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ENHANCING SUPPLY CHAIN RESILIENCE TO CLIMATE CHANGE IN OMAN: CHALLENGES AND SOLUTIONS

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Abstract: Sultanate of Oman is vulnerable to the potential impacts of climate change (Ahmed & Choudri, 2012). Oman is vulnerable to different natural disasters, especially cyclones because it's surrounded by seas and its open to the Indian ocean (Al-Shaqsi, 2011). This study aims to investigate the challenges and opportunities of establishing climate-resilient supply chains in Oman. Three objectives will help to achieve this goal: (1) Examining Oman's supply chains for vulnerabilities and risks related to climate change: Information on specific vulnerabilities and risks will be gathered from interviews with stakeholders, experts, and logistics professionals. Analysis of historical climate data will help understand potential impacts on transportation infrastructure, logistics operations, and overall supply chain resilience. (2) Identifying adaptation strategies for climate-resilient supply chains: A comprehensive literature review and interviews with logistics professionals, policymakers, and experts will expose current practices, challenges, and potential adaptation strategies in the Omani context. (3) Developing guidelines for integrating climate resilience into supply chain management practices: Questionnaires administered to logistics professionals and stakeholder consultations will assess current practices, awareness, and needs. Also, Stakeholder discussions will be used to gather valuable input and feedback, enabling the development of practical guidelines and recommendations. This study will enhance the understanding and adaptation of supply chains for climate-resilient operations in Oman. The findings will provide a guideline inform logistics professionals, policymakers, and stakeholders, enabling them to make informed decisions and implement effective strategies. By fostering climate resilience, supply chains can reduce risks, improve operational effectiveness, and support sustainable development in Oman.

Keywords: Stakeholder interviews, Policymakers, Logistics professionals, Guidelines development

Introduction

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This research article discusses the challenges, strategies, and best practices surrounding the climate-resilient supply chain in Oman. The paper uses literature search and quantitative and qualitative methodologies to unearth different perspectives on building a climate-resilient supply chain in the Sultanate. It also analyzes data collected and provides various recommendations for different stakeholders.

Background Information

Al Buloshi and Ramadan (2015) state that the global supply chain faces numerous challenges that lead to disruption. The most common challenge global supply chain stakeholders complain about is climate change related because of its unpredictability nature. Organizations like the United Nations, through the United Nations Framework Convention on Climate Change, emphasize the world's role in contributing to and alleviating climate change. Al Ruheili (2017) also holds that the GCC region faces the most risk because of its proximity to large water bodies. Sea level rise across the GCC has been documented as the region's biggest threat to logistics and supply chains. However, hurricanes, floods, wildfires, wildfires, temperature fluctuations, and cyclones result from increased greenhouse gas (GHG) emissions (Al-Awadhi, Charabi & Choudri, 2019). The Sultanate of Oman, a coastline state, faces significant risks from these climatic changes. Over time, there has been increased accelerated erosion and inland storms because of Oman's proximity to the Arabian Sea, the Sea of Oman, and the Arabian Gulf. Thus, the supply chain fraternity in the Sultanate should devise adaptation strategies to make the country's supply chain more resilient and adaptable to these climate changes.

Problem Statement

Vulnerabilities in national supply systems must be addressed in light of the growing impact of climate change on global supply chains. Oman, a coastal nation bounded by the Arabian Sea, Sea of Oman, and Arabian Gulf, is threatened by supply chain stability due to climatic challenges like rising sea levels, erosion, and storms. Given the socioeconomic importance of supply chains, increasing their resistance to climate change becomes essential for Oman's sustainable development.

Existing literature emphasizes the importance of fostering supply chains that are climate resilient to ensure smooth flows of goods and services. Although acknowledged, Oman's supply chain management lacks comprehensive guidance for integrating climate resilience. Bridging this gap involves identifying vulnerabilities, formulating robust adaptation strategies grounded in best practices, and seamlessly integrating climate resilience. This study contributes to both academic and practical discourse by enhancing Oman's supply chain resilience amid changing climatic dynamics.

Objectives of the Study 1. Examining Oman's supply chains for vulnerabilities and risks related to climate change.

2. Identifying adaptation strategies for climate-resilient supply chains.
3. Developing guidelines for integrating climate resilience into supply chain management practices.

2. Literature ReviewClimate Change Impacts in Oman

According to Al Ruheili (2017), the global climate is changing because of increased emissions of greenhouse gases (GHGs), aerosols, and land surface changes. These climatic changes directly impact several sectors like transport, infrastructure, and supply chains. Al Buloshi and Ramadan (2015) opine that Oman's Ministry of Environment and Climate Affairs is leading regarding climatic changes since studies reveal that the Sultanate is emitting a significant amount of atmospheric GHGs based on per capita. Oman's extensive coastline makes it

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vulnerable to such climatic changes' effects, for instance, the 2007 Gonu cyclone and the one witnessed in 2010 in Phet (Al-Awadhi, Charabi & Choudri, 2019). Al Ruheili (2017) states that Northern Oman has historically documented major storms and cyclonic events since 1890. These extreme weather events, like the cyclones and heavy rainfall, exposes Oman to adverse effects on its transportation and economic activities.

Al-Jawaldeh et al. (2022) reveal that extreme temperatures, extreme precipitation, high carbon dioxide concentrations, and sea surface temperatures instigated by climatic changes in Eastern Mediterranean Region (EMR) countries like Oman have severe consequences for a country's socio-economic prowess. Al Ruheili (2017) opines that, historically, climatic changes have affected Oman's infrastructural, transportation, and supply chain developments. Similarly, Al-Awadhi, Charabi, and Choudri (2019) reveal that climatic changes affect the Sultanate's transportation systems, affecting the country's supply chain and exposing its citizens to higher food insecurity and stagnating economic development.

