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Resilience in inter-organizational networks of red buses: dealing with their daily disruptions in critical infrastructures

Muhammad Shaheer Zahid [1*]

[*1]*Department of Business Administration, Iqra University, Karachi, Pakistan*

**Corresponding email: muhammad.13548.ac@iqra.edu.pk*

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ABSTRACT

This research aims to determine how the inter-organizational (supply) system that serves and oversees the critical infrastructures might lessen the negative effects of routine interruptions. Furthermore, this research aims to gain insight into the types of disruptions that Red Buses experience and their strategies to manage them. The subject matter of this discourse pertains to the domains of science, numbers, and statistics. This research employs a quantitative research methodology to examine the effects of routine disruptions on inter-organizational systems and to evaluate the corresponding hypotheses. The individuals involved in this investigation work and operate the Red Bus Service in Karachi. By random sampling, a sample of 152 workers and drivers was selected from the Red Bus Service in Karachi. Data was collected from both electronic and non-electronic sources. Data was collected using Google Forms distributed via various internet channels such as WhatsApp and email addresses. Data was analyzed by Structural Equation Modeling (SEM); we used SmartPLS 4 software for that. The finding shows that disturbance co-occurrence has a negative relationship with CI resilience to focal disruption, a positive relationship with non-routineness, and a negative relationship with economic performance.

Keywords: *Resilience, Critical infrastructure, Disruption, Economic performance*

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1. Introduction

1.1 Overview

The production, supply and delivery of services and goods are increasingly organized into networks (Baloch & Rashid, 2022). Scholars have increasingly focused on complete supply networks rather than dyadic inter-organizational relationships (Braziotis et al., 2013). The following is revealed in current supply chain research of international journals (Gremyr & Halldorsson, 2021). To attain firm-level objectives (e.g., schedule, production, adherence) and cooperative network results (e.g., sustainability, environmental), organizations in these supply chains are critically dependent upon one another's performance and inputs (Kim et al., 2011). The most significant supply network is the operation and maintenance of critical infrastructures (CIs). Several critical infrastructures (CIs) provide vital services like transportation, water supply and electricity delivery. These services are highly interconnected and cannot be replaced by many or any alternative systems (Van, Stevenson, & Scholten, 2020).

Critical infrastructures are commonly experienced for supply systems (A, 2014) in minor disturbances (such as human errors or equipment breakdowns) that cause regular service interruptions. The consequences of these disruptions must be contained quickly, although they are initially small and localized (Waugh & Cigler, 2012; Dufort, 2007). However, managing such disturbance within critical infrastructures (CIs) is challenging and complex, as public and private companies may often have differing commercial interests and operational approaches (McConnell & Boin, 2007; Essens & Vegt, 2015). Furthermore, Because of these networks' deep interconnectivity, any local issue or inadvertent mistake one organization makes in resolving a disturbance can affect all CIs (Ouyang, 2014; Chen et al., 2016). Consequently, the UK experienced almost two months of train delays, cancellations, and overcrowding due to a single rail company's schedule change error. The resilience of the CI reflects the effective handling of disruptions by the inter-organizational (supply) network. When resilient, critical infrastructure can rapidly recover and continue operating during disruptions, whereas non-resilient infrastructure suffers extended downtime and diminished performance (McConnell & Boin, 2007; Stevenson et al., 2015). Primarily, a focused and centralized organizational structure (e.g., incident command structures) handles significant disruptions (Roberts & Bigley, 2001). When faced with daily disturbance, Because of this absence of centralized assistance, CI organizations frequently have to organize coordinated responses in addition to their regular responsibilities (Dufort, 2007).

So much research has been done on it, but with different variables and regions. Organizations need to find out whether they can learn how to deal with minor CI disturbances that are more regular and variable from prior research on large-scale disruption management (Bhattacherjee & Premkumar, 2004). This research will be on resilience in the Red Buses network in Karachi, what kind of trouble they face and how they deal with them in their infrastructure.

1.2 Problem Statement

As this is a very fast-paced century, and people want to update themselves with new products and ideas, even though existing studies have provided significant insight into CI flexibility, our understanding of how inter-organizational networks can reduce the unpleasant consequences of CI disruptions in daily operations remains unclear (Bhattacherjee & Premkumar, 2004). Most research on the management of supply chain focuses on network-level phenomena in general (Braziotis et al., 2013) and network flexibility precisely (Van Donk et al., 2020; Stevenson et al., 2015), with a focus on researching the function of the focal organization or a specific dyad between organizations (Kim et al., 2011). As a result, the complicated, non-linear linkages between all the organizations that build supply chains should be considered in this study. On the other hand, previously conducted studies on

the resilience of critical infrastructure (CI) have mainly focused on how CIs can recover from infrequent and widely recognized events such as Hurricane Katrina (Cigler, 2007) credit crisis as a substitute for analyzing how they involved inter-organizational network can manage the more archetypal recurring interruptions that distress CIs every day (Waugh & Cigler, 2012; Dufort, 2007). Moreover, day-to-day troubles typically differ on these dimensions, whereas large-scale disruptions are often non-routine and complicated. Therefore, inter-organizational networks should be able to handle regular and simple disruptions and comparatively complex and unpredictable (Eeten & Boin, 2013). Organizations need to find out whether organizations can learn how to deal with more minor CI disturbances that are more regular and variable from prior research on large-scale disruption management.

