Course: MSc Engineering Project Management

Module: ACEA7011 Procurement & Supply Chain Management

Assignment: Improving Supply Chain Performance

University number: 1809810

Date submitted: 18/04/2024

Word count: 3158

Contents

1. Introduction..... 5

2. FMEA Analysis. 7

3. Supply Chain Resilience. 13

4. Conclusions & Recommendations. 16

5. References..... 22

6. Appendix..... 26

Table of Figures

Figure 1 - Tin Plate Coils 5
Figure 2 - FMEA Analysis Severity Table 26
Figure 3 - FMEA Analysis Occurrence Table 26
Figure 4 - FMEA Analysis Detection Table 27
Figure 5 - FMEA Analysis Risk Priority Scoring 27

Table of Tables

Table 1 - FMEA Analysis 12
Table 2 - Revised FMEA Analysis 21

1. Introduction.

The supply chain analysed is that of a world-leader in the UK steel manufacturing industry, employing in excess of 6500 personnel in Wales and a further 1500 across the rest of the UK. The company manufactures several million tonnes of steel each year (MS, 2024), with a dedicated packaging and recycling division, responsible for the production of tin plate, and processing of batches of steel-strip coil. It is this division of the company that is of interest, as it involves a global supply chain from starting materials to finished products (Tata Steel Europe Limited, 2024).

The strategic location of company's facility provides it with direct access to essential resources and transport routes, facilitating continuous operations and efficient distribution channels. Its proximity to key transportation networks enables streamlined export activities, solidifying its position as a prominent performer in the international tinplate market. Furthermore, the company's success lies within a relentless commitment to excellence and sustainability. Through rigorous quality control measures and sustainable practices, the facility ensures its tinplate products meet the highest standards whilst minimising environmental impact. This dedication to quality and sustainability not only enhances customer satisfaction but also underscores the company's role as a responsible corporate citizen. (Tata Steel, 2024) (Tata Steel Europe Limited, 2024)

Figure 1 - Tin Plate Coils

(Thomas, 2022)

Tinplate produced by the company serves as a versatile material with numerous of applications across various industries worldwide. Tinplate plays a vital role in modern manufacturing in industries such as packaging, automotive, construction, and consumer goods. Its unique combination of properties, including corrosion resistance, formability, and aesthetic appeal, make it indispensable for a wide range of applications. One of the primary applications of tinplate is in the packaging industry. Tinplate's corrosion-resistant properties and ability to form a hermetic seal make it an ideal material for food and beverage packaging. From canned foods to aerosol containers, the company's tinplate ensures product integrity, prolongs shelf life, and protects contents from external contaminants. Moreover, tinplate's aesthetic appeal allows for attractive packaging designs, enhancing product visibility and consumer appeal. (Tata Steel, 2024)

The company's global tinplate distribution network spans continents, with a wide range of tinplate products tailored to meet specific customer requirements, the facility serves as a trusted partner for businesses seeking reliable and innovative steel solutions. The facility's global reach is reinforced by the parent company's extensive presence and reputation as one of the world's leading steel manufacturers. Leveraging collaborations within the parent company group, the packaging and recycling plant seamlessly integrates into the broader ecosystem, capitalising on shared resources, expertise, and market insights to drive growth and deliver value to stakeholders worldwide. (Tata Steel, 2024) (Tata Steel Europe Limited, 2024)

International supply chain performance is critical due to its profound implications on various aspects of the company's operations, competitiveness, and sustainability in the global marketplace. Ensuring an efficient supply chain play a pivotal role in driving the company's economic growth, enhancing customer satisfaction, and fostering innovation whilst mitigating risks and ensuring regulatory compliance. Prioritising supply chain optimisation and resilience allows the company to be better equipped for navigating the complexities of global supply chain, global markets and achieve long-term success (Świerczek, 2014). Periodic assessment of supply chain performance is therefore essential to provide assurance of current processes in place and present opportunity for quality improvement measures to be implemented.

2. FMEA Analysis.

Failure Modes and Effects Analysis (FMEA) is an established tool used across various industries to allow for identification and evaluation of potential failures within a process, product, or system in a methodical manner. It aims to avoid or if not mitigate failures before they occur, allowing for users to prioritise identified failures, based on their potential impact thereby enhancing reliability, safety, and quality (Institute for Manufacturing, 2024).

FMEA process typically involves a multidisciplinary team from their relevant field of expertise. Together, this team systematically analyses the components, subsystems, or processes of the system under consideration, identifying all possible failure modes, in which ways components or processes can fail to perform their intended functions. Furthermore, identified failure modes are assessed for their potential effects on the overall system, including considerations for factors such as safety hazards, environmental impact, customer dissatisfaction, and financial losses (Leeuwen, 2009). Using historical and other relevant information available, in addition to engineering knowledge from the team, the likelihood or frequency of occurrence for various failure modes are assessed and evaluated to identify failures before they impact the system. Further assessment of the effectiveness of existing detection methods or controls in place also feed into the analysis (Kapil Dev Sharma, 2018) (P. Sheikh Damanaba, 2015).

Each of the failure modes is assigned a severity rating based on the defined consequences of the failure using a numerical scale. Multiplying severity, occurrence, and detection scores together calculates a Risk Priority Number (RPN) for each identified failure (Kapil Dev Sharma, 2018). This quantitative measure of risk helps prioritise failure modes, with higher RPN values indicating greater risks requiring immediate attention. Based on the prioritised list of failure modes, action plans to mitigate the identified risks are developed. Taking into consideration how the RPN is calculated, these will often include design changes or process advancements to reduce occurrence, further testing to improve detectability, or the implementation of new control measures to reduce likelihood (P. Sheikh Damanaba, 2015).

Throughout the FMEA process, documentation is crucial to capture all findings, recommendations, and actions taken. Regular reviews of the FMEA ensure that it remains up-to-date and relevant, facilitating continuous improvement in reliability and risk management. See below for FMEA analysis of international supply chain (Institute for Manufacturing, 2024).