Supply Chain Resilience

Li et al. (2023) defines supply chain resilience (SCR) as responding to disruption and returning to its original state. Shishodia et al. (2021) state that the supply chain resilience framework gets stronger through diversification, international partnerships, onshoring, demand management, and stockpiling and capacity. Aguila and ElMaraghy (2019) insist that the supply chain has numerous uncertainties, and only reputable industries have to learn how to handle such situations by balancing the desired performance and the costs of achieving resilience.

For instance, climate change can disrupt the supply chain, and only industries with mitigation plans and strategies bounce back after such disruptions (Baskin, 2020). SCR is vital for any organization because it helps identify risks and reduce their impacts without hurting the revenues and operations (Alfarsi, Lemke & Yang, 2019). Scholars have highlighted that the most sustainable approach to being resilient to climate change disruptions is being the leader in reducing emissions. For instance, Microsoft has pledged to become a carbon-negative company by 2030 by streamlining its procurement and supply chain to be sustainable (Baskin, 2020). Also, Li et al. (2023) opine that the Chinese Pearl River Delta is implementing logistic clusters that are climate resilient.

Vulnerabilities and Risks in Oman's Supply Chains

Scholars have insisted that several vulnerabilities and risks in Oman's supply chains are caused by climatic change. Taderera, Al Qasmi, and Al Balushi (2018) hold that Oman's natural disasters, like hurricanes and regular floods, affect the smooth supply chain management making it very vulnerable. Cyclones account for over 80% of all-natural disasters in Oman. Thus, increasing climate change intensities damage infrastructure and erodes supply chain resiliency. Sharma et al. (2021) also claim that such climate-related disruptions increase shipping costs, leading to manufacturing delays and commercial liabilities.

According to Choudhary et al. (2022), risk assessment framework like the SCREI (Supply Chain Risk Exposure Index) work by fragmenting the supply chain into various interaction nodes whereby firms can know the financial and operational effect of each node and then calculate the consequences if a node stopped operating due to disruptions. On the other hand, Sharma et al. (2021) reveal that supply chain risk modeling is vital in developing quantitative risk measures to make them effectively comparable and prioritized. Ziegler et al. (2021) present a case study of Greenhouse gas emissions of Norwegian seafood and supply chain vulnerability caused by rising sea temperatures, changing migration patterns, and increased GHGs. They state that to mitigate such risks, they

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must diversify fish species, be leaders in advocating for a green environment and explore new markets to minimize supply chain disruptions.

Adaptation Strategies for Climate-Resilient Supply Chains

Choudhary et al. (2022) reveals that adapting to climate-related supply chain disruptions involves assessing and managing risks, collaborating, using technologies, creating sustainable practices, and policy interventions. Saidi, El Alami, and Hlyal (2021) acknowledge that integrating climate considerations into any firm's procurement and supply chain processes is vital for future success. El Alami and Hlyal (2021) opine that this is possible by deploying advanced technological tools that can analyze, monitor and provide predictive climatic analytics that helps anticipate market trends.

Also, scholars have evidenced that building partnerships with suppliers, customers, and other stakeholders helps create a climate-resilient supply chain because more information and resources are vital in responding to market changes. Collaboration through partnerships makes the supply chain more secure and resilient, making it easier to know risks and plan for any climate-related disruption (Choudhary et al., 2022). Similarly, firms should build on sustainability and green practices like being more resource efficient, reducing waste, using renewable energy sources, and implementing other energy-efficient processes. Saidi, El Alami, and Hlyal (2021) also believe that various policy interventions can help build climateresilient supply chains.

Moreover, challenges and opportunities are associated with implementing climate adaptation strategies in supply chain management. Pankratz and Schiller (2022) state that climate adaptation strategies in the supply chain present a firm with opportunities like reducing risks of unexpected disruptions since they can plan for risks, improving efficiencies by reducing time and cost constraints and making the firm more agile and visible when faced with challenges. Organizations with better supply chain climate actions benefit from improved reputation and brand images, which increases customer loyalty and a positive public perception, giving them a better competitive advantage. Conversely, Pankratz and Schiller (2022) reveal that collaborations and partnerships come with challenges of effective communication, building trust, and sharing crucial information, which might be challenging for most supply chains. Also, investing in climate-resilient infrastructure and technologies often come with substantial financial resource requirements, which is usually a challenge as firms struggle to minimize costs. Conflicting and limited policy frameworks also make it difficult to fully adopt these adaptation strategies (Pankratz & Schiller, 2022).

Integration of Climate Resilience into Supply Chain Management

Dasaklis and Pappis (2013) hold that various methodologies, guidelines, and frameworks are used to incorporate climate resilience considerations into supply chain practices and overall organizational strategic planning and decision-making. For instance, the GRI (2023) helps develop and deliver global best practices directing organizational communication and demonstrating accountability for their impact on the environment, economy, and people. The GRI framework is crucial in identifying, measuring, and managing climate risks.

Additionally, the Global Supply Chain Resilience Council (GSCRC) created a framework that involves assessing climate-related risks, mitigating, and monitoring them. These frameworks and guidelines inform supply chain stakeholders to consider long-term projections when making decisions on climate-related risk vulnerabilities. It includes operational practices like diversifying suppliers, flexible production processes, and robust inventory management practices to enhance logistics and transport systems (Dasaklis & Pappis, 2013).

