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Exploratory analysis of a systemic approach to study supply chain integration potential in the UK offshore wind industry

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Abstract

Emphasis has been placed on supply chain management (SCM) and supply chain integration (SCI) within the offshore wind (OSW) industry in the United Kingdom (UK). The UK government has shown an interest in developing a technologically advanced, skilful, and competitive domestic supply chain with the potential to support future OSW developments around the UK coast. The need to develop a more cost-effective and collaborative OSW supply chain has introduced the concept of SCI into discussions of the OSW industry. Notwithstanding the importance of SCM and SCI in the UK OSW industry, and despite the widespread use of these terms within the industry, little has been done to explain these concepts in relation to the context of OSW. The purpose of this thesis is to address this limitation by providing more detailed description of the OSW supply chain from a theoretical standpoint by empirically exploring SCI in the OSW industry to build a greater understanding of the nature and potential of SCI in the OSW. This research focuses on the development and construction phases of 'fixed bottom' OSW farms in the UK. Based on the existing SCM and project-based SCM literature, this thesis provides discussion of the OSW supply chain. The thesis also explores the literature on SCI and systems thinking to form a foundation for an empirical study of SCI in the OSW industry. It applies a systems thinking approach called the Viable System Model (VSM) to qualitatively explore the nature and potential of SCI in the OSW supply chain. This research draws upon Espinosa and Walker's (2017) suggested 'methodology to support self-transformation' as a guideline for the application of the VSM, and conducts interviews with representatives of the OSW supply chain for the collection of primary data. The thesis proposes two SCI strategies based on the VSM; the 'viable SCI strategy' and the 'strategic cluster integration strategy', which demonstrate the potential of SCI within the OSW industry, including what improvements could be made to facilitate the performance of the whole supply chain. The research findings provide insights into the current nature of SCI within the OSW industry, ultimately suggesting that SCI is largely dependent upon the different approaches taken by OSW project developers when managing supply chains. In addition, this research identifies several facilitating and inhibiting factors of SCI. This thesis contributes to the existing body of knowledge by introducing a VSM inspired framework for the analysis of SCI within project-based environments. Furthermore, it proposes SCI strategies to show how OSW supply chains can be integrated and what improvements could be achieved as a result.

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List of Abbreviations

ABEX	Abandonment Expenditure
ANNs	Artificial Neural Networks
AR	Action Research
ATO	Assemble-To-Order
BEIS	Secretary of State for Business, Energy and Industrial Strategy
BIMCO	Baltic and International Maritime Council
BOP	Balance of Plant
BPR	Business Process Reengineering
BTO	Buy-To-Order
C&C	Construction and Commissioning
CABS	Chartered Association of Business Schools (UK)
CAPEX	Capital Expenditure
CAS	Complex Adaptive Systems
CATWOE	Customers, Actors, Transformation, Worldview, Owners, Environment
CfD	Contracts for Difference
CII	Construction Industry Institute
CO2	Carbon Emissions
CPFR	Collaborative Planning Forecasting and Replenishment
CR	Continuous Replenishment
CSCMP	Council of Supply Chain Management Professionals
D&C	Development and Consenting
De-comm	Decommissioning
DEVEX	Development Expenditure
DFD	Data Flow Diagram
DNV Standards	Det Norske Veritas Standards
DP	Decoupling Point
DRP	Distribution Requirements Planning
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
EE	Extended Enterprise
EIA	Environmental Impact Assessment
EPC	Engineer, Procure, Construct
EPCI	Engineer, Procure, Construct, Install
ERP	Enterprise Resource Planning
Ethics-CSR-Man	Ethics Corporate Social Responsibility Management
ETO	Engineer-To-Order
ETS	Engineer-To-Stock
EWEA	European Wind Energy Association
FEED	Front-End-Engineering and Design
FID	Final Investment Decision
FIDIC	The International Federation of Consulting Engineers
GW	Gigawatt
GWEC	Global Wind Energy Council
H&S	Health and Safety
HEIF5	Higher Education Innovation Fund 5
HS&E	Health Safety and Environment
ICT	Information Communication Technology
IEA	International Energy Agency

Info Man	Information Management
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
IT	Information Technology
JIT	Just in Time
KPIs	Key Performance Indicators
LCOE	Levelised Cost of Energy
LCR	Local Content Requirement
LOGIC	Leading Oil and Gas Industry Competitiveness
MDR	Master Document Register
MRP	Material Requirement Planning
MTO	Make-To-Order
MTS	Make-to-Stock
MW	Megawatt
NEC	Engineering and Construction Contract
NGET	National Grid Electricity Transmission
O&M	Operations and Maintenance
OECD	Organisation for Economic Co-operation and Development
OEMs	Original Equipment Manufacturers
Ofgem	Office of Gas and Electricity Markets
OFTOs	Offshore Transmission Owners
OPEX	Operating Expenditure
Ops & Tech	Operations and Technology
Or & Man Sci	Operations Research and Management Science
Org Stud	Organisation Studies
OSW	Offshore Wind
POS	Point of Sale
PPA	Power Purchase Agreement
PSM	Problem Structuring Methodology
R&D	Research and Development
RD&E	Research Development and Engineering
RO	Renewables Obligation
ROC Room	Rehearsal of Concept Room
SAST	Strategic Assumption Surfacing and Testing
SCI	Supply Chain Integration
SCM	Supply Chain Management
SD	System Dynamics
SOVs	Service Vessels
SSM	Soft Systems Methodology
STS	Ship-To-Stock
TASCOI	Transformation, Actors, Suppliers, Customers, Owners, and Interveners
TOC	Goldratt's Theory of Constraints
TSI	Total Systems Intervention
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USP	Unique Selling Point
V&S	Viability and Sustainability

VE	Virtual Enterprise
VMI	Vendor Managed Inventory
VSA	Viable Systems Approach
VSM	Viable System Model

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Chapter One

Introduction

The research discussed in this thesis is an outcome of the author's own personal interest in the UK OSW industry, which developed during her previous involvement as a research assistant in the Higher Education Innovation Fund 5 (HEIF5) research project. The HEIF5 project, which investigated the requirements for smaller businesses to be involved in the UK OSW industry, inspired this research (Danilova et al., 2016). The following section will provide further details on how this research evolved by outlining the background to the study, the main research problem, an overview of the methodology that will be employed, and the thesis outline.

1.1 Research Background

Climate change is becoming an increasing problem due to rising levels of anthropogenic greenhouse gas emissions, which places pressure on countries across the globe to find effective ways to tackle this issue. The energy sector, including fossil fuel combustion and industrial activities, accounted for the majority of carbon emissions (CO2) between 1970 and 2010 (IPCC, 2014). According to the international treaty of the United Nations Framework Convention on Climate Change (UNFCCC), reducing carbon intensity in the energy sector is a key goal of developed countries.

Following the IPCC's (2014) findings on climate change, in 1977 members of the United Nations (UN) in Kyoto, Japan, adopted an international agreement known as The Kyoto Protocol, which set out internationally binding emission reduction targets for its member parties. This resulted in the growth of renewable energy projects across the globe, particularly in the wind power sector (IEA, 2018).

Wind power developments have traditionally been built on land. However, with limitations surrounding the availability of land for potential onshore wind farms, as well as issues such as public concern about noise, visual impact, and wildlife, on land wind power developments have reduced. These concerns created new opportunities for wind power, and the industry has moved away from land-based wind farms to sea-based wind farms, known as OSW. In comparison to on land wind, OSW offers more opportunities for wind farm sites, which provide greater wind resources that can be harnessed for green energy production (Kaldellis and Kapsali, 2013).

