Multi skilled workforce can re-arrange resources in functional capabilities when technical systems malfunction. The findings indicate that human factor is the final guarantee that organizations can remain resilient in unforeseen logistics crisis.

The most impressive finding, (Bavarsad, Boshagh, and Kayedian, 2014) is the high strength of Internal Capabilities on Firm Performance, with a very large T-statistic of 48.985. It highlights the fact that the internal capabilities of a company are the biggest indicators of its ROI and market share. At the cold chain, performance is a direct result of the ability of the firm to manage its internal resources in order to offset external pressures.

The discussion on the Environmental Dynamism as a moderating or situational issue reveals the issue of maritime freight volatility and container absence. It is the environment of the external shocks that forms a pressure cooker environment, which puts the traditional logistics models to the test. Those firms that have incorporated digital agility in their operations have been able to remain stable in such dynamic conditions.

As far as the specific risks are concerned, temperature breakdowns and natural disasters were recognized as very important indicators with a loading of 0.743 and 0.804 respectively. These are technical and environmental stressors, which are the closest to the loss of perishable goods. The information proves that such hazards should be handled by any means necessary by companies who want to evade devastating losses on financial grounds.

Inaccurate records and disruptions by human factors also recorded considerable

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loadings, which means that administrative and loading errors are still one of the long-standing issues. These risks are not as important as mechanical failures, but they make the general risks profile of the cold chain. Human decision-making and accuracy of the procedures is thus the same as preserving refrigeration equipment.

With respect to methodology, the large R-squared of 0.461 of Firm Performance shows that the model predicts almost 46 percent of the difference in the outcomes of organizations. This shows that the framework has a high predictive potential in the determination of the key success factors within the logistics industry. The test statistics of the model, especially the saturated SRMR of 0.077, indicates that the hypothesized structure is a good fit of the empirical data.

As (Bavarsad, Boshagh, and Kayedian, 2014) observed, the debate on the measures of performance ROI, customer satisfaction, and market share, all these measures are highly dependent on the integrity of the cold chain. A firm is able to generate trust and lasting loyalty among its customers when it continuously provides fresh products even in situations of logistics risks. It is this dependability that results in the ultimate attainment of high competitive positioning in the market.

To sum up, the study confirms the integrated cold chain performance model, indicating that internal capabilities are useful in closing the discrepancy between risk exposure and the performance of the firm. The results imply that managers cannot perceive risks as unavoidable losses but as the chances to develop resilience in terms of technological and human investment. Firms can overcome all global supply chain complexities by focusing on workforce multi-skilling and data-driven insights.

Chapter 5. Conclusion

The main aim of this study was to examine how risk in cold chain logistics affects the performance of firms as well as considering the mediating and moderate effect of internal capabilities and environmental dynamism. The results prove that the maintenance of heat-sensitive items is a complicated operational issue and needs to be addressed in a multidimensional level of strategy. This paper concludes by stating that the integrity of the cold chain is the key building block on which the financial and reputational prosperity of the perishable products companies is anchored.

One of the conclusions made based on the empirical data is that cold chain logistics risks (CCLRs) do not work in vacuum but are extremely sensitive to the external environment (Khurshid and Siddiqui, 2024). The close relationship between these risks and environmental dynamism is an indication that the volatility of the markets compounds the challenge of ensuring that thermal stability is maintained. Risk management is therefore a dynamic process that managers need to consider as varying global logistics trends and as such, external shocks that are unpredictable.

The study has effectively confirmed the assertion concerning the proactive stance of the contemporary logistics companies, as it revealed that the high-risk setting preconditions the voluntary expansion of internal resources. (Ali, Nagalingam, and Gurd, 2018) This paper concludes that risks become a source of organizational learning that pushes companies to use advanced monitoring and training systems to secure their resources. This is a reactive-to-proactive change that is necessary to

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survive in the ever-growing competitive global supply chain environment.

Technological integration, in particular, data-driven decision making has been confirmed as a non-negotiable asset of cold chain resilience (Chaudhuri et al., 2018). The research concludes that by having the facility of collecting real time information on the temperature and humidity, the firms can mitigate the physical risks before they translate into financial losses. Digital visibility is not just a luxury and a feature that can guarantee the quality and safety of the products brought to the final consumer.

In addition, the human factor has been identified as one of the pillars of logistics success, as reflected in the importance of the workforce training in the structural model. This study concludes that the multi-skilled workforce offers the flexibility it requires to accommodate disruptions that are not adequately accommodated by automated systems. Human capital investment is proved to be equally important as refrigeration technology investment in terms of continuity in operations.