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According to United Nations Framework Convention on Climate Change (2020), Apple is an example of a multinational corporation that has integrated climate resilience into its supply chain after risk assessments. The company has set carbon emission reduction targets and more supplier engagement to make its supply chain more sustainable and protect the planet by using renewable and efficient energy with low carbon emissions. UNFCCC (2020) highlights that this effort is a lesson to other companies because it emphasizes partner collaborations and the value of setting achievable targets by putting their efforts into renewable energy solutions that reduce carbon emissions. Conversely, Nestlé (2021) has successfully integrated climate resilience into its supply chain by implementing responsible sourcing standards, including climate change adaptation for its suppliers and other partners.

Stakeholders' Perspectives and Engagement

Stakeholders are individuals or groups with current and past experiences coping with and adapting to climate variability and extremes. Siems, Seuring, and Schilling (2022) opine that supply chain and logistics professionals should be leaders in identifying climate-related risks, designing mitigation efforts, and adopting resilient supply chain and logistic practices. Hence, they can enhance supply chain resilience by providing their vast knowledge in warehousing, transportation, and inventory management. André et al. (2023) claim that supply chain policymakers can create an enabling environment for climate resilience by establishing regulations, incentives, and frameworks that encourage organizations to have climate risks and adopt sustainable practices in their strategies. Customers also always lead from the front in demanding sustainable and resilient supply chains, while suppliers effectively collaborate with organizations when implementing sustainable and climate resilient raw products or services (André et al., 2023).

Interviews and surveys are the common methods of gathering stakeholders' climate resilience supply chain perspectives since they allow for in-depth analysis and exploration of their opinions, concerns, and suggestions, which eventually helps develop guidelines and recommendations (Siems, Seuring & Schilling, 2022). Similarly, focus groups and participatory workshops are significant avenues for these stakeholders to gather and discuss climate-resilient supply chains and their phenomena. Siems, Seuring, and Schilling (2022) acknowledge that supply chain stakeholder engagement is vital because it helps identify risks and opportunities that might affect the supply chains.

Impact of Climate on Port Infrastructure and Resilience

Whenever the sea level rises, there is an increased possibility of coastal flooding, which damages and destroys port facilities, disrupting operations and impacting cargo handling capabilities. Portillo Juan, Negro Valdecantos, and del Campo (2022) also hold that sedimentation pattern changes can alter port access channels and navigation capabilities. Thus, ports should have protective structures like sea walls, dikes, and breakwaters to handle storm surges, sea-level rise, or coastal erosion. The port infrastructure should also have climate informed design practices and operational measures which prepare the authorities through early warnings and flexible operations during harsh climatic changes (Portillo Juan, Negro Valdecantos & del Campo, 2022).

Airports and Climate Resilience

Increased storm intensity damages airport infrastructure and buildings, which can temporarily or permanently disrupt operations (ICAO, 2018). Changes in average and extreme temperatures leading to icing conditions or heatwaves often affect aircraft performance, inhibit runway conditions and air-conditioning abilities, lead to

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infrastructure integrity, and affect fuel handling storage. Moreover, ICAO (2018) outlines that airports face wind damage risks and disrupted flight schedules during extreme weather like hurricanes, storms, and cyclones. Thus, airport stakeholders can invest in weather monitoring systems, modify infrastructure to promote climate resilience and develop contingency plans for such disruptions.

Warehousing and Inventory Management

Al-Abri and Taderera (2020) postulate that climate-resilient warehousing and inventory management practices in Oman can experience challenges like shifts in transportation routes, disrupted energy supply which impacts inventory quality and operational efficiency, and numerous extreme weathers which exposes warehouses and inventory to damages and disruption of supply chain continuity. However, these challenges also present opportunities like adopting integrated inventory management systems, diversifying distribution networks, and implementing sustainable and energy-efficient warehousing technologies (Al-Abri & Taderera, 2020).

Distribution Centers and Last Mile

Pankratz and Schiller (2022) claim that distribution centers and last-mile logistics are often disrupted by climate change impacts like extreme weather conditions like floods and hurricanes, resulting in delays and destroyed infrastructure. Pankratz and Schiller (2022) reveal that this makes it difficult for distribution centers to forecast and meet consumer demands effectively. Scholars hold that real-time monitoring and visibility technologies like sensors, data analytics, and the Internet of Things (IoT) can promote distribution center and last-mile resilience.

Cold Chain Management and Climate Resilience

Lu et al. (2022) hold that climate change makes maintaining temperature control throughout the cold chain difficult. Increasing temperatures can pass acceptable temperature thresholds, spoil a product, and damage pharmaceuticals and vaccine efficacy. Also, heatwaves, storms, and floods often disrupt cold chain logistics, causing power outages or damaging equipment and transportation delays. Lu et al. (2022) also hold that using advanced monitoring technologies like data analytics and real-time temperature tracking systems can lead to better monitoring and early temperature deviations or climate-related risks.

Multi-Modal Transportation and Climate Adaptation

Makarova et al. (2023) opine that multi-modal transportation systems promote efficient transportation of goods and services by reducing congestion, unnecessary movement and enhancing flexibility during climate disruptions. Hence, they integrate warehousing and distribution services to form centralized points for handling and transferring cargo (Makarova et al., 2023). Makarova et al. (2023) also insist that they also need advanced, costly infrastructure and effective coordinative efforts among the stakeholders, which might be challenging in the event of miscommunications.

