

Exploring Supply Chain Risks in the Engineering, Procurement and Construction Management Sector

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Abstract

The most recent disruption the world has experienced was COVID-19, which had a significant impact on the world and its economy. Delays were experienced in several sectors, such as mining, manufacturing and logistics.

The object of the study is to explore the supply chain disruption within the EPC and determine the effect thereof on the sector. Various concepts relating to supply chain disruptions were explored through a literature review, which includes supply chain management, supply chain risk, supply chain complexity and supply chain risk management. These concepts were explored to understand the industry norms as part of the cause and effect of supply chain disruptions. Through a qualitative approach, a view of the EPC sector from industry specialists could be provided through semi-structured interviews.

Recommendations were made, emphasising the evaluation based on sharing risk once the parties have signed a contract. While EPC professionals are strong technical individuals due to the nature of the EPC sector, a greater awareness of procurement and supply chain activities is required to improve the effectiveness of the mitigation to be put in place.

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1. Introduction

In the dynamic landscape of modern engineering and construction, the effective management of supply chains has emerged as a pivotal determinant of project success. Within the scope of Engineering, Procurement and Construction Management (EPC), the intricacies of supply chain dynamics hold the power to shape project outcomes, cost structures, and even the quality of the final product. In the EPC sector, the spotlight is on contractors, sub-contractors, and key suppliers, collectively weaving a complex web of needs. However, within this web lies a critical challenge that can disrupt project timelines, costs and the overall quality of work. This challenge is none other than supply chain disruptions.

The emergence of the COVID-19 pandemic during the 2019/2020 period brought about a sequence of disruptions that caught numerous companies off guard. Among those significantly impacted were EPC (Engineering, Procure, and Construction) firms, which possess expertise in turn-key projects—completed and ready for immediate use. These projects offer a streamlined approach for owners to undertake substantial construction ventures through fixed-price or lumpsum contracts. EPC contractors are central to the functioning of supply chain management within this sector. These contractors are responsible for integrating various elements, encompassing designs, construction work, suppliers, materials, equipment, and machinery (Sholeh & Fausiyah, 2018:2).

Based on the aforementioned, the purpose of this research is to investigate the impact of disruptions in supply chains within the EPC sector. In this regard, the study will focus on:

- Creating an understanding how supply chain disruptions affect EPC contractors, suppliers, and clients.
- Exploring existing practices to mitigate such disruptions.
- Providing recommendations to reduce supply chain disruptions.
- The importance of effectively managing the flow of materials and resources in the EPC sector.
- Identifying the challenges of supply chain disruptions and offering practical strategies to enhance project resilience and minimise negative impacts.

1. 1. Problem Statement

Supply chain management is significant in the Engineering, Procurement, and Construction (EPC) sector. According to Carno and Micheli (2011:148), each project within this sector is unique in terms of its specifications, design, manufacturing process, technology requirements, needed skills, and potential risks. This means that the successful management of EPC contracts is heavily reliant on effective supply chain management.

EPC contractors who lead these projects carry substantial responsibilities. They are responsible for ensuring that projects run smoothly from beginning to end. This involves working closely with essential materials and resource suppliers, as Piotrowski & Ellis (2020) highlighted, and overseeing project delivery and construction.

The relationship between EPC contractors and their supply chains becomes particularly crucial when considering the "Engineer to Order" approach often employed in the EPC sector. This approach highlights collaboration between contractors, sub-contractors, and main suppliers.

Within this intricate web of interactions lies a notable challenge: the effective management of supply chain dynamics in the EPC sector. The nature of supply chain management within the EPC sector needs careful examination due to the challenges that can lead to increased project costs and delays. These challenges, in turn, impact the quality of work, affecting the overall outcome of the manufacturing process.

Consequently, there's a vital need to explore the consequences of supply management within the EPC sector. To address this, the researchers investigated the effects of supply chain disruptions and the identification of solutions to mitigate these disruptions.

1.2. Research Objectives

The research objectives are as follows:

- To explore the supply chain disruptions within the EPC sector and the effect of such disruptions on EPC contractors, suppliers and clients.
- To explore existing practices to eliminate supply chain disruptions within the EPC sector.
- To make recommendations to reduce supply chain disruption within the EPC sector.

1.3 Contribution of the Research

Overall, this research contributes to determining the disruptions within the EPC sector and the effect of local and global events that influence this sector.

This research sheds light on the importance of effectively managing the flow of materials and resources (supply chain management). By delving into how materials move through the planning, procurement, and construction process, the study emphasises that these movements significantly affect the success of projects. This research identifies supply chain disruptions as contributing to the challenges experienced with project timelines, escalating costs, and the final product's quality. This understanding contributes to a deeper understanding of the discipline's intricacies of supply chain management.

Furthermore, this research also provides valuable insights into the real-world implications of supply chain disruptions. Moreover, exploring existing practices and recommendations to mitigate supply

chain disruptions equips practitioners with actionable strategies to enhance project resilience. Ultimately, the study empowers managers to make informed decisions and adopt effective measures to minimise the negative impact of disruptions on their projects.

2. Literature Review

The increasing occurrence of disruptive incidents has necessitated a shift in how businesses approach supply chain risk management. This shift involves moving from a reactive response to risks with a "what if" perspective to a more proactive approach focused on anticipating and preparing for potential disruptions. The COVID-19 pandemic serves as a prominent example, underscoring the vulnerability of global supply chains and prompting a re-evaluation of operational continuity (Chambers, 2020:1). The lessons learned from such disruptions, including the pandemic, highlight the importance for businesses to mitigate their impacts pre-emptively. In the context of the Engineering, Procurement, and Construction Management (EPC) sector, disruptions have proven particularly impactful, leading to market fragmentation and diminished profitability, subsequently influencing project timelines and budgets (Piotrowski & Ellis, 2020). These disruptions can even escalate into conflicts between EPC contractors and clients, which may result in financial and reputational consequences.