Tin Plate Distribution FMEA Analysis										
Area	Number	Function	Potential failure mode	Potential effect of failure/defect	Severity	Potential causes of failure/defect	Occurrence	Preventative measures	Detection	RPN
What is the area?	FMEA No	What is the function?	In what ways can it go wrong?	What is the impact if the failure mode is not prevented?	How severe is the effect?	What causes the step to go wrong?	How frequently is the cause likely to occur?	What are the preventative measures in place to stop or detect the failure?	How probable is detection of the failure or cause?	Risk Priority Number?
Plant Operation	1	Raw Material Supply	Poor delivery/performance of raw material supply	Inability to maintain continuity of supply	9	Poor delivery performance Reduction in production	5	Continual monitoring. Buffer stocking of required materials. Contingency storage of material	4	180
	2	Lack of or reduced production	Unable to produce required material or material quantity	Unable to produce or process material	9	Machinery breakdown.	4	Preventative/predictive maintenance. Regular maintenance operations. Monitor maintenance activities. Buffer stocks.	2	72
			Loss of production personnel	Unable to conduct business. Unable to operate production lines	7	No succession planning. Industrial action. Accident resulting in serios injury. Ill health / pandemic.	3	Multiskilled operators. Flexible management team. Negotiation procedures. Buffer stocks. Risk assessments. H&S procedures. Risk assessments. Safe working environment. Contingency planning of work force. Company policy. Government guidelines.	2	42
	3	HSE Action	Closure of line or site	Unable to produce or process material	9	Breach of health and safety or environmental regulations	3	Adequate H&S Policy Robust company H&S management system	3	81
	4	Overhead crane operation	Lack of operation	Unable to move material / stock	7	Machinery breakdown.	4	Preventative/predictive maintenance. Regular maintenance operations. Monitor maintenance activities.	2	56
	5	Loss of plant utilities	No operation	Unable to process or produce materials for despatch	10	Utility failure	3	Utility contingency planning. Redundancy in plant network. Portable utility connection/hook-ups. Electricity/Water/Steam/Gas	2	60
Dispatch Planning	6	Information technology failure	Loss of access to required databases	Inability to conduct business	8	Computer failure. Internet failure. Server failure. Hacking/bugs in information technology system.	4	Company IT management and IT security. Manual dispatch process	2	64
	7	International dispatch instruction raised on customer requirements.	Requirement entered incorrectly with wrong product specified	Incorrect material delivered to customer	8	Incorrect data entry by commercial representative	4	Unlikely to detect, but possible will be noticed throughout processing	5	160
			Accept requirement without capability to produce	Inability to manufacture order requested by customer		Failure to check capacity		Unlikely to be picked up until trying to schedule		
	8	Load Building / create planned loads for despatch, by Transport Planners	Changes by Commercial as plans are created	Delays due to changes in loading schedule	5	Variations in customer requirements not communicated to transport planners	5	Operators may note irregularity on schedules	4	100
			Plan is inaccurate in terms of delivery date	Parts delivered on wrong day/time	6	Manual error in order creation / Planners do not incorporate advised changes	4	Hauliers/Sales checks may detect	4	96
	9	Delivery schedule planning / transmit requirements	Unable to transmit data	Requirement to move to manual process	6	IT maintenance and upgrade management failure	5	Failure would be picked up by hauliers or transport planner	3	90
	10	Assign hauliers /each load has assigned haulier	No haulier available	Inability to meet customers expected delivery date/time	7	Exceptional issues related to Brexit and driver supply	6	Detection obvious	2	84

	11	Load Plan / Create load plan for manufacturing	Wrong details on load plan (date / time / SO)	Disruption and potential to miss customer expected delivery date/time - line stop	5	Load planner does not accurately add information	5	Operator/Sales may note irregularity - Important loads checked	3	75
			Load plan delayed - manpower issues	Delay whilst load plan created		Load planner fails to create load plan		Detection obvious		
	12	Haulier Failure	Haulier cesses trading	Unable to deliver materials	9	Liquidation	4	All transport companies managed and regularly audited. More than one transport company used	5	180
Transport - Weighing in	13	Measure vehicle gross weight (External vehicles)	Wrong vehicle gross weight recorded	Tare weight will be inaccurate. Vehicle may need to be reweighed	7	Vehicle not parked correctly on weighbridge	6	Visual check	2	84
				Tare weight will be inaccurate. Vehicle may need to be reweighed		Weighbridge not correctly calibrated		Visual check - Calibration record		
				Tare weight will be inaccurate. Vehicle may need to be reweighed		Additional weight on weighbridge (e.g. driver)		Visual check		
	14	Measure vehicle gross weight (Internal vehicles)	Wrong vehicle weight recorded	Tare weight will be inaccurate. Vehicle may need to be reweighed	6	Vehicle not parked correctly on weighbridge	6	Visual check	2	72
						Weighbridge not correctly calibrated		Visual check - Calibration record		
						Additional weight on weighbridge (e.g. driver)		Visual check		
	15	Vehicle moves to correct loading bay	Vehicle arrives at wrong bay	Minor delays whilst vehicle routed to correct bay	5	Security advises driver to go to wrong bay	4	Driver will not be able to collect load from wrong bay. Will be picked up by despatch operator	3	60
						Driver has correct directions, but goes to wrong bay		Driver will not be able to collect load from wrong bay. Will be picked up by despatch operator		
Job Picking	16	Locate stock in warehouse using - the location details on database, tag ID	Material not in designated location	Delayed loading whilst material is located.	9	Poor stock control practices	4	Will only detect by audit prior to requirement or when collecting	5	180
			Material cannot be found	Load cannot be completed if no alternative material is available.						
	17	Validate tag - Check details of pick job list and tag details match. Check product characteristics match requirement	Details do not match	Delay to customer load whilst issue investigated	7	Poor stock control practices	4	Will only detect by audit prior to requirement	4	112
				Failure to deliver if issue cannot quickly be resolved and no alternative product available						
			Check not completed, wrong material picked	Wrong material picked and potentially delivered to customer.	6	Operator does not complete check or does not notice mismatch	3	Visual inspection at later stage prior to despatch	3	54
			Labels swapped between packs	Wrong material picked and potentially delivered to customer.	6	Operator selects more conveniently located pack and swaps labels, but pack does not match	3	Difficult to detect if loader has switched labels	6	108
	18	Visual inspection of pack and visible product / Suitable for despatch	Packing damaged or inadequate	Delay whilst product is repackaged or potential for load to be shipped in unsafe condition.	5	Poor material handling or packing at earlier stage	3	Visual inspection	3	45
			Product damaged	Delay or inability to meet load if cannot be reworked and no suitable replacement available	6	Poor material handling	3	Visual inspection	3	54

