EXPLORING RISK MANAGEMENT, DISRUPTIONS, AND RECOVERY STRATEGIES IN THE CHEMICAL MANUFACTURING SECTOR IN SOUTH AFRICA

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Abstract

This study explores risk management, disruptions, and recovery strategies within the chemical Manufacturing companies in South Africa. The emphasis of the investigation is on finding out how risks are identified and assessed by enterprises, and their strategies for mitigating them or recovering from interruptions. Based on semi-structured interviews with business executives, it explores the responses of internal factors and external risk factors, like regulatory changes, labour unrest, natural disasters, and global pandemics such as COVID-19, to alter risk management behaviors. The results indicated that larger firms indeed had more sophisticated risk assessment techniques, but smaller companies were indeed catching up with digital tools to enhance their risk management. In this study, the three most important means for reducing risk and allowing speedy recovery were identified: supply chain diversification, technology, and flexibility of the workforce. firms with more developed information systems could adapt more readily to disruptions, further emphasizing the role of real-time data for operational resilience. It also deduces the relevance of constant adjustments to dynamically alter the external environment, particularly the socio-politically volatile ones. The contributions of this paper are that an understanding of how risk management will be handled can be enhanced and practical insights have been offered through which business sustainability against future interruptions can be assured in South African chemical manufacturing industries.

Keywords: *risk management, disruptions, recovery strategies, chemical manufacturing, South Africa*

Introduction

The chemical manufacturing industry is an important sector within the industrial economy in South Africa and plays a key role in supplying key sectors of the economy: agriculture, mining, and health. According to R, St. Claire 2024, it contributes about 6% to the country's GDP and 25% to the total manufacturing. It contributed over $35.1 billion to revenue in 2023 alone, meaning much to the gross domestic product and employing a sizeable share of its workforce. It is facing risks and uncertainties regarding disrupted supply chains, regulatory pressures, safety, and climate change. The COVID-19 pandemic further deepened these, exposing critical vulnerabilities in global and regional supply chains, including those supporting the Chemical Industry -Avenant. et al. (2024). It is in this regard that risk management and the realization of effective recovery strategies have been deemed critical in sustaining operations with a guarantee of resilience.

Despite the critical relevance of risk management in this sector, research relating to its application in the South African context is still limited. The studies focused broadly on supply chain resilience and operational risks of manufacturing, although the unique challenges faced by the chemical manufacturing industry call for more specific scrutiny (Kunneke and Niemann,2024). This present study will seek to fill this knowledge gap by seeking to answer the following research question: How do the chemical manufacturing firms in South Africa manage risks, respond to disruptions, and develop recovery strategies toward operational resilience?

The objective of the present study is to investigate and establish prevailing practices that occur in the disruption of risk management and the adopted recovery strategies among the chemical manufacturing firms in South Africa. This objective will provide practical insight into how industrial stakeholders should be guided to strengthen their resilience against future disruptions.

Risk management is especially important for ensuring the chemical industry is long-term sustainable. It involves the identification, assessment, and mitigation of risks that could disrupt operations or harm stakeholders. Common risks in the chemical industry include supply chain disruption, equipment failure, hazardous material handling, and regulatory non-compliance (Latosińska et al., 2021). The risk in the supply chain has, however, been heightened by globalization because firms depend on suppliers that are often separated by geographical locations. This is according to Maisiri, W., and Van Dyk, L. (2021). In South Africa, these risks are increased by domestic issues like aged infrastructure, inefficient logistics, and recurrent labour strikes. These are according to Supply-ChainBrain, 2024.

This study could be important to add knowledge on how South African firms can adapt to a rapidly changing risk landscape. Effective risk management assures an organization with minimum chances of disruption and quick recovery after an adverse event has taken place. Recovery strategies, which include diversifying supply sources, investing in technology, and fostering supply chain collaboration, play a critical role in enabling firms to return to normal operations after a disruption (Nel, 2024). This means that such strategies' adoption by the sector may well be expected to raise the sector's resilience, which continues to be imperative to national development (Pénzes et al., 2014.

Literature identifies theoretical and empirical imperatives for agility, flexibility, and collaborative interaction in managing disruptions to supply chains. For instance, Modgil et al. (2021) found that firms that implemented artificial intelligence and advanced analytics into their operations were able to predict and avert risks arising from the COVID-19 pandemic more effectively. Similarly, Scala and Lindsay (2021) emphasized the ability of cross-functional collaboration to help in effective recovery after disruptions has occurred within the healthcare supply chain. These findings emphasize how relevant it will be to approach risk management and recovery in an innovative and collaborative manner within the chemical sector.

Apart from that, the regulatory environment of South Africa further aggravates the problems faced by the manufacturers of the chemical industry. The firms must tackle strict environmental and safety regulations, such as the Hazardous Chemical Agents regulations brought about by the Department of Employment and Labour. Non-compliance with such regulations can be liable to serious sanctions, disruption in operational activities, and reputational loss. This requirement further strengthens the importance of comprehensive risk management frameworks.

Such research has some practical import to policymakers and industry stakeholders engaged in the industrial process. Policymakers could also use these results to plan out specific interventions for the specific features of chemical sector challenges-in, upgrading the infrastructure or fast-tracking the facilitation processes through regulatory easements. As industry stakeholders, such insights would give cause to focus on building specific risk-mitigation-and-recovery actions well-suited for operating conditions.

This study adopted a qualitative research design, focusing on case studies of chemical manufacturing firms in South Africa. Data collection was through semi structured interviews with experts in the field, supported by an analysis of company reports and relevant literature. Thematic content analysis was then used to uncover the main themes and patterns for risk management practices and recovery strategies. This approach shall help the research to draw out rich, contextualized insights that reflect the real-life experiences of practitioners.

This will add to the growing knowledge in risk management and resilience within the chemical manufacturing sector. The best practices and avenues for improvement will be underlined, thus offering a roadmap that firms can follow to enhance their operational resilience. The study also contributes to a wider discussion of the role played by collaboration, technology, and regulatory alignment in mitigating risks and recovering from disruptions.

