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The Supply Chain Management of Cobalt

ACEA7011 - PROCUREMENT AND SUPPLY CHAIN MANAGEMENT

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Abstract

The cobalt industry is facing increasing pressure to improve supply chain sustainability, given the growing demand for cobalt in the production of electric vehicle batteries. This article outlines the application of Failure Mode and Effects Analysis (FMEA) as a risk management tool for cobalt supply chains. The FMEA process involves identifying potential failure modes, assessing their impact, and prioritising preventive measures. There is an evaluation into six steps that can make this supply chain more resilient, including lessons learnt from previous experience, and how to implement improvements into the supply chain.

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1. Introduction

The increasing demand for cobalt, particularly in the production of electric vehicle batteries, has put the cobalt supply chain under the spotlight in terms of sustainability and ethical practices.

The supply chain for cobalt can be complex, involving multiple entities and processes before reaching the end-user. Various factors can affect supply chain management, including geopolitical events, natural disasters, and human rights concerns. To mitigate risk and ensure a sustainable cobalt supply chain, companies can utilise risk management tools such as Failure Mode and Effects Analysis (FMEA). A 1 (low) to 10 (high) scale is used throughout the FMEA as a ranking system to associate the severity, occurrence, and detection before calculating the risk priority number (RPN). The RPN acts as a ranking system to identify the worst potential failures to implement solution before an incident occurs. Within the FMEA, recommended actions will be stated to improve the supply chain for each failure identified, along with the responsibilities to make the changes within the industry.

Further to the FMEA, an evaluation will commence to investigate how the supply chain of Cobalt can be more resilient. Six steps will be analysed to show how lessons have been learnt in historic events to pave the way for a more efficient supply chain for the future. Examples will be given to show what companies have done in different manufacturing sectors to improve the supply chain before giving recommendations on how the Cobalt supply chain can be improved.

2. Failure Mode and Effects Analysis

2.1. FMEA Overview

The Failure Mode and Effects Analysis (FMEA) is a risk management technique commonly utilised in the engineering and manufacturing industries to identify and evaluate possible defects or failures in a product or process, as well as their potential impact on the system as a whole (Kiran, 2017). The process involves brainstorming and listing all conceivable failure modes, followed by assessing the severity, likelihood, and detectability of each mode to establish an overall risk priority number (RPN) for each. Based on the RPN scores, the team can develop and prioritise action plans to address the most critical failure modes and reduce the overall risk (Kent, 2016). By conducting an FMEA, companies can proactively identify and mitigate potential issues before they occur, leading to improved product quality, reduced costs, and increased customer satisfaction (Elahi, 2018).

2.2. Severity

In the cobalt industry, supply chain management can be affected by various factors, which have been analysed in Table 5. The table lists the individual areas of activity of the business entities involved in the flow of goods, along with the potential types of defects and their effects. The severity for each defect is determined on a scale of 1 to 10, with 1 being assigned to minor incidents and 10 extreme incidents, as detailed in Table 1.

Degree	Severity Description	Rating
Minor	Unreasonable to expect this minor failure will have any noticeable effect on the material, system process, or subsequent process. Customer will most likely not be able to detect failure.	1
Low	The customer's inconvenience is minimal. They may observe a slight decline in item or system performance or encounter a minor inconvenience during a subsequent process or assembly operation, such as the need for minor rework.	2-3
Moderate	Customer dissatisfaction can be a result of failure, leading to discomfort and annoyance. The deteriorating performance of the item or system will be noticeable to the customer, which could lead to unscheduled rework or repair, as well as potential damage to equipment.	4-6
High	The failure of an item or system, which renders it inoperable, can cause a significant level of customer dissatisfaction. Although not related to safety or government regulations, such failures can lead to severe disruptions in subsequent processing or assembly operations and may necessitate significant rework.	7-8
Very High	Failure results in a safety hazard or noncompliance with government regulations, potentially putting the machine or assembly operator at risk. This risk level is rated 9 with warning and 10 without warning.	9-10

Table 1 - Severity Matrix for the FMEA

2.3. Occurrence

The second step is to determine the occurrence on a 1 to 10 scale, with 1 being very unlikely to occur and 10 almost inevitable to occur. Within table 2, the estimated frequencies of a failure occurring is stated.

Degree	Occurrence Description	Rating
Remote	It is highly unlikely to experience a failure as there have been no reported failures associated with this process or similar processes (1=1:1.5M)	1
Very Low	This process or nearly identical processes are only linked to isolated failures. (2=1:150K)	2
Low	Failures occurring in distinct processes that share similarities. (3= 1:30K; 4=1:4500; 5=1:800)	3
Moderate	The process has occasional failures, but not in major proportions (6=1:150:7=1:50)	4-6
High	This process or similar processes have often failed (8=1:9; 9=1:6)	7-8
Very High	Failure is almost inevitable (10=>1:3)	9-10

Table 2 - Occurrence Matrix for FMEA

2.4. Detection

The final step is to determine the preventive measures, and the detection parameter estimated in the following step. When rating detection, the roles are 'reversed' as the lower the number, the more detection is available, as outlined in Table 3. Finally, the RPN parameter is assigned, which enables the prioritisation of risks according to the formula in equation 1.

$$Risk\ Priority\ Number\ =\ Severity\ (S) \times\ Occurrence\ (O)\ \times\ Detection\ (D)$$

Equation 1 - Risk Priority Number (RPN) Calculation

This helps to determine the highest-risk threats and the order in which preventive actions should be taken, where table 4 shows a summary of the ranking matrix used in this particular FMEA.