Given the favourable OSW market conditions, such as shallow seas and strong winds, the UK has become the largest OSW market in the world since 2008 and is expected to maintain its leading position with further plans to develop OSW projects (Wind Europe, 2019). The UK's achievement in the global OSW market has made it a major success story and an important national asset, providing opportunities for industrial and economic development (HM Government, 2017).

The development of UK OSW has often been discussed from a SCM perspective in government and industry reports (HM Government, 2019; Whitmarsh, 2019). Specifically, it is understood to have contributed to the development of the UK's domestic supply chain (Whitmarsh, 2019). Furthermore, it provides the opportunity to establish a technologically advanced and skilful UK supplier base in order to support OSW development in the UK, with a view to increase the global competitiveness of UK companies. This vision has been outlined in the UK offshore wind industrial strategy as follows:

> "*Industry and Government work together to build a competitive and innovative UK supply chain that delivers and sustains jobs, exports and economic benefits for the UK, supporting offshore wind as a core and cost-effective part of the UK's long-term electricity mix*" (HM Government, 2013: 5).

Over the past several years the OSW industry has been placed under increasing pressure to reduce its capital and operating costs in order to be more competitive with onshore wind and alternative energy sectors. The need to reduce costs has once more placed discussions of the OSW supply chain at the forefront of many industry and government reports (The Crown Estate, 2012). Achieving efficiencies in the supply chain has been identified as one of the ways to reduce OSW costs. An efficient supply chain is closely related to an integrated supply chain. Therefore, 'supply chain integration' (SCI) has become another commonly used term in the OSW industry. More recently importance has been placed on achieving closer relationships across the supply chain to improve its productivity and facilitate more collaborative OSW developments in the future (The Crown Estate, 2019).

While the concepts of SCM and SCI have been widely used and discussed in the context of OSW, little academic research has been conducted to explain what these terms mean in relation to the OSW industry. At the time of writing this thesis only four academic articles on this topic had been identified (Martinez Neri, 2016; D'Amico et al., 2017; Irawan et al., 2017; Poulsen and Lema, 2017). However, these articles provide only a partial description of the UK OSW supply chain, and only one academic article specifically examines SCI in relation to OSW (Martinez Neri, 2016). However, Martinez Neri (2016) only focuses on providing a review of SCI articles to establish its relevance within the OSW industry, as opposed to providing empirical research on SCI within the industry.

The concept of SCI is relatively established within the SCM literature; an integrated supply chain is understood as being a well-managed supply chain, where its value-adding processes provide the highest level of customer value (Pagell, 2004). The integration of supply chain processes is therefore perceived of as being a central tenet of SCM thinking (Sweeney et al., 2015). There is general agreement within the academic literature that an integrated supply chain leads to greater supply chain performance overall (Frohlich and Westbrook, 2001; Narasimhan and Kim, 2002). However, research on SCI is predominantly concerned with continuous or line manufacturing supply chain environments. Limited research has been conducted on SCI in project-based supply chain environments, such as the supply chain processes of large construction projects like OSW farms (Eriksson, 2015; Martinez Neri, 2016). This is despite the importance of integration in construction and project-based supply chains being highlighted in government sponsored reports (Latham, 1994; Egan, 1998). Both Latham (1994) and Egan (1998) draw attention to the inherent problems in construction project supply chains, including fragmentation and adversarial relationships among supply chain parties, which often lead to inefficient project outcomes. Similar problems have been attributed to the OSW industry (Martinez Neri, 2016). The integration of supply chain processes in construction or project-based environments could help to ensure efficient project outcomes, thus resulting in greater customer value (Dainty, 2001). SCI in project-based environments involve collaborative relationships among project supply chain members, who work together as a unified team (Briscoe and Dainty, 2005).

Despite the importance of SCI within SCM, ambiguity remains as to what constitutes SCI and how it can be achieved given the diverse nature of supply chains (Evans and Danks, 2002; Stevens and Johnson, 2016). Nonetheless, a common perspective in the SCI literature is that there is a need to take systems perspective in exploring SCI, which emphasises the improvement of processes across the whole supply chain rather than focusing on parts of the supply chain only (Sadler, 2007). Many logistics and SCM scholars recognise systems thinking as a relevant concept that can help understand supply chains holistically (Choi et al., 2001; Grant, 2012). However, Lindskog's (2012a, 2012b) literature review on the application of various systems thinking approaches in logistics and SCM discipline shows that they remain underutilised in this field.

The shortcomings of the existing academic research into the OSW supply chain and its integration, in addition to a lack of studies that apply systems thinking approaches to SCI research, provide an opportunity for this thesis to address these gaps in the literature. The aim of this thesis is therefore to explore the nature and potential of SCI in the OSW supply chain by drawing upon organisational cybernetics and the VSM as a systems thinking theory. The VSM provides the basis for assessing and designing viable and sustainable businesses and networks, thus providing a useful approach to the study of SCI (Espinosa and Walker, 2017).

1.2 Research Context

The primary context of this research is the UK OSW industry; specifically fixed bottom OSW farms, as opposed to floating OSW farms. 'Fixed bottom OSW' refers to traditional OSW whose wind turbine foundations are fixed to the seabed. The UK is the global leader in terms of installed OSW farms and has shown great interest in building more efficient and collaborative OSW supply chains (Whitmarsh, 2019). The UK OSW industry therefore provides an ideal case in point to explore the nature and possibility of SCI using the VSM.

The OSW supply chain is predominantly discussed from the perspective of the lifecycle of OSW farms (Poulsen and Lema, 2017; BVG Associates, 2019). The OSW industry typically distinguishes four phases of a wind farm's lifecycle: the development and consenting (D&C) phase, the construction and commissioning (C&C) phase, the operations and maintenance (O&M) phase, and the decommissioning (De-comm) phase. This study is specifically interested in the first two phases of a wind farm's lifecycle because they relate to supply chain processes, which can be characterised as the construction or project-based supply chain environment. The first two phases play an important role in determining how successful the outcome of an OSW project will be (BVG Associates, 2019). Therefore, achieving greater SCI during these phases is considered to be important. The O&M phase involves maintenance processes of completed wind farms that do not relate to project-based environment and is thus excluded from this research. The de-comm phase involves dismantling processes of wind farms that have reached their end of life. The de-comm phase focuses on the reverse processes from those involved in the D&C and C&C phases and therefore is also excluded from this research. Figure 1.1 illustrates an OSW farm's lifecycle phases, which form the context for the system in focus of this research:

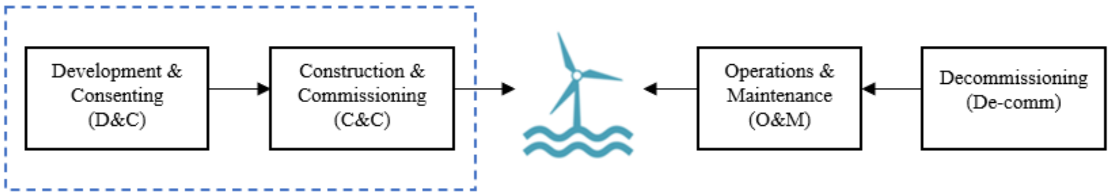

Figure 1.1: OSW industry context of this thesis (Author)

The study sample is drawn from representatives of companies involved in the first two phases of the OSW lifecycle. More information on the process of sample selection will be provided in Chapter Four.