Conceptual Framework

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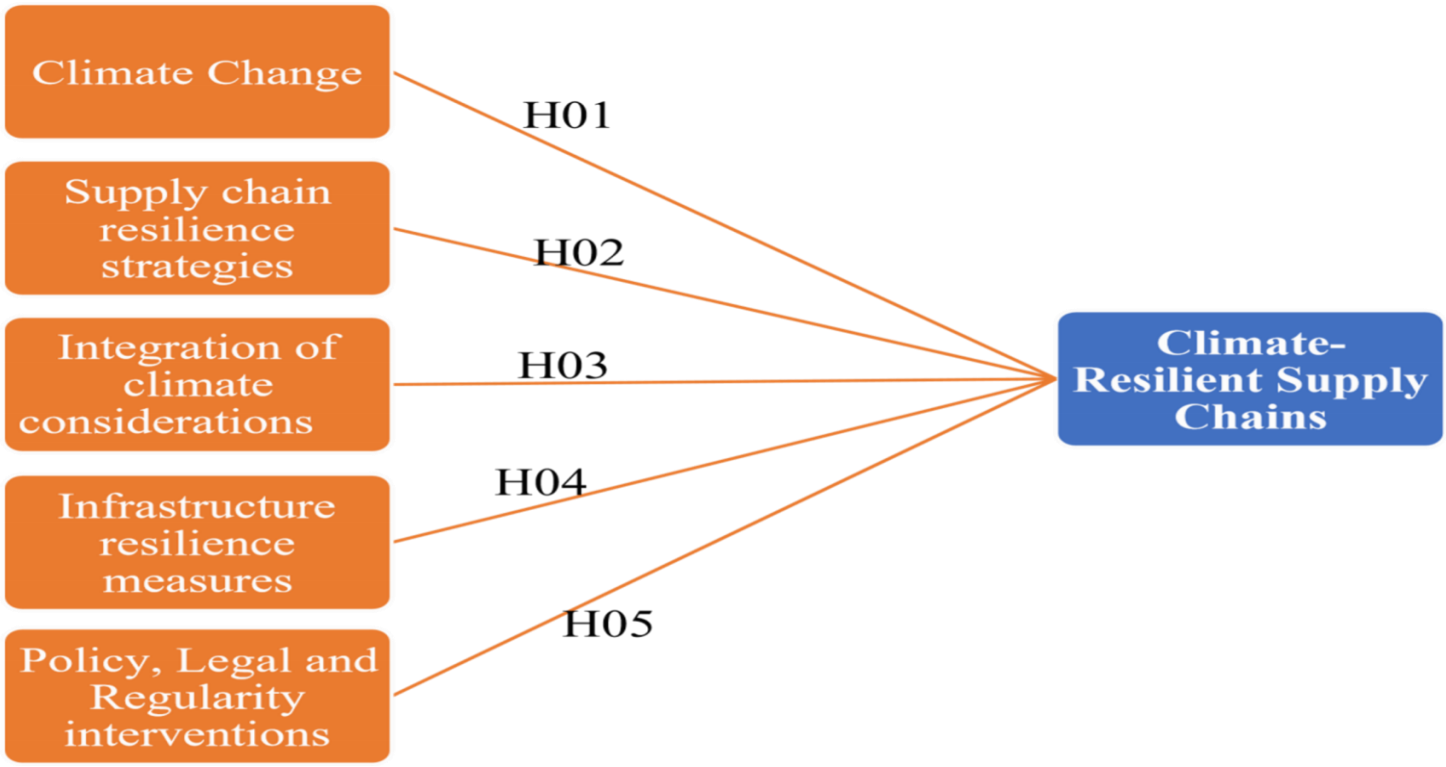

Figure 1 Climate-Resilient Supply Chains

Source: Secondary Data

1. Hypothesis 1: Climate Change

Climate change impacts and vulnerabilities in Oman's supply chains significantly **negatively** affect the resilience of logistics and operations, infrastructure, and resource management.

2. Hypothesis 2: Supply chain resilience strategies

Effective supply chain resilience strategies, including diversification, international partnerships, demand management, collaboration, and sustainable practices, **positively** mitigate climate-related risks and enhance overall resilience.

3. Hypothesis 3: Integration of climate considerations

Integrating climate considerations into procurement and supply chain processes, supported by risk assessment frameworks and modeling techniques, **improves** resilience and sustainability in the face of climate change impacts.

4. Hypothesis 4: Infrastructure resilience measures

Infrastructure resilience measures, such as climate-informed design practices, advanced technologies, and multi-modal transportation systems, **enhance** the ability of ports, airports, warehousing, and distribution centers to withstand climate-related disruptions and maintain smooth operations.

5. Hypothesis 5: Policy, Legal, and Regularity Interventions

Policy interventions that promote climate resilience, combined with multi-stakeholder engagement involving policymakers, logistics professionals, customers, and suppliers, play a crucial role in **fostering** knowledge sharing, collaboration, and aligned strategies for building climate-resilient supply chains.

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3. Methodology Research Design

The study uses a mixed-methodology research design entailing qualitative and quantitative methodologies to effectively investigate the challenges, strategies, and best practices when creating a climate-resilient supply chain in Oman. The study uses a comprehensive literature review to retrieve data and build the conceptual framework, an interview, and a questionnaire (Apuke, 2017).

Population and Sample

This study targets supply chain management professionals and will derive information from logistics professionals, climate professionals, supply chain policymakers, and general consumers. This study targets a sample of 70 from a larger population, comprising 20 for interviews and 50 for questionnaires.

Data Collection

Data is collected using physical and online questionnaires and interviews based on the participant's feasibility and preferences. The researchers will collect data for the study using a literature review, interviews, and questionnaires. The interview sessions will take 15 minutes to 30 minutes to ensure that the participants do not massively interrupt their busy schedules.

Data Analysis and Presentation

Kabir (2016) opines that once data is collected from the field, the researcher must clean it before checking their completeness, accuracy, and consistency. Google Forms and Microsoft Excel are essential data analysis and presentation tools. The results are then presented visually using tables, charts, and graphs to illustrate key findings and features.

Validity and Reliability

Surucu and Maslakci (2020) outline that reliability is a research method's consistency is when measuring an outcome after repeated trials. Conversely, validity can be achieved when experts appropriately check the variables and data techniques.