Degree	Detection Description	Rating
Very High	The failure mode is highly likely to be detected by the current controls in place. There are reliable detection controls available for similar processes. Additionally, the process is designed to automatically halt further processing as a precautionary measure.	1-2
High	There is a high probability that controls will identify the failure mode, and the process itself is capable of automatically detecting the failure mode.	3-4
Moderate	Controls may detect the existence of a failure mode.	5-6
Low	Controls have a poor chance of detecting the existence of failure mode	7-8
Very Low	It is unlikely that controls will be able to detect the presence of a failure mode. There are currently no known controls that can detect this type of failure.	9-10

Table 3 - Detection Matrix for FMEA

Risk Level	Range
Low	0 - 96
Medium	97 - 196
High	197 - 1000

Table 4 - RPN Classification Summary

2.5. Failure Mode and Effects Analysis on the Cobalt Supply Chain

WALLCOLMONOY	Gavin John	FAILURE MODE and EFFECTS ANALYSIS On Cobalt Supply Chain	Rev. 1
	1809103		02-May-23

Seq	Area	Potential Failure Mode	Potential Effects of Failure	Severity	Potential Causes of Failure	Occurrence	Preventative Measures	Detection	R.P.N.	Recommended Actions	Responsible
1	Mining	Exposure to high levels of toxic materials	Serious health problems for workers, including respiratory and cardiovascular diseases, cancer, and other long-term health effects.	8	Inadequate protective equipment	4	Use of appropriate PPE such as respirators, gloves, and protective clothing.	5	160	Regular health monitoring to ensure workers are under exposure limit.	Mining companies
2					Inadequate training and education on the hazards.	4	None	6	192	Providing workers with training on the hazards of toxic materials and how to safely handle them.	Mining companies
3					Lack of proper ventilation	6	None	5	240	Implementation of ventilation systems, enclosed processing areas, and dust suppression techniques.	Mining companies

4		Inefficient or ineffective mining methods	Wasted resources	6	Lack of experience	7	Collaboration with industry associations share knowledge for best practices for sustainable and efficient mining methods.	7	294	Investment in education to learn newer technologies.	International Council on Mining and Metals
5			Increased costs	6	Insufficient or outdated equipment	7	Regular inspections and audits of mining operations to ensure compliance with regulatory and safety standards.	5	210	Use of advanced technologies, such as automated mining equipment and data analytics, to optimise production and reduce waste.	Mining companies
6		Equipment breakdowns and malfunctions	Downtime	6	Inadequate maintenance	8	Regular maintenance and inspection of equipment.	7	336	Continuous improvement to address underlying causes of equipment breakdowns and malfunctions.	Mining companies
7			Lost productivity	6	Lack of spare parts	7	Critical spares.	6	252	Review critical spares list. Implementation of Kanban system.	Mining companies
8		Environmental impact and regulatory compliance	Fines	7	Insufficient attention to environmental concerns	5	Regular audits of mining operations to assess their	6	210	Providing training and education to employees on environmental	International Council on Mining and Metals

							environmental impact and ensure they are complying with local, national, and international regulations.			regulations and best practices.	
9			Legal action	8		5		6	240	Monitoring systems can track air and water quality, noise levels, and other environmental factors.	Mining companies
10			Reputational damage	8	Inadequate community engagement and consultation.	3	None	5	120	Engaging with local communities to understand concerns and work with them to minimise the environmental impact of their operations.	Mining companies
11		Poor occupational health and safety conditions	Risk of accidents	8	Inadequate safety equipment	6	Conduct regular inspections and audits of their operations to identify potential hazards and areas for improvement.	4	192	Investigate automation technologies and work with local institutes.	International Council on Mining and Metals
12			Injuries	8		5	Safe systems of work - barriers, shift patterns and standard	4	160		
13			Fatalities	10		2		4	80		

							operating instructions.				
14			Legal and reputational consequences	7	Insufficient oversight and monitoring of safety practices	3	Accident reporting system.	4	84	Audit accident system to ensure solutions are implemented on reoccurring incidents.	Mining companies
15		Political Instability	Supply chain disruptions	5	Social unrest	5	None	5	125	Monitor political events and changes in government policy that could impact their operations, and adjust their strategies accordingly.	Mining companies
16			Operational challenges	5	Conflict	4		5	100	Work closely with local communities, governments, and other stakeholders to build relationships and promote stability.	Mining companies
17			Increased security risk	5	Changes in government policies	4	Insurance and financial risk management strategies to protect against losses caused by political instability, such as political risk insurance or	4	80	Keep up to date on government policies.	Mining companies
18			Legal and reputational consequences	6		4		5	120		

							hedging against currency fluctuations.				
19		Resource depletion	Reduced production	6	Inefficient resource management practices	4	None	6	144	Implement resource management systems that track the usage and depletion of resources.	Mining companies
20			Reputational consequences	5	Overexploitation of resources	5	None	6	150	Monitor production and resource usage levels and report on them regularly.	Mining companies
21			Legal	7	Exceeding average working hours	3	Clocking systems	7	147	Keep up to date with working time directives	Mining companies
22		Regulatory compliance	Fines	8	Inadequate understanding of regulations and standards	3	Regular internal audits to assess compliance with regulations and identify areas of improvement.	7	168	Establishment of a compliance program with policies, procedures, and training to ensure all employees are aware of and adhere to relevant regulations.	Mining companies
23			Profitability and sustainability of the operation	7	Lack of resources to comply with regulations	3	Implementation of a reporting system to track and report on compliance	5	105	Use of external consultants to provide expertise and guidance on regulatory compliance.	International Council on Mining and Metals

							issues and incidents.				
24			Legal action	9	Inadequate monitoring and reporting of compliance	4	Regular communicatio n with regulatory agencies to maintain positive relationships and stay informed of any potential issues.	5	180	Monitoring of regulatory changes and updates to ensure ongoing compliance.	International Council on Mining and Metals
25			Reputational damage	7	Lack of business	4	Compliance with regulations.	5	140	Keep up to date with changes in international standards.	Mining companies
26		Poor community relations	Social unrest	5	Lack of community engagement and consultation	4	None	7	140	Regular meetings with local communities to understand their concerns and provide information about the mining operations.	Mining companies
27			Reputational damage	7		4	None	7	196	Establishing a grievance mechanism that allows local communities to raise concerns or complaints and have them addressed in a timely and	Mining companies