Literature review

The South African chemical manufacturing industry is critical to the industrial economy of the country, providing raw materials and products for several key sectors such as agriculture, health, and building and construction. According to (Mbeche ,2022), this is a very vulnerable industry to several risks: operational disruption, supply chain, regulatory compliance, and environmental hazards. Poor management of such disruptions can lead to huge losses, loss of productivity, and will take a long duration for the company to recover. This literature review explores the concept of risk management, disruption, and recovery strategies using practical examples in the chemical manufacturing sector in South Africa.

Distinct Contribution of the Present Study

While previous research has focused on the issues of risk management and supply chain disruptions in global or developed economy contexts (Bareith - -Csonka, 2019, Dolgui &Ivanov, 2020; Chowdhury et al., 2021), there is a critical gap in understanding how these dynamics play out within emerging economies like South Africa. Most of the literature tends to generalize findings from advanced industrial contexts, assuming similar institutional capacities, infrastructural reliability, and regulatory stability (Fouzi et al,2024). However, these assumptions remain inapplicable to the context of the chemical manufacturing industry in South Africa, which operates under persistent energy shortages, logistical inefficiencies, socio-political instability, and an unforgiving environmental legislation environment. Very few studies have researched African contexts, focusing on broad manufacturing or agricultural supply chains (Rashidet al., 2022), while the chemical manufacturing industry has become increasingly neglected due to the high level of risk intensity and regulatory demands it faces as a result of the hazardous nature of operations and dependence on the inflow of raw materials from across the globe.

While most of the earlier literature has identified either generic risk management and disruption recovery strategies or cases applicable to specific countries/sectors, this study specifically situates the risk management and disruption recovery strategies within the South African chemical manufacturing context in order to provide a deeper understanding of how firms navigate systemic vulnerabilities and operational uncertainties. Unlike most previous studies that adopted either a purely quantitative or conceptual approach, this research employed an integrated mixed-methods design that amalgamated qualitative insights from industry practitioners with empirical analysis of firm-level risk data. This methodological pluralism allows for deeper investigation into the socio-technical and organizational dimensions of resilience, hitherto excluded from quantitative risk modelling. Further, by focusing on post-disruption recovery and adaptive learning mechanisms, this study transcends the conventional focus on risk identification and mitigation to examine how chemical manufacturers develop dynamic capabilities and strategic flexibility in response to recurring disruptions. This study, therefore, generates an empirical as well as a theoretical contribution (Rodriguez

et al,2025). According to (Nakanwagi, 2024) South African chemical manufacturers handle disruptions tied to infrastructural fragility, environmental regulation, and global supply chain volatility. This study enriches the discourse on sustainable supply chain resilience by contextualizing the global risk management frameworks within the realities of an emerging economy and, therefore, addresses a critical shortage in the literature on industrial resilience in the Global South.

Risk Management in the Chemical Manufacturing Sector

Risk management is described as the procedure that identifies, assesses, and reduces risks that may adversely affect operations. The chemical manufacturing industry is more critical because its nature is extraordinarily complex and regulated with severe risks involved, such as chemical accidents and environmental damage. As indicated by Kougioumtzis et al. in 2023, an effective risk management strategy ensures that the company can identify potential threats and mitigate its impact before the disruption of operations.

One of the major risks to be taken within the chemical manufacturing industry is in the supply chain disruption. For the South African chemical manufacturing sector, the country could stand the burden of import dependency on raw materials and various specialized chemicals. For example, the strike that took place in 2021 at Sasol, the South African Petrochemical Company, seriously disrupted supplies of such vital chemicals as synthetic fuels and lubricants; the repercussions this strike had for the industries based on these products-for instance, car manufacturing-have been enormous (SupplyChainBrain, 2024). Since Sasol relies significantly on both its local and international supply chains, strikes like this clearly show how important it is to have an all-encompassing approach regarding supply chain risk management.

To manage supply chain risks, companies in the chemical manufacturing sector are increasingly adopting a multi-sourcing approach. By diversifying suppliers across different geographic locations, firms can reduce their reliance on any single supplier or region, which in turn mitigates risks posed by natural disasters, political instability, or even economic downturns in one part of the world (Aityassine et al.,2022). A particularly good example of such a company is the multinational BASF, which has implemented a dual-sourcing strategy following the earthquake and tsunami in Japan in 2011 that affected its supply chain for critical raw materials. With suppliers in other regions, BASF was able to minimize the effect of the disruption in supply (Akinyele et al., 2024).

Another pressing concern of the risk management practices in the industry of chemical manufacturing is strict environmental regulations. The Hazardous Chemical Agents regulations from the Department of Employment and Labour have high compliance demands on the manufacturers to be stringent in terms of rules over handling and disposal of hazardous chemicals. Non-compliance may invoke heavy fines, legal actions, and a dent in the company's reputation. For instance, in 2018, the chemical firm AECI was fined due to its poor management of chemical waste, leading to severe environmental degradation and a costly regulatory fine. This also points to the importance of embedding regulatory compliance into the risk management framework to prevent such costly disruptions (Nel, 2024).

Disruptions in the Chemical Manufacturing Sector

The causes of disruption in the chemical manufacturing sector can be different: from natural disasters, operation failure, economic volatility to changes in global market conditions. For example, the COVID-19 pandemic was a particularly good example of an external cause that massively

impacted the sector. According to Modgil et al., 2021, it resulted in massive disruption in the supply chain related to the delivery of raw materials, transportation logistics, and workforce availability. In South Africa, where many chemical manufacturing companies rely on imports, the closure of international borders and the suspension of global trade routes created immediate challenges for the sector (Modgil et al., 2021).

Take the case of the pandemic that befell in 2020: Sasol also suffered from various supply chain shortages, particularly related to acquiring adequate chemical feedstock for production and processing processes within its value chains, with critical lockdowns among its significant supply markets of Europe and Asia (SupplyChainBrain, 2024). At the same moment, it gave a clear revelation of the complete vulnerability of their chemical production sectors to disruptions worldwide.