Therefore, the current study aims to understand better how an inter-organizational network, Red Buses, that uses and maintains a CI might increase the CI's daily resilience. Due to a shortage of time, my research is limited to Karachi and Red Buses. So that we can know how inter-organizational networks can deal with the troubles and what kind of troubles they face. Therefore, the following are the research questions

1. *Is there any negative relationship between disruption non-routineness and CI resilience to the focal disruption?*
2. *Is there any relationship between disruption co-occurrence and CI resilience to the focal disruption?*
3. *Does cross-border information exchange moderate the association between disruption co-occurrence and CI resistance during a disruption?*
4. *Does cross-border information exchange moderate the association between disturbance non-routineness and CI resistance during a disruption?*

1.3 Purpose of Study

The study fills critical gaps in our current understanding of CI resilience by extending the reasoning of OIPT to comprehend how the inter-organizational system utilized and operated by a CI can reduce the adverse effects of the usual problems that impact the CI on every day and to comprehend the way the inter-organizational system is capable of handling such interruptions (Eeten & Boin, 2013; Welch et al., 2018). There are various theoretical ramifications of this finding. By expanding the concept of OIPT to comprehend how the inter-organizational system using and managing a CI might minimize the adverse effects of the regular disturbances which impact the CI regularly, we contribute to the field of CI resilience study. Our research fills crucial gaps in our knowledge of CI resilience by illuminating how the inter-organizational system might manage such interruptions (Van, Stevenson, & Scholten, 2020; Bhattacherjee & Premkumar, 2004), even though "the majority of supply [Chains] are significantly more inclined to be coping with persistent, recurring threats of interruption (Stevenson et al., 2015). By shedding light on the advantages of cross-border exchange of information for the resiliency of supply systems, this study adds to the body of literature on robustness across the particular setting of CIs, contrary to earlier studies (Stevenson et al., 2015).

1.4 Significance of the Study

This study is critical as it contributes to CI resilience research by demonstrating that the advantages of cross-boundary exchange of information rely on the features of the disturbance that this kind of system faces. This research doubts this exchange's general efficiency for enhancing such networks' resilience. Cross-border exchange of information is beneficial for controlling more intricate or irregular interruptions. This supports Feldman and Quick's (2014) assertion that, especially under unfavorable circumstances, the advantages of cross-boundary exchange of information surpass any potential drawbacks, such as prolonged consensus-seeking and making decisions. The results of this study will help managers in the corporate and public sectors deal more effectively with the little disturbances that daily impact their CI. These regular interruptions to a CI might have more negative effects when they co-occur with additional interruptions or are non-routine circumstances. Our

findings indicate that managers should aim for and support the greater cross-boundary exchange of data with other organizations within their organization in these situations in order to share knowledge, create well-integrated defenses, and prevent duplicative or conflicting operations among organizations. However, our study emphasizes that rather than occurring within dyadic inter-organizational connections, such cross-boundary transfer of information should occur at the level of the entire inter-organizational network. Our results show significant direct interaction and knowledge-sharing between pertinent organizations.

The research is limited to analyzing the dealing of red buses with day-to-day disruptions in critical infrastructures in Karachi. There are so many Red Busses (People Busses) routes in Karachi, but due to limited time, I will cover only two routes. The data will be collected by visiting red bus stops from customers and drivers.

2. Literature Review

2.1 Theoretical and Empirical Review

2.1.1 Critical infrastructure resilience, daily disruptions, and service supply networks

A system of interconnected and dependent businesses is referred to as a "supply network," their goal is to better the flow of resources and information from suppliers to end consumers. (Braziotis et al., 2013). The inter-organizational network is concerned with managing and operating a CI. It is a supply network that coordinates the actions of different organizations and combines the resources (e.g., equipment and infrastructure) to ensure efficient operation. Inter-organizational networks guarantee CI resilience by addressing disruptive events that could jeopardize service continuity "Day-to-day disruptions" are a subcategory of those events. According to McConnell and Boin (2007) and Linnenluecke (2017), there is a subcategory of such events called "day-to-day disruptions," which are "Less spectacular but more frequently occurring occurrences like equipment malfunctions, supplier supply delays, and modifications to client order requirements are nonetheless major managerial problems" (Salvador & Tenhiälä, 2014; Van Donk et al., 2020; Stevenson et al., 2017).