1.3 Research Problem

Based on the above discussion, this thesis addresses three underexplored areas: SCM in the OSW industry, SCI in project-based environments, and the use of a systems thinking approach in SCM. Each area will be discussed in more detail in Chapter Two, which will review the literature related to these bodies of knowledge to establish the theoretical foundation for this thesis. The literature review informs the development of the research questions in this thesis. The overarching research problem explored in this study is summarised in the following research question:

How can a systems thinking approach; VSM help to understand the current state of SCI in the OSW industry and reveal potential areas for improvement in order to facilitate greater performance of the whole supply chain?

The following sub-questions have also been proposed to assist in answering the main research question:

Q1. What is the nature of SCI in the development and construction phases of UK OSW farms?

Q2. What are the current factors that facilitate or constrain integration in the development and construction phases of UK OSW farms?

Q3. How can VSM principles help to analyse and improve integration in the development and construction phases of UK OSW farms?

Q4. What potential improvements can be made to achieve a more integrated supply chain based on VSM principles?

1.4 Research Methodology

Given the shortage of research into the OSW supply chain and its integration, there is the need for a more in-depth understanding of these research domains (Eriksson, 2015; Martinez Neri, 2016). In particular, interest in approaching SCI in the OSW industry from a systems perspective using VSM, which has not been done previously, has led this study to take qualitative and exploratory approach (Stebbins 2001). Qualitative approach allows for a detailed exploration of SCI in the OSW by focusing on subjective knowledge creation (Denzin and Lincoln, 2000). In addition, the thesis adopts a case study research design strategy to obtain context-dependent knowledge about the nature and potential of SCI in the OSW industry (Yin, 2014).

This study uses Espinosa and Walker's (2017) suggested 'methodology to support self-transformation' to guide the use of the VSM. This methodology consists of six steps that help to analyse and design viable and sustainable businesses and networks: the first step involves defining the system in focus, the second step involves identifying the levels of recursive organisation, the third step involves a VSM analysis, the fourth step involves deciding on organisational changes necessary to be taken based on the VSM analysis, the fifth step involves implementing changes, and the sixth step involves monitoring and assessing the implemented changes. As the aim of this study is to use VSM for analysis purposes of the SCI potential rather than for implementing SCI in practice, it focuses only on the first three steps of Espinosa and Walker's (2017) methodology. Further discussion of the use of the methodology to support self-transformation is provided in Section 4.3.

The first and second steps of the methodology to support self-transformation are used in this study to determine the system's boundaries for the purposeful selection of the study participants. Semi-structured interviews with the selected participants are then used for data collection. The third step involves using the VSM analysis, which will help to map structural organisation of the system in focus and analyse it based on the primary data collected from the interviews. This step is combined with a thematic analysis to explore SCI and VSM related themes to enable a greater understanding of SCI's potential in the OSW supply chain, as well as what related improvements can be achieved as a result (Braun and Clarke, 2006).

1.5 Thesis Outline

The main discussion in this thesis will begin with a review of the literature in Chapter Two on five main research areas: the OSW industry, SCM, SCI, systems thinking, and the VSM. Chapters Three and Four outline the methodology and research design of this thesis. Chapter Five presents the study findings. Chapter Six proposes SCI strategies based on the results and findings discussed in Chapter Five. Chapter Seven discusses the results and findings in relation to the exiting literature. Finally, Chapter Eight concludes the thesis by summarising its research contributions. Each chapter will now be discussed in more details below.

Chapter Two forms the literature review which builds the theoretical foundation for this research by reviewing the relevant literature. It begins with an overview of the OSW industry, both globally and in terms of the UK, to provide the background information necessary to the discussion throughout the remainder of the thesis. It then reviews the wider field of SCM, including project-based SCM to understand its main concepts and definitions. The background information is then used to characterise the OSW supply chain. Following on from this, the chapter moves to review the SCI related literature to establish what exactly constitutes SCI. This chapter also involves a structured review of publications specifically related to SCI in project-based environments to identify their key contributions to the research area.

This chapter then proceeds with an overview of systems thinking and explores its relevance to the field of logistics and SCM. It then describes the VSM as a chosen systems thinking approach used in this research. A structured review explores VSM's main applications, including its current usage in research on logistics and SCM. Chapter Two concludes by summarising its key findings, which build the foundation for the discussion in subsequent chapters.

Chapter Three discusses the methodology of this thesis by providing an overview of the philosophical approaches used to guide this research. It discusses ontology, epistemology, and axiology more generally, as well as in relation to the systems thinking. It proceeds by discussing the research paradigms, specifically four paradigms defined by Burrell and Morgan (1987), and the subsequent choice of the interpretivist research paradigm. This chapter then provides a background to differences in reasoning, such as inductive, deductive, and abductive and outlines the choice of research approach and research strategy adopted in this thesis. In addition, it considers the quality criteria of qualitative research approach, as the main approach of this study and critically reviews case studies as the chosen research strategy.

Chapter Four forms the research design which describes the design of the research strategy, the approach used to collect and analyse data, and the relevant ethical considerations. It begins by describing the unit of analysis used in this research in accordance with the case study research design. It then moves to explain the three steps of the methodology to support self-transformation (Espinosa and Walker, 2017). In more detail, it defines the system in focus in accordance with the first step of the methodology. Then, following the second step of the methodology, it identifies and describes the level at which the system in focus is embedded, which is known as the recursion level of the system in focus. The resulting system in focus serves as a framework for the selection of the study participants. Overall, this chapter explains the data collection strategy used to collect primary data and outlines the details of the approach used to analyse the data, which involves use of a VSM analysis as the third step of the methodology to support self-transformation.

Chapter Five presents research results and findings. The aggregated findings from the interview data are presented. The results and findings are broadly divided into three main parts. The first part provides details about the selected study participants who form the system in focus. The second part presents the results and findings of SCI related themes, and the third part presents the results and findings of the VSM analysis.

Chapter Six proposes supply chain integration strategies. By drawing upon the results and findings in Chapter Five, this chapter proposes two SCI strategies; ‘viable SCI strategy’ and ‘strategic cluster integration strategy’. It describes each strategy and discusses the potential improvements that each could bring to the OSW supply chain.

Chapter Seven provides discussion of the research findings. This chapter discusses the main findings in relation to the existing body of knowledge and with specific reference to the four research questions formed in Chapter Two of this thesis.

Chapter Eight concludes the thesis. This chapter reflects on the effectiveness of the chosen research design. Following on from this, it summarises the thesis theoretical and practical contributions. Finally, it outlines research limitations along with suggestions for future research.

Chapter Two

Literature Review

2.1 Introduction

The primary goal of this chapter is to establish the theoretical foundations of this thesis by reviewing the published literature related to the main research areas. There are broadly five subject areas that form the main bodies of knowledge for review in this chapter, as highlighted in Figure 2.1. The Figure 2.1 also shows the process flow of the literature review which resulted in formulation of research questions summarised at the end of this chapter.