However, South Africa's own infrastructure woes are also serving to heighten the risk of disruptions. This has been highlighted most clearly in the case of ongoing power cuts due to the strain on the country's limited electricity infrastructure; often, these result from deliberate load shedding. In such power cuts, massive chemical producers, usually reliant on power-consuming manufacturing processes, are being severely hit. For instance, in 2019, a load-shedding event resulted in Sasol having to shut down some of its plants due to power loss, at the cost of several million rands in lost production and supply chain delays (Nel, 2024). This case serves to illustrate how energy disruption could have immense effects on chemical manufacturing and underscores the importance of companies incorporating energy resilience into their risk management strategies.

Besides, labour unrest continues to be a constant headache for the South African chemical manufacturing sector. Strikes and protests by workers over better wages and working conditions are common in the country, with several of them leading to stoppages in production and distribution. A 2022 strike at the petrochemical company Engen led to severe delays in production, affecting the supply of chemicals to various industries, including agriculture and manufacturing. The strike follows a long wave of strikes affecting the labour relations environment, given that more than 70,000 employees in the chemical industry of South Africa have similarly engaged in industrial actions over the last ten years (SupplyChainBrain, 2024). Controlling and mitigating this impact of unrest on the sector remains a growing concern that will require companies to adopt good labour relations management coupled with contingency planning.

Recovery Strategies in the Chemical Manufacturing Sector

Recovery strategies are important for allowing firms to go back to normal operations in the event of a disruption. The effectiveness of any recovery depends on a well-planned contingency plan which can be implemented immediately following the disruption. Of these strategies, common is the diversification of suppliers with the effect of minimizing dependence on any single supplier or region, besides reduced risks of disruptions from specific sources of supply. This is particularly true of the COVID-19 pandemic, which has ravaged chemical manufacturers. Companies whose supply chains have been diversified may source their raw materials from other regions and hence keep production running despite some areas being shut down (Nel, 2024).

The case of AECI, South Africa's major chemical manufacturer during the 2019 labour strike, follows with such positive recovery post disruption. The company responded swiftly through an emergency plan resulting in the change in some of its productions and a network of third-party suppliers to continue supply to primary customers. The approach, consequently, meant that the company reduced the effect of the impact so that the company did not fall in its production because of the strikes (Nel, 2024).

This is a recovery strategy that bolsters the capability of firms to recover quickly from disruptions. AI and real-time data analytics enable manufacturers to keep a close eye on their operations and detect the possibility of a disruption before things start getting out of hand. For example, the chemical company Dow Chemical has invested intelligently in architecting a logistics platform that leverages the power of AI and machine learning to predict every disruption in its supply chain and produce pre-emptive strategies. The technology-driven solution offered opportunities for Dow to improve supply chains' resiliency by reducing disruptions and enhancing resilience to the crisis event in the 2020 COVID-19 virus pandemic period of (Emrouznejad et al.,2023)

Cooperation with the supplying chain partner is the second supporting recovery factor: upon disruptions, an enterprise which is closely cooperating with one's supplier or distributor will also be quicker acting upon recovery. This often encompasses the sharing of information regarding supply chain risks, as well as the joint development of contingency plans. For instance, South African firms like Sasol and AECI have invested in developing relations with key suppliers to ensure that on the occurrence of disruption along supply chains, a rapid response to return operations back to normal with the least amount of time as possible can be ensured. (Scala & Lindsay 2021)

The second essential strategy of recovery is building organisational resilience: Organizational resilience refers to the ability or capability of a firm to absorb, adapt to disruption events, but with no lasting effect. Investment in employee training, risk management frameworks, and contingency planning enable a firm to return more promptly after disruption. As an example, during the power crisis that occurred in South Africa in 2019, Sasol-such was the strong workforce and equally effective contingency planning-continued operations during periods of power loss for extended periods, thus minimizing production losses and getting back into operation faster than less well-prepared competitors could manage to (SupplyChainBrain, 2024).

Exposures to hazards, supply disruptions, labour disputes, infrastructure bottlenecks, and regulatory risks are high within the manufacturing industry of this sector. These are the appropriate identification and implementation of risk management and recovery strategies that will make firms in the sector resilient and sustainable. The main strategies of risk management and disruption recovery include diversification of suppliers, integration of technology, collaboration with supply chain partners, and organizational resilience. Case studies from Sasol, AECI, and Dow Chemical further demonstrate how proactive risk management and swift recovery add value to continuity of operations. Future studies should also dwell on the specific peculiarities of the SMEs in the South African chemical manufacturing industry and investigate the government policy that is supportive of such risk management practices.

Recovery strategies are important to allow firms to return to regular operations after a disruption. The heart of effectiveness in recovery depends on a well-planned contingency plan that can come into effect promptly after the disruption. Common among these strategies is diversification of suppliers with the outcome of minimizing dependence on one supplier or region with reduced risk of disruptions from specific sources. It has been particularly relevant for chemical manufacturers in the COVID-19 pandemic. For instance, companies operating diversified supply chains could source materials from other regions and maintain their production despite some areas going into shutdown; for example (Nel, 2024).

Here the case of AECI, South African major chemical producer, is seen in respect to positive recovery after disruption during the 2019 labor strike. The company responded swiftly through an emergency plan, which resulted in changing some of its productions and a network of third-party suppliers to continue supply to primary customers. Consequentially, the approach meant that the company reduced the effect of the impact so that the company did not fall in its production because of the strikes (Nel, 2024).

Another big recovery strategy is technology adoption, which keeps improving the firms' ability for speedier recovery upon disruptions. AI and real-time data analytics help manufacturing operations in closely monitoring and identifying the possibility of disruption before things go out of hand. For example, the chemical giant Dow Chemical, has created an intelligent logistics platform that makes use of AI and machine learning to anticipate supply chain disruptions and create plans to lessen them. By reducing disruptions and increasing supply chain resilience to the crisis event during the 2020 COVID-19 virus pandemic phase, this technology-driven solution gave Dow the chance to improve supply chain resilience (Emrouznejad et al.,2023).