Resilience, in general, refers to a supply network's capacity to anticipate interruptions, react to them, and rapidly resume normal operations (Chowdhury & Quaddus, 2016; Rotaru et al., 2016; Harrison & Sawyerr, 2020) because of how quickly the inter-organizational network involved tries to restore services to end users, resilience in CIs is therefore readily apparent. As a result, we evaluate a CI's resistance to routine disturbances based on how quickly the inter-organizational network involved can successfully create and implement countermeasures or its recovery time (Mattsson & Jenelius, 2015). A quicker recovery period shows that the organizations were able to immediately separate the disruption's effects, preventing the complete paralysis of the CI (McConnell & Boin, 2007; Welch et al., 2018). On the other hand, a lengthier recovery period suggests that the organizations still need to locate or fix the issue. When this happens, the disturbance continues to impact CI operations and can lead to significant issues for them (Farkas et al., 2008). The appropriate definition of CI flexibility is "a system's ability to regain performance levels after experiencing an interruption" (Britt, 1988).

2.1.2 Building a resilience viewpoint for critical infrastructures based on information processing

Organizations within the inter-organizational network must gather, combine, and interpret all relevant information to ensure CI flexibility to daily disturbance. This information can then be used to make well-informed decisions on how countermeasures must be applied (Eeten & Boin, 2013). According to OIPT, organizations can efficiently deal with this challenging task by applying a theoretical perspective (Galbraith, 1974). A theory initially developed to understand inter-organizational behaviour, OIPT has been expanded to more fully describe the behaviour and performance of a focus (purchasing) organization in dyadic inter-organizational connections (Venkatraman & Bensaou, 1995) in supply systems nowadays (Foerstl et al., 2017). As a result of this

research, we expand OIPT to the system stages of analysis.

OIPT involves the organization's "capacity to deal with unusual, momentous circumstances that cannot be foreseen or predicted " (Galbraith, 1974). OIPT offers helpful details on how businesses should handle disruptions (Nishant et al., 2020; Macdonald & Bode, 2017). OIPT advises attempting to either decrease the volume of information that needs to be processed or raise their capability for processing. " non-standard, significant occurrences." additionally, OIPT suggests that the intricacy and unfamiliarity of the unexpected occurrence determine whether or either technique is beneficial (Repenning & Rudolph, 2002). By lowering slack resources and capacity, minimizing the interdependencies between activities, and reducing slack resources, it is possible to reduce the information processing requirements for less complicated and more routine events. However, tackling more sophisticated or unexpected occurrences can mean these two approaches could be more effective (Galbraith, 1974). To boost their capacity for processing information in such circumstances, OIPT advises organizations to invest in formalized information systems and create lateral links among various organizational components (Venkatraman & Bensaou, 1995).

We propose that the typical daily disturbances CI faces are more complex when they co-occur by merging the conceptual insights from OIPT with more extensive resilience studies (Repenning & Rudolph, 2002; Khansa & Zobel, 2014). Additionally, they must be more familiar with and call for non-standard answers when reflecting on unexpected situations (Macdonald & Bode, 2017). We emphasize that, while facing co-occurring and non-routine CI disturbances, the members of the various organizations should participate in more intense communication to broaden further the intra-organizational-level perspective of OIPT (i.e., cross-boundary) information exchange. We place more emphasis on cross-border information exchange than other OIPT-recommended strategies (like formalized information systems), as it enables real-time adjustments and coordination during disturbance management and has been recognized as a critical policy for ensuring supply network flexibility (Macdonald & Bode, 2017; Harrison & Sawyerr, 2020; Van Donk et al., 2020).

2.1.3 Critical infrastructure resilience and disruption co-occurrence

When more than one critical infrastructure disruption affects the network simultaneously, this is known as a co-occurrence of disturbance in an inter-organizational network (Khansa & Zobel, 2014). Suppose organizations within the system cannot gather the essential data during a specific daily interruption in conjunction with numerous other disturbances within the same CI. In that case, they may become overburdened and overloaded. Organizations may need additional time to create successful preventative measures for the focused disruption when concurrently with multiple interruptions due to the difficulty of understanding and processing all pertinent information for each interruption (Repenning & Rudolph, 2002). Additionally, businesses that experience multiple interruptions require enough time to address and manage the links between potentially impacted vital infrastructure elements (Ouyang, 2014). If a disturbance takes more time to resolve, its negative impacts could linger longer and spread across the essential structures, decreasing its capacity for recovery (Rohleder & Cooke, 2006). On the other hand, organizations can concentrate on obtaining and analyzing information to repair problems with just one interruption (Khansa et al., 2020; Welch et al., 2018). Organizations can build countermeasures more quickly and ensure CI resilience since they are not compelled to investigate the intricate relationships between disruptions in such circumstances (Macdonald & Bode, 2017).