										transparent manner.	
28			Sustainability of the operation	6	Inadequate communication and transparency	5	Conducting environmental and social impact assessments before and during the mining operation to identify potential impacts on local communities and take measures to mitigate them.	5	150	Use social media to promote communications.	Mining companies
29			Impacting the profitability	7	Failure to address community concerns and needs	4		5	140	Engaging independent third-party auditors to review the mining operations and assess the social and environmental impact on local communities.	International Council on Mining and Metals
30		Human resource management	Low productivity	6	Lack of motivation	5	Regularly assessing the impact of human resource management practices on the profitability and sustainability of the operation.	5	150	Maintaining open lines of communication between workers and management to identify and address any concerns or issues in a timely manner.	Mining companies
31			Reducing the profitability and sustainability of the operation.	7	Inadequate staffing levels.	6	Regularly reviewing and updating workforce planning strategies to	6	252	Regular performance evaluations and feedback sessions to identify areas	Mining companies

							ensure that the mine has the necessary skills and resources to meet production goals and respond to changing market conditions.			where workers may need additional training or support.	
32		Child labour	Legal and financial penalties	10	The use of child labour can be driven by poverty, lack of educational opportunities, and cultural norms.	6	Regular audits and inspections of ASM sites to identify any instances of child labour.	5	300	Use the conflict minerals reporting template (CMRT) for compliance.	Mining companies
33			Ethical and reputational risks for companies that rely on ASM for their cobalt supply	10	The lack of regulation and enforcement can contribute to the persistence of child labour in ASM.	5	Providing training and education to workers and suppliers on the importance of eliminating child labour and the legal and ethical implications of its use.	5	250	Conducting thorough due diligence on supply chain partners and ASM sites to ensure compliance with international labour standards and regulations.	Mining companies
34							Engaging with local communities to promote education and alternative livelihoods to	5	250	Use the conflict minerals reporting template (CMRT) for compliance.	Mining companies

							reduce the reliance on child labour.				
35							Collaboration with relevant stakeholders, such as NGOs and industry associations, to share best practices and promote industry-wide efforts to eliminate child labour in ASM.	5	250	Use the conflict minerals reporting template (CMRT) for compliance.	Mining companies
36		Legality of mining	Legal and regulatory compliance risks	9	Inadequate legal and regulatory frameworks	6	Supply chain mapping	6	324	Mines must provide strong evidence that they do not use child labour, and comply to all the regulations set out in the metal bulleting standard.	Mining companies
37					Weak governance and corruption	6	Independent third-party audits	4	216		International Council on Mining and Metals
38			Health and safety risks	8	Lack of government support and enforcement	6	Due diligence assessments	5	240		International Council on Mining and Metals
39			Market access risks	7	Poverty and limited economic opportunities	6	Collaboration with stakeholders	5	210		Mining companies
40	Trader	Market volatility	Fluctuations in cobalt prices due to supply and demand imbalances	5	Inadequate market research or analysis leading to misjudgement of future cobalt	8	Metal costing bulletin.	2	80	Traders can use various risk management techniques, such as hedging, to protect against	Traders

					demand and price trends					market volatility. This can involve using futures contracts, options, or other financial instruments to mitigate price risk.	
41			The emergence of new technologies or materials that reduce the demand for cobalt	4	Inadequate financial resources to withstand price fluctuations	5	None	7	140	Traders can use automated tools to monitor cobalt prices in real-time. This can help identify sudden price changes and enable traders to make quick decisions based on the latest market data.	Traders
42		Counterparty risks	Default or non-payment by customers or suppliers	5	Lack of adequate credit checks and risk assessments of counterparties	4	Conducting thorough credit checks and risk assessments of potential counterparties before entering into business relationships with them.	2	40	Regular monitoring and auditing of counterparty activities to ensure compliance with contractual agreements and to identify any potential risks or issues.	International Council on Mining and Metals
43			Bankruptcy or insolvency of counterparties	5	Inadequate monitoring or control of counterparty activities	3	Maintaining strong communicatio n channels with	5	75	Implementing strict contract terms and conditions that clearly define the	Traders

							counterparties to foster transparency and collaboration			responsibilities and obligations of both parties, including dispute resolution mechanisms and penalties for breach of contract.	
44			Misrepresentation or fraud by counterparties	5	Insufficient contracts or legal protections to manage counterparty risks	3	Implementing internal controls and risk management frameworks to identify and mitigate counterparty risks, including establishing risk thresholds and escalation procedures for high-risk counterparties.	8	120		Traders
45		Compliance risks	Legal penalties	8	Lack of awareness or knowledge of relevant regulations and standards	3	Regular training and education for employees on relevant regulations and standards	4	96	Use of technology such as monitoring systems and software to ensure compliance with regulations and track hazardous materials	Traders
46					Insufficient monitoring or reporting of hazardous material handling and disposal practices	3	Regular internal and external audits to assess compliance with regulations and identify	4	96	Implementation of comprehensive compliance policies and procedures, including those related to	International Council on Mining and Metals

							areas for improvement			hazardous material handling and disposal	
47			Inadequate systems or processes in place to ensure compliance with regulations	8	Insufficient training or resources to implement compliance procedures	3	Regular training and education for employees on relevant regulations and standards	5	120	Collaboration with industry groups and stakeholders to stay up-to-date on changes in regulations and best practices.	International Council on Mining and Metals
48		Reputation risks	Inadequate due diligence or monitoring of supply chain partners	7	Inadequate due diligence or monitoring of supply chain partners	4	Conducting thorough due diligence on supply chain partners, including suppliers, manufacturers, and logistics providers, to ensure compliance with relevant regulations and standards.	5	140	Implementing a robust crisis management plan that outlines steps to be taken in case of negative publicity or reputational damage.	Traders
49			Allegations of human rights abuses or environmental harm in cobalt supply chains	8	Insufficient measures to address human rights and environmental concerns in cobalt supply chains	3		6	144	Become a member of recognised groups such as CMRT	Traders
50		Operational risks	Inadequate risk management or internal control processes leading to errors or losses	6	Inadequate internal control procedures or risk management frameworks	4	Regular internal audits to assess the effectiveness of risk management and internal control processes.	7	168	None at this point intime.	