	19	Pre-prepare load for despatch / relocate stock to holding area, ready for loading on vehicle	Product gets damaged during relocation or label becomes detached (product identification) or switched by operator	Delay whilst material is corrected	5	Crane or Forklift truck (FLT) causes damage or impact with other objects	4	Visual inspection	3	60
				Inability to meet load if cannot be repaired and no suitable replacement available	7	Crane or Forklift truck (FLT) causes damage or impact with other objects	4	Visual inspection	3	84
				Incorrect label attached to product	6	Operator has exchanged labels inappropriately	4	Random audit process	2	48
	20	Confirm pick in company database / Update database	Information not recorded or inaccurately recorded in database	Delay in despatch whilst issue is resolved	6	Operator does not update or records information inaccurately	3	Job screen must show 100% and no red x to progress	2	36
			Unable to pick material as owned by other warehouse (e.g. Profiles)	Delay waiting for transport to update pick	5	Systemic issue related to warehouse set up in database	3	Job screen must show 100% and no red x to progress	2	30
	21	Print replacement labels if required	Failure of printer	Delay whilst printing on alternative printer	6	Printer damage / maintenance	4	Printer failure obvious	2	48
			Wrong label printed	Delay reprinting correct label	5	Operator selects wrong label to print	4	Visual inspection	3	60
			No labels at printer	Locate labels	5	Stock not managed	5	Visual inspection	3	75
	22	Update pack label	Mislabelling of product with wrong labels	Customer receives wrong pack	8	New labels correct but attached to incorrect product item / New label incorrect and attached to planned item	4	Visual inspection during loading	3	96
				Internal failure to be corrected	7	New labels correct but attached to incorrect product item / New label incorrect and attached to planned item	4	Visual inspection during loading	3	84
Loading Process	23	Loading team review loading lists / identify load details and priorities	Load list not available	Delays to preparing loads	8	Database failure	4	Lack of list obvious	2	64
			Priorities not followed	Priority loads are not prepared when required		Inadequate planning by loader		Unlikely to be picked up		
			Loaders allocate incorrect part numbers / quantities to loads	Incorrect products reach customer		Operator error		Only picked up through random audits		
	24	Print loading list or pick list	Local printer does not function (dust) / paper not available	Delay to preparing loads	5	Printer maintenance (IT process)	3	Visual check. Printer failure obvious	2	30
			Database not available	Delays to preparing loads		IT system failure				
	25	Print loading requirements / Instructions for loader	Printer failure	Requirement to print on alternative printer	6	Printer damage/maintenance	3	Visual check. Printer failure obvious	3	54
			No paper available	Delay locating paper		Failure to monitor stock				
			Wrong list printed	Wrong load loaded		Operator selects wrong list				
	26	Confirm stock item availability / list completed	Labels not inspected and validated	Potentially incorrect material supplied to customer	7	Operator does not detect issue	4	Weight discrepancy on weighbridge	3	84
			Labels swapped between packs	Wrong material picked and potentially delivered to customer.		Operator selects more conveniently located pack and swaps labels, but pack does not match		Difficult to detect if loader has switched labels		
			Required product cannot be found	Delay to shipment locating alternative stock		Poor stock management		Obvious pack is unavailable		

	27	Locate trailer for load based on company database instruction	Selected trailer unsuitable for load	Delay whilst relocating a suitable trailer	5	Shunter driver does not inspect trailer	4	Visual inspection by loader	3	60
			No trailers available	Rescheduling of loads whilst suitable trailer is located, leading to delivery failure		Transport planning does not account for number of required trailers		Obvious that there is no trailer		
	28	Validate paperwork prior to loading / transport number and weighbridge ticket are aligned	Paperwork is not aligned	Delay whilst issues are investigated and resolved	5	Weighbridge or transport number incorrect	4	Visual inspection by loader	3	60
			Trailer not weighed in	Trailer returns to weighbridge, delay in loading		Driver has not crossed weighbridge		Will be picked up when leaving he plant, not at this point		
Transport - Weighing Out	29	Loader to instruct driver to return to weighbridge	Driver attempts to leave site without weighing out	Delay to delivery as vehicle will be stopped at weighbridge and returned to be weighed	5	Driver fails to follow process	4	Without gate pass, vehicle will not be able to leave site.	2	40
	30	Load note handed to weighbridge	Driver presents wrong paperwork	Delay whilst correct paperwork located	5	Driver error	4	Weighbridge operator visual check	2	40
	31	Wagon weighed on weighbridge and weights compared to create load net weight	Vehicle not positioned correctly on weighbridge	Incorrect net weight, won't match, delay	8	Driver error	5	Visual comparison	4	160
			weighbridge inaccurate	correct net weight, won't match, delay		Calibration error		Company management system		
			Vehicle was not weighed in	No net weight available		Driver error		Cannot create tare weight		
			Weighbridge broken down	Relocate vehicle to alternative weighbridge		Weighbridge maintenance		Obvious if broken down		
			Vehicle exceeds max gross weight in line with H&S Regulations	Transport of load on roads would be illegal and affect road safety		Excess packs loaded; packs heavier than planned		Weighbridge operator visual check of indicated weight.		
	32	Load weight validated against paperwork and within tolerance	Weights do not align within tolerance	Delay whilst vehicle returned to bay for load check and reweigh	6	Incorrect packs loaded to vehicle or pack weights do not match	4	Visual comparison of paperwork	2	48
	33	Despatch note created / weighbridge operator creates note in Stratix and hands to driver	Despatch note not created or not handed to driver	Vehicle leaves site without paperwork and customer does not have paperwork to book material in	7	Requires failure by both operator and driver	3	High chance that driver will notice he doesn't have paperwork...	2	42
	34	Gate pass issued / required for vehicle to leave site	Gate pass not issued	Vehicle has to return to weighbridge for pass	4	Driver leaves weighbridge before pass is issued	2	Required by security for exit	2	16
			Gate pass has wrong details and doesn't match despatch note	Wrong material delivered to customer		Gate pass allocated to wrong despatch notes		Visual inspection by driver (safety check)		
	35	Controlled exit of vehicle from site / Security retain and file gate passes	Driver leaves site without handing in gate pass	Incomplete records	4	Driver leaves site without handing in gate pass	3	Security requires pass to allow departure	2	24
Company	36	Fraud / Theft	Incorrect information	Loss of product. Financial loss	9	Poor stock management. Untrustworthy transport partner	2	Company management system. Audit and verify delivery company. Regular stock take	2	36
	37	Product liability	Material damaged in transit	Damaged material delivered to customer	6	Material damaged outside of required specification	4	Approved supplier/delivery partners. Regular cross auditing. Driver training. Strapping and slinging training.	2	48
	38	Competitor activity	Erosion of customer base	Loss of business	8	Increased cost of product. Reduced profit. Under-cut by competitors.	6	Continuous improvement activities. Continuous monitoring of competitors and marketplace.	5	240