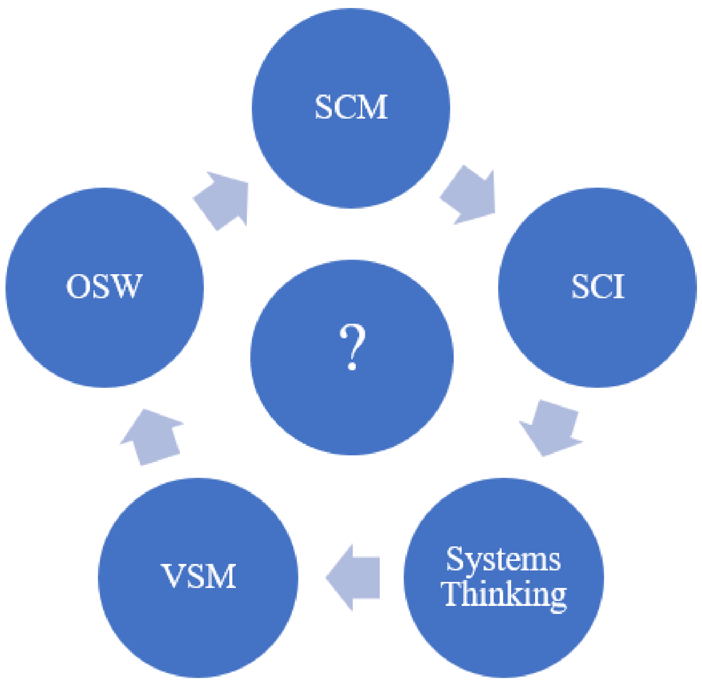

Figure 2.1: Main research areas

This chapter begins with an overview of the OSW industry, both generally and in the UK specifically, which forms the main practical context of this research. It then provides an overview of SCM more broadly and SCM in project-based environments to understand the main concepts and definitions. This background is then used to explore and describe the OSW supply chain. The review then moves to explore the literature on SCI to establish the main concepts, definitions, and elements pertaining to SCI. A structured review is then performed, which specifically relates to SCI in a project-based environment in order to identify key publications in this area.

The literature review proceeds with an overview of systems thinking and related complex systems to understand these subject areas in their broader sense and in relation to logistics and SCM. It then describes the VSM as the chosen systems thinking approach in this research. The chapter moves to provide another structured literature review of publications related to the VSM in order to explore its use in the wider research environment and in the logistics and SCM field, as well as to understand the main context and key issues of VSM applications. This chapter summarises the identified relationships between all of the selected subject areas by highlighting underexplored areas. Finally, the research questions of this thesis will be refined.

2.2 Overview of the Offshore Wind Industry

OSW, together with onshore wind, form one renewable energy source known as wind energy. Wind acts as a natural fuel to generate clean electricity by means of wind turbines, which are designed to convert kinetic energy derived from the wind into electrical energy (EWEA, 2009). When a number of wind turbines are placed close to each other, they form a wind farm. The main difference between an OSW farm and an onshore wind farm is that OSW farms are situated at sea, whereas onshore wind farms are built on land (Thomsen, 2012). Consequently, the installation of wind turbines at sea requires more resources and different types of foundations than those used for onshore wind farms. This is also the key component distinguishing the two types of wind energy, as the mechanics behind the rest of the technology is predominantly the same. OSW farms can be ‘fixed bottom’, which means that turbine foundations can be fixed to the seabed or can be floating. As the name suggests, floating foundations float on the sea’s surface without the need to be fixed to the seabed. However, floating wind is still at a conceptual stage and is not yet a widespread technology, but it does show great potential (The Crown Estate

Scotland and ORE Catapult, 2018). This study is focused on a fixed bottom OSW farm. Picture 2.1 below shows a typical OSW farm of this type:

Picture 2.1: Offshore wind farm (Google pictures)

OSW is considered to be a young industry, although the idea of installing wind turbines at sea goes back to the 1930s, when German inventor and pioneer of wind energy Hermann Honnef first introduced the idea (Kaldellis and Kapsali, 2013). After almost forty years another proponent of wind energy, American professor William E. Heronemus, proposed the idea of floating wind turbine platforms, but neither of these early ideas were initially recognised. It was only in 1990 when the first test facility of OSW technology was installed off the Swedish coast that OSW started to develop. In 1991, Denmark installed the world's first commercial scale wind farm consisting of eleven wind turbines of 4.95 Megawatt (MW) in capacity, and subsequently became the home country for wind turbine technology.

Today, OSW is considered as being one of the key renewable energy sectors, which contributes to the UNFCCC's global emission reduction targets and is one of the most dynamic technologies in the energy system (IEA, 2019; IEA, 2020). Even though OSW remains smaller than onshore wind in terms of overall installed capacity, OSW represents about 3% of the total wind power installations, its potential is almost limitless compared to onshore wind (GWEC, 2018). The availability of land for onshore wind decreases annually, which is slowing down the rate of onshore wind installations, whereas the availability for OSW sites increases every year due to developments in technology (GWEC, 2020). Moreover, OSW provides more energy due to greater and more stable wind resources at sea than on land.

The majority of OSW farms have been installed in European waters, which makes Europe the world's leading region of existing OSW production. More than 80% of the global OSW capacity is located in the North, Baltic, and Irish Seas. According to the latest available figures, the remaining capacity is located predominantly in China, followed by Vietnam, Japan, South Korea, the United States (US), and Taiwan (GWEC, 2018). Figure 2.2 shows the spread of the total OSW capacity by country in 2017, highlighting the current leading markets in the OSW industry.

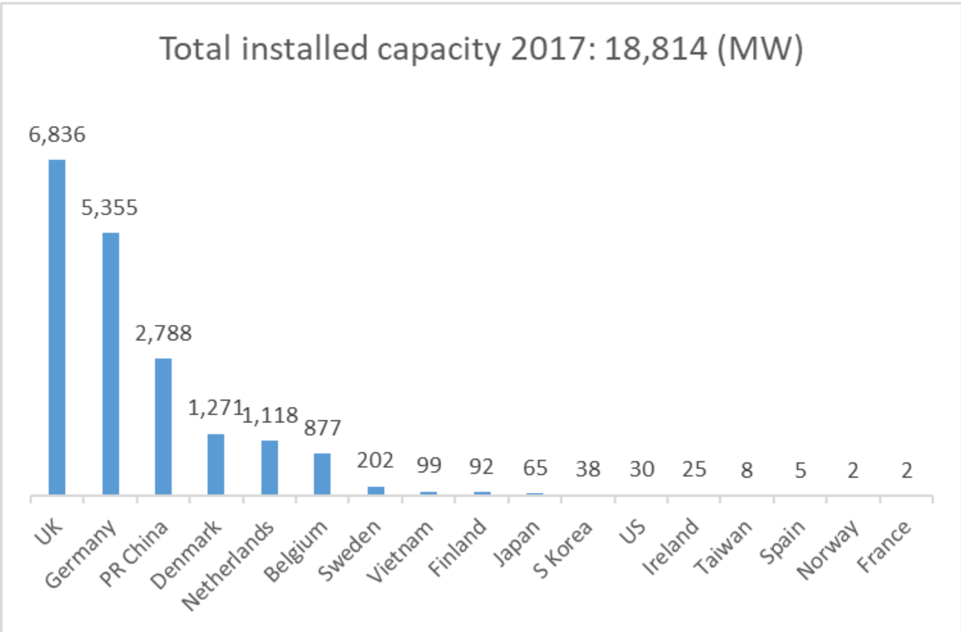

Figure 2.2: Total OSW installed capacity by country at the end of 2017 (GWEC, 2018)

As shown in Figure 2.2, the UK (Scotland included) has the largest amount of installed OSW capacity globally, reaching 6,836MW in 2017 and accounting for nearly 40% of the world's OSW installed capacity. The UK is followed by Germany, accounting for nearly 30% (5,355MW), then China with almost 15% (2,788MW), followed by Denmark with close to 7% (1,271MW), the Netherlands with almost 6% (1,118MW), and finally Belgium which accounts for nearly 5% (877MW) of the global installed capacity. These remain the top five OSW markets after the UK, although the Netherlands and Belgium switched positions in 2019 (GWEC, 2019).