Another component that is essential to recovery is collaboration with supplying chain partners: an organisation that works closely with its distributor or supplier will also be able to recover from interruptions more quickly. This frequently includes exchanging information about supply chain risks and working together to create backup plans. Companies like Sasol and AECI, for example, have made investments in building connections with important suppliers in South Africa so that they can react as fast as feasible and go back to business as usual as soon as possible in the event of a supply chain disruption. Accordingly, (Scala and Lindsay, 2021). Organizational resilience is the organization's ability to absorb and adapt in the event of disruption, with no lasting effect. Investment in employee training, risk management frameworks, and contingency planning enable a firm to return more promptly after a disruption. For instance, the 2019 power crisis that hit South Africa SASOL relied on a professionally trained workforce and contingency plans as the business maintains operations for even extensive periods without power. This thus allowed the company to reduce the losses in production while driving back to business faster compared to the competitors who were not well prepared for such an occurrence. (SupplyChainBrain, 2024)

Chemical industry manufacturing is highly exposed to risks and disruptors to supplies, labour disputes, hindrance of infrastructure, and regulatory risks. Identification and effective implementation of the strategies for managing risks and recovery remain key ingredients towards resiliency and sustainability of firms in the industry. The major strategies for managing risks and recovering from disruptions involve diversification of supplies, technology integration, cooperation with the supply chain partners, and organizational resiliency. Case studies from Sasol, AECI, and Dow Chemical further demonstrate how proactive risk management and swift recovery add value to the continuity of operations. Future studies should also dwell on the specific peculiarities of SMEs in the South African chemical manufacturing industry and investigate the government policy that is supportive of such risk management practices.

Materials and Method

For this study, semi-structured interviews were the primary method of collecting data. Semi-structured interviews are useful for qualitative research, as they allow for a flexible, yet structured, approach to gathering in-depth data. This approach is relevant in exploring the views of participants involved in risk management and recovery strategies in the chemical manufacturing sector in South Africa. This section provides a detailed explanation of the interview method, it involves, participant selection, the interview process, and the rationale behind using this method for the study.

Participant Selection

Purposive sampling, a non-random sample technique that chooses people with pertinent knowledge and experience related to the research subject, was used to select participants for the semi-structured interviews. Personnel employed in the chemical manufacturing industry in South Africa, particularly those in positions pertaining to supply chain management, operations, risk management, and recovery plans, were the subject of this study.
Selection criteria for participants included:

Table 1: Authors compilation

Experience and position	Participants had to have at least five years of experience in the chemical manufacturing industry, with a focus on those positions that had risk management, operational continuity, or disaster recovery as part of their key responsibilities. Examples of such positions include senior executives, supply chain managers, risk managers, and other relevant professionals in local and multinational chemical manufacturing firms.
Geographical Representation	The respondents have been chosen from large multinational enterprises to small local South African firms to provide a broad variation and to appreciate the differences that risk management strategies might have depending on the company size and its reach in the marketplace. This would ensure findings that are not limited to experiences related to just one type of organization but reflect a broader industry context.
Relevance to the Study Objective	The participants were selected, with particular emphasis on their involvement in crisis management, risk assessment, or recovery strategies, and thus can provide an insight into how chemical manufacturing firms in South Africa address risks and recover from disruptions.

The respondents consisted of twelve participants chosen from six different firms within the manufacturing chemicals sector. These companies were diverse in size, scope, and market segmentation, from large international ones with businesses in South Africa to smaller local firms that serviced the South African market.

Participant Representation and Firm Characteristics

Twelve participants were engaged in this study, drawn from six chemical manufacturing firms operating within South Africa's industrial landscape. The sample is inclusive of multinational and locally owned enterprises varying in size, structure, and market reach. Of the twelve participants, about seven represented three large multinational firms with extensive regional operations, while five participants were from three small to medium-sized local companies playing in domestic markets.

The design of this study was to capture a wide range of experiences in managing supply chain risks and recovery processes. Participants of multinational firms contributed on formalized governance frameworks, sophisticated compliance systems, and proactive risk mitigation structures. In contrast, participants of smaller enterprises provided unbelievably valuable perspectives concerning adaptive, experience-driven approaches shaped by resource constraints, local dependencies, and more immediate decision-making processes.

By holding this balance between the global and the local, proportional and in step with each other, the study gained the ability to investigate not only the divergent capability and preparedness of South Africa's chemical manufacturing ecosystem but also the shared vulnerabilities and adaptive ingenuity that constitute it. The inclusion of both firm types enriched comparative analysis, while a complex understanding was gained of how scale, structure, and resource availability influence resilience strategies across the sector.

Table 2: Sample Characteristics of Large Firms and SMEs in the Study (Authors compilation)

Category	**Large manufacturing firms**	**Small and Medium chemical enterprises**
Firm size and structure	Subsidiaries of multinational corporations operating across South Africa (e.g., petrochemicals, industrial chemicals); structured hierarchies with specialized departments.	Locally owned chemical producers supplying domestic markets (i.e., adhesives, detergents, coatings); lean organizational structures.
Interview participants	Senior executives, supply chain managers, environmental compliance officers, and risk managers with 10–20+ years of experience.	Operations managers, production supervisors, and owners/managing directors with 5–15 years of industry experience
Market scope	Operate nationally and regionally; export and import dependency; integrated into global supply chains.	Primarily serve local or provincial markets with limited regional reach.
Operational scale	Large production facilities with high-volume continuous processing; advanced technology adoption.	smaller batch-production facilities; moderate technology use but cost-driven constraints.

Interview Process

To ensure that all interviews addressed the fundamental topics of risk management, disruptions, and recovery strategies in the context of the chemical manufacturing sector, a semi-structured interview guide was developed. The guide included a series of open-ended questions intended to elicit detailed responses from the participants. The semi-structured interviews were conducted between March and June 2024, either virtually or in-person, depending on the participants' preferences and availability. The virtual interviews were conducted using video conferencing tools (such as Zoom or Microsoft Teams), while the in-person interviews were held at the participants' respective workplaces or neutral locations, and the interviews lasted between 45 minutes and an hour.