	39	Loss of accreditation	Erosion of customer base	Loss of business	9	Loss of adherence to business	3	Internal and external auditing of company and procedures. Monthly review of procedures.	3	81
	40	Customer insolvency	Erosion of customer base	Loss of business	8	Bankruptcy / Receivership	3	Blue chip customer base. Blue chip companies are stable, profitable and seen as safe investments in their industries.	2	48
	41	Communication failure	Loss of access to required databases	Delivery failure. Loss of existing and new business. Customer dissatisfaction	9	Communication failure. Internet failure. Server Failure. Hacking/bugs in information technology system.	3	Company IT management and IT security. Key contact list to major customers, use of mobile phones.	3	81
	42	Natural or manmade disasters	Lack of production. Unable to deliver goods and products	Unable to process and supply goods and materials. Damage to goods and plant. Unable to conduct business. Unable to operate production lines	8	Faulty equipment. Incompetence. Lack of maintenance Natural disaster	3	Preventative/predictive maintenance. Regular maintenance operations. Monitor maintenance activities. Monitor global and local news feeds. Review contingency plans.	7	168
	43	Emergency event away from site	Road or shipping network disruption	Unable to safely conduct business	8	Accident or event at customer or supplier Accident or event in delivery supply chain/route	4	None Preventative/predictive maintenance of transport. Regular maintenance operations. Monitor maintenance activities.	9	288
	44	Industrial Action	Industrial action by company personnel Industrial action by transport partners	Loss of facility. Loss of personnel. Loss of production. Loss of customer base. Loss of business. Loss of delivery reliability. Loss of personnel. Loss of customer base. Loss of business	8	Industrial action	4	None All transport companies managed and regularly audited. More than one transport company used	3	96

Table 1 - FMEA Analysis

(Kulińska, 2020) (Forrest, 2010) (Judyta Kabus, 2020) (Chih-Yuan Chu, 2020) (Tata Steel, 2005) (Annick Melanson, 2019)

See appendix for FMEA severity, occurrence, detection and risk priority number tables.

3. Supply Chain Resilience.

As a successful international company, supply chain performance of the company speaks for itself. That being said, although it is acknowledged undertaking the FMEA as an individual exposes a level of subjectivity bias, FMEA analysis has indicated a number of areas that pose a level of risk to supply chain resilience. FMEA numbers 1,7,12,16,31 and 38 are six areas where the risk priority number (RPN) is higher than 160, presenting a level of risk classed as permissible to intolerable (Annick Melanson, 2019), and therefore should be given due consideration for improvement.

The supply of raw material is a pivotal aspect for tin plate international supply chain, serving as its lifeline, directly influencing its efficiency, cost-effectiveness, and resilience. The availability and quality of raw material can significantly impact production schedules, product quality, and ultimately customer satisfaction. The importance of raw material supply lies in its role as the foundation upon which the entire supply chain operates; without a reliable and resilient raw material supply, the company faces numerous challenges, including production delays, increased costs, and potential disruptions to customer orders (McKinsey Global Institute, 2020).

There are several measures that can be taken to enhance the resilience of supply of raw material to the company. By evaluating suppliers on factors such as reliability, financial stability and observance of quality standards, and implementing rigorous supplier assessment mechanisms, including audits, performance tracking, and contractual agreements, assurance of consistent supply and mitigation of risks associated with unreliable raw material supplies can be achieved (Behnam Fahimnia, 2016). Additionally, developing a partnership or collaborations with raw material suppliers and other stakeholders to enhance communication, build trust, and jointly address supply chain challenges. Implementing joint initiatives for advanced tracking and monitoring systems can improve supply chain transparency, enabling better risk management, knowledge sharing and quicker response to potential disruptions, enhancing supply chain resilience (Nabeel A. Mancheri, 2018) (McKinsey Global Institute, 2020).

Optimising inventory levels and maintaining buffer stocks can help mitigate the impact of supply disruptions, ensuring continuity of production, even during unforeseen circumstances. Furthermore, implementing a culture of continuous improvement by learning from past disruptions, staying abreast of technological advancements, and adapting processes to changing market conditions can enhance supply chain resilience, assuring a sustained process (McKinsey Global Institute, 2020).

International dispatch instruction raised on customer requirements, is a pivotal aspect of the tin plate international supply chain, directly impacting customer satisfaction, operational efficiency, and overall business success. It involves aligning dispatch instructions with specific customer demands, ensuring timely and accurate delivery of tin plate. Customer-centricity is paramount (McKinsey Global Institute, 2020). Meeting customer requirements precisely enhances brand reputation, fosters loyalty, and strengthens long-term relationships. Failure to adhere to customer specifications can result in dissatisfaction, loss of trust, and potential business erosion. Efficient dispatch instruction management streamlines operations, minimising lead times, reducing inventory holding costs, and optimising resource utilisation (Timothy J. Pettit, 2014).

The efficacy of international dispatch instruction raised on customer requirements is contingent upon effective execution and resilience strategies. To bolster the supply chain's resilience, several proactive measures can be undertaken (Timothy J. Pettit, 2014). Firstly, a comprehensive risk assessment to identify potential disruptions, such as geopolitical instability, transportation bottlenecks, or supply shortages, whilst developing robust contingency plans to mitigate risks and maintain business continuity, should be conducted. Additionally, diversifying the supply chain can reduce dependency on single suppliers or markets, locations and customer bases, mitigating the impact of localised disruptions enhancing flexibility in response to changing market dynamics (Juneho Um, 2020).

Investing in advanced technologies, such as supply chain management systems and use of predictive analytics to enhance oversight offering visibility, traceability, and decision-making capabilities, can leverage data-driven insights, enabling proactive risk management and operational optimisation (Behnam Fahimnia, 2016). Additionally, embracing a culture of continuous improvement and innovation to adapt to evolving customer needs and market trends, whilst regularly reviewing and refining the company’s dispatch process and incorporating feedback and lessons learned from all stakeholders to enhance efficiency and resilience over time, can enhance supply chain resilience (McKinsey Global Institute, 2020).

The disruption caused by collapse or failure of transportation companies is a critical issue with profound implications for the company’s tin plate international supply chain. Haulier failure can lead to delays and interruptions in transportation, impacting production schedules and delivery commitments. This can result in inventory shortages or surpluses, affecting market dynamics and customer satisfaction (Wilson, 2007), with a resulting ripple effect across the supply chain, affecting upstream and downstream partners. Suppliers are likely to face payment delays or defaults,

whilst customers could experience shortages or quality issues. Such disruptions can erode trust and strain relationships within the supply network, potentially leading to long-term consequences for competitiveness and market positioning. Additionally, the financial repercussions of haulier failure can be significant, with increased costs stemming from re-routing shipments, re-negotiating contracts, or seeking alternative transportation providers (Wilson, 2007) (Marieke S. van der Tuin, 2020).

