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Resilience of Marine Energy Supply Chains: The Manufacturers Challenge

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Abstract— Companies are operating in an era where **V**olatility, **U**ncertainty, **C**omplexity and **A**mbiguity (VUCA) is commonplace in manufacturing companies. To manage effectively in this environment, manufacturing supply chains need to adopt resilient strategies. Organisations continue to adopt various technologies in order to manage the VUC environment and Marine Renewable Energy (MRE) supply chains are seen as a front runner in emerging technologies which has an impact on the business environments and supply chain practices globally. In this study, the authors undertook a systematic literature review of 95 scholarly articles published on Marine-driven supply chains and explore the impact and importance of manufacturing resilience. A bibliometric analysis was carried out via the Scopus database and results filtered, coded, and analysed using the bibliometric-R package. The authors then evaluated the thematic areas of Marine Supply Chains and explored identified challenges and proposed areas of development to move towards a resilient manufacturing supply chain.

Keywords— Marine Renewable energy, Supply chain, VUCA, Manufacturing Resilience.

1. Introduction

Supply Chain Management theory explores the importance of understanding and adequately responding to uncertainty and risk within our supply chains [1]. Evidence suggests that although numerous projects are being implemented in the UK to harness Marine Renewable Energy (MRE), they are often subjected to various challenges from, establishing required supply chain capacity for the manufacture and implementation to ongoing maintenance and monitoring [2]. In particular, the supply chains of relatively new and technologically advanced products, such as MRE technologies, are deemed to be more volatile, uncertain, complex and ambiguous to challenges, risks, and disruptions [3]. This VUCA environment can be created due to several factors contributing to increasing the probability of exposure to risks and their associated impact on the supply chain, such as; availability of capacity, identification of appropriate suppliers, establishing new collaborative networks, and learning curves associated with new technology and processes etc. Previous research has indicated concern regarding the

MRE sector's readiness to respond quickly to rapid growth in demand and the impact of capacity availability to respond and therefore the increased sensitivity and impact of disruptive events. This has reinforced a call for a better understanding of how to improve supply chain resiliency in the marine energy sector. The future resiliency of the MRE supply chain sector, to a large extent, depends on adopting a dynamic, responsive strategic policy decision-making process in response to uncertainty and risk [4].

This research has specifically utilised the term Marine Supply Chain (MSC) to indicate research that focuses on regional players within the marine sector. It should be noted that the term MSC was utilised to capture the wider influencing network on the MRE supply chain. This allows the literature search to ensure the inclusion of research that focuses on exploring in depth the sustainability and resilience of the MRE supply chain practices embedded within the wider context.

A comprehensive evaluation of the complex dynamics and multi-dimensionality surrounding MRE projects is key to determining the fundamental changes and subsequent actions required to transition from fossil-fuel based energy sources to MRE technologies. Although the underlying mechanisms associated with the concepts of supply chain resiliency have been extensively researched in recent years, the wider adoption of tools designed as part of academic research to improve operational performance has been limited [5]. .

2. Material And Methods

To fulfil the objectives of the study, the authors conducted scientific mapping through a bibliometric analysis of articles filtered via a systematic literature review. The scientific mapping of the articles identified was conducted via the Bibliometrix R package [6]. From the bibliometric analysis authors identified the research themes representing the objectives of the study. To explore VUCA and resilient strategies and their linkage within published literature with the MRE supply chain, a set of key search terms were identified. The search terms utilized to identify the literature were "Marine"; "Renewable"; "Supply Chain" using the logical operator AND. This was then followed by the terms "Risk"; "Disruption"; "Resilience"; "Responsiveness"; "Disaster"; "VUCA" using the OR operator. These terms have been utilized in previous studies by [4] and [7]. Further, the search term was focused on the broader theme of MSC with supply chain practices only. Using the search criteria, the initial database search yielded 270 articles which through the filter process resulted in 95 journal papers for inclusion in the analysis. Figure 1 describes the search and filtering process.

