Integrated risk management performance and manufacturing capabilities in the energy sector

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Summary

There is extensive research on the field of supply chain risk management and risk management in manufacturing. However, there are a few studies that have focused on the energy sector in particular. In this paper, we focus on this topic and sector by using a qualitative methodology, semi-structured interviews were conducted with chief risk officers from different organisations in the UK and Portugal to understand their practices, tools, and organisational views around risk management. The results show that managers recognise the innovation behind their respective management strategies and are committed to continuing embracing technological paradigms that enhance risk management. Some recommendations to managers in the sector are provided. The paper concludes with a summary of the research, limitations and avenues for future research.

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1. Introduction

Managing risk in supply chains and organisations has become more critical as the business environment continuously changes (Christopher *et al.*, 2011). The energy industry is particularly volatile, prices change and are set in distinguished ways varying upon demand, availability of resources, fuel costs and power plant availability (Mulhall and Bryson, 2014), which also increases its research interest since supply chain operations run differently than other sectors such as fashion and retail (Handfield *et al.* 2020). There are specific risks and bidding contracts that can contribute very negatively to manufacturing (Axon and Darton, 2021). Furthermore, energy projects greatly depend on governmental consent and production limitations (Urcioli *et al.*, 2014).

Through inductive reasoning and a choice of qualitative methods, particularly interviews with energy industry professionals with decades of experience, a rich collection of data is presented, analysed and discussed. Demonstrating how different organisations see, embrace and perform risk management. A few still assume it is more of a contingency and mandatory action, but the majority understands the value added and extra competitive advantage when you assume this as a new management approach. Curiously, those participants who expressed lesser views of risk management also belong to a country (Portugal) where innovation and technological embrace falls short in comparison to UK organisations. The findings also include several risk types and their probability of occurrence and impact on operations and the respective mitigation action plans for risks internal to the firm and the supply chain and external to the supply chain.

The research question addressed in this paper is: *"How are risk management capabilities used in manufacturing organisations in the energy sector?"* Important themes such as, supply chain risk management, enterprise risk management, risk assessments and risk types specific for the energy sector. As for manufacturing, the core themes are resource-based theory,

responsiveness, flexibility and modularity of suppliers, technological capabilities, and intelligent manufacturing.

This paper is structured as follows. Section 2 presents a literature review about manufacturing energy sector, supply chain risk management, and risk management in the energy sector. Section 3 provides the qualitative methodology. Section 4 presents the analysis and findings. Section 5 provides some discussion about this research based on the data and a comparison to relevant previous literature. Section 6 draws the conclusions as well as provides some limitations and avenues for future research.

2. Literature review

2.1. Manufacturing: The Energy Sector

As some manufacturing firms cannot compete on costs, they are obligated to compete on value. This notion was introduced in the 1980's by a great economist and professor Michael Porter. Defending that the resource-based view capabilities are the best solution to reach that competitive advantage, hopefully because of how valuable and rare they might be (Sminia *et al.*, 2018).

Manufacturers in the energy sector, particularly oil and gas manufacturers are referred to as being in the process industry, since the production requirements are so unique (Aaldering and Song, 2021). This type of production outputs less differentiated goods and in low variety and is associated with high fixed costs and very insufficient pricing power. Hence, to achieve competitive advantage, manufacturing capabilities are of great importance (Zaborek and Mazur, 2019). Process industry managers align the capital expenditure to balance short and long-term production in a volatile environment where product prices are market-based (Moser *et al.*, 2021). In addition, these organisations often have long and complex supply and value chains and in order to construct manufacturing strategies they need to fully understand the total production system and the design of the material transformation system (Lager *et al.*, 2017).

Regarding the manufacturer's little control over the products' price, in this case oil, it derives from accords made between the Organisation for Petroleum Exporting Countries (OPEC) and non-OPEC-international investors who operate privately. The organisation upholds the objectives of security and coordination in oil exporting policies amongst joining members (Ji *et al.*, 2019). Ultimately to ensure fair and constant prices for producers. Although this coordination faces challenges derived from the country's individual differences, fiscal stances and enforcement mechanisms (Rousan *et al.*, 2018). The OPEC and non-OPEC alliance, or OPEC+, is responsible for oil prices because there are contracts and limitations to production dependant on market demand. So, member countries cannot independently extract and produce petroleum as they please and initiate price wars. Other determining parameters are the non-OPEC producing behaviour and the financialization of oil (Razek and Michieka 2019). The respective member countries care for building infrastructures, increasing revenue, and providing employment to better the economy. And in order to control seasonal fluctuations and its impact, inventory is kept in refineries and storage terminals. Throughout the years the oil sector has seen many disruptions, mainly the oil price crisis of 1985 and 2014 onwards. Currently, the pandemic decreased global demand for fuel because of the constant lockdowns, however the past few months have shown improved market conditions (Meredith, 2021).

2.2. Supply Chain Risk Management

Supply chain risk management is a critical and developing research field, since supply chain risks deeply impact strategic decisions. Emerged from uncertainties and unexpected factors alike capacity constraints, quality problems, labour shortage and supply-demand mismatch (Sreedevi and Saranga, 2017). Said uncertainties lead to delivery delays, financial losses, excessive production and use of resources (Chen and Liu, 2021). The relevance of this research field is aligned with the discussions about the ever-changing business environment and global supply chain vulnerability. When there is extension across geographical areas, organisations

are susceptible to external economic (energy costs, prices and resource availability), social (demanding customers) and natural disasters risks. To survive, supply chains should set flexibility as the structural approach to adapt to changes. Information technologies help improve supply chain performance by bettering communication, acquitting and transmitting data and easing the decision-making process (Ben-Daya *et al.*, 2017; Baryannis *et al.*, 2018).