Table 3: Authors compilation

1. *Risk Identification:* How do companies in the chemical manufacturing sector identify potential risks? What are the most common risks faced by firms in this sector?
2. *Risk Assessment and Mitigation:* What strategies are used to assess and mitigate risks? How do companies evaluate the effectiveness of these strategies?
3. *Disruptions and Recovery:* Can you describe a recent disruption that affected your company? What actions were taken to recover from this disruption? How do recovery strategies differ based on the type or scale of disruption?
4. *Impact of External Factors:* How do external factors (e.g., regulatory changes, economic downturns, natural disasters, or labour unrest) influence risk management and recovery strategies?
5. *Future Challenges and Strategies:* What challenges do companies in the chemical manufacturing sector face in terms of risk management, and how are these challenges expected to evolve? What future strategies are being implemented to improve resilience?

The semi-structured format allowed for flexibility in the interview process, providing participants with the freedom to elaborate on their experiences and perspectives. While the interviewer followed the guide, they also allowed space for participants to introduce new topics or issues that they felt were relevant but had not been anticipated by the questions.

Rationale for Using Semi-Structured Interviews

Semi-structured interviews were chosen for this study because they strike an ideal balance between structured data collection and flexibility. This method allows the researcher to obtain detailed, contextual insights into the participants' experiences with risk management, disruptions, and recovery strategies while ensuring that the key themes of the study were explored consistently across all interviews (Clark et al., 2021).

Table 4: Author's compilation

Flexibility and Depth
The semi-structured format allows follow-up questions and probing of detailed responses. It is especially beneficial in understanding a complex process that may be organizational or industry-wide, such as risk management, as shown by (Rahman, r.b.a., 2023). This flexibility in the approach means the researcher can investigate emerging areas from the interviewee, adding to the richness of the data.
Standardization with Room for Improvement
Although the interviews were based on the same set of questions, their semi-structured nature allowed participants to explain and respond to these questions in their terms and in considerable detail. This flexibility may ensure that diverse experiences and varied strategies adopted or used by different organizations in chemical manufacturing are grasped.
Expert Insights
The semi-structured interviews were specifically designed to collect expert insights on the practice of risk management in the critical sector. The participants were key actors within their companies and provided detailed insights into the operational, strategic, and organizational levels of managing risks and recovery following disruptions.
Contextual Understanding
Semi-structured allowed the researcher to delve into depth into the contextual factors influencing risk management of chemical manufacturing companies in South Africa. Issues concerning the regulatory frameworks, local challenges about the infrastructural situation, and general socio-political environments would subsequently form questions geared to the position held by each participant. These can now allow the researcher to receive more contextually in-depth knowledge relating to South Africa.

Data Handling and Analysis

All interviews were audio-recorded with the participants' consent and subsequently transcribed precisely. Thematic analysis, one type of approach to identifying patterns across data, was used to analyse the transcripts. First, the transcripts were read to obtain an idea about the content, followed by identification and coding of key themes pertaining to risk management, disruptions, and recovery strategies. This process of coding was iterative; through progressing with the analysis, themes were refined.

Semi-structured interviews, supported by thematic analysis, have thus been used to gain an in-depth understanding of how South African chemical manufacturing companies manage risks, respond to disruptions, and develop recovery strategies. Such rich qualitative data, combined with a systematic approach to analysis, ensures that findings represent the perspectives and experiences of those working within the sector.

Contextual Novelty of the Study

While this study does not seek to propose a new theoretical model, its novelty is embedded in its contextual application and empirical depth. It investigates the South African chemical manufacturing industry-a context that has received limited scholarly attention within global discussions of risk management and supply chain resilience. By setting the investigation against South Africa's unique

regulatory, infrastructural, and socio-economic environment, this study extends prior theoretical understandings into a context characterised by persistent energy instability, port congestion, and shifting environmental compliance requirements. This context-specific exploration provides a useful empirical contribution, offering reality-based insights into how both multinational and local firms operating in an emerging economy identify, assess, and recover from disruptions (Ivanov & Dolgui, 2020). In so doing, it advances the methodological and contextual pluralism of risk management studies and overcomes an important literature gap that traditionally favours developed economy perspectives.

Research Limitations

The use of a small sample size of participants, twelve drawn from six firms in the South African chemical manufacturing industry, was both deliberate and appropriate for the exploratory objectives of this study. As Creswell and Poth (2016) argue, qualitative studies deliberately focus on smaller numbers but richer insights. The purposive strategy is targeted at capturing participants with specialized knowledge and direct experiences in risk management, disruptions, and recovery processes. In this approach, complex phenomena, situated in wide contexts, can be investigated in detail, capturing diverse firm-sizes and market-orientation perspectives (Marshall & Rossman, 2014). Thus, this small sample size enabled intense engagement with the participants to get an insight into firm-level practices and perceptions that might be hidden in large-scale quantitative surveys. What is commonly referred to as a limitation within qualitative research, namely subjectivity, was embraced in this study as an inherent part of the interpretive process. Qualitative inquiry recognizes knowledge as being co-constituted by the researcher and participants and interpretation inherently influenced by social context (Tenny et al, 2017). To ensure reflexivity and transparency, the researcher kept detailed field notes, was continuously self-reflective, and used triangulation by comparing data across firms and respondent roles.

The qualitative findings do not have statistical generalization, this study seeks to attain analytical generalization (Yin, 2018) whereby insights from the sample provided add to an overall theoretical and conceptual understanding of risk management and supply chain resilience in emerging economies. The intent was not to generalize to all firms within the manufacturing sector, per se, but to provide contextually grounded explanations of how chemical manufacturers in South Africa perceive, respond to, and recover from disruptions.

Results

The findings are organized around the key themes identified through thematic analysis: risk identification, risk assessment and mitigation, disruptions and recovery strategies, and the role of external factors. These results reflect the experiences, challenges, and strategies discussed by participants in relation to managing risks and recovering from disruptions in the chemical manufacturing sector.