2.1.4 Impact of economic performance

Productivity in the supply chain is crucial for the smooth functioning of economies, and issues can result in constraints that have a detrimental effect on productivity and economic growth (Salvatore, 2020). Although supply chains have a variety of components, their efficient (often successive) operation is essential for the timely delivery of goods to customers and contributions to companies (Chen et al., 2016). Economic growth continues to be the main force behind the prosperity of nations and the sustainability of their political structures. However, the new coronavirus outbreak

poses unforeseen challenges to the countries' growth paths. This necessitates reevaluating the forces that shape monetary evolution, especially considering variables pertinent to the present situation. The financial crisis of 2008–2009 caused the most recent interruption to the world's supply chain. Even so, there are some subjective disparities even though historical examples might be instructive now. At that moment, it was more of a supply-side than a demand-side issue, but the present crisis has significantly affected demand and supply. Global value chains (GVCs), mandate that items be produced in various nations before being assembled in another.

2.1.5 Red bus service in Karachi

A developed nation is one where the well-off and low-income people use public transport, not one where the poor own vehicles. One of the biggest and most important problems facing the majority of the population in the world is road mobility. Karachi and other major cities experience regular delays in traffic. Congestion in traffic frequently causes delays, obstacles, and unproductive economic activity in urban areas. Plenty of research on traffic-related problems is being carried out under different groups, considering economic and budgetary concerns. Congestion in traffic has been linked to financial losses in several urban areas worldwide. According to research, Karachi's traffic jams cost the city more than $1 billion annually in 2018. This represents 2% of Karachi's annual gross domestic product (GDP). That rate is calculated by necessary time, Utilizing energy and oil prices.

Long commutes, the growth of private and shared transport, and the decrease of public transport are all characteristics of Karachi's transport system, which only provides mobility for some. 2.8 million passengers are served daily by 4,000 privately operated buses and roughly 4,000 public vehicles. These loosely regulated services are unpredictable and must set stops and client expectations. Congestion worsens, and safety is compromised as drivers fight and stop randomly to pick up customers or wait idly on the edge of the road until the vehicles are filled. It is usual for commuters to hang over the sides of moving cars or sit on rooftops during rush hour. The irregular network's automobiles need to be updated and in better condition, which raises operating expenses and pollution. For the urban poor, services are typically expensive because they have to pay for each mode change. Now, the Sindh Government has provided Karachi's desperately needed public transport. The "Peoples Bus Service" is the name of the new buses in Karachi. These Pink Buses (Dedicated for Ladies), White Buses, and Red Buses (Electric Buses) will travel along eight distinct routes throughout Karachi, linking important housing hubs with business and industrial centers (think transportation). Finally, there is a daring new bus service in Karachi. The company's buses are brand-new, cooled, and crimson red. The good thing is that. However, the bus system is already developing bad habits that have ruined previous transportation attempts in the city.

2.2 Theoretical Model/ Framework

Information Processing Theory is a theory of cognition. IPT concentrates on how data survives in our brains. The theory describes how the brain filters information by keeping track of what we are currently concentrating on before going on to what is stored in our short-term and long-term mental memory. These involve how the brain processes information. Primary research refers to the procedures of obtaining, storing, and retrieving information. As per Information Processing Theory, creating long-lasting memories happens in stages. In the first stage, we view or observe something through our senses, which comprise everything we can see, hear, smell, or taste. Then, we use our temporary memory to store information briefly, like telephone numbers. And at last, permanent memory is stored permanently in our brains. As in IPT, we save information in long-term memory so that it stays longer. There are some steps in IPT, including: 1. break the information into small parts. Allowing your students plenty of rest periods and time to assimilate the knowledge. 2. Make it significant. Your students are more likely to retain a lesson if you connect it to real-world events and your personal experiences. 3. Connect the point. By providing sufficient background information and drawing links between the current lesson and what has previously been taught and what will be cultured next, you can "layer" the content to make it more likely that it will be retained information for the extended term. 4. Repeated Information. One of the simplest methods for encoding fresh

information into permanent memory is by repeatedly presenting it in different forms, such as oral, written, graphical, and tactile. We will apply organizational information processing theory (OIPT; (Galbraith, 1974). The notion provides a significant viewpoint on how companies might manage consequential occurrences, such as disruptions that cannot be entirely expected (Nishant et al., 2020). According to OIPT, demands to process information will typically increase as events become more complex or different (Venkatraman & Bensaou, 1995; Repenning & Rudolph, 2002). In order to process information more quickly, OIPT declares that a more robust information switch within and crossway companies (i.e., cross-boundary processing is required when information processing demands increase (Galbraith, 1974). With this theoretical insight in mind, the inter-organizational network accountable for the operation of a CI should align its extent of cross-border exchange information with its disruption challenges. We propose that organizations within a system can deal with CI troubles most effectively by aligning the strength of exchanging cross-boundary information with the non-routineness and complexity of daily disruptions. IPT will help us to repeat the information and to keep this information in long-term memory so that we can solve any trouble more quickly. Hence, it makes the inter-organizational network more resilient. We will check in our research that if the information processing system of an organization will be effective, how much it will easier for them to sort out the trouble.