The difficulty in quantifying all the risks stemming from a turbulent business environment is high. Especially since these can be internal to the firm, internal to the supply chain and external to the supply chain for instance, transportation risks have internal effects inside the supply chain, but their occurrence may derive from external factors. The Suez Canal traffic incident, caused by a giant container vessel stuck sideways blocking the waterway, obstructed more than 400 other vessels. The legal and financial repercussions of this accident were tremendous for organisations and government authorities (BBC, 2021). Felea and Albastroiu (2013) identify other risks and allocate them into four areas: business environment, customers, products/services and suppliers. Respectively, these are the diminished control and supply chain dependencies, higher expectations and loss of loyalty, increasing transportation and warehousing costs and increased use of outsourcing.

2.3 Risk Management: The Energy Sector

Based on literature findings the prevalent articles regarding risk in the energy sector mostly refer to oil and gas manufacturing and renewable energy sources like wind power. The production of energy has an impact on the economic and social development of a country since production activities in all other industries require energy as an expected input. Its presence is crucial in any modern economy (Zahid, 2008). The energy sector is everchanging, whether it is on the technology front whether it is the demand that rules its production (Kerste *et al.*, 2015). The same market can include differing types of production technologies for different

energy varieties like coal, gas, wind, hydroelectric and solar power. Many uncertainties and disruptions are associated with their manufacture (Oliveira and Ruiz, 2021).

As for the oil sub-sector, the main challenges revolve around oil spills, a country's unforeseeable fluctuations in price and foreign exchange earnings from sales (Samimi, 2020). In depth, oil spill cases are unfortunately too occurring in history, and Levalainen *et al.* (2016) defends the concern for spills in the arctic marine environment since arctic petroleum reserves seem to be the new project for oil and gas exploration. Hence, ecological risk assessments should be performed to understand fully the probability and intensity of harmful ecological human activities. Accounting the variables of oil type, oiled area, acute impact area, oil persistence, recolonisation, reproduction and long-term effects.

Furthermore, legal systems, e.g. Civil Law regime in China, are active to ensure enterprises are responsible for such damages (Pillsbury, 2021). The total cost of an oil spill is calculated by adding clean-up costs, fishery costs, tourism, etc. And quantitative methods to assess the civil and criminal liabilities in oil ports are established to diminish both risks. Other countries have set their own systems and failure datasets: Der Norske Veritas, the Dutch National Institute for Public Health and Environment and the British Health and Safety Executive (Zhong *et al.*, 2021).

As for risks in renewable energy production, namely wind power, these originate from the technological advances that allowed such an innovative production. But the maintenance, the legislative support and the investor and public support greatly determine its success (Abbasi *et al.*, 2019). And the health and safety risks associated are great, for instance the global workforce fluctuations, physical danger when installing turbines, offshoring installation accidents like drowning, loss of anchor, difficult accessibility and long work hours. Plus, the

weather-related risks wind farm workers may be subjected to if the locations are remote, i.e., lighting strikes (Karanikas *et al.*, 2021).

Ultimately, to meet the resilience goals and have a shared information culture, a promotion of learning and infrastructure security measures, there needs to be a cooperation between the industry and the government- the private and the public (Zhilkina and Akhmetshin, 2019).

3. Methodology

3.1. Research Strategy

Once the project reaches its analysis/discussion segment that data is interpreted solely by the authors, hence attention is paid to any traits, demographic attributes, personal values and different points of view that can influence coding decisions. Coding means giving a meaning to certain portions of data- interviewees responses and the secondary data found. For efficient coding, organisation skills and systems are key, especially if some transcript passages are difficult to understand and ethically, they should not be overlooked (Gray, 2018).

Some of the data were not in English language, but in Portuguese language- the first author's mother tongue- from a desire of broader ideas of both Latin and Saxon energy manufacturing companies and have a larger pool of choices to contact. As advised by Saldaña (2015), it is in the researchers' best interest to keep the syntax and nuances intact when translating the coding into to English language.

Furthermore, the interviews were conducted via Microsoft Teams and recorded so that they could be replayed multiple times as the answers are given. When coding begins, the first out of two cycles combined structural and "In vivo" coding methods. Structural coding helps to start organising data based on the research questions and "In vivo" coding is tailored for interview transcripts so the researchers can relate better to the participant's language (Saldaña, 2015; Bernard and Ryan, 2010).

In depth, structural coding employs a topic on inquiry to a particular part of the data collected that corresponds to a research question, this way everything is organised in categories. It was also chosen because of its suitability for semi-structured interviews with multiple participants. Regarding the second cycle of coding, here ideas are refined and reanalysed to ensure a more selected list. Focused coding was adopted because out of the possible research strategies, i.e., Grounded Theory, Ethnography, Action Research, Case Study, Archival Research and Narrative Inquiry, Grounded Theory is the most suitable one to explain the meanings that social actors give to make sense of the world. Afterwards, there was a development unto axial and theoretical coding (Saunders *et al.*, 2019; Saldaña, 2015).

Focused coding takes the coded data in the first cycle and categorises it based on themes, for instance, data on energy manufacturing/distribution and data on risk management. Axial coding is good for a great variety of data alike interview transcripts, journals and videos and explores how categories and subcategories relate to each other. And theoretical coding is good to create a new theory, and to discover the central category that identifies the primary research theme.

Furthermore, as the coding of the transcribed and/translated data, it will mostly rely on theoretical links between the codes, considering the articles read were insightful and peer reviewed which gave the researchers a broader sense of the topic area. Also, data-driven codes based on actual terms used during the interviews. See ***Figure 1***.