Ethical Consideration

The study adheres to ethical guidelines and ensures that the research participants have informed consent. The researchers also ensure that they uphold data privacy and confidentiality that protects such data from landing in the hands of the wrong people (Franco, 2020).

4. Discussion of Results

The data was collected using physical and online questionnaires and interviews: the target was 20 interviews and 50 questionnaire respondents.

Interview Results:

The results were obtained from 17 out of 20 targeted responses to the interviews. The interviews were conducted with audiences from various industries. 35% of respondents worked in supply chain-related jobs, such as contract managers, transport engineers, procurement managers, etc. Other respondents included academists, policymakers, climate professionals, and customers/dealer.

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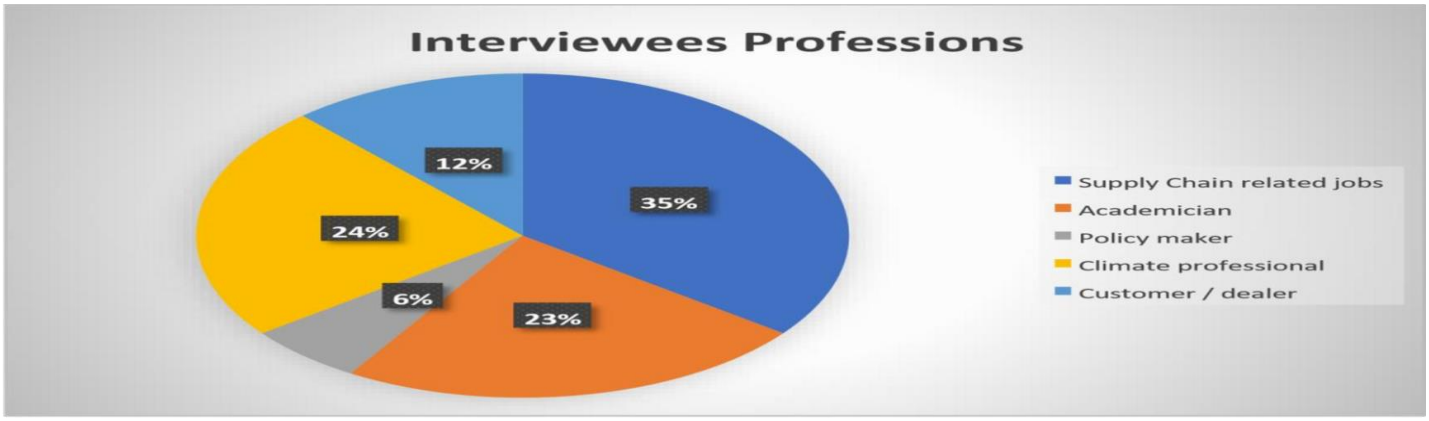

Figure 2 Interviewees Professions

After data collection and throughout the analysis, the following are the results of the common responses from the interview. It's worth mentioning that several interviewees could not answer some questions due to a lack of awareness about this topic. The results are arranged according to each hypothesis.

Hypothesis 1: Climate Change:

1. Increased frequency and intensity of extreme weather events causing disruptions in transportation infrastructure and supply chain flow.
2. Disruptions to transportation routes due to extreme weather events.
3. Impact of climate change on resource availability and reliability, including water scarcity and increased energy demands during extreme heat.
4. Managing inventory and manufacturing challenges due to climate-related factors such as heat and lack of rainfall.
5. Rising sea levels and coastal erosion impact ports and coastal facilities, leading to shipping delays.

Hypothesis 2: Supply chain resilience strategies

1. Supply chain diversification to reduce dependence on vulnerable regions.
2. International partnerships for risk-sharing and knowledge exchange related to climate adaptation and risk management.
3. Demand management through efficient forecasting and inventory practices.
4. Adoption of sustainable practices to reduce carbon emissions and enhance resilience.

Hypothesis 3: Integration of climate considerations:

1. Limited data availability for accurate risk assessments and adaptation planning.
2. High initial costs of implementing climate-resilient infrastructure.
3. Resistance to change from stakeholders in adopting sustainable practices and climate resilient measures.
4. Limited awareness and understanding of the importance of climate considerations in supply chain processes.

Hypothesis 4: Infrastructure resilience measures:

1. Climate-resilient infrastructure, including ports and warehouses built to withstand extreme weather events and rising sea levels.

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2. Real-time monitoring through advanced technologies for early detection and response to climate-related disruptions.

3. Integration of renewable energy sources, such as solar power, to reduce dependence on fossil fuels.

4. Development of comprehensive contingency plans to manage disruptions caused by extreme weather events.

Hypothesis 5: Policy, Legal, and Regularity Interventions

1. Providing incentives and financial support for adopting sustainable practices and investing in climate resilience.
2. Collaboration and partnerships among stakeholders, including public-private partnerships.
3. Balancing short-term and long-term goals to ensure both economic growth and climate resilience.
4. Ensuring compliance with climate-related regulations and building capacity and awareness among stakeholders.
5. Knowledge sharing, information exchange, and raising awareness about climate risks and opportunities among stakeholders.

Questionnaire Results:

The results were obtained from 49 out of 50 targeted responses to the questionnaire. 35% of respondents worked in supply chain-related jobs, such as contract managers, transport engineers, procurement managers, etc. Other respondents included academists, policymakers, climate professionals, and customers/dealers. The figure below shows the respondents' professions.

