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Improving Supply Chain Performance

MODULE – PROCUREMENT AND SUPPLY CHAIN MANAGEMENT (ACEA7011)

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Abstract

This paper investigates failure mode and effect analysis (FMEA) and its use in the electrical wire supply chain.

Firstly, an overview of supply chain and supply chain management is detailed. This is followed by a brief overview of FMEA, including a history of where FMEA was first deployed, the steps required when carrying out an FMEA, followed by the desired outputs of the FMEA. The actions required because of the outputs are then discussed.

Following the introduction, an overview of the severity, occurrence and detection tables are listed. These list the failure degree rankings, effects, and criteria for each ranking.

The paper then documents an FMEA of an electrical wire manufacturer and distributor. This includes a full FMEA including corrective actions and the department responsible for fulfilling those actions.

The steps that would ensure a more resilient supply chain are then discussed. Although there are many other steps of the supply chain that could be improved upon to increase resilience, the six detailed within this paper are particularly relevant to the electrical wire supply chain.

Finally, the paper ends with a conclusion and potential future research opportunities.

Introduction

Supply chain management

A supply chain is a network of organisations that are involved through upstream and downstream linkages contributing to the different processes that are involved in the production of value in the manufacturing of goods or the provision of services (Habib, 2011)

A basic supply chain is pictured below.



Figure 1 - Basic supply chain (Chopra & Meindl, 2001)

Supply chain management (SCM) is the process of managing the flow of these materials, goods, services and information through the various suppliers, manufacturers, distributors, retailers, and customers to ensure the production and delivery of products and services to the end user.

The primary focus of SCM is to ensure that the process from raw material through to the delivery of the finished product or service to the customer is efficient, cost effective and to the customers satisfaction.

SCM involves multiple activities, these include procurement, manufacturing, production planning, inventory management, logistics, transportation, and distribution. The process begins with determining the demand for the product/ service by the customer and ends with the delivery of the finished product or service. SCM amalgamates all these elements to ensure the right products are provided to the right customers, at the right price and at the right time (Lee, 2004)

Effective SCM requires close collaborations with all stakeholders. It also requires data analytics and other tools to optimise the supply chain and improve visibility, efficiency, and responsiveness. With proper SCM, businesses can reduce costs, increase revenue, improve customer satisfaction, and gain competitive advantage within their operating market. FMEA is one of the tools that can be used to assist with effective supply chain management (Mentzer, et al., 2008).

FMEA introduction

FMEA is Failure Mode and Effects analysis, it is a structured and systematic method of identifying and preventing potential issues or failures within a system or process before they occur. FMEA was introduced in the late 1940s by the US military, in the 1960s, FMEA was used by the aerospace industry as a design methodology for reliability and safety requirements. In the 1970s, Ford Motor company introduced FMEA to the automotive sector for safety and regulatory consideration (Sharma & Srivastava, 2018). FMEA is now widely used across multiple sectors including manufacturing, healthcare, and engineering to proactively identify and address potential failures with processes and products.

FMEA consists of the following steps:

1. Identifying the system or process to be analysed.
2. Breaking down the system or process into its individual components or steps.
3. Identify potential failure modes for each component or step.
4. Assessing the severity, frequency occurrence, and detection probability of each failure mode.
5. Assigning a risk priority number (RPN) to each failure mode based on the severity, frequency/occurrence, and detection scores.
6. Identify actions that can be taken to reduce the RPN for each failure mode.
7. Implement the recommended actions and re-evaluate the RPN for each failure mode.

An FMEA uses three criteria to assess a problem, 1, the severity of the effect on the customer, 2, the frequency in which the problem is likely to occur, and 3, how easily the problem can be detected. Each criterion is scored between 1 and 10, 1 being low and 10 being high. When all three elements have been scored, the risk priority number (RPN) can be calculated. The formula for calculating the RPN is, $RPN = \text{severity} \times \text{occurrence} \times \text{detection}$ (Dendera-Gruszka & Kulińska, 2020)

There is no definitive threshold for determining which RPN output requires most attention, this requires further input from other elements, such as whether the problem is safety, legal or regulatory related. A starting point for prioritising corrective actions could be to review the Pareto principle. The Pareto principle states that 80% of issues are caused by 20% of the problems, which are the vital few (Forrest, 2010).