To gain a deeper understanding of the repercussions of supply chain disruptions in the EPC sector, it becomes imperative to understand the fundamental underpinnings of turn-key projects. These projects, which are fully developed and ready for immediate operation upon handover, play a pivotal role (Mishra, 2022). Within this scope, two prominent business models dictate the landscape: EPC (Engineering, Procurement, and Construction) and EPCM (Engineering, Procurement, and Construction Management). These models wield distinct implications for the various stakeholders involved. EPC contracts place the responsibility of managing the entire supply chain on the contractor, entailing significant risk. In contrast, EPCM contracts empower the owner with greater control and accountability, shaping project outcomes and financial structures (Global Intelligence Alliance (M-Brain), 2015). In this research, the focus is on EPC rather than EPCM.

The impact of delays in turn-key projects extends beyond the immediate disruption. Escalating project costs necessitate additional funding, affecting investor returns and amplifying risk exposure (Biser et al., 2020:4). These delayed returns further elevate investor risk by introducing additional capital requirements and opportunity costs. Moreover, disruptions can erode market confidence, diminishing investor trust and decreasing share value. Furthermore, contractual defaults due to delays can disrupt loan disbursements and other contractual agreements. These far-reaching consequences underscore the multifaceted challenges posed by supply chain disruptions, thereby underscoring the urgency for comprehensive mitigation strategies.

The role of supply chain management (SCM) in EPC projects is pivotal, regardless of the contractual framework. EPC contracts, due to the accountability and minimal owner involvement, may afford greater flexibility in product and supplier substitutions (Sholeh & Fausiyah, 2018:2). This aspect becomes crucial considering the inherent risks inherent in EPC projects, encompassing issues such as delays, quality concerns, strained relationships, and informational gaps (Sholeh & Fausiyah, 2018:2). Notably, supply chain mapping is a valuable tool that provides a visual representation of relationships, thereby aiding in risk assessment (American Express, 2022). The concept of supply chain agility complements this mapping process by facilitating swift adjustments to changes and disruptions (Delbufalo, 2022:701; Gölgeci et al., 2019:173). Recent disruptions emphasise the significance of preparing supply chains for unforeseen events, necessitating readiness and flexibility and underscoring the relevance of concepts like supply chain mapping and agility (Ray, 2021).

The Vitality of Supply Chain Resilience

In light of the ever-evolving landscape of disruptions, the EPC sector is urged to take a deeper dive into the concept of supply chain resilience. This resilience extends beyond mere reaction to disruptions; it involves pre-emptive preparedness for uncertainties and the capacity to adapt to unforeseen events. Noteworthy crises, such as the Covid-19 pandemic and geopolitical conflicts, have illuminated the fragility of supply chains across various industries, thereby accentuating the importance of evaluating and bolstering supply chain resilience (White *et al.*, 2022:4). The intricacies of supply chain complexity and interdependencies amplify the propagation of disruptions, leading to what is termed as a "ripple effect" across the supply chain network (Park *et al.*, 2022:4693). Effective management of risks demands a profound understanding of the dependencies that thread through tiered supplier networks, compelling stakeholders to navigate these complexities in a bid to mitigate the spread of disruptions (Christopher & Gaudenzi, 2015:58). A cornerstone of supply chain resilience is the strategic selection of diversified suppliers, which serves to enhance resilience without incurring high redundancy costs (Kahiluoto et al., 2019:272). By incorporating diverse critical items or suppliers, businesses can engender a supply chain that embodies resilience, balancing preparedness and adaptability (Kahiluoto et al., 2019:273).

Operational risks and supplier diversity

Operational risks loom as substantial threats to supply chains, warranting particular attention as per the findings of a PwC 2020 survey (PwC, 2022). These risks stem from internal processes or managerial shortcomings and encompass a range of factors, including labour disputes, disruptions in distribution, instances of bankruptcy, factory closures, and equipment malfunctions (Stockton, 2022). The assessment and mitigation of these operational risks are complex due to varying supplier transparency and susceptibility (Stockton, 2022).

Managing localised supply chain insufficiency

The inadequacy of localised supply chains has emerged as a substantial risk category, ranking fifth in the PwC survey. Companies are increasingly driven to address this risk as a strategy to mitigate the impact of environmental and other disruptions (Shih, 2022). Despite the cost efficiencies associated with global sourcing, recent disruptions have illuminated vulnerabilities in specific dependencies, particularly regarding manufacturing capabilities and logistical constraints (Shih, 2022).

Balancing Supply Chain Agility and Resilience

Supply chain agility and resilience, though interconnected, are distinct in nature. Agility equips supply chains to respond promptly to changes, while resilience centres on absorbing disturbances and maintaining long-term stability (Delbufalo, 2022:701; Gölgeci et al., 2019:173). As disruptions surge in frequency and complexity, the EPC sector is tasked with adopting strategies that harmonise the speed of agility with the endurance of resilience.

Developing a path toward supply chain resilience

Within the Engineering, Procurement, and Construction (EPC) sector, the pursuit of supply chain resilience involves several key strategies. These strategies encompass the deliberate selection of diverse suppliers, the management of operational risks, and the creation of plans to address vulnerabilities in local supply chains. As businesses navigate the intricate web of interconnected relationships and dependencies within their supply chains, they are faced with finding the right balance between flexibility and robustness. In the face of an ever-evolving global landscape, the insights collected from recent disruptions serve as a reminder of the importance of proactive readiness and strategic cooperation. These elements stand as cornerstones in constructing supply chains that exhibit resilience and adaptability.

3. Research Methodology

The researchers aimed to understand the supply chain disruption within the EPC sector based on participants' experience of the phenomena where the investigation was conducted over a single period in the short term; therefore, the study is in the form of a cross-sectional study and we used inductive reasoning. We also implemented an interpretive research paradigm to conduct this qualitative research.