Risk Identification

A recurring theme from the interviews conducted was the initiative-taking risk identification is quite crucial as the first step toward effective risk management. All respondents have identified the fact that the process of identifying risks is ongoing and requires attention and adaptation on a continuous basis to both internal and external factors. Companies engaged in chemical manufacturing typically identify their risks through a combination of internal audits, consulting experts, and monitoring industry trends and global current events.

One of the key observations that can be found out from the data is that risk identifications are done majorly by the risk management teams and senior management. These teams are often involved with risk assessments and make use of risk matrices or scenario planning to point out potential perils. For example, the senior risk manager of a large multinational chemical company said:

"It is emerging risks management team periodically reviews all types of data coming from both within and outside. "Everything ranging from the failure of vital equipment to any kind of alteration in the regulatory regime and a shift in the global supply chain is needed to keep the company secure."

Moreover, most of the respondents pointed out the identification of external risks, which included geopolitical ones, changes in regulation, and natural calamities. For example, one participant from a local South African chemical company described how recent floods had highlighted the need for a rethink of physical infrastructure risks:

"We had to re-evaluate our facilities when some of our warehouses were hit by heavy flooding. It was a wake-up call that our risk identification process needs to consider environmental risks more seriously, and infrastructure resilience needs to be a priority."

Risk Assessment and Mitigation

Assessed risks are mitigated through various strategies employed by the companies in the sector. Based on the interviews, risk assessment is usually qualitatively done by expert opinions and quantitatively by risk mapping and Monte Carlo simulations. However, there was considerable variation in how rigorously the assessments were made, especially between larger multinational firms and smaller companies that were more locally based.

One of the respondents from a multinational company identified the extensiveness of risk assessments in their company:

"We use both qualitative and quantitative measures to assess risk. We have Monte Carlo modelling, for instance, to understand what a supply chain disruption potentially could be as a budgetary impact. On the other hand, we also follow expert judgment-especially when evaluating risks that will deal with people and labour issues."

The smaller companies were more interested in the simple risk matrices and qualitative assessment, basing their arguments on historical experience and expertise within the industry. In the words of a risk manager at a local firm:

"Our risk assessments, compared to big companies, would be less formal. We have quite a lot of experience with the industry; therefore, in most cases, we would look more at the historical data or experience from the team, mostly on labour strikes or changes to local regulations."

The strategies of mitigation matched the risks identified. Diversification of linkages within supply chains was primarily the avoidance strategy. Most participants reported that their mitigation strategy in case of a shortage in the raw materials or disruption of transport was diversification of suppliers and markets. For example, a multinational company's supply chain manager reported:

"We're working for supply chain diversification. Material procurement has been made from different regions and suppliers so that if one is disrupted, then production does not completely come to a standstill."

Other risk mitigation strategies include investments in technology and automation, especially where there is considerable risk from the failure of any equipment or inefficiency in operations. Many firms had invested in predictive maintenance programs and real-time monitoring systems to detect failures before they occurred. One participant said,

We have invested a lot in sensor technology and predictive maintenance. The ability to detect equipment issues before they become breakdowns is a big competitive advantage in managing operational risk.

Disruptions and Recovery Strategies

From the interviews, it was revealed that the chemical manufacturing industry in South Africa has faced all manner of disruptions in recent years, ranging from labour strikes, economic challenges, supply chain interruptions, and even natural disasters. One key finding from the interviews is that companies adopt different natures and scales of disruption in their strategies for recovery, but what came out clear for all participants is speed and efficiency in responding to minimize losses in finances and ensure operational continuity.

One participant from a multinational chemical company described how their company responded to a major labour strike that disrupted production for several weeks:

"When the labour strike occurred, we were able to turn to our contingency plans, which included bringing in temporary staff and shifting production to other sites. We also communicated with our clients to manage expectations. Recovery was quicker because we had clear plans in place."

Similarly, many chemical companies also use their suppliers and customer relationships to help get the companies up and running again after a disruption. According to a responding senior executive of a local South African chemical company:

"This really hammered our supply chain during the COVID-19 lockdowns, but we had to negotiate with suppliers to extend the payment terms and to re-schedule deliveries. It is this flexibility that comes from partners that has made recovery so much smoother."

Technology was another important recovery factor because firms that had invested in digital tools to monitor production and manage their supply chains were able to react faster when trouble arose. According to a supply chain manager for a multinational firm:

"Having access to real-time data on inventory levels, production status, and transportation routes enabled us to quickly divert shipments and re-allocate production tasks. Our IT systems are at the heart of recovery-it allows us to be agile when things go wrong."

Regarding organizational resilience, most of the participants emphasized the culture of flexibility and adaptability by the staff as an important characteristic. A participant from a locally owned company said:

"The human factor cannot be ignored. We train our teams to be flexible, to adapt to changing circumstances. For example, during the shortage of raw materials, our staff found a way of continuing to function with other materials."

The Role of External Factors

Other external factors identified by participants as influential in risk management and recovery strategies included government policy, global economic trends, and environmental events. Indeed, many participants voiced concerns about changing regulatory environments, especially those

touching on environmental regulations and safety standards. For example, one participant spoke to the probable impact of increased stringency in environmental regulations on operations:

"The government is increasing environmental regulations, which translates to more investment in compliance and waste management. This is a challenge, but it is also an opportunity to improve our sustainability practices."

Another strong theme stemming from the interviews was the impact of the COVID-19 pandemic. Many companies had to rapidly adjust to the disruptions caused by lockdowns, supply chain breakdowns, and health-related risks to workers. One participant described it as:

"COVID-19 was a completely unprecedented disruption. It tested our risk management systems in ways that we never thought possible. The recovery strategies we put in place-remote working, enhanced safety protocols, and new communication strategies-have now become part of our long-term planning."