The actions to be implemented to reduce the RPN will be specific to each process, but typically to reduce the severity, a more robust product or process could be implemented to be able to be able to tolerate and withstand a failure without effecting the end user. To reduce the chance of occurrence, steps can be taken to understand the root cause of the issue and eliminating it, this could be achieved through root cause analysis and implementing control through training or reliable equipment and processes. Detecting the failure before it causes a problem to the end user may be achieved by introducing more quality control procedures, implementing more frequent inspections, and improving communications between the different teams proving the product or service (Hartwell, 2022)

FMEA tables

The three elements, severity, occurrence, and detection used to determine the risk priority number are shown in the tables below. The numerical values assigned to each element are dependent on the severity of failure, probability of occurrence and likelihood of detection respectively are detailed (Díaz & Soares, 2020).

Severity scale		
Rating	Failure effect	Description
10	Apocalyptic safety or regulatory issue, apocalyptic impact on customer satisfaction	The failure mode has an apocalyptic impact on the product or service. It may cause an apocalyptic level of performance issues or inconvenience to the customer. There may be apocalyptic safety or regulatory non-compliance issues associated with it.
9	Extreme safety or regulatory issue, extreme impact on customer satisfaction	The failure mode has an extreme impact on the product or service. It may cause extreme performance issues or inconvenience to the customer. There may be extreme safety or regulatory non-compliance issues associated with it.
8	Catastrophic safety or regulatory issue, catastrophic impact on customer satisfaction	The failure mode has a catastrophic impact on the product or service. It may cause catastrophic performance issues or inconvenience to the customer. There may be catastrophic safety or regulatory non-compliance issues associated with it.
7	Critical safety or regulatory issue, critical impact on customer satisfaction	The failure mode has a critical impact on the product or service. It may cause critical performance issues or inconvenience to the customer. There may be critical safety or regulatory non-compliance issues associated with it.
6	Severe safety or regulatory issue, severe impact on customer satisfaction	The failure mode has a severe impact on the product or service. It may cause severe performance issues or inconvenience to the customer. There may be severe safety or regulatory non-compliance issues associated with it.
5	High safety or regulatory issue, major impact on customer satisfaction	The failure mode has a major impact on the product or service. It may cause major performance issues or inconvenience to the customer. There may be high safety or regulatory non-compliance issues associated with it.
4	Moderate safety or regulatory issue, significant impact on customer satisfaction	The failure mode has a significant impact on the product or service. It may cause significant performance issues or inconvenience to the customer. There may be moderate safety or regulatory non-compliance issues associated with it.
3	Low safety or regulatory issue, moderate impact on customer satisfaction	The failure mode has a moderate impact on the product or service. It may cause moderate performance issues or inconvenience to the customer. There may be some safety or regulatory non-compliance issues associated with it, but they are low.
2	Slight safety or regulatory issue, minor impact on customer satisfaction	The failure mode has a slight impact on the product or service. It may cause minor performance issues or inconvenience to the customer. There may be some safety or regulatory non-compliance issues associated with it, but they are minor.
1	No safety or regulatory issue, minor impact on customer satisfaction	The failure mode has little or no impact on the product or service. It may only be a minor inconvenience to the customer, and there are no safety or regulatory non-compliance issues associated with it.