An EPC company manages projects through different phases, including engineering, procurement and construction management. Professionals in the companies are responsible for one phase or all of them; therefore, individuals from each phase were approached for interviews as they better understand the process and disruptions experienced within the sector. They are also in the best position to share preventative action measures. This provided a holistic picture of disruptions within the sector. The

inclusion of contract managers is deliberated as they need to be ahead of disruptions and possible threats to the work. These managers usually seek mitigations should any dispute result from a contract.

3.1 Sampling

As the study focuses on the disruptions experienced within the EPC sector, the focus was placed on individuals working within that sector. For this study, the researchers focused on companies in the Gauteng area as it is the business hub of South Africa.

The general notion for qualitative research regarding the population size is that the data collection and analysis should continue until no new themes or information that indicates new themes present itself (Van Rijnsoever, 2017:2). As soon as no new themes can be identified, the study would have reached data saturation (Van Rijnsoever, 2017). Considering the above, the researchers selected a minimum of 10 participants to participate in the research or data was gathered until data saturation was achieved.

The researchers made use of non-probability, purposive sampling. Non-probability sampling is described as a method where the researchers need to know the population size of the investigated field (De Vos *et al.*, 2011). Purposive sampling is a method founded on the researchers' judgement referring to characteristics and elements typical of the population considered and which served the study the best (De Vos *et al.*, 2011).

3.1.1 Inclusion criteria

Criteria for inclusion that were considered:

- Participants need to work within the EPC sector responsible for the project delivery part of the supply chain.
- Individuals within the EPC with various levels of experience be considered as disruptions in the sector or processes can be experienced at any stage in the project life cycle.

3.1.2 Exclusion criteria

The exclusion criteria were as follows:

- All subordinates of the researchers were excluded from the study, as the researchers want the employee to be comfortable and free of any judgement, remove any biased element from the study, and avoid any conflict of interest.

3.2 Study Population

The population for the research was selected from a company that specialises in EPC projects and has a 30-year history. The company has offices located around the world, operating in three regions referred to as EMEA (Europe, Middle East and Africa), APAC (Asia-Pacific) and AMER (Americas). The participants were in the EMEA (Europe, the Middle East and Africa) group. The head office of the EMEA portion is within South Africa, focusing on project delivery in Africa.

3.3 Designing the measurement instrument

Semi-structured interviews were conducted according to an interview schedule. The researchers made use of open-ended questions during the interview. Open-ended questions allowed the participants to express themselves more freely while elaborating on the answers (De Vos et al., 2011).

Examples of the question the researchers posed to the participant are as follow:

- Please tell me what your role in supply chain management is in the organisation.
- What is the most recent disruption experience affected your packages/project?
- How does local and international disruption affect your packages/project outcome?
- What mitigation did you implement to reduce the effects on your packages/project?
- Was the mitigation implemented to benefit the EPC contractor, client, or supplier?
- In your opinion, what are the constraints of the contracts currently in use for either supply or construction to deal with disputes brought on by disruptions?

3.4 Data analysis

Lester *et al.* (2020) suggest that qualitative research data analysis needs to be structured or systematic as qualitative analysis, in principle, is flexible. They suggest that their approach to data analysis is well-suited for thematic analysis, wherein the researchers aim to produce broad descriptive statements that reflect their overall understanding of the data in response to their research questions (Lester *et al.*, 2020).

3.4.1 Trustworthiness

Trustworthiness is a term used to describe the criteria used to determine the validity of qualitative content (Elo *et al.*, 2014:2). In accordance with the notion by Kortjens and Moser (2018:120), the criteria used in this research to establish trustworthiness, focused on credibility, transferability, dependability, and confirmability.

3.4.1.1 Credibility

The research team employed a co-coder to establish credibility who independently validated the extracted information and interpretations. This rigorous process of peer review enhances the accuracy and authenticity of the research findings, aligning with the statement that credibility ensures the validity of the study's outcomes (Korstjens & Moser, 2018:120).

3.4.3 Dependability

Dependability was maintained by adhering to the prescribed data-gathering and analysis methods. Detailed documentation of each step of the research process was diligently maintained. These measures ensured consistency in the research approach and contributed to a trail of evidence that supported the reliability of the research (Korstjens & Moser, 2018:120).

3.4.4 Transferability

The researchers satisfied transferability through a detailed research process used during the research. The researchers enriched the study's conclusions by incorporating participants' responses and integrating them into the findings. This approach increases the applicability of the results to various contexts, in line with ensuring the transferability of research outcomes (Korstjens & Moser, 2018:120). Furthermore, the study outlined supply chain disruptions in the EPC sector to enhance transferability, comparing them with other industries. Using cross-sector supply chain theories ensured broader relevance. Examining different EPC projects and proposing replicable strategies for other sectors highlighted its practical value for industries facing supply chain challenges.

3.4.5 Confirmability

Confirmability was assured through regular self-reflections during the interview process and the maintenance of an interview guide. These practices provided insights into the decision-making processes and ensured that personal biases did not influence the research outcomes. Such measures should align to establish confirmability by promoting transparency and objectivity (Korstjens & Moser, 2018:120).

Lastly, the study successfully addressed the trustworthiness criteria by implementing specific strategies to enhance credibility, dependability, transferability, and confirmability. The rigorous application of these strategies underscores the researchers' commitment to ensuring the qualitative research findings' validity, reliability, and broader applicability.

4. Ethical Requirements

Informed consent was required from each participant. Permission was also requested from the relevant Head of Operation. The researchers were acting in accordance with the POPIA Act in ensuring that no personal data was shared and anonymity was maintained. All other ethics protocols and permissions were adhered to according to the ethical policies of the North-West University.