51			Inadequate cyber security measures leading to data breaches or other security incidents	6	Outdated IT systems	5	None	8	240	Upgrade IT systems to newest technology and software when possible	Traders
52		Geographical restrictions	Safety risks	7	Geopolitical tensions	6	None	6	252	Conducting regular risk assessments of supply chain partners and identifying any potential geographical restrictions that may impact the supply of cobalt.	Traders
53			Supply shortages	5		5		6	150		Traders
54		Delays	Missed deadlines	5	Transportation disruptions	7	Developing contingency plans for potential delays	7	245	Conducting root cause analysis on any delays that do occur can help to identify underlying issues and develop strategies to prevent similar delays in the future.	Traders
55			Dissatisfied customers	5	Customs clearance issues	8	Providing all relevant shipping document to border forces.	6	240	Keep up to date with changing requirements.	Traders
56			Lost business opportunities	6	Supply chain inefficiencies	5	None	7	210	Regular auditing of suppliers	International Council on Mining and Metals

57		World events	Lack of production	6	COVID/Brexit/War	7	Traders should stay up-to-date with news and events that could impact the cobalt market.	9	378	Implement a wider supply base covering different continents	Traders
58		Customs clearance (Harmonised System (HS) code 8105.20.00.00	Not delivered on time to customer	6	Not paying any applicable customs duties and taxes	5	Ensure all payments are maid prior to despatching	6	180	Training employees on import compliance and customs clearance procedures.	Traders
59					Physical inspection	6	Quality control checks during packaging	6	216		Traders
60					Not providing supporting documents	5	Proving all documents prior to despatching	6	180		Traders
61	Smelter	Downtime	Lack of raw material	6	Reliant on one supplier	6	None	7	252	Implement a diverse supply chain, having multiple sources or raw material.	Smelter
62		Human rights violations	Legal actions and fines	10	Loss of profits from fines.	4	Regular monitoring of suppliers' compliance with human rights standards and use of ethical sourcing practices.	5	200	Use the conflict minerals reporting template (CMRT) for compliance.	International Council on Mining and Metals
63					Damage to reputation	3		5	150		
64		Cost fluctuations	Buying at high price	6	Reduced profits	7	Metal costing bulletin.	2	84	Use of hedging strategies, such as forward contracts or options, to	Smelter

										mitigate the impact of price fluctuations.	
65		High inventory	Increased inventory	6	Loss if profits during revaluation of material and unable to move at current market price	7	Regular inventory management and optimisation to ensure that the smelter has adequate inventory levels without excess or obsolete stock.	4	168	Use of inventory management software and tools can also help streamline inventory management.	Smelter
66		Supplier variation	Delayed or disrupted production due to inconsistent or unreliable supply of cobalt from suppliers.	5	Limited availability of cobalt from preferred suppliers due to production issues, political instability, or supply chain disruptions.	6	Conducting regular reviews of supplier performance can identify any issues with consistency or reliability of supply, as well as variations in quality or composition.	3	90	Developing relationships with alternative suppliers can provide backup options in case of disruptions to supply from a primary supplier.	Smelter
67		Poor quality	Production delays to identify and remove low-quality material from the production process.	6	Inadequate quality control procedures, such as insufficient testing or sampling	4	Limited testing of raw material	6	144	Define a specification the raw material must hit, and analyse sample on receipt of goods.	Smelter

68			Reduced product quality due to the presence of impurities or other defects in the cobalt material.	6	Poor handling or storage practices	3	Audit supplier handling and storage processes	6	108	Use of advanced quality control technologies, such as machine vision or spectroscopy.	Smelter
69			Increased production costs due to the need for additional quality control measures, such as testing or sorting	5	Inadequate training or supervision of personnel responsible for quality control	2	None	6	60	Develop quality controls, like 'house of quality' to measure performance and propose solutions.	Smelter
70	Component Producer (Dental)	Contamination with Nickel	Major Health implications	9	Specification of material not checked	4	Perform regular testing and analysis of the cobalt material for nickel content.	4	144	Secondary sign off for booking goods into material management system.	Component Manufacturer
71		Porosity		7		4		6	168	Performing visual inspections and quality control checks during the manufacturing process to identify any porosity in the material.	Component Manufacturer
72		Carcinogenic material		8	Raw material not handled correctly	4	Use of PPE such as respirators and gloves.	4	128	Regular health monitoring to ensure workers are under exposure limit.	Component Manufacturer
73		Elongated particles	Blockages in equipment	7	Downtime	5	Quality control checks during the production process to	6	210	Implement calibration routines on particle	Component Manufacturer

							identify any elongated particles.			measuring equipment.	
74					Damage to equipment	3	Using sieving or filtering methods to remove any elongated particles from the material before it is used in the manufacturing process.	8	168		Component Manufacturer
75					Dissatisfied customers	4	Customer assurance	6	168	Audit customer complaints and work through systematically.	Component Manufacturer
76	Car Battery Manufacturer	Spontaneous ignition of battery	Fire	9	Severe damage to car	3	Thermal runaway testing during battery development and production	2	54	Infrared cameras to monitor battery temperature during use	Car battery manufacturer
77					Increased insurance premiums for end user	2	Regular inspection and maintenance of battery systems	4	72	Liability policies with manufacturers to be taken into consideration with insurers.	Car insurers
78					Dissatisfied end user	2		3	54		
79					Damaged reputation	3		3	81		
80		Toxic exposure	Health implications	9	Damaged components in battery causing fire during testing	3	Use of protective equipment during battery production and handling	3	81	Monitoring of air quality in production facilities	Car battery manufacturer