Summary of Results

The interviews reveal that risk management in the South African chemical manufacturing industry is proactive, multi-faceted, and focused on the identification of risks, assessment, and mitigation strategies, which include supply chain diversification and investment in technology. It also emphasizes recovery strategies that need to be flexible and responsive to the type of disruption. The continuous regulatory changes and global events are still two of the major external factors that continue to influence and shape risk management practices and recovery plans. In general, these interviews show how companies in the chemical manufacturing industry have been able to take some positive steps towards managing risks and responding to disruptions, but an ongoing need still exists for adaptability and upgrading of risk management frameworks.

Table 5: Author's own compilation

Theme	**Key Findings from interviews**	**Comparative insights (Large firms vs SMEs)**
Risk identification	Risk identification is viewed as an ongoing, proactive process involving constant monitoring of internal and external threats such as regulatory shifts, infrastructure instability, and environmental hazards.	Large firms employ formal risk registers and data analytics for continuous monitoring. SMEs rely on experiential awareness and periodic reviews informed by past disruptions.
Risk Assessment and Mitigation	Firms demonstrate multi-dimensional assessment practices, combining qualitative and quantitative tools to prioritize and mitigate risks.	Multinationals adopt advanced modelling tools (e.g., Monte Carlo simulations) and standardized frameworks. SMEs use qualitative methods based on expert judgment due to resource limitations but show growing interest in digital tools.

Disruption response and recovery strategies	Recovery emphasizes flexibility, speed, and communication. Firms reported activating contingency plans, reallocating resources, and maintaining transparent supplier and customer communication.	Multinationals use formal business continuity protocols and digital dashboards for real-time recovery. SMEs depend on managerial agility, local partnerships, and rapid resource redeployment.
Supply chain diversification	Diversifying suppliers and logistics networks emerged as a primary risk-reduction strategy, particularly given South Africa's infrastructural and socio-political vulnerabilities.	Large firms maintain multi-tiered supplier bases and contingency sourcing across regions. SMEs diversify within local networks, balancing cost constraints with supply assurance.

The results of this study shed light on the risk management techniques, disruption experiences, and recovery strategies of South African chemical manufacturing organisations. By comparing these findings to current research, this discussion investigates the important themes of risk identification, risk assessment and mitigation, disruptions and recovery measures, and the involvement of external factors. It also considers the practical ramifications of the chemical manufacturing sector in South Africa, providing both theoretical and operational viewpoints.

These findings underline that the identification of risk proactively is most critical to the overall process of risk management among chemical manufacturing firms. Identification, according to the participants, is not a spot event but rather a process that calls for constant attention to internal and external threats. This therefore supports the existing literature that emphasizes continuous risk identification as the very foundation of organizational resilience. According to (Gurtu, A., and Johny, J. 2021), (Wang, B., and Wang, Y. 2021) are of the view that geopolitical instability, change in regulations, and natural causes have been strongly emphasized in South Africa. This agrees with global research on the rising demands of enterprises, particularly those located in volatile areas, to carefully observe environmental and socio-political risks. (Wu, C., Lin, Y. and Barnes, D. 2021); (Mallapragada et al.2023). For instance, the experience of floods in South Africa prompted companies to reassess infrastructure-related risks, reflecting a broader trend in industries worldwide to account for the rising frequency of natural disasters and environmental challenges (Mallapragada et al.,2023). These findings point to the necessity for companies to adapt their risk identification processes in response to dynamic and often unpredictable external factors.

The research showed that, regarding risk assessment and mitigation, significant variances exist between multinational corporations operating in South Africa and local companies. Larger firms use more formal and quantitative risk assessment techniques, like Monte Carlo simulations, to assess risks from many dimensions, including financial, operational, and strategic impacts. This is consistent with international studies, which emphasize that large organizations, particularly multinational firms, have the resources to implement sophisticated risk management tools (Cozmiuc, D.C. and Pettinger, R., 2021; Aven and Thekdi, 2021). Smaller, local businesses, on the other hand, typically employ simpler, qualitative risk assessment approaches that rely primarily on expert judgement and historical data. This method reflects the resource and capability restrictions that smaller enterprises experience when implementing more complicated risk assessment models (PwC, 2020).

Nonetheless, even these smaller businesses recognised the growing need of adopting modern technology into their risk management plans, such as predictive maintenance systems and real-time monitoring software. This development corresponds to the global transition towards digitalisation in risk management, in which technology enables businesses to improve their ability to foresee, analyse, and mitigate risks proactively (Haouel, C. and Nemeslaki, A., 2024).

One prominent issue that came out of the interviews was how supply chain diversification is widely used as a major risk-reduction tactic. This is in line with the findings of (he et al.,2024), who contend that diversifying the supply chain is an essential strategy for lowering disruption susceptibility. To guarantee business continuity in the event of disruptions, participants underlined the necessity of having backup suppliers and marketplaces. This approach is especially more important in South Africa, where supply chains can be disrupted by political unrest and transportation infrastructure is frequently under stress. In addition to lowering the chance of production delays, diversification helps businesses protect themselves from local hazards like strikes, infrastructure failures, and other outside disturbances.

Throughout the interviews, there was also a consistent focus on automation and technology as a mitigating measure. To mitigate operational risks like equipment failure or inefficiency, participants from larger organisations reported making large expenditures in automation and predictive maintenance solutions. To increase productivity and avoid unscheduled downtime, digital tools and smart technologies are being incorporated into production processes, which is in line with worldwide industry trends (Okoye et al., 2024). Although smaller businesses may adopt these technologies more slowly, they are nonetheless thought to be crucial for preserving competitiveness and lowering operational risks. Modern risk mitigation tactics are acknowledged to require the ability to anticipate failures and put preventative measures in place before problems develop, which emphasises the significance of using Industry 4.0 technology for risk management (Gonyora and Ventura-Medina 2024).