Figure 2 - Severity rating scale

Occurrence scale		
Rating	Probability	Criteria
10	Extremely high	1 in 10
9	Very high	1 in 20
8	Repeated failures	1 in 50
7	High	1 in 100
6	Moderately high	1 in 500
5	Moderate	1 in 2000
4	Relatively low	1 in 10,000
3	Low	1 in 100,000
2	Remote	1 in 1,000,000
1	Nearly impossible	Failure is eliminated through preventive control measures

Figure 3 - Occurrence rating scale

Detection scale		
Rating	Detection	Criteria
10	Almost impossible	No known controls to detect failure mode.
9	Very remote	Very remote likelihood current controls will detect failure mode.
8	Remote	Remote likelihood current controls will detect failure mode.
7	Very low	Very low likelihood current controls will detect failure mode.
6	Low	Low likelihood current controls will detect failure mode.
5	Moderate	Moderate likelihood current controls will detect failure mode.
4	Moderately high	Moderately high likelihood current controls will detect failure mode.
3	High	High likelihood current controls will detect failure mode.
2	Very High	Very high likelihood current controls will detect failure mode.
1	Almost certain	Current controls will almost certainly detect failure. Reliable detection controls are proven on similar processes.

Figure 4 - Detection rating scale

FMEA Analysis

This paper and FMEA looks at the global supply chain of electrical cable. International supply chains can be vulnerable for many reasons. Some of the more prevalent reasons are (Sambukumar & Makharia, n.d.).

- Transportation disruption: Supply chains, particularly international are heavily reliant on transportation of varying types. Disruption of these systems through natural disasters, geopolitical conflict and pandemics can cause delays and stoppages of the movement of goods.
- Unstable political and economical conditions: Unstable politics and economic downturns can cause disruption in supply chains through import/ export restrictions, currency fluctuations and changes in trade policies.
- Single supplier dependency: If a business relies too heavily on a single supplier, any disruption to that supplier will have a knock-on effect on the entire supply chain.
- Cybersecurity threats: With the increase of digitalisation and automation of processes, the risk of cyber attacks is a growing concern.
- Environmental risk: Extreme weather, natural disaster and resource scarcity can be a disruption for supply chains, this is particularly difficult where suppliers must rely on certain regions for a particular product.

The below FMEA looks at the failure modes and effects of the supply chain of electrical cable.

FMEA Analysis										
Product Name: Electrical cable			Prepared by: Shaun Farthing			FMEA date revised: 28.04.2023				
Responsible: Shaun Farthing			FMEA date original: 17.04.2023							
Process Step	Potential Failure Mode	Potential Failure Effects	Severity (1-10)	Potential Failure Causes	Occurance (1-10)	Current Controls	Detection (1-10)	RPN (Sev*Occ*Det)	Action To Be Taken	Responsible Person
What is the process step or feature under investigation?	In what ways could the step or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?	How severe is the effect on the customer?	What causes the step or feature to go wrong? (how could it occur?)	How frequently is the event likely to occur?	What controls exist that either prevent or detect the failure?	How probable is the detection of the failure mode?	Risk priority number calculated.	What are the recommended actions for reducing the occurrence of the cause or improving detection?	Who is responsible for making sure the actions are completed?
Raw material availability (base metals, plastics)	Scarcity of required material, downturn in product production.	Lack of product available, increase in purchase cost.	7	Lack of raw material through overuse. Natural disasters and extreme weather. Reliance on single supplier.	7	Working with multiple suppliers of the product to ensure robust supply.	6	294	Regular reviews with supplier to ensure availability of product, and future forecast of product availability. Build relationships with multiple suppliers to create a robust supply network. Ensure an open and collaborative working relationship with good communication. Implement damage clauses for unfulfilled or late delivery of material.	Procurement manager.
Quality of raw material.	Raw material below the required quality level.	Downturn in production availability. Inferior quality product produced.	6	Quality controls at supplier not effective. Substandard production methods.	6	Improve quality control measures. Working with supplier to ensure visibility of requirements.	4	144	Create a performance matrix to score suppliers. Ensure robust inspection regime on product received. Communicate the required standard thoroughly with supplier.	Quality department.
Valued custom.	Insufficient supply quantity. Increased purchase cost.	Downturn in production availability. Increased production costs.	6	Relationship breakdown between supplier and customer. Not being a regular customer. Inconsistent orders.	7	No known controls.	5	210	Improve relationship with supplier through workshops and creating a partnership. Improve communications and be honest with feelings and expectations. Ensure increased engagement with alternative suppliers.	Business development manager.
Availability of material.	Delayed delivery of raw material.	Delayed production. Delayed delivery of finished product.	6	Supplier lacks adequate inventory management systems.	8	Inventory management systems. Inventory audits.	6	288	Improve inventory management system. Introduce supplier forecasting software. Increase safety stock levels. Increase stock level audits.	Procurement manager.
Availability of material.	Supplier could go out of business.	Loss of supplier. Lack of material.	8	Lack of resource. Poor business model. Competition.	7	Regular financial audits. Strong resource pool.	6	336	Increase audits of company finances. Conduct employee satisfaction reviews. Ensure company has strong ethical values.	Business development manager.