Beyond these top five OSW markets, the US continues to expand its OSW developments, despite the complexity of its regulatory regime due to differences between the rules and regulations of different states. Japan is looking to enter full-scale OSW development, and Vietnam, India, Brazil, and Australia are considered to be emerging OSW markets due to their high OSW potential (GWEC, 2019).

With a growing interest in OSW across different countries, the developments in OSW technology have also continued to grow. Figure 2.3 shows the evolution of wind turbine sizes by considering the average sizes of OSW wind turbines (IRENA, 2019). In the early 2000s, the average rated capacity of a wind turbine was approximately 1.6 MW with a rotor diameter of roughly 44 meters. The average size of turbines installed in 2019 was 7.8 MW, reaching close to 164 meters of rotor diameter, which can be compared to an area the size of 2.5 football pitches (Wind Europe, 2019). The most powerful wind turbine available to date is the GE Haliade-X, which is 12 MW in capacity with a rotor diameter of 220 meters. However, the evolution of wind turbines is expected to reach an average wind turbine capacity of 20 MW, with a rotor diameter above 230 meters.

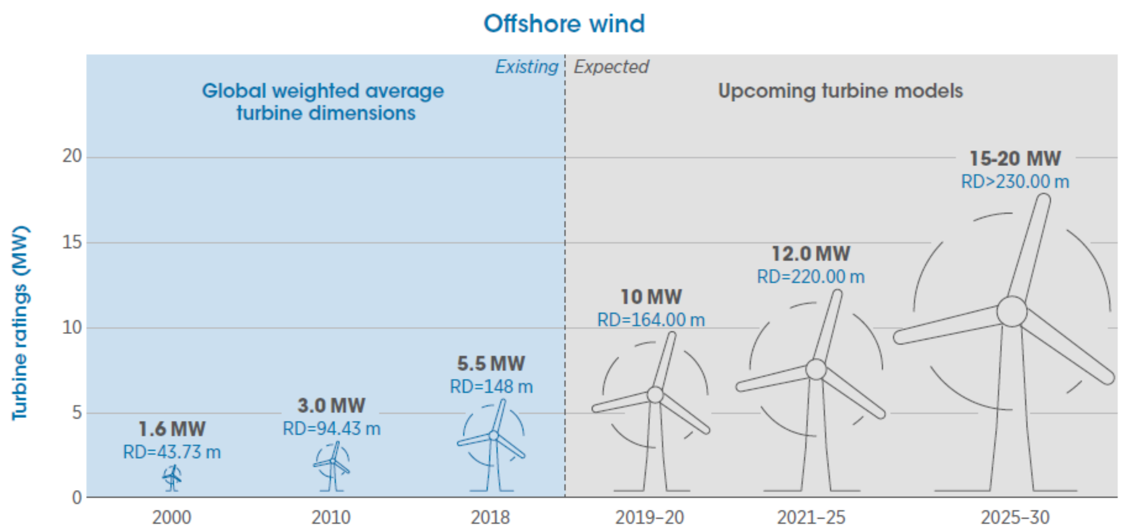

Figure 2.3: Evolution of the size of wind turbines (IRENA, 2019: 56)

One of the key reasons behind these ongoing technological developments and innovations in the OSW industry is to reduce the average cost of energy of OSW (Stentoft et al., 2016; Brink, 2017). This continues to remain one of the biggest issues facing the OSW industry (LEANWIND, 2017). The reduction in cost is commonly explained as the need to reduce the Levelised Cost of Energy (LCOE). This is a common metric used to calculate the cost of electricity and is a common measure used to compare energy prices from different energy sources. LCOE measures a wind farm's lifecycle cost, which takes into consideration the development cost (DEVEX), capital expenditure (CAPEX), operation cost (OPEX), and abandonment cost (ABEX), divided by energy production (Collum and Borg, 2016).

Since the first OSW farms were built close to the shore in shallow waters, OSW projects have since moved to deeper waters further from the shore (GWEC, 2020). Moreover, as mentioned above, the size of the OSW turbines that form the largest CAPEX have grown. All of these conditions have resulted in more challenging OSW installation processes, consequently resulting in increased costs. This has therefore made cost reduction in OSW a key concern for the whole sector, across OSW farms lifecycle and supply chain (Stentoft et al., 2016; LEANWIND, 2017).

During recent years, however, the cost of OSW has reduced. This has been attributed to developments such as advances in wind turbine technology that require less turbines to be installed, OSW installation processes, O&M processes, and supply chain efficiencies (Johnston et al., 2020). Nevertheless, the need to further reduce the LCOE of OSW to increase competitiveness with other energy sources remains a key objective for future OSW developments (IRENA, 2019; GWEC, 2020). Considering this issue, representatives of the OSW industry often mention the term 'supply chain' to refer to different industry developments, and the 'OSW supply chain' is a term often included in many industry reports and conferences (Wind Europe, 2019; GWEC, 2019). However, the use of the term 'supply chain' in OSW is often limited to include the need to develop an efficient supply chain to reduce OSW costs (IEA, 2019). More recently, some industry players, as overheard at different industry conferences, also include the term 'SCI', which closely relates to the term 'supply chain efficiencies' (Martinez Neri, 2016; Stentoft et al., 2016). Despite the importance of the supply chain in OSW, there has been little information available in both academic and practical circles that describe and explain the OSW supply chain in more detail. A similar discourse on OSW supply chains has been noted in relation to OSW development, specifically in the UK (Danilova et al., 2016; Whitmarsh, 2019), an overview of which will be provided in the next section.

2.3 An Overview of UK Offshore Wind

Denmark dominated the OSW market until the UK installed more OSW turbines than any other country in 2008, overtaking Denmark and becoming the world's leader in OSW installed capacity (EWEA, 2009). The UK arguably has the most favourable conditions for OSW developments due to its shallow seas and strong wind conditions, which makes it an attractive location for OSW and helps to maintain its leading position in the OSW market (UKTI, 2014; GWEC 2020). This makes OSW an important renewable energy source that contributes to the UK's national greenhouse gas emission reduction targets. The UK plans to reduce at least 80% of greenhouse gas emissions by 2050 from baseline levels given in 1990 (Climate Change Act, 2008).

One of the key driving forces of renewable energy developments in the UK, including OSW, was the Renewables Obligation (RO) policy introduced in 2002, which was later replaced with the Feed-in Tariff with Contracts for Difference (CfD) subsidy mechanism in 2017. The aim of the RO was to increase the share of renewable energy supplied by all licensed electricity providers in the UK to comply with UNFCCC targets to keep global warming below 2^{o} C (IPCC, 2014). Following UNFCCC targets and the introduction of the RO policy, the UK began large-scale development of OSW around its coasts.