The importance of addressing haulier failure lies in its potential to disrupt the flow of goods, increase costs, and undermine reliability and efficiency. There are several steps that can be taken to enhance resilience of the supply chain. Relying on a single haulier increases vulnerability, whereas engaging multiple carriers, the company can mitigate risk, ensuring continuity of service. Building strong relationships with multiple haulage providers and fostering collaboration involving joint contingency planning, information sharing platforms, or even pooling resources for alternative transportation solutions, can provide flexibility and alternative options during disruptions. In addition, contractual agreements should be strengthened to include provisions for contingencies such as haulier failure, outlining responsibilities, liabilities, and dispute resolution mechanisms to minimise disruptions and financial losses (Shanjiang Zhu, 2011) (K. Katsaliaki, 2021) .

Improving supply chain visibility and monitoring of current transportation operations, by investing and implementing advanced technologies including GPS tracking and real-time monitoring systems can allow for proactive risk management and timely intervention in case of potential disruptions. In addition, investing into resilient building initiatives such as redundant transportation networks, emergency response plans, or insurance coverage tailored to mitigate the impact of haulier failure can assist in enhancing supply chain resilience.

Locating stock in the warehouse using the company's database is crucial for efficient warehouse management and overall supply chain performance. By leveraging accurate location data the company can streamline inventory tracking, reduce search times, and optimise resource allocation. This can enhance operational efficiency, minimise stockout risks, and improve customer satisfaction through timely order fulfilment (Alterity, LLC, 2024). Its effectiveness hinges on several factors. Firstly, the accuracy and reliability of the database is paramount as discrepancies or outdated information can lead to errors in locating stock, resulting in delays and disruptions. Additionally, technological infrastructure must be robust and resilient and ensure uninterrupted access to database information and scanning devices. Human error and inadequate training also pose risks, highlighting the importance of effective training and procedural adherence among warehouse personnel (Shashidharan, 2021) (McKinsey Global Institute, 2020).

To bolster resilience of the supply chain, several measures can be adopted. Firstly, supply chain mapping can assist identification of vulnerabilities to develop contingency plans, whilst risk assessments and management strategies proactively address potential threats. Inventory optimisation ensures adequate stock buffers to cushion against disruptions, whilst collaborative relationships foster continuous communication and co-operation among stakeholders (Shashidharan, 2021). As noted above, investing in visibility technology can provide real-time monitoring and offer proactive risk management, whilst comprehensive contingency planning prepares the company for various scenarios. Regulatory compliance and continuous improvement efforts will further enhance resilience, ensuring readiness to navigate evolving challenges in the global tin plate market, safeguarding operations and maintaining competitiveness in the industry (Aidil Hanafi, 2023).

Accurate measurement of load net weight ensures compliance with regulatory requirements and international trade standards, preventing legal issues and potential fines. Facilitation of precise inventory management, enabling stakeholders to accurately track/trace the tin-plate movement throughout the supply chain, enhances transparency and accountability, whilst reducing the risk of inventory discrepancies and associated financial losses (National Institute of Standards and Technology, 2011). Correct determination of load net weight is essential for billing and invoicing purposes, ensuring fair transactions and maintaining trust between trading partners and customers. Accurate weighing of departing transport helps optimise transportation logistics by enabling efficient loading and distribution of tin plates, minimising costs and reducing environmental impact (Sylwia Stawska, 2021) (McKinsey Global Institute, 2020).

Implementing advanced weighing technologies, such as automated weighbridge systems equipped with sensors and IoT capabilities, can improve accuracy and efficiency in transportation weight measurement. This can assist to reduce reliance on manual processes prone to errors and enhance real-time data visibility (Sylwia Stawska, 2021). Implementing a regular maintenance schedule for the weighbridge and weighing equipment to be inclusive of calibration checks, cleaning, and inspection for any signs of wear or damage, can reduce the risk of errors, minimise the risk of failure and ensure continuous accuracy. Training company personnel responsible for operating and maintaining weighing equipment can ensure they possess the necessary skills and knowledge to perform duties effectively. Well-trained staff can identify issues promptly, and take appropriate action for resolution (National Institute of Standards and Technology, 2011) (Karim Helmi, 2014).

Additionally, developing comprehensive risk management strategies that include contingency plans for unforeseen weighing facility downtime can assist with minimising the impact of unforeseen events, assisting in enhancing supply chain performance. Risk assessments should be reviewed and updated whilst remaining informed of evolving regulatory requirements and trade policies to ensure adherence to legal standards, reducing the risk of non-compliance penalties or trade disruptions (National Institute of Standards and Technology, 2011).

Competitor activity holds paramount importance in strategic management of the tin plate international supply chain. Continuous monitoring and analysis of actions, strategies, and capabilities of rival companies operating within the same market space, assists with providing an understanding of competitor activity, whilst offering several critical advantages (Pedro Garrido-Vega, 2021).

Competitor analysis provides invaluable insights into market dynamics, trends, and consumer preferences. By closely monitoring and scrutinising competitor strategies, the company can identify emerging market opportunities or potential threats, allowing for more informed decision-making. Moreover, it can assist with benchmarking performance against industry standards and identify areas for improvement (Inda Sukati, 2012). By anticipating competitive moves such as pricing changes, product launches, or market expansions, the company can proactively adjust their own strategies to maintain or enhance a competitive position, enabling early identification of vulnerabilities in the supply chain, and pre-emptive measures to be taken. Studying of competitor weaknesses and gaps in the market enables the company to identify opportunities for product innovation, service enhancements, or strategic partnerships. This proactive approach not only helps in staying ahead of competitors but also in creating unique value propositions for customers (Pedro Garrido-Vega, 2021) (Inda Sukati, 2012) (Alex Yaw Adom, 2016).

To enhance the resilience of the company's international supply chain whilst monitoring competitor activity there are several measures that can be implemented. Developing collaborative partnerships with suppliers, customers, and logistics partners by jointly investing in technology or infrastructure, such as blockchain, Internet of Things (IoT), or artificial intelligence (AI) that enhances supply chain visibility, traceability, and responsiveness, allows for real-time data to be analysed, enabling informed decision-making and risk management (Karim Helmi, 2014) (McKinsey Global Institute, 2020). Developing contingency plans, continuous monitoring and conducting comprehensive risk assessments for various scenarios for managing disruptions collectively, inclusive of alternative sourcing strategies for production, diversifying and distribution channels across geographies and establishing alternative sourcing options, can enhance the company's supply chain resilience (Sylwia Stawska, 2021).

4. Conclusions & Recommendations.

The evaluation of the FMEA for the international tin plate supply chain demonstrates critical vulnerabilities and potential disruptions inherent to operation. Through comprehensive examination of failure modes, their causes, and the associated impacts, key areas of concern that threaten supply chain operation have been identified. It is essential to acknowledge the identification of risks is not sufficient; proactive measures must be implemented to fortify the resilience of the supply chain against the identified potential disruptions.