Availability of material.	Supplier could experience natural disaster.	Delayed production. Delayed delivery of finished product. Lack of material. Increased costs through alternative procurement.	8	Supplier is located in an area prone to natural disasters.	6	Forecasting for extreme weather. Defences in place where possible.	6	288	Improve defence mechanism. Move facilities to less susceptible area. Ensure additional suppliers are engaged with.	Procurement manager.
Transportation delay.	Delayed delivery of raw material.	Delayed production. Delayed delivery of finished product.	7	Lack of available transport. Lack of transport operators. Breakdown of transport. Transport company ceases business operations.	8	Use of third party transport company. Regular service of transport fleet.	5	280	Improve relationship with specialist transport company. Increase maintenance periods of company vehicles. Invest in newer vehicles.	Transport manager.
Transportation damaged product.	Delayed delivery of raw material.	Delayed production. Delayed delivery of finished product. Additional cost of material.	7	Incorrect loading of transport vehicle. Poor knowledge and training of personnel.	9	Supervision of material being loaded.	6	378	Sufficient training of personnel. Ensure final check by supervisor of the secured material before shipping.	Transport manager.
Import/ customs.	Delays at customs. Refusal of entry at borders.	Delayed production. Delayed delivery of finished product. Additional cost of material.	8	Wrong or incomplete documentation. Non compliance to customs and tariff laws. Strikes by border control personnel.	8	Checking suitability and completeness of documentation by another employee. Check local government websites for strike details.	4	256	Engage with third party company for checking customs documentation. Check with borders along route prior to transport leaving to ensure alternative route is not required.	Transport manager.
Raw material storage.	Loss of material through theft and incorrect storage. Insufficient material for production.	Orders being received later than agreed.	8	Product not being stored securely. Product being incorrectly labelled.	7	Store is fitted with sufficient locks. Material storage is documented manually.	4	224	Improve security through installing CCTV and employ security staff. Improve inventory monitoring and control through an automated process.	Warehouse manager.
Production errors.	Incorrect product being manufactured.	Wrong product being delivered to customer.	9	Poor staff knowledge and training. Product being marked incorrectly.	7	Quality control measures in place to ensure correct product as per order.	5	315	Additional training and product knowledge to be delivered to staff. Increase amount of inspections before product is delivered to warehouse to ensure product is marked correctly.	Production manager.
Production breakdown.	Machinery breakdown.	Delay in receiving order.	8	Lack of maintenance on production machinery. Equipment failure.	8	Annual maintenance procedures followed.	6	384	Increase maintenance routine to 6 monthly. Ensure sufficient quantity of spare parts in maintenance stores. Increase quantity of maintenance personnel to decrease downtime.	Maintenance manager.