5. Discussion

The intent was to interview 10 participants. Eight interviews were held and data saturation was then reached. The participant's code and their respective roles in the EPC sector can be seen in Table 1:

Table 1: Participant role within the EPC sector (compiled by the author)

Participant Code	Role of the Participant in the EPC Sector
PA01	Project engineer and raise boring contract owner.
PA02	Mechanical engineer
PA03	Mechanical engineer and the structural steel contract owner
PA04	Mechanical engineer and bulk material handling contact owner
PA05	Project engineer – electrical
PA06	Civil engineer and the earth-work contract owner
PA07	Reliability engineer - execution
PA08	Mechanical engineer - water handling contacts owner

Through data gathering and analysis of the gathered data, themes and subthemes were identified. Table 2 outlines the themes and subthemes identified during the study's data-gathering phase.

Table 2: Themes and subthemes

Theme	Sub-theme
1. Engineer's responsibilities in the EPC sector	1.1 Mediator 1.2 Procurement activities
2. International disruptions experienced by the EPC supply chain	2.1 Covid-19 pandemic 2.2 Logistics 2.3 Equipment shortage
3. Local disruption experienced by the EPC supply chain	3.1 Load shedding 3.2 Strike actions 3.3 Steel shortage 3.4 Logistics
4. International and local disruption experienced by the EPC supply chain	4.1 Effect on packages
5. Mitigation applied by engineers during the previous disruption experienced	5.1 Risk mitigation meeting 5.2 Float management acceleration measures
6. Mitigation implementation strategy suggested for future disruptions	6.1 Risk assessing 6.2 Supplier diversification 6.3 Vendor evaluation
7. Contractual clauses in the EPC sector	7.1 Positive perception of the clause's capacity to assist with disruptions 7.2 Challenges faced with the general contract used in the EPC sector

5.1 Theme 1: Engineers' responsibility in the EPC sector

The engineer has an important role in the EPC sector. The FIDIC contract generally used in the sector appoints an engineer as the person or entity responsible for project management and contract administration. In this research, the participants shared the following narratives regarding the responsibilities of engineers in the EPC sector:

- PA01: *“all it would be from handling the contractual or basically executing the contractual terms for the client and which was set up by the client and the procuring or the engineering, procuring and managing the construction on behalf of the client and then obviously dealing with the contractor and managing them accordingly.”*

- PA04: *“I deal with the procurement, the fabrication management, quality management and also ensuring all goods and services reach their destination without damage or short supply.”*

It was interesting to note that their responsibilities would depend on their role within their sector as well as the type of package assigned to them. Elliott (2021) is of the opinion that there is a limitation to the engineer’s powers. In the execution of the contract, the engineers do not have the right to amend contracts. They cannot relieve a person or entity of responsibility towards the agreed contract (Elliott, 2021). It can, therefore, be concluded that the engineer acts on the client’s behalf but does not make any definitive decisions on the contract agreed upon between the client and the supplier. The researchers identified two clear responsibilities of engineers in the EPC sector. These are 1) mediator and 2) procurement activities. These will be discussed as subthemes in the following section.

5.1.1 Sub-theme 1.1: Mediator

The engineer's responsibility as a mediator between the supplier and the client is essential when managing the disruption and its implied effect on the projects. The participants referred to being a mediator between the client and supplier, which was supported by the following narratives:

- PA02: *“So I am, in a sense, the middleman [mediator], so I have to make sure that the needs of the client are met through a certain engineering solution.”*
- PA07: *“As EPC, we had the total autonomy of how we dealt with contractors, and you know you, you did the best for the client at all costs to make sure that quality, costs are reduced and also the time of delivery.”*

This is critical as the main distinction between the EPC and the EPC contract type is that the EPC contractor provides services that include engineering and procurement but is only a mediator in the contracts (PEGAZ, 2022).

5.1.2 Sub-theme 1.2: Procurement activities

During this study, it was evident that a large part of the function of an EPC contractor is procurement and procurement-related activities. Procurement, in terms of the turn-key project sector, is the process of buying various equipment and services as part of the execution of the deliverable of the project. Elliott (2022) emphasises that procurement has more to do with negotiating a contract with the relevant supplier and less with the equipment or service required. The participants stated the following concerning the procurement activities:

- PA02: *“I am also responsible for the procurement of that equipment or the facilitation of the procurement via third party” [Indicating the engineer is participating as 3rd party to the contract.]*
- PA04: *“So, I deal with the whole procurement process.”*

As participant PA02 alluded, the EPC contractor or engineer facilitates the procurement process and will assist and advise on the client's best strategy. Regarding procuring equipment or services, the contracts with various suppliers will be direct contracts between suppliers and clients (Construction Management Guide, 2008).

Overall, the participant interviews highlighted the pivotal role of engineers as mediators and managers within the EPC sector. This role aligns with the complexity of supply chain management discussed in the literature, emphasising the need for effective coordination and communication among various stakeholders (Reference: Participant Interviews - Theme 1; Literature - Supply Chain Complexity).

5.2 Theme 2: International disruptions experienced by the EPC supply chain

Globalisation has resulted in more extensive market accessibility for various suppliers in providing a more stable supply chain, which could result in reduced lead time, lower prices, or material security, to name a few. While it offers several advantages, it creates a dependency on these markets to operate as a sustainable business. Thus, should disruptions occur, it will affect the supply chain of the supplier as well as the supply chain of the EPC contractor in managing the suppliers on the client's behalf to deliver on the project deliverables, contributing to project success.