3. Review Analysis and Results

To understand the article's spread with respect to the domain area; countries and the research areas, the authors used a sankey diagram to represent the relationship between countries, research area and source journals. The Sankey diagram is shown in Figure 2, where the flow between the countries; research areas and journals are established, and width of the flow represent the strength of relationship [6]. The analyis was focused on identifing and grouping the author's keywords which represent the constructs of MSC and Supply chain practices in the collected dataset. The tree diagram shown in Figure 3 shows hierarchical data with nested rectangles.

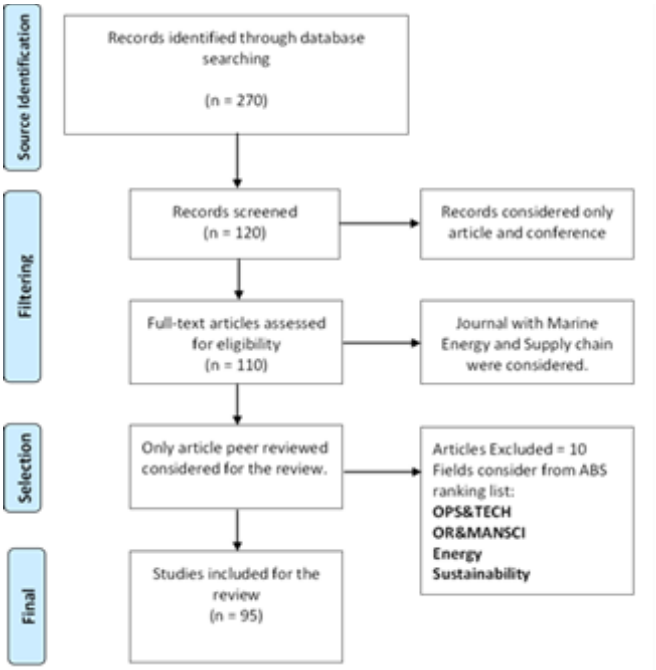

Figure 1 PRISMA Process for Literature Review Design

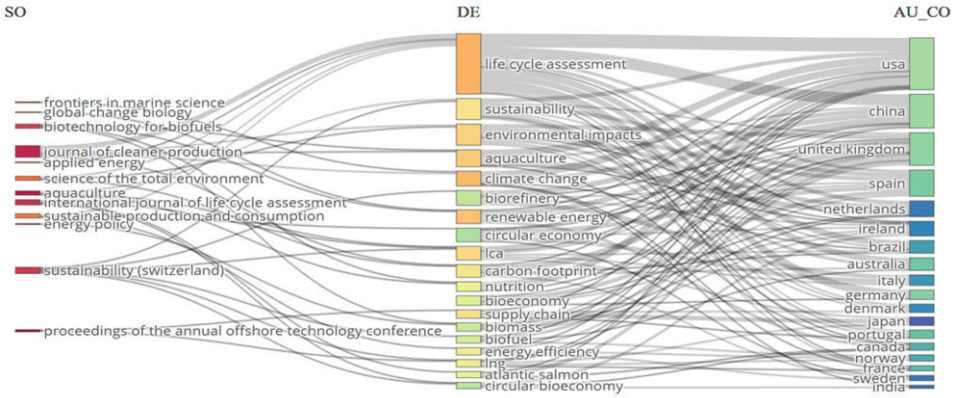

Figure 2 Flow between the Countries; research area and source

Each branch is a rectangle divided into smaller ones for sub-branches [6, 8]. Each cluster contributes to the three thematic areas as follows:

(1) Impact of MRE on supply chain practices
(2) Resilience in the Marine- driven supply chain
(3) Addressing disruption in Marine-driven supply chain

The clusters obtained from the tree map address the research question. Moreover, based on the thematic areas the authors evaluated the articles related to each theme and performed a content analysis to explore the research questions.