81		CO2 emissions	Increased CO2 usage	6	Periodically changing batteries making them less greener then petrol cars	5	Emissions testing during battery production and use	4	120	Use of renewable energy sources in battery production	Car battery manufacturer
82		Mileage range	Periodic battery changes	4	Increased cost for changing batteries	5	Quality control of battery cells and packs during production	6	120	BMS to monitor and optimize battery performance	Car battery manufacturer
83		Pollution	Non recycling batteries	6	Increased costs	5	Recycling of end-of-life batteries to reduce waste and pollution	6	180	Regulation and enforcement of environmental standards in battery production facilities	Society of Motor Manufacturers and Trader

Table 5 - Failure Mode Effects Analysis on the Supply Chain of Cobalt

3. Steps to Make the Supply Chain More Resilient

3.1. The Use of Cobalt

Cobalt is an element that is highly sought after, especially in the automotive industry for battery production, due to the rapid increase in demand for greener energy. It is typically extracted from mines as a by-product from mining nickel and copper, and like many raw materials, it is linked to carcinogenic properties, making it critical to handle and mine with care (Donghai Qiao, 2023). Figure 1 shows an overview of the Cobalt supply chain, from the upstream suppliers to the downstream users.

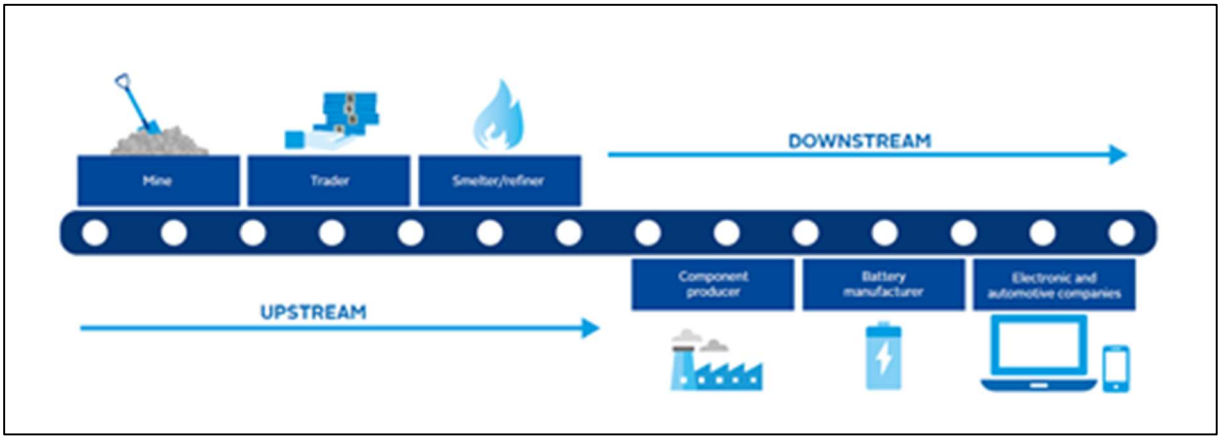

Figure 1 - Overview of the Cobalt Supply Chain (Investments, 2018)

3.2. Complexity with Mining Cobalt

The supply chain for Cobalt can be complex, involving several processes before reaching the end-user. The majority of Cobalt comes from the Democratic Republic of Congo (DRC) (72%) (Kelly, 2023). However, 20% of the 70% mined in DRC comes from artisanal mining which employs child labour, making it crucial to know the source of the mining origin at every step of the supply chain (Lawson, 2021).

3.3. Complexity with Trading Cobalt

Traders like Traxys are responsible for transporting the raw material from the mine to the smelter, where it is refined into ingot form. They offer contracts that include systems such as 'Delivered Duty Price', which benefits the buyer by allowing consignment stock to be held at the buyer's location and charged only when used in production but can disadvantage the seller as it may take time before they see a return on the product supplied (Brink, et al., 2020). The price of Cobalt changes daily, which can be problematic to finding the optimum time to buy. Figure 2 shows how volatile the costs have been over the last 13 years.