5.2.1 Sub-theme 2.1: Covid-19 pandemic causing disruptions

Internationally, Covid-19 was a disruption that affected packages and projects for most of the participants. Some of these large projects were stopped, usually to resume work later. The pandemic was a disruption that had a far-reaching impact on the world and some of the effects will still be experienced for some time. One participant shared that, even though COVID-19 started in 2020, the impact can still be felt two years later:

- PA02: *“Covid-19, since even up to very recent times, I've experienced delays on some packages there.”*
- PA08: *“There was quite a large delay on importing steel from a Chinese manufacturer and this was mainly due to the COVID-19 regulations that were sitting and essentially delayed the shipments or of these items, which eventually led to those items being late our doorstep and also resulting in our orders from our clients being delivered late.”*

During this research, it was clear that port closures caused the majority of delays, and the following narratives support this:

- PA01: *“.....due to some of the port closures, especially in China, that caused delay in terms of shipping and because of that delay and I mean, I'm not talking about shipping delays in terms of the freight being on the water, but because of port closures now product could not get out of the ports.”*

- PA05: *“Actually, there was a risk because China's ports were being locked down.”*

The logistic constraint was further burdened with a sudden increase in consumption after the pandemic subsided, quickly leading to an imbalance in supply and demand and overwhelmed logistics infrastructure (Huld, 2022).

Overall, the impact of international disruptions, like the COVID-19 pandemic, on the EPC supply chain aligns with the concept of global interdependence and the susceptibility of extended supply chains to disruptions. The interviews emphasised how global events can cause delays and highlighted the importance of proactive preparedness (Participant Interviews - Theme 2; Literature - Globalisation and Supply Chain Resilience).

5.3 Theme 3: Local disruption experienced in the EPC supply chain

The researchers identified three apparent local disruptions that the EPC contractor dealt with. These are 1) Load shedding, 2) Strike actions and 3) Steel shortage. The disruption experience depends on the packages the EPC contractor dealt with; not all disruptions affect a package. This is discussed as subthemes in the following section.

5.3.1 Sub-theme 3.1: Load shedding

Load shedding has become a disruption the South African manufacturing and fabrication sector had to overcome. Wroughton (2022) describes load shedding as distributing demand for electrical power across multiple power sources to relieve pressure on the primary energy source when the electricity demand exceeds what the primary power source can supply. He (Wroughton, 2022) has an opinion on why South Africa has to manage load shedding and boils down to the ageing fleet of coal-fired power plants, a lack of maintenance, corruption, theft and vandalism. Thus, it is not a single source that brought the country's power generation sustainability here but several contributing factors over a long period.

Several participants identified load shedding as a package disruption, especially those dependent on manufacturing or fabrication. The following narratives support this:

- PA05: *“The only local problem was delays due to load shedding. Some of my packages have been greatly affected by that and I had to make contingency plans for some suppliers to ensure that we stay on track to meet the actual delivery dates.”*
- PA06: *“So they've experienced a quite a lot of delays on the delivery of HDPE piping from South Africa due to load shedding that impacts on the fabrication of the HDPE pipes.”*

In terms of the manufacturing and fabrication sector, which is an integral part of the supplier's ability to supply equipment as agreed upon and ultimately forms part of the EPC supply chain, the availability of sustainable electricity is required to function at an optimal level.

Load shedding brought difficulty in managing the supplier and achieving the contract completion dates to mitigate the available risk. As shared by PA05, he would have to take responsibility and develop contingency plans to avoid any delays on the package.

5.3.2 Sub-theme 3.2: Strike actions

In this study, strike action was identified as another local disruption experienced by the EPC supply chain. Motala (2014) indicated that the strikes occurring in South Africa boil down to today's strike demand being reduced to crude annual wage increases and basic trade union recognition tussles.

One of the most recent strikes, as indicated by PA07, relates to the logistic sector, with unrest on the national road mainly used for transportation. This strike was from truck drivers across the country fighting against the long-standing issue of employing foreign nationals in the trucking sector, who appear to be favoured by employers because of lower wages (Motala, 2014). Some of the participants stated the following concerning local disruption experience:

- PA04: *“OK, so some of the local issues experienced were a shortage of trucks to site, steel supply shortages. Uh, the local strikes and this all had a negative impact on my package in terms of the schedule and cost. Then, on the international side, there were strikes in Congo which delayed transport from South Africa to the site.”*
- PA07: *“I would say I've classified more as an industrial labour strike. There is always the issue of trucking companies using local vessels, foreign African foreigners to drive the trucks from South Africa to the neighbouring countries. Umm. And then, you know, that's like actually went outside the realm of what was supposed to be. Because it was sort of like illegal strike and couldn't be contained.”*

The delays this caused, influenced the package being managed by the EPC engineers with little possible mitigation once the equipment was on route to the port or in the port ready to be dispatched:

- PA04: *“So, because the transport is quite a big value, it affected the packages. The local strikes all had a negative impact on my package in terms of the schedule and cost.”*

5.3.3 Sub-theme 3.3: Steel shortage

The disruption of steel shortage can be viewed as a single action that delays production or works in the EPC sector but can also be seen as a chain action of the disruption causing the next. While the local disruption can be identified through what was experienced, it remains to adhere to the four pillars framework, as Schlegel and Trent (2016:37) indicated. The local environment is not isolated from the international environment, with several global factors affecting the local market. This is reiterated by PA02, who stated the following:

- PA02: *“I mean, locally, we are very dependent on imports and everything from chips to steel. So, anything that happens internationally will spill over to our local production capacity or local supply capacity very, very effectively, unfortunately.”*

During and after the COVID-19 pandemic, major steelmaking economies worldwide struggled to meet the international rebound in steel demand (Cilliers, 2021). The hard lockdown imposed by the Government resulted in South Africa’s steel producers shutting down temporarily for an extended period, affecting the country's steel availability (Cilliers, 2021).

Overall, the participant interviews reveal how local disruptions, such as load shedding and strikes, affect the EPC sector. These disruptions underline the vulnerability of local supply chains and relate to the challenges discussed in the literature regarding local supply chain risks (Participant Interviews - Theme 3; Literature - Local Disruptions and Supply Chain Vulnerabilities).