The FMEA process has provided valuable insight into the company's international supply chain vulnerabilities. Various failure modes, including logistical bottlenecks, internal company procedures, geopolitical tensions, natural disasters, and supply chain disruptions have been highlighted. Each of these failure modes poses a unique challenge and risk, which, if left unaddressed, could have severe consequences for the entire supply chain network. As a result, it is imperative to approach risk management and resilience building in a holistic manner. To mitigate identified risks and to enhance supply chain resilience for the six identified steps in the FMEA, a series of proactive steps must be taken.

Firstly, there is a need for greater collaboration and communication among stakeholders across the supply chain. This is essential for fostering strong relationships with suppliers, manufacturers, distributors, and other partners to facilitate information sharing and co-ordination during times of crisis. By establishing robust communication channels and forging strategic partnerships, the supply chain can better respond to disruptions and mitigate their impact. Investing in technology such as IoT or AI is essential for improving the responsiveness and efficiency of the supply chain. To further anticipate potential disruptions and offer stakeholders the advantage of proactively implementing contingency measures, advanced analytics, predictive modelling techniques, and real-time monitoring are key. Furthermore, incorporation of blockchain technology can provide increased transparency and traceability within the supply chain, thereby decreasing any opportunity for fraud.

Diversification of transportation providers is critical for reducing dependency on single organisations. By developing multiple partnership with transportation partners and establishing alternative supply routes, the supply chain can mitigate the impact of, possible insolvency, geopolitical instability, trade disputes, and natural disasters. Proactive risk management strategies, such as scenario planning and embracing continuous improvement strategies, must be integrated into the company's processes. Additionally, by simulating various potential scenarios and assessing their

potential impact, stakeholders can identify vulnerabilities and develop robust contingency plans to mitigate risks effectively, enabling the supply chain to adapt quickly to changing market conditions and emerging threats.

The evaluation of the FMEA for the company's international tin plate supply chain highlights the importance of pro-active risk management and resilience building. Identifying key failure modes and implementing targeted measures to mitigate risks, stakeholders can enhance the reliability and robustness of the supply chain. For the six areas where the risk priority number (RPN) is higher than 160, the identified, improved and additional preventative measures have been applied and re-scored, demonstrating a reduction in the RPN, as shown in the FMEA table below. Supply chain resilience is a continuous endeavour that requires continuous monitoring, adaptation, and improvement. With ever evolving challenges and uncertainties, it is essential for stakeholders to remain vigilant and proactive in efforts to safeguard the reliability of the international supply chain (Sime Curkovic, 2013).

Revised FMEA Analysis											
Area	Number	Function	Potential failure mode	Potential effect of failure/defect	Severity	Potential causes of failure/defect	Occurrence	Preventative measures	Detection	RPN	RPN Reduction
What is the area?	FMEA No	What is the function?	In what ways can it go wrong?	What is the impact if the failure mode is not prevented?	How severe is the effect?	What causes the step to go wrong?	How frequently is the cause likely to occur?	What are the preventative measures in place to stop or detect the failure?	How probable is detection of the failure or cause?	Risk Priority Number?	Risk Priority Number Reduction
Revised Areas	1	Raw Material Supply	Poor delivery/performance of raw material supply	Inability to maintain continuity of supply	9	Poor delivery performance Reduction in production	5	Continual monitoring. Buffer stocking of required materials. Contingency storage of material. Audit supplier, performance tracking. Improved rigours contractual agreements to ensure supply. Partnership with suppliers to ensure raw material supply. Advanced supply chain tracking and monitoring	3	135	45
	7	International dispatch instruction raised on customer requirements.	Requirement entered incorrectly with wrong product specified Accept requirement without capability to produce	Incorrect material delivered to customer Inability to manufacture order requested by customer	8	Incorrect data entry by commercial representative Failure to check capacity	4	Unlikely to detect, but possible will be noticed throughout processing. Advanced technology to enhance system and process visibility and traceability. Culture of continuous improvement and innovation to enhance processes.	3	96	64
	12	Haulier Failure	Haulier cesses trading	Unable to deliver materials	9	Liquidation	4	All transport companies managed and regularly audited. More than one transport company used Partnership with hauliers to ensure continuous and reliable operation. Advanced supply chain tracking and monitoring. Emergency response strategy. Continuous improvement activities.	4	144	36
	16	Locate stock in warehouse using - the location details on database, tag ID	Material not in designated location Material cannot be found	Delayed loading whilst material is located. Load cannot be completed if no alternative material is available.	9	Poor stock control practices	4	Will only detect by audit prior to requirement or when collecting. Supply chain visibility technology for real-time monitoring of warehouse stock and planned dispatch. Culture of continuous improvement and innovation to enhance processes.	4	144	36
	31	Wagon weighed on weighbridge and weights compared to create load net weight	Vehicle not positioned correctly on weighbridge weighbridge inaccurate Vehicle was not weighed in Weighbridge broken down Vehicle exceeds max gross weight in line with H&S Regulations	Incorrect net weight, won't match, delay correct net weight, won't match, delay No net weight available Relocate vehicle to alternative weighbridge Transport of load on roads would be illegal and affect road safety	8	Driver error Calibration error Driver error Weighbridge maintenance Excess packs loaded; packs heavier than planned	5	Visual comparison. Weighbridge operator visual check of indicated weight. Company management system. Obvious if broken down. Cannot create tare weight. Advanced weighing technology to improve accuracy and efficiency. Regular maintenance and calibration of equipment. Rigorous training for operation and maintenance staff. Continuous improvement activities.	3	120	40

	38	Competitor activity	Erosion of customer base	Loss of business	8	Increased cost of product. Reduced profit. Under-cut by competitors.	6	Continuous improvement activities. Continuous monitoring of competitors and marketplace. Develop collaborative partnership with suppliers and customers. Technology or infrastructure to ensure supply chain visibility, traceability and responsiveness. Comprehensive contingency planning	4	192	48

Table 2 - Revised FMEA Analysis

(Kulińska, 2020) (Forrest, 2010) (Judyta Kabus, 2020) (Chih-Yuan Chu, 2020) (Tata Steel, 2005) (Annick Melanson, 2019)

5. References.

Alterity, LLC, 2024. *www.acctivate.com.* [Online]
Available at: https://acctivate.com/inventory-and-warehouse-management/
[Accessed 05 04 2024].

Aidil Hanafi, N. S. K. N. S. S. I., 2023. *www.researchgate.net.* [Online]
Available at:
https://www.researchgate.net/publication/369948706_improving_warehouse_eFFiciency_through_eFFective_inventory_management_practices
[Accessed 05 04 2024].