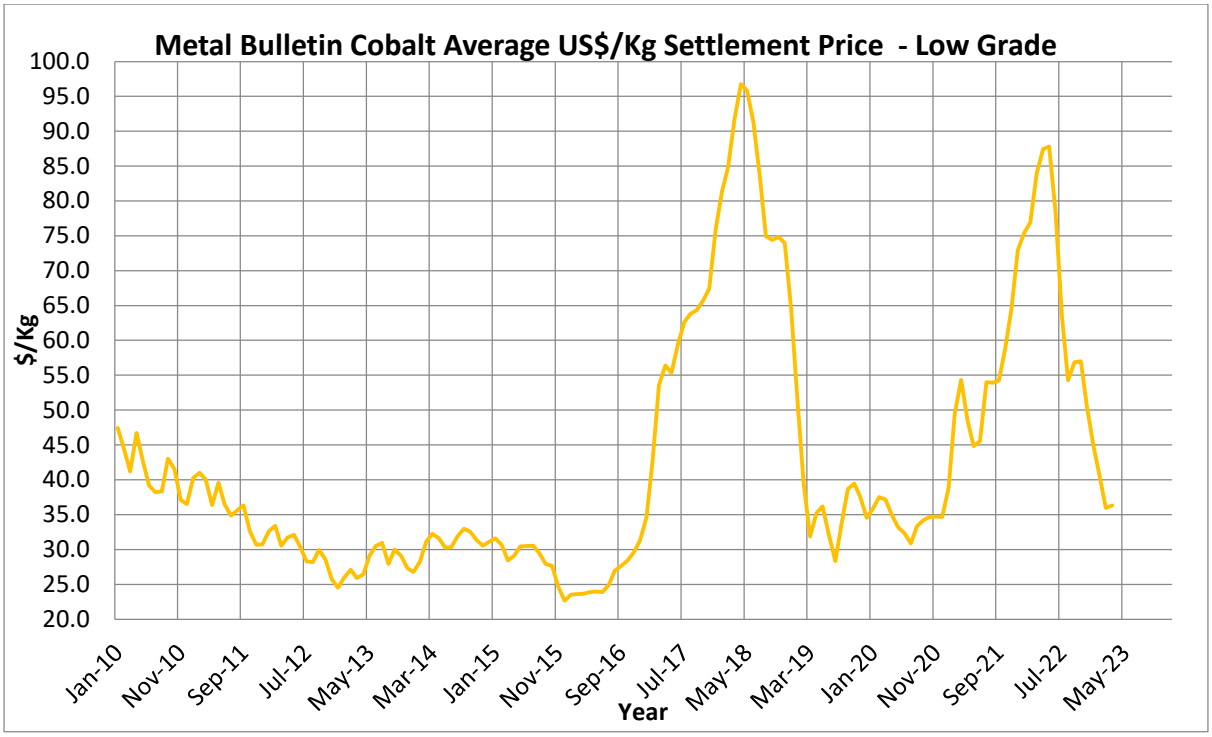

Figure 2 - Cost Fluctuations of Cobalt Since 2010. Courtesy of (Colmonoy, 2023)

3.4. Manufacturing Reliance on Cobalt

Cobalt has three main uses - in alloy form for the dental, aerospace, and oil and gas industries, as a material for coating jet engines and producing prostheses and implants; and as a key material in the production of high-density, stable, and low self-discharge rate batteries for electric vehicles, which can store a lot of energy in a small space and maintain performance over many charge and discharge cycles (Heslop, 2013).

3.5. Step One - Diversify Suppliers

3.5.1. Vulnerabilities of Single Source Supplier

Having a single supplier or location for critical components or materials can create vulnerabilities in the supply chain. The 2011 earthquake and tsunami in Japan demonstrated this vulnerability as many automakers relied heavily on Japanese suppliers for critical components, resulting in significant disruptions and production stoppages. To improve supply chain efficiency and reduce risks, it is recommended to diversify suppliers. This approach can help mitigate the impact of natural disasters, geopolitical events, and pandemics by reducing the severity and occurrence of disruptions (Son, et al., 2020).

3.5.2. Case Study: Toyota

For instance, Toyota was able to keep its production going during the Fukushima disaster by diversifying its supply chain, sourcing critical parts from alternative suppliers, and even outsourcing some component builds. In the current global shortage of microchips and semiconductors, Toyota's ability to quickly adapt has led to positive growth, while its competitors have experienced losses (Wheatley & Ramsay, 2011).

3.5.3. Case Study: Apple Inc.

Apple Inc. is also known for diversifying its suppliers across multiple countries to improve resilience and mitigate risks. When faced with a significant disruption in 2012 due to employee strikes at one of its suppliers, Foxconn's factory in China, Apple shifted its production to other suppliers in countries like Vietnam, Thailand, and Malaysia (McGee, 2023).

3.5.4. Potential Future Solutions

Given that DRC (72%), Russia (5%), and China (1%) currently supply 78% of the world's cobalt, it is necessary to explore alternative sources of cobalt such as Australia (3%), Canada (2%), and the United States (<1%), as shown from figure 3. The mining industry in DRC has been plagued by issues such as child labour and poor working conditions, while Russia and China have been criticised for their controversial politics (Garside, 2023). Additionally, Russia's recent conflict with Ukraine highlights the need to shift cobalt supply to more ethical countries that prioritise safe and sustainable working environments and have limited political implications.