5.4 Theme 4: Effects brought on by international and local disruption experienced by the EPC contractors

Both local and international disruptions are identified in Theme 4:

5.4.1 Sub-theme 4.1: Effect on packages

(I) Covid-19:

Participant PA02 indicated the effect of COVID-19 specifically on their package: *“... But however, due to some of the port closures, especially in China. You know, that caused a delay in terms of shipping and because of that delay and I mean, I'm not talking about shipping delays in terms of the freight being on the water, but because of port closures now product could not get out of the ports.”*

It is evident that this participant was more focused on the closure of ports brought on by Covid-19 due to reduced labour capacity due to each country’s regulations. This meant that equipment could not be loaded onto or offloaded from vessels, resulting in the vessel standing idle without getting the equipment to the client’s premises.

(II) Quality:

Several participants identified quality as a disruption or package delay. Participant PA05 identified quality as a disruption brought on by the supplier or manufacturer. This disruption can be seen as a downstream risk:

- PA05: *“One [Disruption] is with the compressor supplier, and one is with the trash screen supplier, is quality of work. The supplier is not adhering to our quality standards. So, the work gets rejected and then it's causing severe delays, specifically on the compressor side”.*

Quality is managed by the EPC contractor procuring equipment with dedicated professionals to assist the EPC contractor in his task of successful execution of the supply package. The effect on the package, as indicated above by participant PA05, is that the quality of work was not accepted, resulting in the work being rejected and causing a delay in the supply. Repairs, rework, or scrap and replacement must be considered possible mitigation.

It was further argued that, in isolated cases, contingencies and float only catered for time and cost-related problems and ignored quality. Quality is an equally important constraint on a project because projects of poor quality whose standards do not meet the minimum specifications are deemed unsuccessful despite such projects being completed on time and within cost (Taylor, 2022).

(III) Ripple effect:

While cost and time have been highlighted as the main effects of the disruptions in the EPC sector, another effect, as seen from the above discussion, is the knock-on or ripple effect. The ripple effect is clearly defined by Taylor (2022) as a term used to describe how disruptions ripple from a point throughout part of or the entire supply chain, which is generally accounted with increasing effect on the supply chain:

- PA01: *“needed to be repaired within the bonded storage yard, which also caused the further delay in terms of getting the equipment to site, which in turn then as well caused the delay for the guys on site to do the construction and the, obviously had the material effect on the overall schedule as well as the claims that needed to be processed for tanks being late causing extension of time claims to come from the SMPP who erected the tanks. The civil guys could do their job, so that did not really affect them, but there were some small plinths that needed to be cast on the pipe runs, which obviously there are some portions of an extension of time and then cost that needed to be reclaimed.”*

5.5 Theme 5: Mitigation applied by engineers during the previous disruption experienced

5.5.1 Sub-theme 5.1: Risk mitigation meeting

Risk mitigation meetings are an activity that is initiated through an early warning issued from a contractor due to the occurrence of a delay event or disruption. Once the event has occurred or perceives a risk that might lead to a delay in the project, an early warning notification is sent to the EPC engineers. It is the responsibility of the engineer to inform the client then and arrange for a risk mitigation meeting as indicated by participant PA01 below:

- PA01: *“...because the goal is for when the early warning does come in to facilitate the risk mitigation meeting from an EPC point of view.”*

Leloup (2016) indicates that, in the case of a disruption or delay event, the client or supplier may instruct the other to attend a risk reduction meeting, and those who also attend may cooperate. Furthermore, the contract in use does not mention that it is an obligation to have the meeting but a source of the mitigation process. Thus, the purpose of this meeting is to provide ideas or make a proposal to reduce the risk of the delay event or disruption and decide on the actions to be taken and by whom, in accordance with the contract (Leloup, 2016).

5.5.2 Sub-theme 5.2: Float management

Float is a project term Taylor (2022) describes as a numerical value indicating the maximum time a specific task or package can be delayed, causing a ripple effect and starting to affect other packages and the project. Float is usually applied alongside the project's critical path, which is a tool to assist professionals in the project sector in managing their tasks, packages and projects more efficiently (Taylor, 2022). As stated below, participants indicated the possibility of using float or float management to buffer against disruptions that may cause a delay.

- PA03: *“If your project schedule allows you to put in a certain buffer, it would be good to have, say, two to four weeks as a buffer to take into account any of the force majeure events or any unforeseen events.”*
- PA04: *“Then also issuing a letter of intent to suppliers so they can start the fabrication before contact placement. So yes, because the contract placement is such a long process, so you get ahead of the game.”* [a way of generating float]

The ownership of the float allowance typically lies with the client but can be utilised to avoid disputes if the risks to the projects are understood (Deir & Theodore, 2016).

For participant PA03, float will be ideal risk mitigation for disruption in the local sense as it makes allowance for the disruption experienced by the participant, which relates to the extent of the duration. PA03 indicated the following:

- PA03: *“Once the disruption was sorted, things cleared out, and the floods surpassed, their business was back to usual. So, I'd say more like a four-to-five-day period.”*

5.5.3 Sub-theme 5.3 Acceleration measures

Acceleration measures as mitigation can be beneficial to mitigate delays caused by delay events or disruptions in a supply chain. This can be seen as a proactive and reactive mitigation to delay events or disruption in a supply chain if it has been allowed or if an amendment has been made to the contract. Participant PA04 indicated the following regarding acceleration measures:

- PA04: *“So, airfreight all critical equipment to reach site earlier and not delay construction on site then the airfreight, this is now just to accelerate delivery, if I can say it like that.”*

Acceleration methods as mitigation allow suppliers and contractors to claim additional remuneration for the work to be completed. Acceleration claims are claims for other payments made due to the costs associated with speeding up work, as defined by Benarroche (2020).