Most of the UK's seabed, approximately a twelve nautical mile territorial limit, belongs to the Crown Estate in England, Northern Ireland, and Wales, and the Crown Estate Scotland in Scotland (BVG Associates, 2019). The Crown Estate and, recently formed in 2017, The Crown Estate Scotland act as landlords of the UK's seabed and other property assets belonging to the monarch. The Crown Estates therefore have the rights to explore and utilise the natural resources on the UK's continental shelf (BVG Associates, 2011).

The Crown Estate has introduced so-called seabed leasing or tender rounds, where interested parties can bid for the right to utilise seabed sites for OSW developments. Four development rounds have been announced to date. The first OSW leasing round was announced in 2000, consisting of sixteen projects with two extension sites, all of which are now fully operational and generate over 1 gigawatt (GW) of clean electricity, with the exception of three projects that were withdrawn for technical or financial reasons. The announcement of round 2 followed in July 2003, initially consisting of seventeen projects with an aggregated capacity of 7 GW, two of which were withdrawn for environmental and financial reasons. In 2008 the Crown Estate announced round 3, which has been the largest round so far and has produced large-scale OSW developments that have played a transformational role in industrialising the UK OSW sector (The Crown Estate, 2019). Over 32 GW of OSW capacity was planned in round 3, of which 24 GW worth of projects are currently being developed; that is almost three times the size of all previous rounds. Nearly a decade later, an initial announcement was made for round 4 for the potential of 7 GW worth of new OSW capacity towards the end of 2017. As part of this round, four potential areas for further OSW developments were identified. Figure 2.4 below shows the seabed areas considered in round 4, also known as bidding zones:

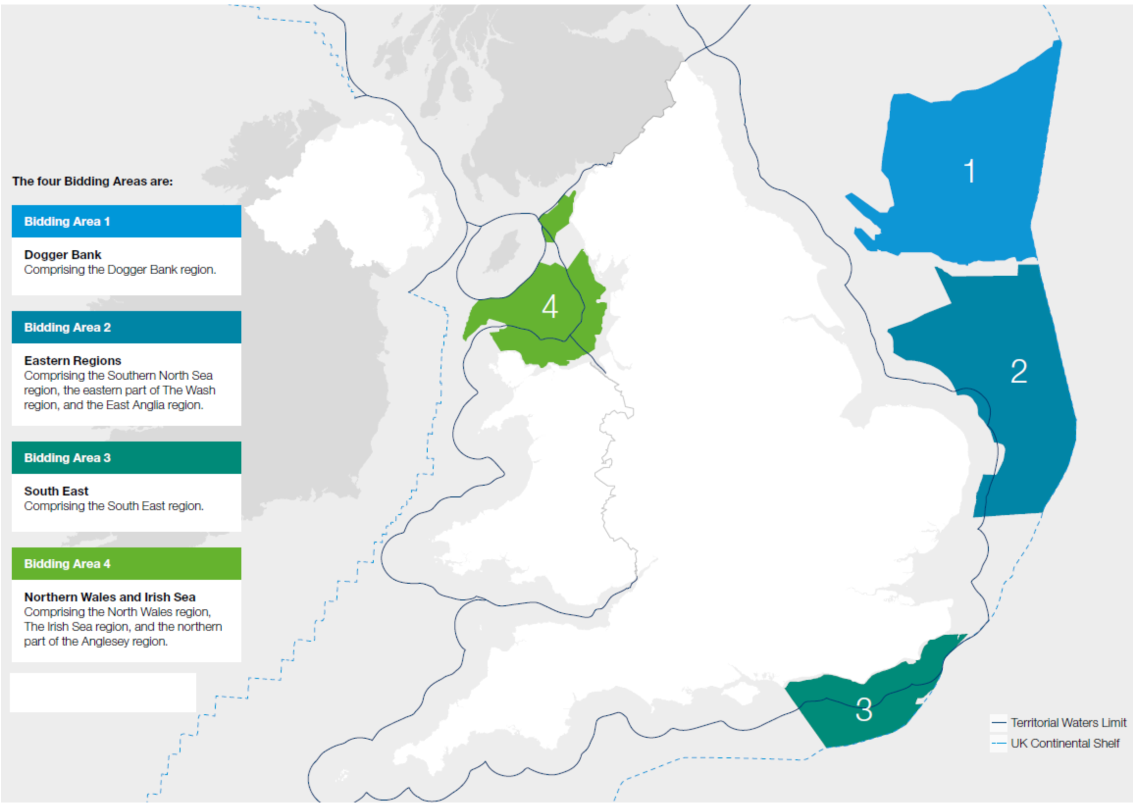

Figure 2.4: Round 4 bidding zones (The Crown Estate, 2019: 17)

Scotland is not part of leasing round 4 as the Crown Estate Scotland launched its own cycle of seabed leasing in Scottish territorial waters, known as ScotWind (The Crown Estate, 2019). The approximate OSW capacity anticipated by ScotWind is 10 GW (The Crown Estate Scotland, 2020).

There are currently 38 fully operational OSW farms around the UK (Scotland included), bringing a total of 7.9 GW of clean electricity (The Crown Estate, 2018). An additional 1,064 MW, or more than 1 GW of new OSW installations was added during 2018. This was enough to provide clean electricity to roughly 6.9 million homes. To continue to support OSW growth and maintain its leading position, the UK government and the OSW sector agreed their commitments as outlined in a Sector Deal, which was released in March 2019. This commitment outlines the UK government's vision for 30 GW installed OSW capacity by 2030, provided that the OSW sector continues to reduce its costs (HM Government, 2019; Allan et al., 2020).

The growth of OSW in the UK to a large-scale commercial renewable technology has made it an important national asset, which plays a key role not only in terms of national targets to reduce greenhouse gas emissions, but also to the UK's economic development (HM Government, 2017). The UK government has viewed OSW as an opportunity to develop a capable domestic supply chain by encouraging local investment and the participation of local companies in OSW developments (Allan et al., 2020). With an outlook to enhance the international competitiveness of UK companies, this vision was outlined in the 2013 OSW industrial strategy (HM Government, 2013), and again in the recent Sector Deal:

> "*The Deal will drive the transformation of offshore wind generation, making it an integral part of a low-cost, low-carbon, flexible grid system and boost the productivity and competitiveness of the UK supply chain. This focus on building the capability of our supply chain will allow companies to play a greater role in the UK's global leadership in offshore wind generation while enhancing their competitiveness internationally*" (HM Government, 2019).

In order to drive domestic supply chain development, the UK government requires all companies that take part in developing and building OSW farms of 300 MW and above, referred to as developers, to produce a supply chain plan as part of the CfD allocation mechanism. The supply chain plan should detail developers' plans for how they will support the development of skills, innovation, and competition in the UK's supply chain (BEIS, 2016; Welisch and Poudineh, 2020). Such a requirement is commonly understood as the local content requirement (LCR). LCR can be explained as a policy "*imposed by governments that require firms to use domestically manufactured goods or domestically supplied services in order to operate in an economy*" (OECD, 2016). The LCR policy has been increasingly adopted by both developed and developing countries as a tool to achieve national green growth strategies and to stimulate the development of renewable energy projects comprised of infant industries, such as wind, solar, hydro, and others (UNCTAD, 2014). According to Warner (2011), new industry development is the most common justification for the use of LCRs as it provides the potential for local companies to participate in new industry. Stern's (2008) review of climate change economics supports the view that the growth of new low-carbon technology markets, such as the OSW industry in the UK, does indeed present commercial opportunities; it has been estimated by Stern (2008) that markets for low-carbon energy products could be worth $500bn and above per year by 2050.