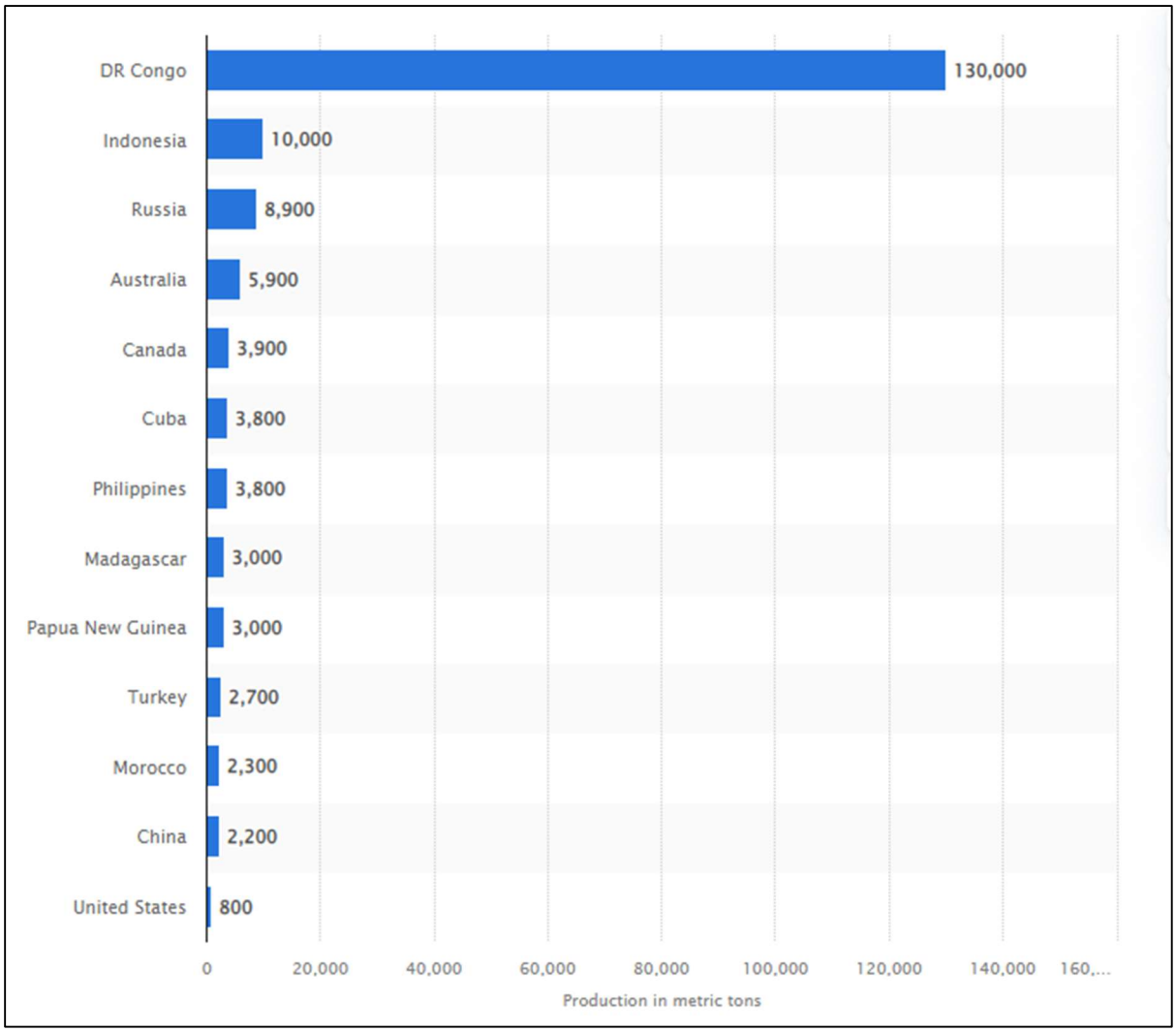

Figure 3 - Production of Cobalt from Mines in 2022. Courtesy of, (Garside, 2023)

3.6. Step Two - Use Technology to Track and Monitor the Supply Chain

3.6.1. Inadequate Visibility into the Supply Chain

Inadequate visibility into the supply chain can pose a challenge in recognising potential threats and vulnerabilities. As an illustration, the collapse of a garment factory in Bangladesh in 2013, which claimed more than 1,100 lives, revealed the lack of transparency in the supply chain of the garment industry, including the poor working conditions and inadequate safety protocols, as it produced clothing for international brands such as Walmart and H&M (Grier, et al., 2023).

3.6.2. Case Study: GPS Tracking

Real-time monitoring of inventory, transportation, and shipping can facilitate early detection of potential issues, thereby enabling prompt corrective measures and enhancing the supply chain's resilience. For instance, a global logistics firm could use GPS tracking on its delivery vehicles to monitor and reroute shipments in real-time (Blume, 2023).

3.6.3. Case Study: Walmart’s E-Coli Outbreak

Walmart has leveraged blockchain technology to monitor and track its supply chain, enabling it to swiftly identify and respond to possible issues. For instance, in 2018, when an E.coli outbreak was traced to romaine lettuce, Walmart could trace the origin of the lettuce to specific farms and promptly remove it from its stores (Rossow, 2018).

3.6.4. How to Improve the Supply Chain

Most of the world's cobalt comes from the Democratic Republic of Congo (DRC), which is one of the poorest nations globally. This poses a challenge as the data that can be extracted from the mines is likely to be limited due to outdated IT infrastructure and limited traceability. However, further down the supply chain, especially in Europe and the US, manufacturers can track and share progress with customers, enabling more accurate forward order planning and creating a more efficient manufacturing sector (Cedillo-Campos, et al., 2022).

3.7. Step Three - Implement Risk Management Strategies

3.7.1. Diversification of the Supply Chain to Mitigate Disruptions

Diversifying the supply chain can help mitigate the impact of potential disruptions, such as natural disasters or geopolitical events. For instance, in 2011, the global hard disk drive (HDD) market was severely affected by floods in Thailand, resulting in shortages and price hikes. However, Western Digital, a major HDD manufacturer, had established a diversified supply chain across various locations, including Malaysia, Singapore, and the Philippines. Consequently, the company was able to continue production and avoid major disruptions.

3.7.2. Proactive Risk Management Strategies in the Supply Chain

To proactively manage risks in the supply chain, companies can conduct risk assessments to identify potential disruptions and develop contingency plans to mitigate them. These strategies may include setting up backup suppliers, maintaining safety stock, and creating response plans for different types of disruptions. By implementing effective risk management strategies, companies can increase the resilience of their supply chain and minimise the impact of potential disruptions (Manuj & Mentzer, 2008).

3.7.3. The Conflict Mineral Reporting Template (CMRT) for the Cobalt Supply Chain

The Conflict Mineral Reporting Template (CMRT) is a standardised template for gathering supplier data on conflict minerals, specifically the 3TG minerals. Managed by the Responsible Minerals Initiative (RMI), which follows the guidelines of the Organisation for Economic Co-operation and Development (OECD) Due Diligence Guidance, the purpose of the CMRT is to help companies collect supplier data on 3TG within the cobalt supply chain. The CMRT ensures that companies meet all the conflict mineral reporting requirements accepted by the US and EU for the supply of cobalt. Ultimately, this template ensures that no child labour is being used and that working conditions are adequate throughout the supply chain. After completing the document, evidence is required, and the company is liable to ensure risk-free management from legal action for labour activities throughout the supply chain (Intelligence, 2022).

3.8. Step Four - Foster Collaboration

3.8.1. Importance of Supplier Relationships and Collaborations

Establishing strong relationships and fostering collaboration with suppliers is essential for effective supply chain management, as it can enhance the quality of production and improve the resilience of the supply chain. After the 2011 Tohoku earthquake in Japan, Toyota's suppliers collaborated to quickly resume production, which helped Toyota to recover faster than its competitors (Matsuo, 2015).

3.8.2. Communication with Suppliers

Communication and cooperation with suppliers and partners can facilitate efficient risk management in the supply chain. By sharing information and working closely with suppliers, companies can identify potential risks and develop strategies to mitigate them. For example, Walmart has a dedicated team that collaborates with its suppliers to identify potential risks and develop contingency plans (Dudovskiy, 2016).