Acceleration measure is an option to undo the effect of a delay event or disruption to minimise the impact on the package or project. These acceleration mitigations can be negotiated by budgeting and agreeing in the contract to allow for acceleration cost in terms of overtime worked or additional resources required. This allowance can be called on should the need arise with fair compensation to the supplier and contractor.

5.6 Theme 6: Mitigation implementation strategy suggested for future disruptions

In this analysis, risk assessment, supplier diversification and vendor evaluation were prominent themes indicated by the participants and are discussed next.

5.6.1 Sub-theme 6.1: Risk assessment

Risk assessment was a popular response from participants regarding risk mitigation.

Bonnie (2022) defines risk as “An uncertain event or condition that has a positive or negative effect on a project’s objectives.” Through the assessment process, potential threats to your project are identified and consequences are analysed in case they occur (Sienkiewicz, 2022):

- PA07: *“I think they should have identified that risk, or maybe also on my side, there's a packaging engineer who should have put some of my area of risking depth so that when we do the analysis, we are able to identify what are the risks.”*

Once the risk assessment is done based on the package, supplier, and disruption, this can be translated or quantified to a duration the EPC contractor can build into the schedule as a buffer or float. This float or other contingencies can assist with contractor-related risks. A provision can be made in the current contract and project plan to increase the float to manage the identified risks (Amar, 2017).

5.6.2 Sub-theme 6.2: Supplier diversification

Supplier diversification is mitigation in the general supply chain of companies, which has the merit of application in the EPC sector:

- PA03: *“If you identify a few small suppliers that procure stock and don't necessarily move it through the workshops. Going to quick or through a six-month basis. You can look at keeping those relationships open and procuring those steel from them.”*

- PA04: *“But for example, if it's on a critical path and the supplier says, look, we can get another type of motor to you and that will reduce the lead time to meet schedule, then they can put in a concession and if the client agrees.”*

A supplier diversification strategy can be beneficial in reducing the risk of disruption, especially regarding the supplier's ability to provide the equipment on time. This strategy involves creating a network of additional suppliers encompassing different sizes, locations and capabilities.

5.6.3 Sub-theme 6.3: Vendor evaluation

Part of the procurement process is the tender and adjudication of the tenders is a subprocess. This process is where the tender submitted from a supplier is evaluated.

This subtheme builds on subtheme 6.1 in terms of risk assessment and subtheme 6.2 regarding diversification:

- PA01: *“So, for sure, you have the guys that you've tried and tasted, vetted you've, you know that the schedule has the correct amount of float in it because they have discussed and have enough contingency plans in place to make the works reality within the set-out time frame.”*
- PA08: *“Something as a company or an external or even internal person to your company. We evaluate the risk of a supply chain and you can put that down on the sheet and compare that to.....”*

This problem's foundation is the need for robust processes to identify and successfully manage growing supply-chain risks as the world becomes more interconnected (Bailey *et al.*, 2019).

Overall, the interviews explore strategies to address disruptions, such as risk mitigation meetings and acceleration measures. These strategies resonate with the literature's emphasis on proactive measures and building resilience through risk assessment and mitigation planning (Participant interviews - Theme 5, 6; Literature - Resilience strategies and mitigation planning).

5.7 Theme 7: Contractual clauses in the EPC sector

The EPC sector is primarily driven through contracts as administration and resolution tools to ensure that all parties to the contract have clearly defined responsibilities and liabilities. Two aspects were highlighted and are discussed in the sub-themes below:

- The contract is perceived positively in facilitating the risk mitigation process brought on by a delay event.
- While the feedback is positive, one main challenge seems to make it difficult to execute as an EPC contractor, which refers to the parties' maturity and understanding of the contract in the EPC sector.

5.7.1 Sub-theme 7.1: Positive Perception of the Contract Clause's Capacity to Assist with Disruptions

FIDIC is the general contractor of choice in the EPC sector. The participants had an all-around good perception of the contract and its ability to facilitate mitigation, should a disruption occur, as well as of the dispute resolution, as indicated below. FIDIC offers an international model of contract conditions that are supposed to strike a fair balance between the parties:

- PA02: *“I think it is sufficient measures within FIDIC and there, “I think it is sufficient measures within FIDIC and there are definitely measures for both parties to issue their necessary communication and trigger the certain clauses.”*
- PA03: *“...are definitely measures in for both parties to issue their necessary communication and trigger the certain clauses.”*

The reason for the satisfaction could be the FIDIC contracts being very clear in their terms and clauses with sufficient detail and covering all kinds of issues that can happen during the construction process to reduce the risk of future disputes (Amar, 2017).

FIDIC contracts are drafted to provide the same favour to both parties agreeing and also provide a degree of protection for both parties (Amar, 2017). However, the start of the process is the most important: deciding on the correct type of contract within the FIDIC allowance.

5.7.2 Sub-theme 7.2: Challenges faced with the general contract used in the EPC sector

Theme 7.2 provides relatively positive feedback to the clauses in assisting with disruptions to mitigate or facilitate the mitigation of delay events or disruptions as they occur. This depends on the understanding of the contract by both parties entering a contract on turn-key projects. Based on the participant's statements below, the main challenge to effective implementation and management of the contract is the supplier's lack of understanding or stated differently; it depends on the suppliers' maturity in working on turn-key projects.

- PA05: *“Well, if there's any constraint, it's the user's own fault because it's a very flexible contract.*
- PA07: *“But what tends to happen is sometimes the client will always overwrite some of the protection of the clauses in the contract. Oh, you know, making it a bit sometimes difficult for the EPC engineer in charge a bit toothless”.*

Should a delay event or a disruption occur that will impact the package delivery and the project, the supplier needs to initiate the notification process to open up mitigation measures, as the contract and relationships can be damaged if not done correctly. BCI (2021) indicates the importance of both parties understanding the contract, as it is better to know how it works. It will reduce the likelihood of disputes

arising caused by a delay event. However, when disputes arise, it is crucial that both parties follow the provisions of the clause as set out in the contract (BCI, 2021).