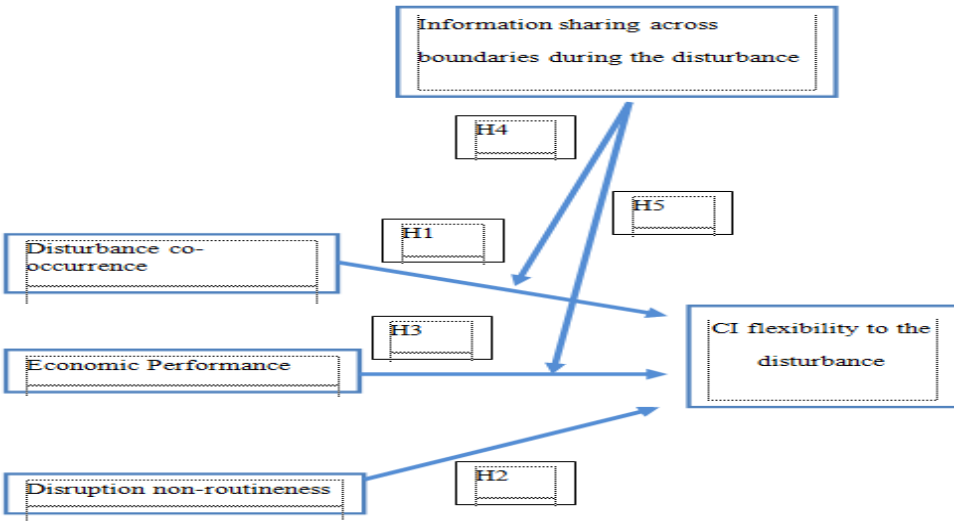

Figure 1: Research model (author's creation)

H1. There is a negative relationship between disruption co-occurrence and CI resistance to focal disruption

H2. A negative relationship exists between disruption non-routineness and CI resistance to focal disruption.

H3. There is a negative relationship between economic performance and CI resilience to focal disruption.

H4. The association between disruption co-occurrence and CI resistance to concentrated disruption is moderated by cross-border information exchange during disruption. When cross-border information flow is minimal, this negative association is enhanced, and when it is high, it is attenuated.

H5. The link between Economic Performance and CI disruption resilience is moderated by cross-border information exchange during disruption. When cross-border information flow is minimal, this negative association is enhanced, and when it is high, it is attenuated.

3. Methodology

Quantitative research methods are frequently employed in studies aimed at assessing an issue, ascertaining particulars such as "what" or "how many," and comprehending the relationship between dependent and independent variables in a population (Rashid et al., 2023). The primary objective of this research is to examine how the inter-organizational system of Red Buses responds to routine disruptions in their critical infrastructures. Furthermore, this study aims to gain insight into the types of disruptions that Red Buses experience and their strategies to manage them. The subject matter of this discourse pertains to the domains of science, numbers, and statistics (Rashid & Amirah, 2017; Rashid, 2016). The utility of qualitative research methods lies in their ability to furnish comprehensive portrayals of intricate phenomena, illuminate the interpretation and experience of infrequent or exceptional occurrences, amplify the voices of marginalized perspectives, and facilitate the conduct of preliminary research in uncharted domains to engender theories, hypotheses, and elucidations (Rashid & Rasheed, 2023). The present study employs a quantitative research methodology to examine the effects of routine disruptions on inter-organizational systems and to evaluate the corresponding hypotheses.

Deductive research is founded on literature reviews, hypotheses, and theories, enabling logical conclusions (Rasheed & Rashid, 2023). The validity of these propositions is subsequently tested through the collection and analysis of empirical data. Formulating a research hypothesis based on an existing theory and devising a plan to verify the hypothesis is the fundamental principle of deductive research. Given that our objective is not to formulate a novel theory but to scrutinize an established one, our investigation adheres to this rational approach. The research methodology employed in this study is primarily deductive and quantitative. Statistical analysis is a fundamental aspect of deductive methods that reveal latent associations among various factors (Rasheed et al., 2023). The present study employs the SmartPLS 4 software for Structural Equation Modeling (SEM) analysis.

3.1 Sampling Strategy

Sample design is an established strategy for drawing a sample from a specific population and the number of things to include in the sample. (Rashid et al., 2022a, b). Sampling is essential to the entire research process since it significantly impacts the reliability of study findings. Improper sampling practices can cause interpretation issues, for example, forming incorrect inferences about a population (Rashid et al., 2021; Hashmi et al., 2021a, b). The veracity of a study's findings is significantly contingent upon the precision of the sampling methodology. Hence, it is imperative to establish the sample design meticulously. The target audience is the subgroup of those for whom the programmer is intended, for whom you will aggressively recruit and retain employees, and for whom you will hold yourself accountable for results (Hashmi et al., 2020a, b). The individuals involved in this investigation work and operate the Red Bus Service in Karachi. The sample size is crucial to research methodology (Rashid et al., 2020). A sample of 152 individuals, comprising both workers and drivers, was randomly selected from the Red Bus Service in Karachi. The methodology for sampling is Random sampling, a probabilistic sampling technique, which was utilized due to its simplicity and efficiency in terms of time and resource requirements (Alrazehi et al., 2021; Das et al., 2021; Haque et al., 2021).