Alex Yaw Adom, I. K. N. G. N. K. S., 2016. *ww.core.ac.u.* [Online]
Available at: https://core.ac.uk/download/pdf/234696346.pdf
[Accessed 06 04 2024].

Annick Melanson, S. N., 2019. *www.researchgate.net.* [Online]
Available at: https://www.researchgate.net/figure/Risk-Priority-Number-RPN-scale_fig1_330561116
[Accessed 09 04 2024].

Behnam Fahimnia, A. J., 2016. *www.sciencedirect.com/science.* [Online]
Available at: https://www.sciencedirect.com/science/article/abs/pii/S1366554516000296
[Accessed 01 04 2024].

Chih-Yuan Chu, K. P. G. E. K., 2020. *www.sciencedirect.com.* [Online]
Available at: https://www.sciencedirect.com/science/article/abs/pii/S1474034620300227
[Accessed 01 04 2024].

Christiansen, B., 2024. *www.limblecmms.com.* [Online]
Available at: https://limblecmms.com/blog/dfmea-pfmea/
[Accessed 19 03 2024].

Forrest, G., 2010. *www.isixsigma.com.* [Online]
Available at: https://www.isixsigma.com/wp-content/uploads/2013/05/FMEA-Round-1.gif
[Accessed 17 03 2024].

Inda Sukati, A. B. A. H. R. B. M. N. A., 2012. *www.researchgate.net.* [Online]
Available at:
https://www.researchgate.net/publication/265251123_Competitive_Advantage_through_Supply_Chain_Responsiveness_and_Supply_Chain_Integration
[Accessed 06 040 2024].

Institute for Manufacturing, 2024. *www.ifm.eng.cam.ac.uk.* [Online]
Available at: https://www.ifm.eng.cam.ac.uk/research/dmg/tools-and-techniques/fmea-failure-modes-and-effects-analysis/#:~:text=FMEA%20provides%20a%20structured%20approach,of%20potential%20modes%20of%

20failure.
[Accessed 17 03 2024].

Judyta Kabus, I. M. L. P., 2020. *www.researchgate.net.* [Online]
Available at: https://www.researchgate.net/publication/345393489_Risk_in_Supply_Chain_Management
[Accessed 06 04 2024].

Juneho Um, N. H., 2020. *www.emerald.com.* [Online]
Available at: https://www.emerald.com/insight/content/doi/10.1108/SCM-06-2020-0248/full/html
[Accessed 01 04 2024].

K. Katsaliaki, P. G. S. K., 2021. *www.ncbi.nlm.nih.gov.* [Online]
Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7792559/
[Accessed 03 04 2024].

Kapil Dev Sharma, S. S., 2018. *www.researchgate.net.* [Online]
Available at: https://www.researchgate.net/profile/Kapil-Sharma-41/publication/333209894_Failure_Mode_and_Effect_Analysis_FMEA_Implementation_A_Literature_Review/links/5ce26881a6fdccc9ddbed894/Failure-Mode-and-Effect-Analysis-FMEA-Implementation-A-Literature-Review.pdf
[Accessed 16 03 2024].

Karim Helmi, B. B. A. M., 2014. *www.researchgate.net.* [Online]
Available at:
https://www.researchgate.net/publication/269352130_Accurate_measurements_of_gross_vehicle_weight_through_bridge_weigh-in-motion_A_case_study
[Accessed 05 04 2024].

Kulińska, M. D.-G. a. E., 2020. *www.intechopen.com.* [Online]
Available at: https://www.intechopen.com/chapters/71351
[Accessed 15 03 2024].

Leeuwen, J. v. M. N. D. d. K. Y. O.-R. M. O., 2009. *www.sciencedirect.com.* [Online]
Available at: https://www.sciencedirect.com/science/article/abs/pii/S0731708509004208
[Accessed 17 03 2024].

Marieke S. van der Tuin, A. J. P., 2020. *www.etrr.springeropen.com.* [Online]
Available at: https://etrr.springeropen.com/articles/10.1186/s12544-020-0398-9
[Accessed 04 04 2024].

McKinsey Global Institute, 2020. *www.dln.jaipuria.ac.in.* [Online]
Available at: http://dln.jaipuria.ac.in:8080/jspui/bitstream/123456789/14300/1/Risk-resilience-and-rebalancing-in-global-value-chains-full-report.pdf
[Accessed 01 04 2024].

MS, V. G., 2024. *www.gov.wales.* [Online]
Available at: https://www.gov.wales/written-statement-tata-steel-uk-ltd#:~:text=TSUK%20currently%20employs%20directly%20more,of%20steel%20production%20in%20Wal

es.
[Accessed 22 03 2024].

Nabeel A. Mancheri, B. S. S. D. S. B. Y. R. B. L. D. R. K. A. T., 2018. *www.sciencedirect.com.* [Online]
Available at: https://www.sciencedirect.com/science/article/pii/S092134491730352X
[Accessed 01 04 2024].

National Institute of Standards and Technology, 2011. *www.nist.gov.* [Online]
Available at: https://www.nist.gov/system/files/documents/2017/04/28/hb-155-final.pdf
[Accessed 05 04 2024].

P. Sheikh Damanaba, S. A. Y. R. P. M. S. V., 2015. *www.researchgate.net.* [Online]
Available at: https://www.researchgate.net/profile/Parisa-Moshashaei-2/publication/281307263_Failure_modes_and_effects_analysis_FMEA_technique_a_literature_review/links/64c285a6141074110edc4159/Failure-modes-and-effects-analysis-FMEA-technique-a-literature-review.pdf
[Accessed 16 03 2024].

Pedro Garrido-Vega, M. S.-D. J. M.-F. R. A.-L., 2021. *www.researchgate.net.* [Online]
Available at:
https://www.researchgate.net/publication/355649689_The_role_of_competitive_environment_and_strategy_in_the_supply_chain's_agility_adaptability_and_alignment_capabilities
[Accessed 06 04 2024].

Quality Engineer Stuff, 2024. *www.qualityengineerstuff.com.* [Online]
Available at: https://qualityengineerstuff.com/aiag-vda-dfmea/
[Accessed 19 03 2024].

Shanjiang Zhu, D. L., 2011. *www.researchgate.net.* [Online]
Available at:
https://www.researchgate.net/publication/226885097_Disruptions_to_Transportation_Networks_A_Review
[Accessed 03 04 2024].

Shashidharan, E. a. M., 2021. *www.researchgate.netm.* [Online]
Available at:
https://www.researchgate.net/publication/350828004_Importance_of_an_Efficient_Warehouse_Management_System
[Accessed 05 04 2024].