Flexibility and reaction to interruptions were the main focusses of the recovery strategies that the participants described. All businesses placed equal emphasis on speedy recovery and adaptability while managing distinct kinds of disruptions. To control expectations, businesses reported redistributing resources, contacting suppliers and consumers, and triggering backup plans. These tactics are in line with crisis management best practices, which stress the value of readiness and the capacity to rapidly mobilise resources in an emergency (Pettit et al., 2013). Utilising digital systems and real-time data was essential to guaranteeing recovery. Businesses that had made investments in innovative IT systems discovered that they could recover faster by rerouting shipments, modifying manufacturing schedules, and more efficiently redistributing resources. This is consistent with research by (Ivanov and Das 2020), who discovered that the usage of digital solutions to manage supply chain disruptions and aid in recovery efforts is growing. By giving decision-makers reliable and timely information, real-time technological monitoring of operations and supply chains not only lessens the immediate effects of interruptions but also promotes longer-term recovery.

Additionally, businesses underlined how crucial communication is throughout the recovery process. To control expectations and lessen the detrimental effects of interruptions, proactive communication with suppliers and consumers was considered crucial. According to the literature, one of the most essential elements in guaranteeing a successful crisis recovery is effective communication since it preserves trust and keeps problems from increasing (Wodak, R., 2021). To preserve relationships and reduce operational disruption, the COVID-19 pandemic experience highlighted the significance of open and regular communication with stakeholders (Savic, A. and Dobrijević,

2022). This was made clear in the interviews, as businesses stated that using effective communication techniques enabled them to regain the trust of suppliers and customers while navigating the pandemic's interruptions.

The focus on a flexible workforce as part of recovery plans was another important discovery. Numerous participants emphasised how crucial it is to have a workforce that can be swiftly mobilised to adjust to changing conditions, especially during labour-related interruptions. Given the prevalence of strikes and labour instability in the manufacturing industry, this flexibility was especially important. Reflecting larger trends in crisis management that support workforce adaptation during tough times, the capacity to swiftly modify workforce practices during labour conflicts or other disturbances is viewed as a crucial component of resilience (Musee et al.,2023).

The COVID-19 pandemic, economic trends, and regulatory changes were among the external elements that were found to have a significant impact on recovery and risk management plans. Participants agreed that South Africa's regulatory landscape is always changing, with a greater focus on safety regulations and environmental sustainability. (D.J. Paustenbach ed., 2024). Businesses emphasised the unique nature of the disruption and the necessity of promptly modifying their risk management frameworks in their discussions of the COVID-19 pandemic's effects on business operations. The pandemic compelled businesses to reevaluate their approaches to operational continuity during lockdowns and risk management for health and safety. In the face of unanticipated circumstances, the global pandemic highlighted the value of resilience and adaptation, highlighting the necessity for companies to create adaptable, comprehensive risk management strategies that can withstand unexpected disruptions (Savic, A. and Dobrijević, 2022).

This study concludes by highlighting the intricate and varied aspects of risk management in the chemical manufacturing industry in South Africa. The results indicate that although businesses are using proactive and strategic methods to recognise, evaluate, and reduce risks, the ever-changing external environment necessitates ongoing innovation and adaptation in risk management procedures. To increase resilience and bounce back from setbacks, South African businesses are spending more in technology, diversifying their supply chains, and improving personnel flexibility and communication. However, the risk landscape is still being shaped by external variables, including economic trends, regulatory changes, and global disruptions like COVID-19. As a result, businesses must continue to manage risk in an adaptive manner. The study's conclusions have important significance for industry professionals and legislators who want to enhance the chemical manufacturing sector's sustainability and resilience.

Conclusion

This study has investigated the multifaceted landscape of risk management, disruptions, and recovery strategies in the chemical manufacturing sector of South Africa and thus provided insightful understanding into the resilience and adaptive strategies of the sector in the face of the current challenging environment. Through semi-structured interviews with key participants within the industry, this research underlined several ways of identification, assessment, and mitigation of risks, while firms recover and adapt to these shocks. The findings demonstrate that while risk management frameworks in South Africa's chemical manufacturing sector are increasingly sophisticated, the sector must continuously evolve in response to the dynamic nature of internal and external risks.

The research revealed that risk identification and mitigation are critical components of a comprehensive risk management strategy. South African chemical manufacturers have been proactive in the identification of several specific risks, particularly those emanating from its socio-political and environmental surroundings. Among the risks it identified include those that have to do with changes in regulations, labour unrest, and natural disasters. The study also underscored how technology and digitalization, playing vital roles in the enhancement of risk mitigation, whereby companies hire advanced tools to monitor and act against operational risks. While larger firms tend to use more formal and quantitative techniques for risk assessment, smaller ones have begun to adopt digital tools to manage their risks, which simply shows the overall change the sector is undergoing towards technologization.

On the strategies of recovery, quick responsiveness was found to help the companies in bringing down the severity of disruption. The firms have adopted flexible staffing, resource redeployment, and communication with the stakeholders as strategic tools for quick recovery. It was also observed that those firms which had invested in technologies, such as real-time data monitoring systems, were better able to recover from disruptions. The COVID-19 pandemic gave a full stress test to the crisis management capabilities of companies and showed preparedness and adaptability as key to business continuity.

Other external factors, like regulatory changes and the global economic outlook, also have a significant bearing on the definition of risk management practices in the chemical manufacturing industry. The regulatory environment in South Africa, particularly regarding environmental sustainability and safety concerns, has prompted companies to work constantly at adapting their risk frameworks to maintain compliance. More recent global disruptions, such as the COVID-19 pandemic, have only underlined the importance of embedding flexibility within organizations to manage crises for which they are least prepared.

The present study adds to the existing literature on risk management in the manufacturing sector through an in-depth analysis of challenges faced by South African chemical manufacturers and strategies used to mitigate risks and recover from disruptions. Results obtained indicate that the chemical manufacturing industry needs to further develop its risk management practices by embracing technology and innovation in line with emerging developments in the environment. Future research could investigate the sustainability of these strategies over time and assess long-term impacts of recent global disruptions on the sector's risk management frameworks.

Finally, the South African chemical manufacturing industry has done a great deal to mitigate risks and recover from disruptions. However, there is still a great need for continuous adaptation, especially considering global and local challenges. With the integration of sophisticated risk management strategies, embracing digital technologies, and fostering organizational agility, South African chemical manufacturers can enhance their resilience to ensure their ability to navigate future risks and disruptions effectively.

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