3.8.3. Improvements to be Made in the Supply Chain

Within the Cobalt supply chain, this can be implemented through multi-stakeholder initiatives such as the Responsible Cobalt Initiative (RCI) and the Cobalt Institute. These initiatives bring together stakeholders from across the supply chain, including mining companies, smelters, and downstream users, to address sustainability issues such as human rights, environmental impact, and supply chain transparency (Dehman, et al., 2022). With the surge in demand for Cobalt, this initiative will allow the global demands to be met with sustainability as it allows for knowledge sharing between stakeholder to also ensure an ethical supply chain. Adoption of shared platforms and technologies for tracking and tracing cobalt through the supply chain can be implemented. By using a common platform, stakeholders can share information and data in real-time, enabling greater visibility and transparency through the supply chain. This can help to reduce inefficiencies, increase accountability, and improve collaboration between different stakeholders, ultimately leading to a more sustainable and responsible cobalt supply chain. However, to implement this, there would need to be funding given to the miners, especially in DRC as this investment wouldn’t be considered a priority, even with the benefits it would give downstream in the supply chain (Maiott & Katz, 2022).

3.9. Step Five - Maintain Inventory Buffers

3.9.1. Importance of Inventory Buffers

A lack of sufficient inventory buffers can leave a supply chain exposed to disruptions. The COVID-19 pandemic highlighted this vulnerability as many companies faced shortages of critical components and materials due to disrupted supply chains. Those with low inventory levels were particularly susceptible to these disruptions, as they lacked the buffer stock to weather the disruption (Hasan, 2023).

3.9.2. Mitigating Risks

To address the risk of stockouts during the pandemic, many retailers and manufacturers increased their inventory buffers. For example, Walmart ramped up its inventory of essential items like cleaning supplies, toilet paper, and hand sanitiser to ensure its stores remained stocked despite supply chain disruptions (Leonard, 2021).

3.9.3. Safety Stocks

While maintaining inventory buffers can help companies cope with disruptions, it comes at a cost. Safety stock can help bridge the gap between supply and demand during times of disruption, providing time for the company to find alternative sources of supply. However, the optimal level of safety stock should be carefully considered to balance the benefits of resiliency against the costs of holding excess inventory (Jr. & Srivastava, 1998).

3.9.4. Buy Low, Sell High Strategy

Over the past several decades, the manufacturing industry has learnt numerous lessons as a result of global crisis and natural disasters. This has led to the adoption of various inventory management techniques in the raw material industry. As a results of the Russia and Ukraine war, raw materials such as Cobalt are regularly in a volatile market. This means when the stock price is lower than the average, the majority of the supply is purchased, and the circle continues. This strategy has several limitations as the customer will have to have an efficient warehouse management system to be in line with the forward planning of production. However, this can lead to loss in profits when having to revaluate the cost of the inventory, especially if the cost of the raw material drops. Although this can work the other way and profits can increase if the material cost increases (Noble, 2022).

3.10. Step Six - Invest in Supply Chain Agility

3.10.1. The Importance of Supply Chain Agility

A supply chain that cannot adapt to changing market conditions is vulnerable to disruptions. For instance, the 2011 floods in Thailand caused significant disruption to the global HDD market, and Western Digital, a major HDD manufacturer, faced shortages and price spikes due to its lack of agility in quickly shifting production to alternative locations (Haraguchi & Lall, 2015).

3.10.2. Strategies for Building Supply Chain Agility

Investing in supply chain agility can improve a company's ability to respond quickly to disruptions. This can involve setting up flexible manufacturing processes, using modular product designs, and building redundancies at critical points in the supply chain. For example, a company might establish a local manufacturing facility in a key market to reduce lead times and increase flexibility (Alamsjah & Yunus, 2022).

3.10.3. Case Study: Nike's Manufacturing Revolution

Nike has been investing in supply chain agility to enhance its ability to respond to changing market conditions. The company has implemented a "manufacturing revolution" strategy that leverages technology and automation to produce products closer to the markets where they will be sold. This has enabled Nike to reduce lead times and promptly respond to changes in demand. For instance, during the COVID-19 pandemic, Nike shifted its production to manufacture personal protective equipment (PPE) for healthcare workers in response to the shortage of supplies (Rowsell, 2022).

3.10.4. The Future of Cobalt Sourcing & Supply Chain Agility

As the demand for greener energy continues to sore, the sourcing of Cobalt will continue its exponential importance. The International Council on Mining and Metals must research alternate ways to produce Cobalt to take the reliance from one major continent producer. Like Nickel, Cobalt may be able to be refined, which will be more sustainable for the future and will ensure agility across the supply chain when it is needed most.

4. Conclusion

In conclusion, as the demand for cobalt continues to grow, so does the importance of ensuring that its supply chain is sustainable, ethical, and resilient. The use of FMEA as a risk management tool can be highly effective in identifying and prioritising potential failure modes and the corresponding preventive measures. In particular, diversifying suppliers and utilising technology to track and monitor the supply chain are essential steps in mitigating risk and reducing vulnerabilities.

By taking action to improve supply chain sustainability and mitigate risk, companies not only contribute to a more ethical and responsible cobalt supply chain but also stand to benefit financially by improving product quality, reducing costs, and increasing customer satisfaction. Furthermore, implementing these measures can help companies meet evolving regulatory requirements and fulfil commitments to social responsibility. Overall, it is clear that a sustainable and ethical cobalt supply chain is critical to ensuring the long-term viability of the industry, and companies that prioritise these goals will be better positioned for success in the years ahead.

Within the FMEA, there are several high severity outcomes, with the majority being in the mining sector. The biggest problem the mining industry faces is Human Rights violations and poor working conditions. The predominant source is situated within the Dominic Republic of Congo where over 70% of Cobalt in the supply chain originated from. It was found that 20% of the mines in DRC are in breach of the Human Rights regulations, which adds scrutiny to the supply chain. Thus, it is critical, that an alternative manufacturer route is researched and proposed to create a more sustainable supply chain.

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