3.2 Instrument of Data Collection

Data was collected from both electronic and non-electronic sources. Data was collected using Google Forms distributed via various internet channels such as WhatsApp and email addresses. The data was obtained through in-person interviews with Red Bus drivers and passengers at predetermined locations. Data was collected from both electronic and non-electronic sources. Data was collected using Google Forms distributed via various internet channels such as WhatsApp and email addresses. The data was obtained through in-person interviews with Red Bus drivers and passengers at predetermined locations.

This quantitative analysis aims to elucidate the impact of different factors on the variables under investigation. The investigation is supported by empirical evidence, with statistical evaluation conducted through the Structural Equation Modeling (SEM) technique implemented in SmartPLS 4 (Rashid & Rasheed, 2022). The questionnaire I used in my research is divided into two sections. The first section deals with demographic information, which I calculated on a nominal scale. The main research topic is discussed in the second section of the questionnaire. It comprises six criteria and nineteen objects rated on a five-point scale. One represents a severe disagreement, and five represents firm agreement (Hashmi & Modh, 2020). All of the constructs employed in the investigation were derived from past studies. The source count for the items in the questionnaire is detailed in Table 1. The entire questionnaire is also included as an appendix.

3.3 Respondent's Characteristics

The census takers went to different red bus stops and their offices; 200 questionnaires were distributed and received 152questionnaire. Table 2 displays the profile of the responders. 22.3% of the 152 responders were female, while 77.6% were men. Regarding their ages, we discovered that 4.6% of respondents were between the ages of 15 and 20; 3.2% were between the ages of 21 and 25; 25% were between the ages of 26 and 30; 34.8% were between the ages of 31 and 35; and 31.5% were between the ages of 36 and 40. According to the results of the educational categorization, 42.7% of the participants did matric certificates, 23.6% did inter, 23.6% did bachelor's levels of education, 7.8% followed advanced degrees, and the other 1.9% did other education.

Table 2: Respondent Profile

Characteristic	Frequency	Percentage (%)
Gender		
Male	118	77.60%
Female	34	22.30%
Age		
from 15 to 20	7	4.60%
from 21 to 25	5	3.20%
from 26 to 30	38	25%
from 31 to 35	53	34.80%
from 36 to 40	48	31.50%
other	1	0.60%
Qualification		
Metric	65	42.70%
Inter	36	23.60%
Bachelor	36	23.60%
Master	12	7.80%
Other	3	1.90%

Source: SmartPLS output

4. Results and Findings

4.1 Descriptive Analysis

The descriptive analysis Table 3 contains important reliability and validity statistics for the measurement constructs used in this research. The result shows that Cronbach's alpha 0.696 of DC (Disruption Co-occurrence), while slightly below the typical threshold of 0.7, is still acceptable, indicating reasonable internal consistency (Rashid et al., 2019). The composite reliability of 0.832 surpasses the recommended threshold of 0.7, suggesting good reliability (Rashid & Rasheed, 2023). The AVE of 0.624 indicates that the construct explains a substantial proportion of the variance in the items, demonstrating adequate convergent validity (Fornell & Larcker, 1981; Khan et al., 2023a; b). Like DC, DN demonstrates good internal consistency and reliability, with Cronbach's alpha and composite reliability exceeding 0.7 (Hashmi, 2022; Khan et al., 2021). The AVE of 0.660 suggests that this construct also possesses convergent validity.

Table 3: Descriptive Analysis

	Cronbach's alpha	Composite reliability	AVE
DC	0.696	0.832	0.624
DN	0.742	0.853	0.660
EP	0.689	0.826	0.614
Flexibility to the disturbance	0.680	0.807	0.531
Info Sharing during disturbances	0.813	0.863	0.512

Source: SmartPLS output

In EP (Economic Performance), Cronbach's alpha is slightly below 0.7, and the composite reliability is above the threshold, indicating satisfactory internal consistency. The AVE of 0.614 suggests reasonable convergent validity, and the construct "Flexibility to the Disturbance" demonstrates acceptable reliability with a Cronbach's alpha above 0.7 and composite reliability above the threshold. However, the AVE of 0.531, while still reasonable, suggests that there may be room for improvement in convergent validity. This construct exhibits excellent internal consistency and reliability, with Cronbach's alpha and composite reliability well above 0.7 (Hashmi, 2023; Khan et al., 2022). The AVE of 0.512 indicates reasonable convergent validity. In summary, most of your constructs (DC, DN, EP, and Info Sharing during Disturbances) demonstrate excellent internal consistency and reliability. The AVE values suggest that these constructs have reasonable convergent validity, with Info Sharing during Disturbances being particularly strong. The construct "Flexibility to the Disturbance" has a slightly lower AVE, indicating a potential area for improvement in convergent validity.