Sime Curkovic, B. J. W. T. V. S., 2013. *www.researchgate.net.* [Online]
Available at:
https://www.researchgate.net/publication/263733916_Using_FMEA_for_Supply_Chain_Risk_Management
[Accessed 12 04 2024].

Świerczek, A., 2014. *www.sciencedirect.com.* [Online]
Available at: https://www.sciencedirect.com/science/article/abs/pii/S0925527313003654
[Accessed 13 04 2024].

Sylwia Stawska, J. C. M. B. K. B., 2021. *www.researchgate.net.* [Online]
Available at:
https://www.researchgate.net/publication/348490387_Comparative_Accuracy_Analysis_of_Truck_Weight_Measurement_Techniques
[Accessed 05 04 2024].

Tata Steel Europe Limited, 2024. *www.tatasteeleurope.com.* [Online]
Available at: https://www.tatasteeleurope.com/construction/sustainability/performance-at-our-sites/trostre
[Accessed 22 03 2024].

Tata Steel, 2005. *Process/Product FMEA.* LLanelli: Tata Steel.

Tata Steel, 2024. *www.tatasteeleurope.com.* [Online]
Available at: https://www.tatasteeleurope.com/packaging/products/tinplate
[Accessed 29 03 2024].

Thomas, H., 2022. *www.bbc.co.uk.* [Online]
Available at: https://www.bbc.co.uk/news/uk-wales-62687063
[Accessed 09 04 2024].

Timothy J. Pettit, J. F. K. L. C., 2014. *www.onlinelibrary.wiley.com.* [Online]
Available at: https://onlinelibrary.wiley.com/doi/abs/10.1002/j.2158-1592.2010.tb00125.x
[Accessed 01 04 2024].

Wilson, M. C., 2007. *www.sciencedirect.com.* [Online]
Available at: https://www.sciencedirect.com/science/article/abs/pii/S1366554505000967
[Accessed 04 04 2024].

6. Appendix.

Design General Evaluation Criteria Severity (S)		
Potential Failure Effects rated according to the criteria below		
S	**Effect**	**Impact to End User (when known)**
10	High	Affects safe operation of the vehicle and/or other vehicles, the health of driver or passenger(s) or road users or pedestrians.
9		Noncompliance with regulations.
8	Moderately high	**Loss** of primary vehicle function necessary for normal driving during expected service life.
7		**Degradation** of primary vehicle function necessary for normal driving during expected service life.
6	Moderately low	**Loss** of secondary vehicle function.
5		**Degradation** of secondary vehicle function.
4		Very objectionable appearance, sound, vibration, harshness, or haptics.
3	Low	Moderately objectionable appearance, sound, vibration, harshness, or haptics.
2		Slightly objectionable appearance, sound, vibration, harshness, or haptics.
1	Very low	No discernible effect.

Figure 2 - FMEA Analysis Severity Table

(Quality Engineer Stuff, 2024)

Rating	Occurrence	
	Probability of Failure	**Criteria**
10	Very High: New technology/new design with no history	≥ 100 per thousand pieces >/= 1 in 10
9	High: Failure is inevitable with new design, new application, or change in duty cycle/operating conditions	50 per thousand pieces 1 in 20
8	High: Failure is likely with new design, new application, or change in duty cycle/operating conditions	20 per thousand pieces 1 in 50
7	High: Failure is uncertain with new design, new application, or change in duty cycle/operating conditions	10 per thousand pieces 1 in 100
6	Moderate: Frequent failures associated with similar designs or in design simulation and testing.	2 per thousand pieces 1 in 500
5	Moderate: Occasional failures associated with similar designs or in design simulation and testing.	.5 per thousand pieces 1 in 2,000
4	Moderate: Isolated failures associated with similar design or in design simulation and testing.	.1 per thousand pieces 1 in 10,000
3	Low: Only isolated failures associated with almost identical design or in design simulation and testing.	.01 per thousand pieces 1 in 100,000
2	Low: No observed failures associated with almost identical design or in design simulation and testing.	≤.001 per thousand pieces 1 in 1,000,000
1	Very Low: Failure is eliminated through preventative control	Failure is eliminated through preventative control

Figure 3 - FMEA Analysis Occurrence Table

(Christiansen, 2024)

Rating	Detection		
	Detection	Criteria: Controller	Criteria: Mechanical
10	Absolute Uncertainty	Cannot Detect	No current design control; Cannot detect or is not analyzed
9	Difficult to Detect	N/A	Design analysis/detection controls have a weak detection capability; Virtual Analysis (e.g. CAE, FEA, etc.) is not correlated to expected/actual operating conditions.
8	Post Design Freeze and Prior to Launch		Product verification/validation after design freeze and prior to launch with pass/fail testing (Sub-system or system testing with acceptance criteria e.g. Ride & handling, shipping evaluation, etc.)
7	Post Design Freeze and Prior to Launch	N/A	Product verification/validation after design freeze and prior to launch with test to failure testing (Sub-system or system testing until failure occurs, testing of system interactions, etc.)
6	Post Design Freeze and Prior to Launch	Test and Validate in HIL, not possible to set in SIL	Product verification/validation after design freeze and prior to launch with degradation testing (Sub-system or system testing after durability test e.g. Function check)
5	Prior to Design Freeze	N/A	Product validation (reliability testing, development or validation tests) prior to design freeze using pass/fail testing
4	Prior to Design Freeze	Test and Validate in SIL	Product validation (reliability testing, development or validation tests) prior to design freeze using test to failure (e.g. until leaks, yields, cracks, etc.)
3	Prior to Design Freeze	N/A	Product validation (reliability testing, development or validation tests) prior to design freeze using degradation testing (e.g. data trends, before/after values, etc.)
2	Virtual Analysis - Correlated	Test and Validate in MIL - Design Flaw of functionality. Directly impacts results of model	Design analysis/detection controls have a strong detection capability. Virtual Analysis (e.g. CAE, FEA, etc.) Is highly correlated with actual and/or expected operating conditions prior to design freeze.
1	Detection not applicable; Failure Prevention	Detection not applicable; Failure Prevention	Failure cause or failure mode cannot occur because it is fully prevented through design solutions (e.g. Proven design standard/best practice or common material, etc.)

Figure 4 - FMEA Analysis Detection Table

(Christiansen, 2024)

Risk Priority Numbers (RPN)	Description
225 and higher	Intolerable
175 à 224	Unacceptable
125 à 174	Permissible
50 à 124	Acceptable
5 à 49	Negligible

Figure 5 - FMEA Analysis Risk Priority Scoring

(Annick Melanson, 2019)