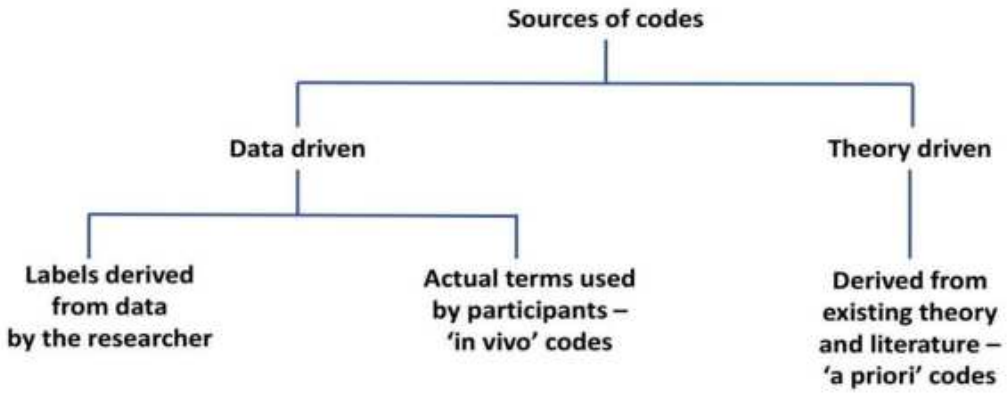

Figure 1. Sources of data codes (Saunders, *et al.*, 2019, p.655).

3.2. Interviews

Semi-structured interviews with five different chief risk officers working in the energy sector begin with a calculated list of topics and questions, approximately 20, in which were explored with each participant, so that in the discussion comparisons are made. Initially, the interviews will start with the same introductory questions, such as *"What is your position in the organisation, and could you elaborate your role a bit?*". This type of easy question makes the participants feel more at ease and willing to open up more as the interview progresses (Denzin, 2001), see ***Figure 2***. In the ***Appendix***, the list of questions is presented.

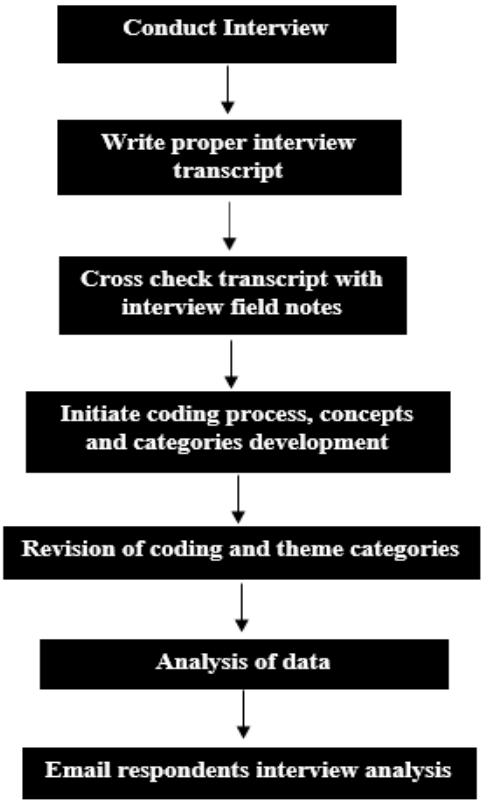

Figure 2. Observation of material and interpretation process.

4. Findings

4.1. Risk Management Activities

Without disclosing confidential information (interviewee's company name) the companies operate either exclusively or with both electrical and oil and gas energies. On the renewable energies side, offshore wind farms are developed to manufacture electrical energies for which the project's life cycle is of six to seven years. A risk assessment of supply chain risks for projects in different countries is conducted to analyse any enforcement of local content in production and level of governmental engagement.

Another scenario involves seeing risk management as a contingency plan, meaning handling a risk if it occurs which does not reduce the probability of occurrence but reduces the impact if or when it happens. It is preparing the energy distribution network for any event based on previous experience. The company in this specific scenario is a TSO (Transmission System

Operator) so European risk management rules are common amongst all TSOs because a disturbance in the European electric system can spread across different countries.

A differing setting happens for oil and gas organisations, there are certain conventions one should oblige to, in the case of maritime transportation of petroleum and offshore construction of sea platforms, risk management practices are in line with SOLAS- Safety of Life at Sea- which belongs to IMO- International Maritime Organisation. This treaty originated after the Titanic incident to prevent calamities as the like. Additionally, to improve practices tailored to sea platforms and vessels besides SOLAS a more specific security code was created called ISM- International Safety Management- in the early 90's and is always updated to remain relevant today.

4.2. Key Risks and Risk Assessment

A comprehensive list of risks was developed mostly based on the answers given to questions 3 and 6.2. which are respectively: *"Name the risks that your department considers the most important and prevalent by rating their probability of occurrence and impact on the company from 1 to 5 (1 being the least probable of happening and the least impactful)"* and *"After the disruptions from the pandemic and from the emergence of new technologies, over the next 3-5 years, which three new risk types do you think will increase the most in their importance for your business?"*. All risks went through a risk assessment and were given a probability of occurrence (PO: 0-100%) and an impact (I: 1-5) which is shown on the tables below and the respective mitigation strategies are discussed throughout the dialogue and analysed further on.

The respondents expressed concern for mostly external risks as the majority holds a high probability of occurrence as well as impact. For instance, scarcity of resources corresponds to materials and labour (PO: >60% and I: 5) and increases as a risk with the rising number of projects being developed worldwide and since it's a niche industry, most developers have

similar backgrounds, being both good and bad as *"some people have maybe worked in oil and gas for 30 years and can transition to renewables, but the skill set at the moment is a bit of a concern in terms of getting a hold of new people"* (Senior Risk and Insurance Manager, Company C). Contrarily, risks like cyberattacks are currently seen as deeply hurtful but due to their different mitigation strategies hold a low probability of occurrence. All organisations have assigned cybersecurity teams and training for all employees and some use own or Amazon's cloud computing to backup information by the second.