4.2 Discriminate validity

Fornell and Larcker's (1981) standards for evaluating discriminant validity were applied to this investigation. Table 4 presents the outcome's executive summary. The findings indicate that the variables tested in the research are unique and special because the AVE values square root are more significant than the Pearson Correlation values. (Fornell and Larcker, 1981; Agha et al., 2021).

Table 4: Discriminate Validity

	DC	DN	EP	Flexibility to the Disturbance	Info Sharing during Disturbances	Info Sharing during Disturbances x DC	Info Sharing during Disturbances x EP
DC							
DN	0.953						
EP	0.961	0.853					
Flexibility to the Disturbance	0.821	0.615	0.775				
Info Sharing during Disturbances	0.640	0.763	0.652	0.605			
Info Sharing during Disturbances x DC	0.388	0.351	0.339	0.151	0.171		
Info Sharing during Disturbances x EP	0.320	0.335	0.426	0.260	0.280	0.786	

Source: SmartPLS output

Three direct and two moderate hypotheses have been put forth by my research. In this research, I used scaling to test the hypotheses. Table 5 illustrates the findings of the hypothesis.

Table 5: Hypothesis Result

	Beta	STDEV	T statistics	P values	
DC ->Flexibility to the Disturbance (H1)	0.414	0.098	4.233	0.000	accepted
DN ->Flexibility to the Disturbance (H2)	-0.083	0.088	0.939	0.348	rejected

EP ->Flexibility to the Disturbance (H3)	0.230	0.099	2.317	0.021	accepted
Info Sharing during Disturbances x DC ->Flexibility to the Disturbance (H4)	-0.139	0.100	1.383	0.167	rejected
Info Sharing during Disturbances x EP ->Flexibility to the Disturbance (H5)	0.085	0.101	0.849	0.396	rejected

Source: SmartPLS output

The finding of my research is in favour of all the direct hypotheses except the subsequent one (1) DN effects elasticity to the trouble (β 5 -0.083, t 5 0.939, p > 0.05). Similarly, in the moderating hypothesis relationships, our findings do not favour both moderating hypothesis relationships. Info sharing during disturbances x DC -> flexibility to the disturbance (β 5 -0.139., t 5 1.383, p > 0.05) and Info sharing during disturbances x EP ->flexibility to the disturbance (β 5 0.085., t 5 0.849, p > 0.05).

5. Discussions, Conclusion, Policy Implications and Future Research

5.1 Discussion

Hypotheses	Conclusion
H1. There is a negative relationship between disruption co-occurrence and CI resistance to focal disruption	Accept
H2. There is a negative relationship between disruption non-routineness and CI resistance to focal disruption.	Rejected
H3. There is a positive relationship between economic performance and CI resilience to focal disruption.	Accept
H4 The association between disruption co-occurrence and CI resistance to concentrated disruption is moderate by cross-border information exchange during disruption. When cross-border information flow is minimal, this negative association is enhanced, and when it is high, it is attenuated.	Rejected
H5. The link between disruption Economic Performance and CI disruption resilience is moderated by cross-border information exchange during disruption. When cross-border information flow is minimal, this positive association is enhanced, and when it is high, it is attenuated.	Rejected

Source: Results outcome

My research has explored various facets of this intricate relationship, shedding light on the dynamics between disruptions, organizational characteristics, economic performance, and the role of cross-border information exchange. This discussion aims to provide a nuanced understanding of the implications of our research in the context of critical infrastructure resilience.

We found substantial evidence to support Hypothesis 1, which posited a negative relationship between disruption co-occurrence and critical infrastructure (CI) resistance to focal disruption. This finding underscores the significance of coordinated response mechanisms within inter-organizational networks of Red Buses. Organizations that effectively manage disruptions through collaborative efforts are better equipped to resist the impact of focal disruptions, ultimately contributing to CI resilience (Barratt-Pugh et al., 2020). Contrary to our expectations, Hypothesis 2 was rejected, suggesting a negative relationship between disruption non-routineness and CI resistance to focal disruption. This unexpected result highlights the adaptability and versatility of Red Bus networks in responding to disruptions of varying natures. A certain level of non-routineness can be advantageous, allowing organizations to adapt quickly to unexpected challenges.

Our analysis supported Hypothesis 3, indicating a positive relationship between economic performance and CI resilience to focal disruption. This finding underscores the importance of economic stability in bolstering CI resilience. Red Bus networks prioritizing economic performance are better positioned to withstand the adverse effects of disruptions through investment in contingency planning and resource allocation (Bhamra et al., 2011). Our research did not support Hypotheses 4 and 5, which proposed that the association between disruption co-occurrence and Economic performance with CI resilience would be moderated by cross-border information exchange during disruption. This suggests that the impact of information exchange on CI resilience may be more complex than initially anticipated. It emphasizes the need for further investigation into how information exchange influences resilience within inter-organizational networks.