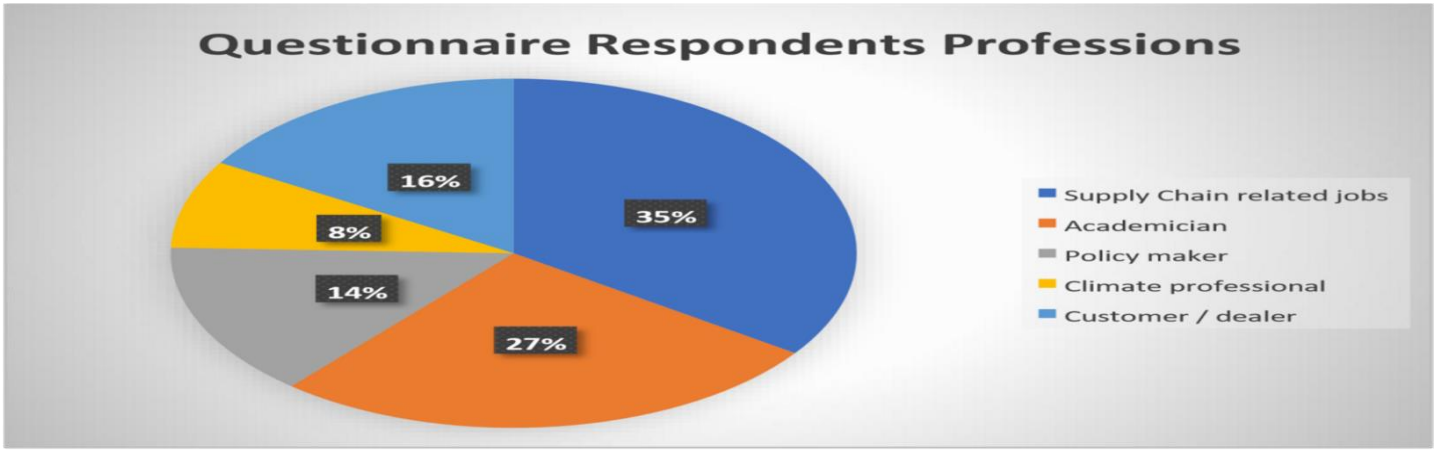

Figure 3 Questionnaire Respondents Professions

Most respondents agreed with the statements given. There were only a few responses of disagree or strongly disagree. The results of the questionnaire responses are shown in the following figures and sorted according to the hypothesis.

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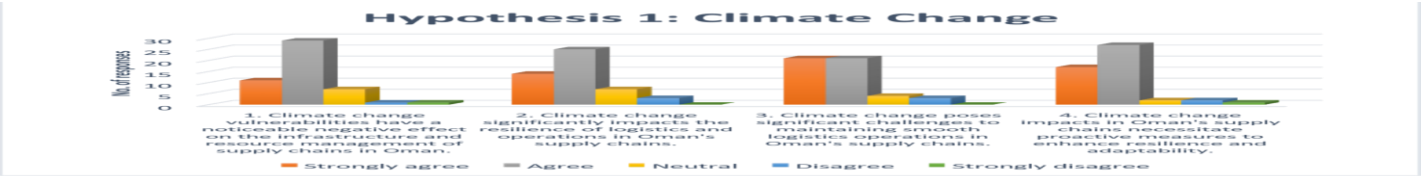

Figure 4 Results of Hypothesis 1

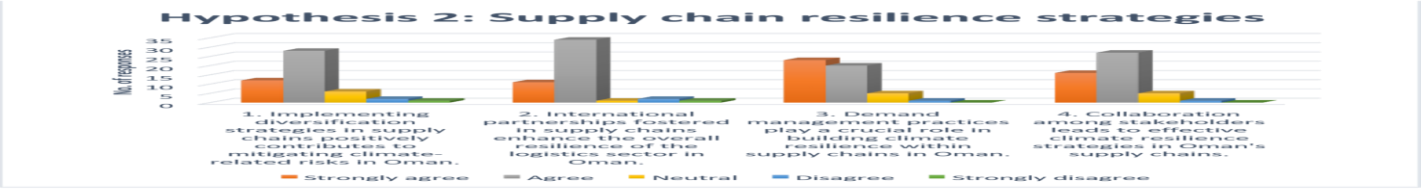

Figure 5 Results of Hypothesis 2

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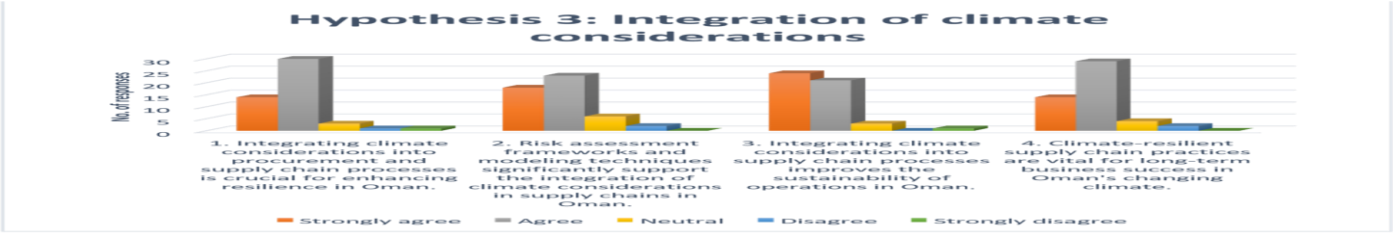