Quality control.	Faulty products could be delivered to customer.	Customer will receive a product that is not to the required standard.	8	Lack of quality control measures.	7	Quality control procedures are in place but not being utilised correctly.	5	280	Provide quality department staff additional training. Introduce a recognised third party accreditation (ISO9001) to ensure standards are met.	Operations manager. Quality control department.
Warehousing.	Loss of product through theft. Damage to packaging of product.	Insufficient product to fulfil orders. Damage to product packaging.	7	Insufficient security measures. Poor handling of products.	7	Warehouse is locked when unoccupied.	5	245	Improve security though installing CCTV and employ security staff. Ensure products have a specified storage area to mitigate accidental damage. Limit access to warehouse to specific staff who require access. Introduce door locks that require access badge to open to monitor access.	Operations manager. Warehouse staff.
Distribution.	Damage to products.	Customer will receive damaged goods. Supplier receives increased costs.	7	Poor handling of products. Poor shipping methods. Mishandling by haulier.	5	Using reliable transport company.	4	140	Implement procedures to ensure the correct handling of goods. Carry out quality checks of goods received. Conduct regular spot checks on transport company when loading and off loading products.	Transport manager.
Taxes, costs and regulations	Increased operational costs.	Increased costs to customer.	8	Costs relating to operating, regulatory and taxes could outweigh the profitability of the business. Loss of custom due to increased costs. Company could cease trading.	4	No known controls.	5	160	Review business strategy to ensure business is running as efficiently and effectively as possible. Stream line operations where possible. Ensure raw material is lowest cost available. Relocate manufacturing operations to area with less resource costs or within area where most sales take place to avoid export duties.	Operations manager.
Exportation.	Denied access for goods in receiving country.	Customer does not receive products.	8	Wrong or incomplete documentation. Non compliance to customs and tariff laws.	5	No known controls.	4	160	Engage with third party company for checking customs documentation. Set up a base in the receiving country so the company is also registered in the receiving country.	Operations manager.

Figure 5 - FMEA

Steps to make the supply chain more resilient.

The supply chain is a fundamental part of the running of a business. Without an efficient and effective supply chain, businesses will not operate. The importance of having a trusted supply chain is key to successful operations. The steps detailed below help create a more resilient supply chain regarding the electrical wire supply chain.

Alternative suppliers.

The use of alternative and varied suppliers reduces the risk of disruption of supply. The primary supplier may encounter a natural disaster, labour strikes or financial issues and may not be able to deliver on the agreed material. Having an alternative supplier base ensures continuity of supply should any of the above happen. In the case of the electrical wire industry, raw materials, particularly base metals are mined, this industry is particularly challenging, having options of suppliers ensures that production can continue through multiple supply routes.

Having a varied supplier base also ensures that the material the company is purchasing is at a competitive price. A comparison can be made considering the cost and lead time for the material to be supplied. This is particularly important in the case of copper and aluminium, the cost of these products changes frequently.

Including multiple suppliers in the procurement process also provides insight into innovative products. Although, within the electrical wire industry, copper and aluminium are industry standards for conductor material, the insulation parts of the cable are developing. Purchasing products with better fire rating properties and less environmentally impacting products ensure that the company is trading ethically and is environmentally conscious (Costantino & Pellegrino, 2010)

Multiple transportation modes.

Multiple transportation modes offer many benefits. Cost savings can be achieved by evaluating which method of transport is most suitable. As an example, with electrical wire transportation, it may be more cost effective to fill a container on a ship rather than use multiple road lorries. This may improve the delivery time, reduce cost and be more environmentally beneficial. This may not always be the case; transport will require review dependant on where the product may need to be sent. Often, multiple transportation modes may be used during a delivery.

Utilising various modes of transport also reduces the risk of reliance on one mode of transport. Weather, labour strikes or other disruptions may be an issue with a particular transport mode but not on another, having the flexibility to choose another will improve efficiency and reduce the likelihood of delayed deliveries.

The electrical wire industry from raw material to finished product spans the globe, having the availability of a diverse transportation network is imperative for effective and efficient operations (Knowledge center, 2022).