Overall, the participant interviews explore the role of contractual clauses in managing disruptions. This aligns with the literature's emphasis on collaboration and contractual agreements to navigate disruptions effectively. The challenges participants face in fully understanding and implementing the contract relate to the importance of clear communication highlighted in the literature (Participant interviews - Theme 7; Literature - Collaboration and contracts in supply chain resilience).

6. Managerial Implications

The following managerial implications are identified for effectively managing supply chain disruptions.

- **Establish a dedicated supply chain disruption team:** Create a specialised team focusing on monitoring, analysing, and managing supply chain disruptions. This team should collect data on historical disruptions, identify trends, and develop strategies to address potential future disruptions proactively. Having a dedicated team ensures continuous awareness and preparedness.
- **Promote collaboration:** Encourage collaboration among EPC contractors, suppliers, and clients. Arrange regular meetings and create open communication lines to discuss challenges, share ideas, and jointly develop plans to handle risks. Working together helps better understand risks, act faster, and strengthen the supply chain.
- **Include risk assessment in projects:** Consider possible problems when planning and doing projects. Project managers should consider potential disruption when creating schedules and allocate extra time to accommodate delays. By having risk assessment a standard practice, managers would be prepared to deal with disruptions before they happen.
- **Embrace advanced technologies:** Invest in tools that help managers see and understand our supply chain better. These tools give managers real-time updates on how things are going and even predict problems using data. These tools let managers make informed decisions based on information and react well when things go wrong.
- **Strengthen Suppliers:** Establish programs to make important suppliers more robust. Assess suppliers' risk management capabilities and work together to improve their operations. Building solid relationships with suppliers helps reduce the impact of disruptions on the whole supply chain.

7. Recommendations

Against the above conclusion regarding mitigation, the following recommendations are made to reduce the risk of supply chain disruption in the engineering, procurement and construction management sector and to improve project success.

7.1 Recommendations about the supplier

- Suppliers are the main source of supply chain disruption that an EPC contractor needs to manage to ensure that the equipment or services will be on time and within budget. Therefore, they need to recognise that any risk in their supply chain transfers to the project, which could impact project success.
- Suppliers planning to enter the EPC sector or a business supplying goods or works need to understand the contract they enter into to effectively execute the clauses regarding delaying events, disruptions, or Force Majeure events. This can be done through appointment or consultation for legal representation specialising in commercial law to provide the needed understanding or correct interpretation of the contract or to assist in the delay notification and claim processes.
- Suppliers need to be aware that, when selected as the preferred supplier, the contract can be negotiated and not just expected at face value in fear of losing the tender.
- Suppliers need to learn from history as similar disruptions tend to reoccur in different parts of the supply chain.

7.2 Recommendation about the EPC contractors

- A package strategy session is to be done in consultation with the client to identify the correct FIDIC contract from the start and include it in the tender process so that suppliers can grasp the intention and the full scope of the contract. The strategy session will also need to reference disruptions to the specific packages from the engineer's perspective, related to general risk experience on previous packages. These disruptions need to be populated directly to a master risk register to identify risk categories and the potential effect of the disruption.
- Multi-sourcing can be applied to mitigate supply chain disruption or distribute the risks among various suppliers. Multi-sourcing can be applied in two ways:
 - Placing a portion of the scope on various suppliers.
Not all suppliers will be affected the same way during disruptions and there is the flexibility to move between various suppliers should a disruption cause significant delay for one supplier.
 - Critical equipment or suppliers of client-preferred brands need to be sourced to have a network of suppliers who can assist should a shortage arise due to a disruption.

- Vendor evaluation as part of the procurement process. While the procurement process considers the business as a whole, price is king, meaning that the lowest-priced vendor will most likely be awarded the contract or work. This might not be the best company in terms of supply chain readiness to absorb delays or maturity to execute the contract effectively. Therefore, as a minimum requirement for the tender documentation, the vendors must submit supply chain flow sheets or supply chain maps indicating the various suppliers' tiers.
- The maturity of vendors has been mentioned as a challenge, especially in contract execution, which accelerates the process of mitigation and client involvement. Training in terms of the contract can be provided to identify what is required according to the contract and what is expected by the client.

7.3 Recommendations about the client

- A constraint identified is client specifications about the specific type of motors, variable speed drive (VSD), or electrical equipment in general. This equipment makes out a large part of an EPC supply. Therefore, client teams need to consider alternative equipment or brands of equipment that are interchangeable with the current mine design to allow different avenues when supply chain disruption occurs on these items, which tend to be long lead items and on the project's critical path.
- Allowance of acceleration cost. This provision can be made and is only enforceable during a delay event or disruption that impacts the project's success. This allowance, for example, can be rated, which allows for overtime to be worked, different sub-suppliers to be used, where available stock is, or even a rate, should material be essential and there is no local supply.

8. Limitations of the Research

While the study was centred around the perspective of the EPC contractor, it can be expanded to include more role players. Firstly, through participating suppliers who provide a product or service to a turn-key project and secondly, through client participation to provide perspective on what the client expects to see regarding supply chain disruption.

9. Conclusions

From the findings, it is clear that supply chain disruptions do adversely affect the multiple packages within the project and the project itself, leading to delays in schedule and increased cost to reputational damage. The supplier's supply chain is essential to provide reliance against disruption for the supplier to deliver as agreed upon in the contract. This risk is directly transferred to the project's success, which needs to be managed through supply chain mapping and vendor evaluation in terms of the supply chain risks, providing mitigation in advance should the disruption occur. All parties involved in the process

are exposed to risk in the EPC sector with no idea of the following significant disruption affecting the project. Thus, effective consultation between all parties is critical to success in the EPC sector.

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