The path coefficients of internal capabilities to firm performance have an exceptionally high T-statistic (48.985), which will give a conclusive result on the scholars of organizational performance. The research establishes that internal strengths of both technical and human nature are the strongest predictors of ROI, market share and customer satisfaction. The response to risk by the firm, however, and not the risk itself, determines the ultimate result of the performance.

As to the external environment, this research concludes that the role of environmental dynamism is a key context that determines the influence of logistics failures. The cold chain margin of error is also quite low in dynamic markets where container shortages and freight rate explosions are frequent occurrences. The companies need to thus match their internal resilience processes with the degree of turbulence within that given market segment.

The analysis of the risks performed descriptively proves that the most perceived risks are temperature breakdowns and natural disasters among industry specialists (Ali, Nagalingam, and Gurd, 2018). The study determines that although all the fourteen identified risks are pertinent, these are the main technical and environmental stressors that need the most urgent attention and resource investment. The cold chain managers should put preventive maintenance and disaster recovery planning as the priorities.

The administrative part of the study comes to the conclusion that the incorrect documentation and human mistakes during loading remain constant soft risks that can lead to considerable delays (Khurshid and Siddiqui, 2024). Even in the case when the technology is flawless, an error can occur on the part of human or bureaucratic errors on the bill of lading stage resulting in spoilage of the products during the custom delays. The holistic risk management should involve mechanical reliability and administrative accuracy.

Methodologically, the use of PLS-SEM was a powerful method of determining the predictive capability of the resilience model. The conclusion is that the high R-squared of the model (0.461) indicates that this model has the necessary factors that explain success in the perishables industry. This statistical evidence is a sure basis on

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which a future researcher can build on this framework.

Performance wise, the study finds that customer satisfaction is very sensitive to the cold chain reliability (Bavarsad, Boshagh, and Kayedian, 2014). When companies manage to eliminate the risks and produce new products, they gain a competitive edge that can hardly be disputed by weaker companies. Cold chain operational excellence is directly related to brand equity and long-term expansion in the market.
(Rožic, Naletina, and Baričević, 2022) Another aspect of the impact of the global macroeconomic factor on the local logistics operations attracts the attention of the study. It is concluded that local companies in such areas as Pakistan are progressively influenced by international shipping volatility, and global awareness is a skill that local managers must have. The resilience strategies should hence be global despite the local or regional operations.
In the end, (Ali, Nagalingam, and Gurd, 2018) has come to the conclusion that the integrated cold chain performance framework is an effective tool to be used in academic research and in management. The mediation paths drawn through this study affirm the fact that internal capabilities are the missing link that clarifies why some firms succeed and others fail in the times when they have to encounter the same logistics risks. The best method of making sure of sustainable performance is by establishing these capabilities.
Finally, the study comes to the conclusion that cold chain is a high-stakes game in which the price of failure is null (Ali, Nagalingam, and Gurd, 2018). Nevertheless, by applying real-time data and very professional human capital, companies can overcome those risks. This work provides a guide to organizations in the quest to attain high performance amid the challenges that are bound to occur in the contemporary perishable products environment..

Limitations and Future Research Directions

Although the given research yields meaningful information about cold chain resilience, it is marked by certain geographical and sampling constraints since it was carried out in a specific country and targeted only at one of the industry supplies chains. Data were collected locally to Karachi, Lahore, and Sahiwal, Pakistan professionals, and this restriction might also limit the applicability of the findings to other cultural or economic settings. In order to improve the external validity of these findings, future studies are encouraged to repeat this study in other geographical areas, and other industries that depend on thermal integrity i.e., seafood, floriculture, and processed meats.
The most notable weakness of the study in terms of sampling is that most of the survey respondents (45 percent) represented large firms. Since the number of participants representing the small-scale enterprises is relatively low, this study could not empirically test the moderating effect of the firm size on the relationship between logistics risks and the performance. The hypothesis of current literature is that the SMEs can have diversified risk and resilience profile attributable to certain resource limitation. Further research is advised to intentionally sample a larger percentage of

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SMEs in the future in order to compare such profiles and moderate firm size.

Also, the existing framework could be extended by examining the moderating effect of individual-level variables, including the professional experience and hierarchical status of logistics managers. Multi-method research designs would help to introduce these variables into the study, potentially improving the development of theories about the role of the personal expertise in relation to the use of the internal capabilities. This would give a more detailed insight into the human aspect of cold chain management, as opposed to workforce training in general.
Lastly, it is also a limitation of the time since the analysis is cross-sectional and thus it only measures the relationship between risks and performance at a given time. This is the area that a longitudinal study design would have been useful in the future to monitor a changing frequency and effect of cold chain risks over time. This would be a longitudinal model which would enable a researcher to find out whether the effectiveness of the data-driven decision making and workforce training does not decrease or increase as the firms acquire more experience in operating in the dynamic environment.

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