In respect to internal risks there is abundance over own and contracted labour and transportation risks. For instance, poor labour performance in maintenance particularly of an electric network distribution line (PO: 10% and I:5) will impact the entire quality of service if it impedes the consumer from receiving energy at any point. Which happens when human mistakes are made without further supervision. Although, the occurrence is low because of a constant analysis of key risk and quality indicators and the presence of a command control team that authorizes any on-filed interventions in substations. Also, transportation and damage to components (PO: 20% and I: 5) refers to risks in manufacturing with contractors and it's assigned a high impact if the materials are key electrical components but a low probability of occurrence due to intense supplier monitoring actions. See ***Table 1*** and ***Table 2***.

Table 1. Risks external or dependent on the business environment.

External Risks	Probability of Occurrence (0-100%)	Level of Impact (1-5)
Climate risk: Changes in atmospheric electricity discharge	50%	3
Cyberattacks	30%	5
Covid-19	<10%	5
Financial and Economic Crisis	40% - 50%	5
Scarcity of resources	>60%	5
Climate risk: Global Warming and Permafrost	70% – 80%	5
Bidding regimes in renewable energies	60%	5
Forced to use Local Content	60%	3/4
Jones Act (USA)	100%	4
Failure in securing supply of components	30%	4

Table 2. Risks internal to the firm and the supply chain.

Internal Risks	Probability of Occurrence (0-100%)	Level of Impact (1-5)
Poor Labour Performance	10%	5
Internal Communication	30%	3
Transportation and Damage to components	20%	5
Uncertainty in contractor's skilled manufacturing labour or shortage in the market	30% - 40%	3
Insecurity of supply (2nd tier, etc.)	20%	3/4

Through the assessments given by participants we can calculate the risk score for each type, this entails assigning a number that reflects the severity of a risk due to some factors. For instance, a risk that has a high probability and a medium impact would be calculated by multiplying both variables (Intaver, 2021). Risk scores are categorised as catastrophic ($x \geq 4$), serious ($3 \leq x < 4$), moderate ($0.6 \leq x < 3$) and low ($0 < x \leq 0.5$). They have to account for schedule precedent network and critical path. If a high probability and impact risk is not near the critical path then its score is low and vice-versa. Although participants were asked what the most important risks for their organisations and the industry were. So, the risks presented must affect activities in or predecessor to activities in the critical path. Plus, the specific data about cost and time delays is unknown but based on the risk category we assume the score corresponds correctly. Below is a table of risk scores for better visualisation and for those risks where impact or probability are divided then the lowest score is chosen.

Table 3 illustrates only one catastrophic risk, the Jones Act, however this one, affects energy construction projects in the USA not all projects, because the government enforces that exclusively American flag vessels (and all these organisations are European headquartered)

can be in American maritime ports, which of course delays or even stops offshore projects. The majority are moderate risks and the mitigation actions futurity discussed prevent those from moving up to serious. As for low risks, their score derives from the low probability of occurrence, since global pandemics are extremely rare and poor labour performance is controlled with monitoring and training.

Table 3. Risk score values.

Risk	Score	Category
Climate Risk	1.5	Moderate
Cyberattacks	1.5	Moderate
Covid-19	0.5	Low
Financial Crisis	2	Moderate
Scarcity of Resources	3	Serious
Global Warming	3.5	Serious
Bidding Regimes	3	Serious
Local Content	1.8	Moderate
Jones Act	4	Catastrophic
Failure in Securing Supply	1.2	Moderate
Poor Labour Performance	0.5	Low
Internal Communication	0.9	Moderate
Transportation and Damage	1	Moderate
Uncertainty	0.9	Moderate
Insecurity of Supply	0.8	Moderate

4.3. Key Market Trends

This section exhibits six market trends derived from or connected to the identified risks, these being cybersecurity, global warming, financial and economic crisis, telecommuting, renewable

energies and digital learning and engagement. In the charts the timeline chosen is from the year 2000 to 2024 with intervals of eight years. Such choice is deducted from question 6.2. (see ***Appendix***) as part of the emergent risks in 3 to 5 years.

- Cybersecurity: Continuously increasing in importance as new technological paradigms emerge. From 2011 to 2014 the concept of Industry 4.0 was being incremented and in 2016 the business environment had shifted towards information technologies, IoTs, cloud computing amongst others. However, from 2020 onwards with a push from Covid-19, the way businesses and supply chains work has disrupted and is opening a new digital paradigm with telecommuting and extensive e-commerce. Deepening the need for security against cyberattacks.
- Global warming: Always rising as a risk throughout the years even with company/governmental measures to be plastic or carbon emission free until 2050. Global warming leads to an increase of probabilities of occurrence of external supply chain risks alike natural disasters. For instance, in Portugal, forest fires are becoming more common every summer as temperatures rise and many company assets are exposed to natural and human made disruptions, if an electrical line is compromised so is the service's quality.
- Financial and Economic crisis: Prediction of a second economic rupture due to the monetary injections of i.e., the EU into different governemnts and organisations to sustain losses from the pandemic. If this happens and there is no development in the economy than there is no development in the consumer front, so companies stagnate.
- Telecommuting: This trend began full-time alongside the pandemic as back office teams started remote work with great use of information systems safely- cybersecurity- and one organisation even has its own telecommunations network. Organisations are considering the future presence of telecommuting, perhaps not integrally as that might affect mental

health and motivation, but part-time is an interesting solution for optimisation and cost reduction. Graphically, cybersecurity and telecommuting increase almost side by side.