5.2 Practical and Managerial Implications

The acceptance of Hypotheses 1 and 3 highlights the practical significance of fostering collaboration among Red Bus organizations and prioritizing economic performance. Organizations should strengthen their inter-organizational ties and focus on financial robustness to enhance their CI resilience. Additionally, the rejection of Hypothesis 2 underscores the importance of flexibility and adaptability within these networks. Policymakers and regulators can leverage our findings to shape policies promoting inter-organizational network resilience. Potential policy actions include encouraging the development of standardized procedures for cross-border information exchange, incentivizing investments in infrastructure maintenance, and establishing contingency planning requirements. Practitioners should invest in training and development programs for their teams. Training in crisis management, communication protocols, and scenario planning exercises can enhance the readiness of Red Bus network members to respond effectively to disruptions (Barratt-Pugh et al., 2020).

5.3 Limitations and Future Research

We applied the Information Processing Theory to analyze the dynamics within these networks. We tested hypotheses related to disruption co-occurrence, non-routineness, economic performance, and the moderating role of cross-border information exchange. The results of our study offer valuable insights for practitioners, decision-makers, and policymakers in the transportation and critical infrastructure sectors. Our study has provided valuable insights, but there is room for further research. Our study has laid the groundwork for further research. Future studies could delve deeper into the specific mechanisms through which information sharing influences resilience. Additionally, exploring the role of emerging technologies such as AI and IoT in enhancing response capabilities is a promising avenue for future research.

5.4 Conclusion

In conclusion, our research on resilience in Red Buses' inter-organizational networks dealing with critical infrastructures' daily disruptions offers practical and managerial implications. The findings emphasize the importance of collaborative response, adaptability, economic stability, and information exchange. By implementing the recommendations outlined above, organizations and policymakers can contribute to the resilience and reliability of critical infrastructure networks, ensuring their continued functionality in the face of disruptions. The conducted study presented understandings contributing to the discussion about how much SCRs and SP are influenced by implementing the LM practices in the SME sector of Pakistan, which resultantly enhances firm performance. It was revealed that LM positively related to SCR (SCR) and SP (SP), which enhanced firm performance. Results indicated that the direct impact was not as strong as others. However, it contributed to a significant extent. It showed a positive direct relation when exploring the direct impact of LM in enhancing SP because it primarily focuses on reducing waste and improving efficiency. Implementation of LM techniques and tools also improved SP indirectly by enabling cooperation and building trust between supply chain partners.

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Appendix: Questionnaires

Please rate how strongly you agree or disagree to the following statements by placing a check mark in the appropriate box.

1- Strongly disagree
2- Disagree
3- Neutral
4- Agree
5- Strongly agree

CI Flexibility to the Disturbance (Dependent Variable)

5. We have outlined measures to address vulnerability to disruption?
6. Do we have the capacity to adjust the necessities of partners and environmental conditions in the shortest possible time?
7. The firm has fast reaction and recovery from turbulence?
8. we are proactive in our SC risk management Supply Chain Resilience And Operational Performance?

Economic Performance (Independent Variable)

9. A strong economic performance of critical infrastructure enhances its resilience to disturbances in the supply chain?
10. Sustaining a stable economic performance in critical infrastructure operations improves its ability to absorb and recover from disruptions in the supply chain.
11. Maintaining a high level of economic performance in critical infrastructure supports its overall resilience and ability to cope with supply chain disruptions.

Disturbance Co-occurrence (Independent Variable)

12. The simultaneous occurrence of disruptions across critical infrastructure elements undermines (weaken) their overall resilience to disturbances in the supply chain?
13. The interconnectedness of critical infrastructure systems increases their vulnerability to disturbances, leading to a higher likelihood of co-occurring disruptions during supply chain disturbances.
14. Effective management of co-occurring disruptions in critical infrastructure contributes significantly to its overall resilience and ability to recover from supply chain disturbances.

Disruption Non-routineness (Independent Variable)

15. Higher levels of disruption and non-routines challenge the resilience of critical infrastructure when faced with disturbances in the supply chain.
16. Higher levels of non-routine disruptions within critical infrastructure hinder their ability to effectively respond to disturbances in the supply chain, reducing overall resilience.
17. The presence of non-routine disruptions significantly influences the critical infrastructure's resilience against disturbances in the supply chain.

Information Sharing Across Boundaries During the Disturbance Co-occurrence CI Flexibility to the Disturbance (Moderating Variable)

18. To what extent do you agree with the statement: Effective information sharing across supply chain boundaries during disturbances reduces the likelihood of multiple

disturbances occurring simultaneously?

19. Please indicate your level of agreement with the following statement: Cross-boundary information sharing enhances the coordination of responses to supply chain disturbances, leading to decreased co-occurrence of disruptions.
20. Collaborative information sharing during disturbances improves supply chain resilience and reduces the likelihood of simultaneous disruptions.