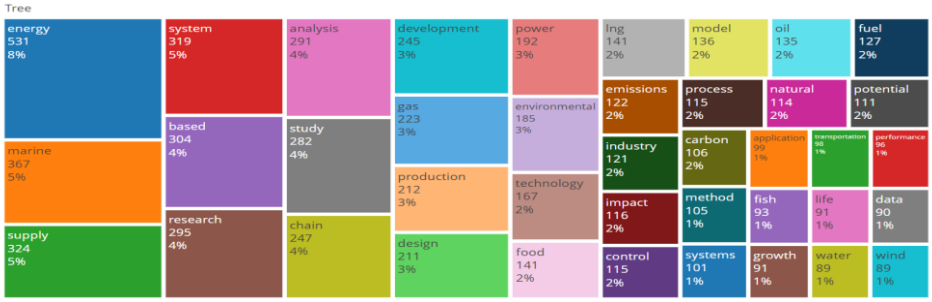

Figure 3. Tree map for unique areas

4 Review of the Three Thematic Areas

4.1 Impact of MRE on supply chain practices

Real-time data updation – enabling in-depth forecasting decision making, sensor-driven and IoT based devices capturing data in real-time [9]. *Supplier to customer visibility on a common platform* – decision support system ensures that data is used to create a single virtualized data layer for the ease of understanding the customer requirement in real-time. *Integrated business planning* shows that firms require availability and access to the wider triple helix environment including government policy, research and organizational experience thereby allowing integrated system analysis for developed action plans.

4.2 Resilience in the Marine driven Supply Chain

Predictive analysis - Adoption of capturing relevant system data and analyzing the considerable dataset, MSC is improving the capabilities of all the companies in areas of Predictive demand, network planning, delivery estimation, inventory planning and extend MRP [9]. *Smart Systems complexity* –the adoption of smart systems within the MSC primarily from a materials handling perspective. Bots are commonly used to restock the empty shelves or to deliver the stock from one destination to another inside a warehouse reducing errors and updating systems continually [10],[11]. However, these bots cannot solve issues autonomously, it requires human intervention because they pose narrow Artificial intelligence (ANI). However, the interface that connects the sensor network (Radiofrequency Identification - RFID; Near-field communication NFC) with the bot can be sophisticated and requires trained professionals to monitor and ensure smooth operations. *Customer uncertainty* **-** MSC-enabled chat Bots are smart that can interact with the end-user in the B2C industry to provide real-time delivery information and the status of the delivery [12]. Likewise, in some cases, it can even predict the accurate time in which the order will be delivered. However, the bots are in the early stage of interaction and trying to mimic human interaction through Super Artificial Intelligence (ASI).

4.3 Addressing disruption in the Marine-driven supply chain

Supply chain practices are managed globally with different stakeholders. Therefore, the organization ensures their practices can face risk and uncertainty. Baryannis et al. [8] reported Mathematical programming was preferred in risk management. Similarly, the Security and risk for food supply chain were addressed by [13] using the discounted system involving Markov decision process as well as a review on responsiveness, risk and resilience showed that ensuring responsiveness is crucial for supply chain operations [14].

5. Challenges to Consider for the Manufacturer

The literature review analysis undertaken within this research highlighted the following significant challenges and setbacks that impact the MRE supply chain resilience, these included: *Lack of quality & quantity in data mined* - Computational processes require a large amount of data and artificial intelligence is no exception to that. *Machine learning* (ML) hugely depends on data to learn and predict the outcome for the given scenario. However, getting the required data from different sources and siloes is a challenge for the organization. Further, the investment in data extraction through the data management module with the interlinked system is cumbersome [15]. *Short term optimization*- Supply chain networks tend to consist of many players and systems connected within a complex network, with maturity at distinct levels. So, it is easy to lose sight of the process control and monitoring, leading to unpredicted consequences [16]. Short term solutions will lead to uncertainty as it may promote the restructuring of the supply chain design, creating ambiguity in the system and will incur significant loss to the system. Such a scenario creates volatility in supply chain optimization and transactions. So, the decision system will fail to achieve its optimal performance especially in terms of achieving resilience, resulting in arguable self-imposed complexity in the supply chain practices *Lack of Marine driven supply chain understanding* - Since there is a myriad of choice of available platforms the Marine driven supply chain could adopt and utilize, it can take time to understand, adapt and work within the context of the MRE sector [17]. There is a requirement to develop strategic relationships and collaborative strategies to ensure decisions are made with the supply chain in mind to reduce the additional issue of incompatible systems being adopted. The learning curve and bedding in time can reduce the productivity and efficiency level of the supply chain optimization in the short term or indeed mean the fully competitive advantage is not achieved in the long run thereby resulting in failure to improve the resilience [18]. *Global Uncertainties* – 'Black Swan' events like the COVID 19 pandemic have a huge impact on the supply chain industry and as examples show can easily disrupt the flow of goods and services and can quickly cripple a supply chain as the world responds for example with global curfews and the temporary ban on global trade [19]. These uncertain situations are difficult to predict even with sophisticated machine language or supply chain management software. Therefore, continued development of forecasting and prediction tools to optimize the supply chain dynamic performance and provide resilient strategies will continue to be one of the biggest challenges, and an area of continued research focus for the future.