- Renewable energies: Greatly focused around offshore wind farm manufacturing and generally has shown exponential increase for the past decade. Government authorities expressed concern over the consumption of fossel fuils and pledged to decrease by half greenhouse gas emissions until 2030 (Newburguer, 2021). These goals can be possible if more energy manufacturers, particularly oil and gas ones, embrace other forms of sustainable energy. Combining also a waste or lean management approach. Although, as was discussed in an interview, that is the reality right now, but the more interest different countries and companies have over renewables the more expensive are bidding contracts.

  "The prices to try and develop these areas are shooting up. [...] We spent over 10 years trying to keep prices down through innovation, R&D and contracting strategies. And now they put up leases that we have to pay the governments and authorities that are really expensive. So that's a big risk." (Senior Risk and Insurance Manager, Company C).

- Digital Learning and Engagement: Embodying telecommuting, training and developing a new skills set. The fewer the number of people mastering this paradigm's skills, the scarcer will labour resources be.

  "Online learning. Online engagement. Working remotely. I think companies need to be super flexible and if they're not, they're gonna get behind.[...] Need to make use of collaborative tools as well, the way we edit documents, how we sign and review documents. Need to embrace digital technologies to do that." (Senior Systems Manager, Company A).

4.4. Mitigating Action Programs

Based on the answers from question 8.1. *("Regarding preventive risk mitigation action programs can you rate from 1 to 5 your detection of operational risks, for instance internal or supplier monitoring, inspection and tracking."*) The researchers were able to conduct a list and

have a sense of their development and efficacy. Ultimately, all organisations perceive their mitigation strategies to be close to flawless. See ***Table 4***.

Table 4. Mitigation Strategies.

Detection of Operational Risks	Ranking (1-5)
Internal or Supplier Monitoring	4
Inspection and Tracking	5
Quality management team	5
Credit Rating	4
Supplier Selection	4
Relationship with suppliers	4

4.4.1. Supply Chain Risks: Mitigation and Preventive Action Programs

Throughout the discussion there was great knowledge shared over internal risk mitigation strategies derived from questions 3.1 and 8 and systems for detection of operational risk from question 8.1 (see ***Appendix***). As shown in ***Table 2*** most internal risks draw from one of three supply chain variation sides: upstream from supplier's performance, downstream from customer's demand and internally from the production of the local firm. The strategies discussed thus derive from great presence of suppy risks. Those refer to deviations in terms of time, quality and quantity that result in uncomplete/delayed orders and that inconsistency of a supplier's performance will increase supply risks (Chen *et al.*, 2013).

To prevent such disruptions several strategies were identified, such as redundancy- scenario wherein an employer reduces their workforce in the event that a certain job is no longer needed. Most systems are automated but anytime there is human intervention a control team is notified,

and nothing happens without authorisation beforehand. When facing an installation various levels are reviewed a week before and throughout the project. This system is prepared to contain spreading of negative impact.

Furthermore, supplier selection is essential with requested supply chain project plans, Gantt charts for key components, and when placing orders, a full list of second tier suppliers is needed plus the factory's location. These organisations perform background research on their supplier's factories to be attentive of safety measures and standards to prevent for instance slave work. If a supplier does present problems, for them to be hired in the first place, they have to go through rigorous change management processes and also contractual protections are in place if material prices increase afterwards as that will not be the hiring organisation's problem. They see it as the suppliers' responsibility to uphold certain regulations. There also exist contractual penalties- a lump-sum compensation to the non-defaulting party for damages- in case a supplier opts for a component that was not on the approved materials list.

Besides supplier selection, supplier monitoring is a key strategy to prevent operational risks. The organisations expressed deeply rooted internal and supplier monitoring systems and sensors. Firstly, suppliers are asked to show credit ratings and manufacturing timescales as well as order bookings for the following 2-3 years. And inspection and tracking systems to ensure good quality of service and of key components is constantly performed by quality management teams that physically travel to the countries where the components derive from, such as USA and China. This way there is immersion within the supply chain.

A few companies suggested that commonly in the industry, framework contracts are arranged with multiple suppliers as an agreement to establish long-term relationships. In practice, when new project opportunities arise and companies evaluate how many they can manufacture, an arrangement with for instance Vestas, for a good and set price considering the consented

projects will be manufactured with their components then that gives security and traceability of supply and assurance that projects will move forward. Ultimately, this is another action program to mitigate those supply related risks. Although, as the saying goes “putting all your eggs into one basket” can be a risk in itself. To prevent/mitigate this, parent company guarantee (PCG) related strategies take action. A monetary offer part of the business or the project is offered in exchange for a bond and considering there may be breaches on behalf of the supplier-failure in delivery- that bond plus a performance bond will be taken by the contracting part.

Another strategy involved flexibility of supply and transportation infrastructures. Whenever a supplier is contracted to incentivise them through extrinsic rewards like payments, these can be sent in on a monthly basis or at every milestone. And to diminish transportation risks, companies decide to have suppliers transported by sea only during summer seasons, or in canals only after high rain season- prevent accidents like The Suez Canal. Ultimately, it is important to have multiple groups of supply and multi-routes.