Figure 6 Results of Hypothesis 3

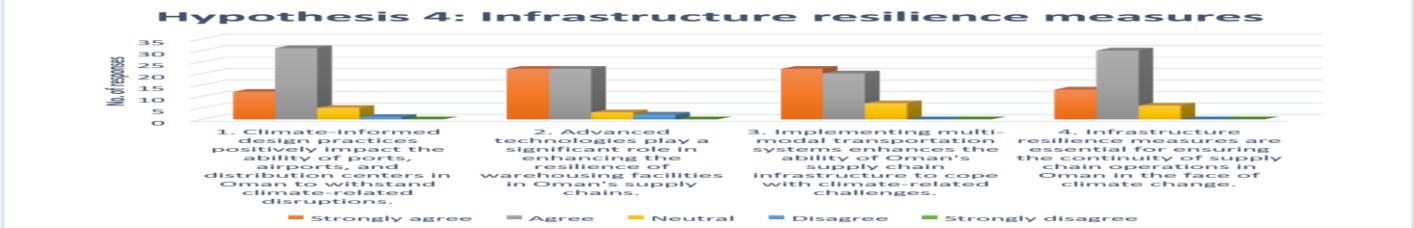

Figure 7 Results of Hypothesis 4

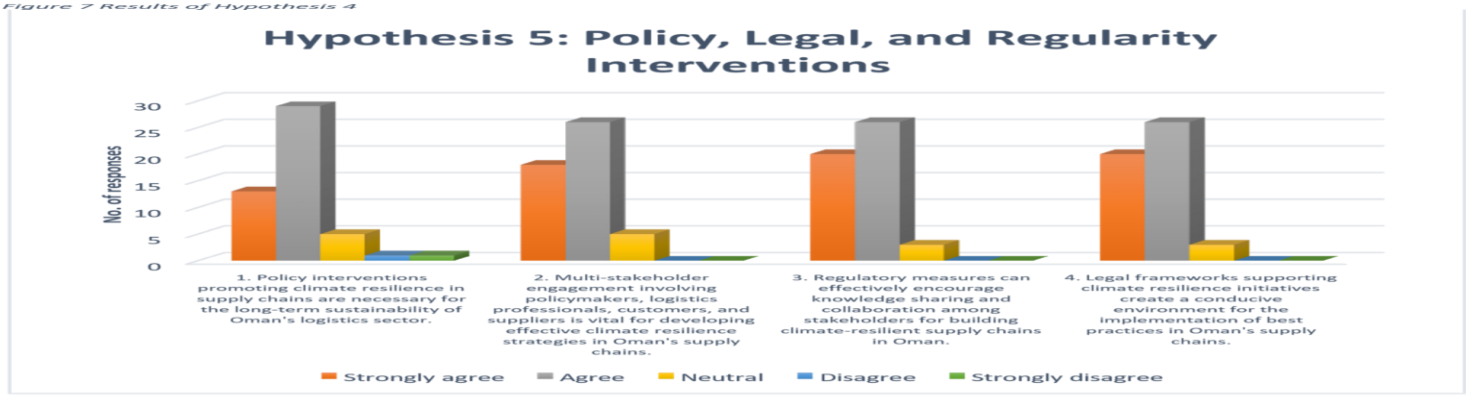

Figure 8 Results of Hypothesis 5

The consolidated results of points in the questionnaire are shown in the figure below.

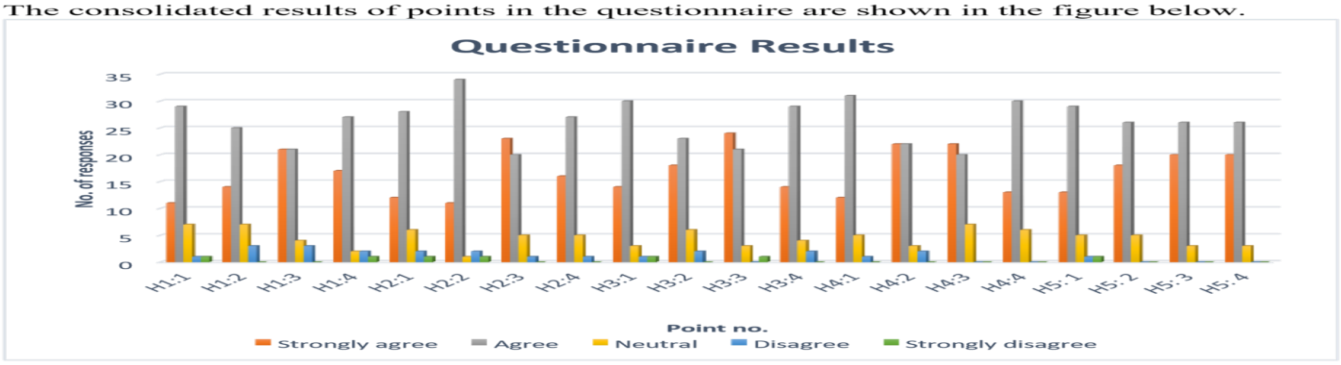

Figure 9 Consolidated Questionnaire Results

After further analysis of the data obtained from the questionnaire, it has been observed that respondents have re-arranged the importance of the hypothesis and how significant they are in building a resilient supply chain. The results of those who chose Strongly Agree and Agree were put in ascending order.