This emphasis on building a capable and competitive domestic supply chain has been reflected in many industry reports, which provide a regular review of the UK supply chain and recommendations on its development (BVG Associates, 2013; BVG Associates, 2014; Chinn, 2014; Whitmarsh, 2019). A similar emphasis on the supply chain has also been made at various OSW related conferences, as based on the author's personal experience of participating in conferences organised by various industry bodies, such as Wind Europe and Renewable UK. Considering the ongoing need to reduce the LCOE, attention is often given to building more efficient supply chains in relation to cost, time and quality of project deliverables (The Crown Estate, 2012; Stentoft et al., 2016; IEA, 2019). Discussions about building more efficient or more cost effective supply chains have often involved use of the terms 'SCI' and 'collaboration' as providing the potential to collectively resolve industry issues (Martinez Neri, 2016; Brink, 2017; Whitmarsh, 2019).

Despite the widespread use of the terms 'supply chain' and 'SCI' and their importance to the UK OSW industry, there has been no unified description or perspective provided about what is the OSW supply chain, or what SCI means, in the context of OSW. Most available reports predominantly focus on OSW subsectors when referring to the OSW supply chain, such as turbines, foundations, substations, cables, and vessels (BVG Associates 2014). Few include supply chain terminology that classify different OSW players into tiers. For example, Whitmarsh (2019) used tier-one term to refer to prime contractors, tier-two to refer to principle suppliers, and tier-three to refer to specialist suppliers. However, such explanations still do not provide a full description of the OSW supply chain, moreover the use of 'tiers' in relation to the OSW, is a little inaccurate, according to textbooks' description of supply chain (Chopra and Meindl, 2016). This limitation in description of the OSW supply chain makes it difficult for all interested parties, especially those from research backgrounds, to contribute and develop this subject area further. This suggests a need to address this issue and contribute towards building a greater understanding of the terms 'SCM' and 'SCI' in the OSW industry. The next sections will provide an overview of the SCM field and SCM in project-based environments to enable a description of the OSW supply chain, which will follow after these sections.

2.4 Understanding Supply Chain Management

To understand the concept of SCM, the word 'logistics' first needs to be defined. The term 'SCM' first appeared in the early 1980s in the practitioner world and later in academic world, and it was initially built upon ideas of inventory management and production management, which were hitherto understood as logistics tasks (Oliver and Webber, 1995).

While logistics has evolved in its capabilities, along with innovations in transport, technology, and information management, its core function revolves around the concepts of materials management and physical distribution (Langley, 1995). The most widely accepted definition of 'logistics' is provided by The Council of Supply Chain Management Professionals (CSCMP), previously known as The Council of Logistics Management, a worldwide professional association for logistics and supply chain professionals, who define logistics management as:

> "*that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements*" (The CSCMP cited in Grant, 2012: 2).

This definition emphasises how logistics is considered to form part of a wider concept of SCM; highlighting that its activities are considered to be within the boundaries of a specific firm's activities and only within the context of that firm. However, according to Larson and Halldorsson (2004), perspectives on whether logistics should be viewed as part of SCM vary. The authors distinguished four perspectives on logistics and SCM: traditionalist, unionist, intersectionist, and re-labelling. The traditionalist perspective suggests that SCM should be viewed as part of logistics. In other words, logistics viewed as wider concept than SCM. The unionist perspective suggests that instead logistics should be viewed as part of SCM. The intersectionist perspective views SCM as more strategic by considering business functions, such as logistics, marketing, operations management, and procurement, whilst strategically including elements of these in decision-making, rather than trying to unite all of these functions into one. The re-labelling perspective simply renames logistics as SCM. Taking these perspectives into account, this study accepts the unionist perspective as the primary perspective on logistics and SCM because it considers logistics being part of SCM.

By considering the different perspectives surrounding logistics and SCM, it can be argued that the function of logistics is unique to every business and every industry, depending on which goods and services need to be moved and managed. Common logistics activities include the management of transportation, inventory, warehousing or storage, information technology, production, and operations management, as well as procurement and customer service (Grant, 2012). These activities, which have a number of functions in themselves, make logistics quite a broad subject area. However, another definition provided by The Chartered Institute of Logistics and Transport (UK) highlights the main value of the logistics function through the so-called seven 'rights' of customer service, by defining logistics as "*...getting the right product to the right place, in the right quantity, at the right time, in the best condition and at an acceptable cost*". The seven 'rights' perspective of the logistics function is summarised in Figure 2.5 below:

Figure 2.5: The seven 'rights' of the logistics function (adapted from Rushton et al., 2010)

The ability to meet customer requirements or needs, which vary from industry-to-industry and firm-to-firm, is therefore one of the key outputs of logistics activities (Langley,1995; Grant, 2012).

Based on the aforementioned unionist perspective (Larson and Halldorsson, 2004), the concept of SCM builds on logistics management ideas. However, SCM is a wider concept that goes beyond the boundaries of a single firm. Its core idea, which resulted in the coinage of the term ‘supply chain management’ in 1982 by consultants, was to view the chain of supply as a single entity (Oliver and Webber, 1995). The fundamental aspect of SCM is to connect logistics with the internal functions of a firm, such as procurement, production, distribution, and sales, as well as with external organisations, by making ‘supply’ a shared objective of every function of the chain (Ellram and Cooper, 2014). Therefore, SCM implies that the chain should be managed ‘end-to-end’, which also makes the integration of supply chain processes a central principle of contemporary SCM thinking (Sweeney et al., 2015).

A common representation of the structure of a supply chain is depicted in Figure 2.6 below. The figure shows that supply chain of a focal firm, or a firm at focus, is usually considered. First-tier suppliers are immediate suppliers to a focal firm or, in other words, direct suppliers. Second-tier suppliers refer to the direct suppliers of first-tier suppliers, then third-tier suppliers would refer to direct suppliers of second-tier suppliers, and so on, up to raw material suppliers. Direction towards raw material suppliers is called ‘upstream’. Products flow ‘downstream’ towards end customers. Customers may also be classified as direct or tier-one customers of the focal firm; tier-one customers then have their own customers (tier-two customers), and so on. It is important to note that, for instance, a single firm could be a tier-one supplier for one organisation and a tier-four for another as it may be involved in different supply chains of different products, which would change a focal firm’s position in terms of tier or level within its supply chain.