4.5. Operational Risk Management Methodologies

Finding how integrated and well developed certain operational risk management methodologies are at each firm was chosen because identifying the threats within people, internal systems or external events aids to proactively protect the company’s assets and value-adding activities (Halkos and Tsirivis, 2019). To accomplish this, activities like risk/incident reporting, scenario analysis, risk assessment and evaluation of key risk indicators should be performed on a regular basis. In detail, risk reporting can be done through ISO standards to have an understanding of what is common for all or most organisations and it refers to collecting and reporting sufficient information over risks prior to any decision-making. Scenario analysis enables knowing the occurance and impact of operational losses by risk professionals, and is done with analysing internal and external lost data to discover risk exposures. Risk assessments are key to identify a risk and opportunities in risks as well as their

impact on operations. Lastly, key risk indicators (KRI) are quantitative measures used to foresee changes and calculate the organisations' alignment to uncertainty avoidance or acceptance (Young, 2019).

From the qualitative investigation these practices were explored with real examples and rated 4 or 5 (1-5) on their degree of efficiency. When a manufacturing project begins it first goes through a standardised risk management in which at every milestone, risk reviews are conducted with robust registers to show the KRI, schedule risk analysis to be conscious of supply chain delays and what consequences that brings to the building project. Lead times are incorporated for every component with the respective government consent after indicating the types of vessels, cables, turbines, etc. Contrarily, in minority, some intervieews expressed that risk assessments are usually seen as unnecessary perhaps due to perceiving their operations and systems as flawless. Which might seem somewhat narrow-minded since most organisations are shiffting toward a risk-based approach to ensure proactivism and adhere to regulatory requirments related to governance. Here planning is done without risk analysis for normal operations however when severe risks occur to mitigate them, operations are moved to time frames and weather conditions that will diminish its impact.

All share thorough risk reporting actions and KRI reasoning. The first is performed with specific teams, composed of long and short-term planners, equipment supervisors and other specialties, that meet every 2 months to discuss reports of graver risks with aspects for improvement. Sometimes those reports are sent for exterior analysis to licensing and regulatory entities. The KRI discussed are 4 in total and list as: supplier and competition monitoring, market changes, commodity prices and non-delivered energy which are better explained in ***Table 5***.

Table 5. List of Key Risk Indicators.

NAME	DESCRIPTION
Market Changes	• A good supplier relationship and monitoring helps know changes in current market projects and how much orders their suppliers are receiving from competitors.
Competition	• To understand when and where projects are receiving consent. Their timelines and there is factory engagement to be aware of lead times. • Soft indicators
Commodity Prices	• Knowing the prices of materials for construction (steel and copper) is crucial and to understand if there is shortage of materials • Covid aggravated the prices and shortage.
Non-Delivered Energy	• Quantatively calculate the amount of energy that was not delivered to the consumer because of a disruption. • The lower this KRI is the better.

4.6. Qualitative and Quantitative Risk Assessments

When discussing risk assessment strategies, the participants were asked to also distinguish between qualitative and quantitative practices used with renewables and petroleum energies. When discussing offshore oil refineries, sea platforms or vessels, countries and companies that do not embrace risk management fully, either it is through new technologies for risk identification and management with drones for industrial and patrimonial security and artificial intelligence or through older ones like the ISM coding which is always being updated and refined. Leads to accidents like shipping boats sinking in the Amazon river because legislation and control is borderline non-existing.

Risk and quality management lead to a better quality of service and can be done through many techniques' alike probability-impact matrixes, decision trees, pareto diagrams or stochastic simulation models (Muriana and Vizzini, 2017). Regarding qualitative risk assessments, these

were harder to describe but ultimately are experience based which may vary from person to person and for electricity for example involve interactive scoring sheets and tailored scoring schemes to different projects, countries and phases.

In respect to quantitative assessments, these are more detailed and complex. Starting by giving risk owners perhaps a choice of 7-8 distributors with the cost over time and then use beta plan distribution which is similar to a triangular distribution with weightings and accounts directed more to cost and time duration of a risk. Then from the quantitative inputs they do a multicolour analysis to provide cumulative frequency diagrams and charts for key levels and contingency. Combined with all the risk assessments from project, all values, and their total cost they put into a model which causes combinations of what risks could cost. The cumulative frequency diagram is a curve and one can select a *P* value to size up the contingency. For instance, if that *P* value is high that means the environment in which the project might happen is uncertain and unstable, but if it is lower, then the environment, the supply chain and the way businesses work is known and stable, i.e., UK's supply chain. To conclude, all risk information is united in terms of time and scheduling with the statistical modelling to understand when a project might finish accounting for risks.

Furthermore, quantitative assessments are also done through statistical historic studies of 10 years ago to see a percentage of failures in the system. As quoted *"looking back to 10 years we see that for a certain scenario only 5% of a risk type happened, so looking at tomorrow we assume that there is a 95% chance of safety" and "we are always being conservative with our statistics, seeing as if something goes terribly wrong and we identified there was a 60% chance instead of 95% of success we would be entirely liable if we proceed"* (Head of Operational Risk, Company D). This view of risk assessment seems purely to protect the company against external lawsuits instead of viewing it as this progressive management approach that can shift

an entire supply chain to be cost effective, innovative, prepared for research and development, and concerned with all stakeholders.

4.7. Risk Management and Smart Technologies

Throughout this section the emphasis will be on automation and risks which accompanied the industry 4.0 such as cybersecurity and software tools that maximise efficiency whilst improving communication in a cost-efficient manner.

4.7.1. Automation

When new technologies to be used in manufacturing arose in the market alongside trends of bringing back offshore factories into western countries, one big technological advance was incremented which was automation. Connected with immediate cost reduction and risk minimization, namely human made ones which are ultimately more occurring than machine made. A specific company entered this digital paradigm only after being presented with constant disruptions, you could say they served as a wake-up call. The electrical network was not automated and was becoming outdated compared to other foreign systems. A specific incident which led to an entire region without electrical power for some time, affecting businesses and personal consumption was a huge reinforcement to innovate. As well as the emergence in the market for aeolian energy which required new technologies. All this combined made the organisation enter a new paradigm of digital disruption and become more robust. At the moment, the emergence and risk/opportunity with solar energy might be a new push for a further innovation process. Understandably, automation mixed with a new system leads to having a premier quality of service.