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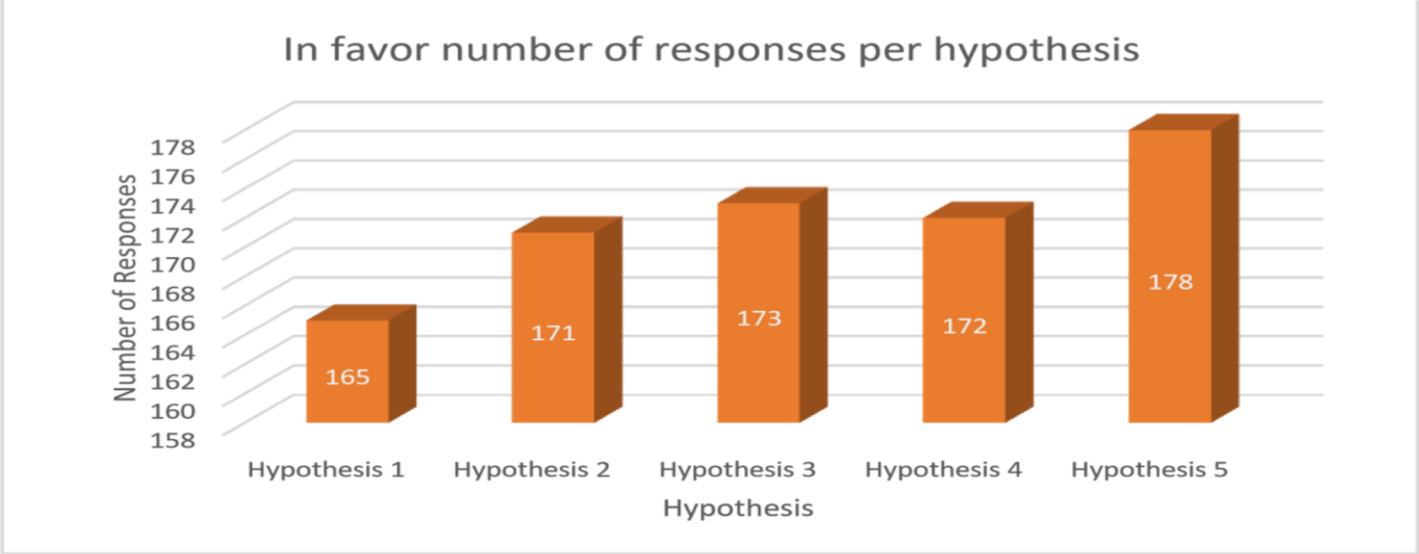

Figure 10 Results per Hypothesis

It can be clear that most respondents think that Hypothesis 5: Policy, Legal, and Regularity Interventions is the most significant factor in building a resilient supply chain. Followed by Hypothesis 3: Integration of climate considerations. The remaining hypothesis was ranked 4, 2, and 1, respectively.

The interviews and questionnaires results show strong connections between theory gained from literature and respondents' current understating and knowledge. The key finding that both tools agree on is that the biggest challenge for building a resilient supply chain is the cost. This includes many factors such as initial costs of implementing climate-resilient infrastructure and compliance with climate-related regulations. The second occurring challenge found was the lack awareness and therefore lack of knowledge on how to build climate-resilient SC. The results also exposed the relationship between climate-related disruptions and supply chain performance metrics. The organization will likely record huge losses due to these disruptions and struggle with inventory turnover, transportation costs, reliability, lead times, and infrastructural damages when they do not have SCM-resilient strategies.

5. Conclusion

From the results obtained by primary data from the interviews and the questionnaires and with linking to literature. It's concluded that the biggest challenge for building a resilient supply chain is the cost. These factors such as initial costs of implementing climate-resilient infrastructure and compliance with climate-related regulations. This challenge can be mitigated by Collaboration and Partnerships Foster Resilience. Collaboration among stakeholders and public-private partnerships is pivotal in building climate-resilient supply chains. Stakeholders can leverage resources, expertise, and diverse perspectives to enhance their resilience by working together. Such collaborations facilitate knowledge sharing, alignment of strategies, and the development of joint initiatives to mitigate climate risks.

The second key challenge is limited data availability regarding climate impacts and a lack of awareness regarding climate considerations pose challenges in building resilient supply chains. Overcoming these challenges requires

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investing in data collection and analysis and raising awareness among stakeholders about the importance of climate resilience and its benefits.

Also, the results highlight the significant impact of climate-related disruptions on transportation infrastructure and the flow of supply chains. Extreme weather events, such as cyclones, storms, and floods, have led to disruptions in transportation routes, causing delays and increased costs. Moreover, adopting sustainable practices emerges as a crucial factor in enhancing the resilience of supply chains. These practices include energy-efficient transportation, eco-friendly packaging, and renewable energy sources. Encouraging and incentivizing businesses to adopt such practices is essential for improving resilience against climate-related challenges.

Finally, balancing short-term economic interests with long-term climate resilience goals presents a significant challenge. While ensuring immediate profitability is important, organizations must also prioritize climate considerations to ensure the long-term sustainability of their supply chains.

6. Recommendations.

Based on the conclusions drawn from the results, the following are key recommendations for businesses, policymakers, and stakeholders to consider in building climate-resilient supply chains:

- **Invest in Climate-Resilient Infrastructure:** Prioritize the development of climate resilient infrastructure, including elevated structures and flood barriers, to minimize the impact of extreme weather events on supply chain operations.
- **Foster Collaboration and Partnerships:** Collaborate through public-private partnerships and industry associations to share knowledge, resources, and best practices, collectively mitigating climate risks and enhancing resilience.
- **Integrate Climate Resilience into Policies:** Governments should incorporate climate resilience considerations into transportation, infrastructure, and logistics policies, creating an environment conducive to adopting resilient practices.
- **Invest in Data Collection and Analysis:** Overcome limited data availability by investing in comprehensive climate data collection and analysis, enabling informed decision making and risk assessment.
- **Raise Awareness and Build Capacity:** Increase stakeholder awareness about climate considerations in supply chain processes through training programs and educational initiatives to foster a culture of climate resilience.
- **Incentivize Adoption of Resilient Practices:** Offer incentives such as tax benefits, grants, and financial rewards to businesses implementing climate-resilient practices, encouraging infrastructure upgrades and risk management strategies.
- **Adopt Sustainable Practices:** Integrate energy-efficient transportation methods, ecofriendly packaging, and renewable energy sources into supply chain practices to reduce carbon emissions and enhance overall resilience.
- **Balance Short-term and Long-term Goals:** Recognize the importance of balancing shortterm economic objectives with long-term climate resilience strategies, ensuring profitability and operational stability.

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