6. Optimizing the MRE Supply Chain

Deploying an effective MRE supply chain strategy is challenging because of range of issues including: *Detection and collection of data*; setting the *parameter and constraints*; *sensor and decision support systems*; *networking with stakeholders*; *process mapping and monitoring* and, *feedback and response mechanism*. An integrated MRE supply chain that enables collaborative information sharing can serve as a mechanism to address these difficulties and improve supply chain performance. Therefore, the authors highlight that the organization should make ample investment in a Marine-driven ecosystem including policy development and communication, and resourcing (including time and financial). When viewed holistically the supply chain practices consist of the *Design: manufacturing Modelling; Network Coordination; Transaction; Collaboration and Optimization* some of which can be monitored by sensor systems [13]. Moreover, the

adoption of an appropriate framework aids the organization in supply chain practices for better risk mitigation leading to improved resilience of the individual players as well as the holistic supply chain. An effective MSC is big data focused and driven with inputs from multiple sources, which is evaluated by the decision support system for effective decision making. The MSC can serve as a platform for monitoring global supply chain operations and avoid or at least minimize the impact of supply chain disruption through predictive analytics from the historical data. Moreover, the entire information must flow through the blockchain, therefore, making the information flow reliable and secure. However, the MSC requires skills development and training to enable research utilizing the data set to understand the nature of black swan events. Thereby enabling an understanding and development of contingency plans to cope with and manage even if the occurrence of black swan events, and decision-makers can validate the strategy to understand the efficiency of the MSC resilience. The literature reviewed indicates limited adoption of supply chain practices in this context are Marine driven. However, the MSC's usage classifies the nature of the supply chain practices. They are as follows: *Reactive Supply chain* - reacts to input with limited stimuli; *Responsive supply chain* – responds to inputs and produce feedback; *Intelligent supply chain* – understand the need and work with other entities and, s*elf-aware supply chain* – capable of human-like thinking and decision making.

7. Conclusions

From, the articles reviewed, many provided an empirical solution based on model development; however, the studies are specific to the industry. However, contribution to theoretical and conceptual research was limited. Further, most of the articles focused on conducting simulation-based studies and used a different algorithm. out of which, Decision Theory; robust optimization; swarm optimization and genetic algorithm were widely used. Approximately 50 studies reported on developing a decision model to address their issues in life cycle assessment. However, many studies have not developed any model for decision making. This therefore requires more in-depth research to explore the importance of utilising DSS to enhance the MRE supply chain resilience.

Further, the research indicated that risk and uncertainty in supply chain operations are very volatile, and life cycle assessment alone cannot provide an effective solution without sustainability and circular practices being examined and included. Interestingly only, 4% of the study coupled their decision support system with circular economy and 2% paper discussed the use of energy efficiency. This creates a gap in providing a decision on a real-time basis. The impact of Marine driven supply chain is arguably widely addressed within the literature examined however, the level (and depth) of the MRE supply chain that decides the nature of the practices employed and utilized requires more attention. Furthermore, more detailed understanding and testing in industry of effective models for crisis/risk management and disaster management needs to be undertaken to explore and address the changing situations especially given the projected rise of the MRE sector. This is especially important to ensure proposed enhancements and improvements to the MRE supply chain practices will optimise rather than hinder the resilience of the holistic system.

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