Inventory management.

Inventory management is an important aspect of supply chain management. Holding enough stock to ensure customer demands can be met whilst not holding excessive stock levels that ties up capital and creates storage costs is a balance. This is particularly important in the electrical wire supply chain, as with larger cables, the costs can be quite extensive. Only carrying required stock levels also reduces the storage costs, handling costs and insurances.

Although, having stock available allows the company to be able to react to customer needs, being reactive when they require the product is important. This allows the customer to build confidence in the company and increase the chances of return custom. Stockouts are also less likely to occur when inventory is managed effectively. Having an accurate picture of available product also allows for better forecasting and reduces bottlenecks in the manufacturing and distribution processes (Ewen, 2022).

Strong supplier relationships.

A strong relationship with suppliers is critical to the business. A strong supplier relationship ensures consistency of supply, the company can rely on the supplier to provide the goods and service required, at the right time and to the correct standard. This aids in the reliability of the companies' operations.

Building a strong relationship with suppliers also ensures quality standards are consistently being met through feedback and review. Having this element consistent reduces the likelihood of defective and substandard products or services, which reduces the chances of downtime, revenue loss, and penalties.

Working with specific suppliers and placing most orders with one supplier strengthens the opportunity to negotiate costs of material. This can decrease manufacturing costs and increase the potential profit. This will give the business a competitive market advantage. This is particularly true within the electrical wire sector as the raw material costs tend to fluctuate quite rapidly (Gadde & Snehota, 2000).

Contingency planning.

Contingency planning is useful for highlighting potential risks in the supply chain and creating strategies to overcome these disruptions. Creating a contingency plan allows businesses to overcome issues in raw material supply, manufacturing, storage and distribution by being aware of other options if these issues were to arise. Having a contingency plan allows the business to avoid delays and fulfil customer expectations, therefore maintaining reputation. Having a contingency plan also helps with avoiding financial loss through having to procure additional material or receiving penalties through loss of product delivery. Raw material supply for electrical wire manufacture is a difficult process, a contingency plan is vital to ensure no delay in production (Black & Glaser-Segura, 2020).

Investment in technology.

Investing in technology is a crucial part of the supply chain, technology allows for processes to be improved for efficiency and productivity. The electrical wire making process can be automated to allow for increased output, less chance of error, and a faster, safer, and more reliable manufacturing process.

Improved technology can also aid with raw material order and product delivery. Having real time tracking and up to date material and product levels can help in optimising inventory levels, optimise logistics and reduce operating costs. This will give visibility to the business requirements.

Utilising available technology can help streamline a business, reduce operating costs, and create a more reliable service. This will in turn improve customer experience and satisfaction (Ashaolu, 2021).

Conclusions and suggestions for further work/research

The supply chain and its management are ever-evolving fields. The key areas requiring further work and research are:

- Sustainability and ethical practices. There is more focus than ever on sustainability and social and environmental responsibility. The supply chain must evolve in a way where harm to the environment is limited, waste must be reduced and recycled, and ethical practices must be developed and implemented. This area of the supply chain is of particular importance to ensure the longevity of natural resources.
- Digitalisation. Although there is risk through cyber security, the future of efficient supply chains is utilising technology. Artificial intelligence, advanced analytics and IoT are key drivers to the future supply chains. Further research into the utilisation of these technologies will create an optimised, efficient, reliable, and robust supply chain.
- Circular economy. The circular economy model states that waste should be minimised, and products should be reused and recycled. The supply chains of the future must adapt this approach and develop systems that are durable and recycles and reduces waste through the network. Further research into this field will be beneficial for supply chains.
- Automated transportation. With the limitations around driving hours for hauliers. Automated transportation could be a worthy avenue of research. Automation of transportation could improve delivery time and reduce the risk of accidents through tiredness and other human factors.

I feel that the points documented above are some of the most important factors for the future of supply chains.

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