On the operational side, automate risk sensing is crucial for maintenance teams to immediately know if a component like an oil or gear box is rising in temperature then they are notified that a risk is forming as materials are getting damaged.

4.7.2. Enterprise Project Risk Management

As mentioned in the literature review the concept of enterprise risk management arose with the development of smart technologies with the intuit of combining RM practices with the cyberspace and sophisticated manufacturing. In practice, this is achieved with, as discussed between me and interviewees, IoTs and cloud computing. A new online tool called active risk management is used by everyone in an organisation to flag, assess and mitigate risks as well as engage in RM is general. The tool can be used on personal or work devices and enables insider looks all the way down the supply chain since all employees are vigilant and can report a risk when they see it. It is the perfect tool for proactive RM as it is fore sighting the future for risk.

In addition, contract managers are pushed to have suppliers log in any issue on active risk management. *"It is very inclusive"* (Risk and Control Officer, Company B; Senior Risk and Insurance Manager, Company C). This tool is great to manage the operational side of the business and operational risks, since it has united people, particularly manufacturers and suppliers. If a component is damaged and disrupted production in for example a wind farm that same component is rejected in future projects and the respective lead time is also reported on the tool to be shared across the business to reach quality management teams.

4.7.3. Quality Management and Cybersecurity

As expected, new revolutions bring new risks attached, as is the case with cyberattacks. Besides following several ISO standards such as ISO 9000 and 9001 (ISO, 2021), having quality management trackers and inspectors who speak the language of the locals for on-site inspections, the active risk management tool is prepared for any disruptions in the cyberspace in order to keep information and market/company knowledge safely stored with by the second backups on the Amazon purchased cloud. Moreover, this tool also helps with risk sensing and to improve RM decisions since all information comes directly from people and is always updated.

4.7.4. Communication and a Digital Future

Within organisations there may be too many interpretations and each individual has their own language and when a risk impact is passed onto stakeholders, meanings can be lost if their link has too many repetitions in between. Covid-19 worsened this with slower communication, but job rotation was pointed out as a solution due to a narrow notion of what others are responsible for. On the other hand, to better communication companies need their projects and information all in one tool, like active risk management. To have a commonality of understanding and language, for instance everyone should have the same definitions of risk and consequences. Having a common tool increases accessibility and standardisation. In addition, having peer reviewed work by people from other departments enables continuous innovation and refinement.

5. Discussion

The themes emerging from the interviews help answer the research question *"How are risk management capabilities used in manufacturing organisations in the energy sector?"* and address how prevalent smart technologies are for effective risk management today and in the future.

When 15 risks were identified and assessed by respondents, the researchers developed their risk score, so energy organisations know where they stand in relation to these risks. They might raise questions, such as *"how do we address them?"* and so crucial mitigation actions were defended. In addition, an interesting article by Chen *et al.* (2013), argues that supplier collaboration leads to diminished supply chain risks.

Supply chain collaboration is about companies adopting a long-term perspective together to create value that alone could not be as high. With intensified competition, individual companies may find it difficult to compete alone however aligning their supply chain partners to achieve

collaborative advantage could be the key. Perhaps this strategy is not well-suited for our oil and gas companies but could be an interesting strategy for the TSO and to help battle renewable energy project bidding wars. The oil and gas sector is too competitive not just between companies but also amongst countries so perusing the "one for all and all for one" mindset will take a lot of reimagining (Barbosa *et al.*, 2017). However, the TSO professional mentioned that since TSO's have the common goal of cutting costs efficiently so that overall, the European Electric System can offer the consumer the best options and be able to, if they so choose, receive energy from another country because it's cheaper. Then they can make that happen with supplier collaboration which was not mentioned but may be already present. This collaboration grants information sharing in problem-solving and new product development to refine operations and enhance competitiveness. It provides a superior approach compared to the market in collecting and integrating knowledge over production processes, technology development, market trends, and customer preferences. Also, a good solution for the rigorous change management processes suppliers have to go through as they can oversee quality management being done at the buying company and which programs are in place by visiting premises and also receive the adequate training.

Furthermore, interestingly the researchers noticed a recurring trend in which big revolutions happen worldwide and within organisations which refers to establishing great risk management tools or innovating management systems only after a great disruption and asset loss. In this case, an incident in the electrical network pushed a new paradigm of digital innovation and the Titanic sinking finally shifted mindsets of ship crew members and responsible government authorities, leading to the creation of SOLAS. Before it was expected for staff to drink alcohol on shift, to not have restrictions to prevent accidents on board or the appropriate emergency exit strategies.

The findings confirm the importance of enterprise risk management and smart manufacturing through automation and quality management systems as discussed in the literature, reinforcing themes, but also suggests that not all organisations make autonomous/proactive changes to adopt these. However, those that do are extra competitive in the market and are able to accept more projects and receive consent more easily. There are also specific programmes mentioned for example active risk management, and specific KRIs like non-delivered energy that managers can embrace and train employees on. These findings and analysis are a good insight to this industry because anyone who reads them has access to real examples. Oftentimes the existent journal articles may not present these specific programs especially through surveys unless one is already experienced in the sector, which may not be as perceptive to readers that are not.

6. Conclusions

The purpose of this study was to discover what risk management meant for industry professionals and the tools involved for its effectiveness. Especially in today's business environment where technological innovation is so present and is changing the way we communicate with each other and how its incinerating job roles that 10 or 20 years ago were considered key. Risk management is viewed as incremental, but still relatively seen as a mandatory action instead of a value-adding activity. The literature was extensive accounting for oil and gas companies but still lacking when discussing electric and renewable energies hence the relevance of this study. The findings showed this by presenting a deep analysis of tools used but also some belief that operations run so smoothly that risk management may be unnecessary. Perhaps why they are smooth is because it is already embedded in people's minds without them realising. In addition, samples were collected from different countries with distinguished innovation levels and cultural values and country related beliefs impact organisations differently.

There were some limitations on data collection methods and literary gaps but overall, these were successfully overcome. It is difficult to generalise findings from five interviews, so the results here only apply to the countries involved: UK and Portugal. As the interviewees were chief risk officers, it would have been good to contrast their views with those having entry-level expertise. For instance, the researchers read academic journals for similar studies performed with interviews which also displayed the respective questions, although from approximately a sample of 100 papers, 90% used surveys and the 10% that used interviews did not publish their questions.

This study may be viewed as an exploratory work, and a more detailed investigation involving multiple interviewees from different hierarchies in the organization, as well as different stakeholder perspectives is a pre-requisite before any inferences can be drawn on effective risk management.

Future research could focus on relating risk management to the impact of use of particular aspects of Industry 4.0, SC digitalisation and new business models.

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***Appendix*: Semi-structured interviews questionnaire**

1. What is the company's position in the supply chain with respect to risk management? Specifically, how is your role related to the management of risk in your company and its supply chain?
2. As you may have noticed from the documents I have sent you the core subjects of this Master dissertation project are risk management and manufacturing capabilities. Hence as you may have predicted due to the nature of your operations the scope of this interview will focus on the first and most crucial part- risk management.
-To start off, how well developed would you say are these operational risk management methodologies at your organisation: Risk assessments, Incident reporting, key risk indicators and causal event analysis.
3. And if you can please name the risks that your department (system's management) considers the most important and prevalent by rating their probability of occurrence and impact on the company from 1 to 5 (1 being the least probable of happening and the least impactful).
-Perhaps dividing them between type, for instance those external or dependent on the environment (i.e., climatic risks and shortage of skilled labour), internal to the firm (i.e., high labour costs) and internal to the supply chain (i,e., packaging material quality and delivery delays).
(Identify at least one for each category)
3.1. I would like to be specific now on the risks that are internal to the supply chain, specifically those related to manufacturing such as labour and machinery. It can be the material availability, labour performance and shortage of skilled labour, etc. Can you specify which ones you consider of most importance and your strategies to mitigate them.
4. I would like to discuss a possible connection between the industry 4.0's related technologies like the Internet of Things, cloud computing and business decision modelling tools with your risk management practices.
In practice, information technologies help improve supply chain performance, by bettering communication, acquitting and transmitting data and easing the decision-making process. (Deloitte, 2019).
For instance, AI revolutionised quality inspection by allowing firms to reduce quality control efforts and operational costs on exponential levels.

-How does your organisation use the latest technologies in its operations and that ultimately help it to cope with supply chain risks?
4.1. How is quality management done at your organisation? Does it involve these latest technologies?
4.2. Do these technologies help you spot and perform risk assessments? Assigning probability, impact and response strategies.
4.3. Which new risks arose for your operations? Perhaps you were more attentive of cyberattacks.
4.4. How did you apply or how can you apply predictive analytics, risk sensing, and other smart technologies to improve your risk management and decision support capabilities? (Peirson *et al.*, 2020)
4.5. What advice would you give so that organisations communicate better about risk across their organisation? In a way to dismantles barriers between risks for different departments. Since ultimately the whole organisation will be affected. And how can one portray more clearly a risks impact to stakeholders.
5. Continuing the risk assessment implementation. Could you elaborate more on your qualitative as well as quantitative risk management practices?
If both are present. For instance, qualitative methods help characterize the degree of importance through the choice of response. Some companies use expert risk assessment as it involves forecasting and risk analysis based on the opinions of experts who have experience in the implementation of innovative projects. And quantitative risk assessments are more objective by attributing a number to extant risks and dependant on data from fluctuations in resource costs, average activity completion time, logistics etc.
6. Furthermore on the evolution of risk management I would like to enter Covid-19 into the discussion. How has covid affected your operations and supply chain activities? And was this a chance to upgrade and reposition your risk management strategies?

6.1. Regarding covid's impact on your operations and management practices. From the correlation made in the research in these types of organisations, a just in time and lean management is prevalent right? Which is suitable for stable environments. Although covid opened up room for researchers to doubt if agile manufacturing practices or a hybrid mix for certain operations is more appropriate. Can you verify this and explain if you think this is possible and which operations could be agile and which should remain lean?
6.2. After the disruptions from the pandemic and from the emergence of new technologies, over the next 3-5 years, which three risk types do you think will increase the most in their importance for your business? For instance, is it cybersecurity, credit, regulatory and compliance, environmental, etc. (Deloitte, 2020).
7. To what extent do you think an organisations future is about digital and how can energy companies improve their provision of the right skills and training. Especially since the future is about renewable and sustainable energies which are possible with the development of new technologies.
8. Regarding distribution and logistics flexibility, could you indicate how prepared for unexpected supply chain breakdowns you are with the use of multi-modal, multi-carrier and/or multi-route transportation methods. (Sreedevi and Saranga, 2017).
8.1. Regarding preventive risk mitigation action programs can you rate from 1 to 5 your detection of operational risks, for instance internal or supplier monitoring, inspection and tracking. (Sreedevi and Saranga, 2017)