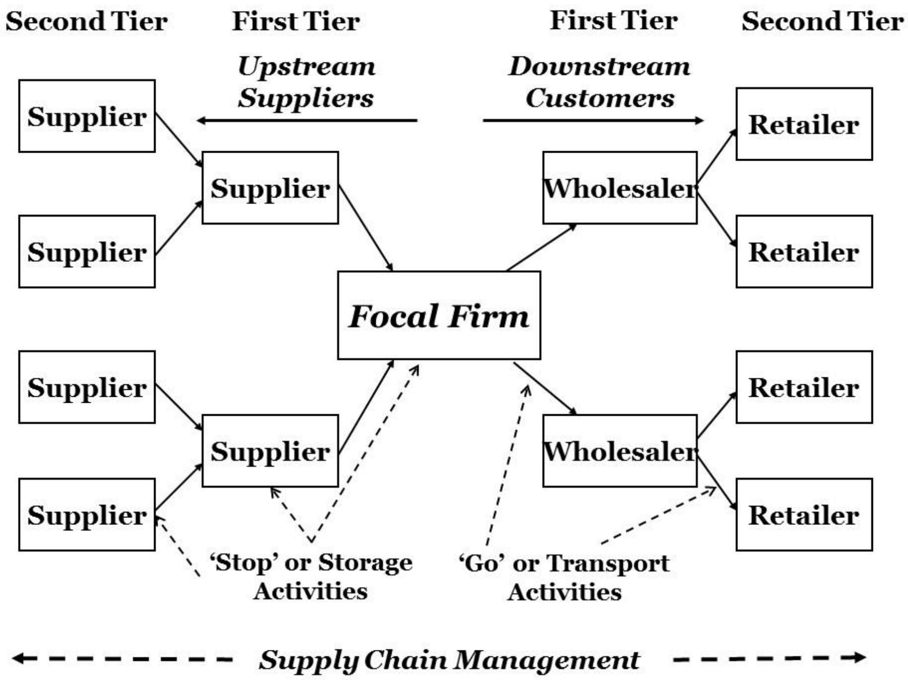

Figure 2.6: Supply chain structure (adapted from Grant, 2012)

The growing importance of SCM as a strategic function in business management can be largely attributed to the problem of disconnected decision-making by various business functions, such as marketing, manufacturing, and distribution. Different business functions often act in their own interests and to their own objectives in order to maximise profits, especially if these functions have different owners. Such disconnected behaviour often results in major inventory surpluses or shortages along the supply chain, which is due to delays and distortions in the information passing through different stages. This phenomenon is described as the 'bullwhip' or Forrester effect, often demonstrated through the business simulation game called the Beer Game (Grant, 2012). More specifically, the bullwhip effect refers to fluctuations in orders that increase as they move upstream the supply chain (Chopra and Meindl, 2016). Therefore, one of the main purposes of SCM is to strategically balance supply and demand based on firmwide objectives, which requires the integration of key business functions and a supply chain-wide perspective or 'end-to-end' perspective, as mentioned previously (Oliver and Webber, 1995; Senge, 2006). This interpretation of SCM is further summarised by the CSCMP's definition of the concept, who explain SCM as encompassing the following:

> “*the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies*” (The CSCMP cited in Grant, 2012: 3).

Given the aforementioned differences between logistics and SCM perspectives (Larson and Halldorsson, 2004), there is no consensus among academics in terms of a definition of SCM. Moreover, according to Sweeney et al. (2018), divergence also exists between the understanding and adoption of logistics and SCM in practice. In relation to the traditionalist, unionist, intersectionist, and re-labelling perspectives, there is an agreement that practitioners, in similarity to academics, often have multiple perspectives of what the terms ‘logistics’ and ‘SCM’ mean. However, unionist and intersectionist perspectives are more favoured in practice (Sweeney et al., 2018).

In addition to Larson and Halldorsson’s (2004) identified four perspectives on logistics and SCM, Ellram and Cooper (2014) identify five perspectives of SCM given in the existing SCM literature. These include the perspectives of SCM as a process, discipline, philosophy, governance structure, and function. According to the authors, the process perspective is more generally concerned with supply chain activities and processes, which are designed to produce an output for a particular customer or market, as well as the integration of these processes for improved performance of the whole supply chain. Examples of a process perspective of supply chain include ‘lean production’, an approach often cited as a Japanese success story within the automotive industry (Davenport, 1993). SCM as a governance structure is more concerned with the relationships and collaborations between organisations by exploring the boundaries between firms, ownership structures, and types of relationships most suited to achieving the best results. The discipline perspective questions whether SCM meets the criteria of an academic discipline. Harland et al. (2006) and Chicksand et al. (2012) concluded that SCM is not yet a scientific discipline due to a lack of theoretical unity. The functional perspective of SCM views SCM as a business function or management role and is therefore primarily a managerial perspective. Finally, SCM as a philosophy implies philosophy of integration across firms (Ellram and Cooper, 1990). This dates back to the original idea of viewing the supply chain as a single entity and is concerned with the synchronisation of all supply chain activities to create customer value (Mentzer et al., 2001). Taking Ellram and Cooper’s (2014) identified perspectives of SCM, this thesis accepts the philosophy perspective of SCM, considering the systemic nature of this research.

Close to the idea of the philosophy perspective of SCM many authors, argue that the term 'supply chain' should be understood as a 'supply network', given that supply chains consist of multiple organisations involved in different activities and processes, both upstream (the supply side) and downstream (the customer side), forming multiple, interconnected networks (Christopher, 2016). It is also important to note that any one organisation can be part of numerous supply networks (Aitken, 1998).

Despite different interpretations and perspectives of SCM that exist in the academic literature, the common themes of SCM include the integration and alignment of all intra and inter-firm processes and linkages of supply chains and the recognition that the 'whole is greater than the sum of its parts', which is also an underlying philosophy of systems thinking (Jackson, 2019). The closest definition of SCM that captures these themes is the definition provided by the CSCMP, which is accepted as the primary definition of SCM in this thesis. The CSCMP definition also captures the unionist and the philosophy perspectives of SCM accepted in this research. The CSCMP is provided again below:

> "*the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies*" (The CSCMP cited in Grant, 2012: 3).

2.5 Project-Based Supply Chain Management

This thesis focuses on the development and construction of OSW farms that can be viewed as large-scale, complex, megaprojects which often exceed the cost of $1 billion (Flyvbjerg, 2017; PMI, 2017). Therefore, this section provides a general review of SCM in a project-based environment to gain a greater understanding of the main tenets pertaining to project-based supply chains. A project-based environment can relate to various types of projects, ranging from a relatively small types of projects like new product development to large construction projects like shipbuilding, construction of oil and gas platforms, buildings and renewable energy developments (Vrijhoef and Koskela, 2000; Basu, 2011; Söderlund, 2011; Eriksson, 2015). Due to their scale and complexity, OSW projects closely relate to construction projects described as megaprojects (Flyvbjerg, 2017; Miller et al., 2017). This section therefore reviews the literature related to project management and SCM in the context of large construction projects.

Relatively little has been written on the subject of SCM in project-based environments (Vrijhoef and Koskela, 2000; Aloini et al., 2015). This gap in the literature may be partly explained by the fact that SCM concept is said to have originated from manufacturing and retailing industries, where SCM is now recognised as a source of competitive advantage (Oliver and Webber, 1995; Chopra and Meindl, 2016). According to many authors, project-based industry environments, like for example construction, aerospace and shipbuilding have different characteristics from stable manufacturing industries, thus the requirements of SCM in project-based environments arguably differ too (Green et al., 2005; Sanderson and Cox, 2008; O'Brien et al., 2009; Segerstedt and Olofsson, 2010; Lundesjö, 2015).

The main difference between manufacturing and project-based industries is that manufacturing industries involve continuous production processes and repeated supplier relationships, whereas project-based industries are often characterised by 'one-off', discontinuous nature (Segerstedt and Olofsson, 2010; Flyvbjerg, 2017). Tommelein et al. (2009) explain this difference further by saying that, in contrast to the ongoing business operations of manufacturing industries, projects have a start time and an end time, making it possible to describe projects as temporary production systems, or temporary organisations (Davies et al., 2016). This one-off nature of large projects may be another reason for limited discussion of SCM in project-based environments. Literature often treats SCM and project management as two different disciplines (Dalcher, 2016; Meredith et al., 2017; PMI, 2017). However, as noted by several authors, the importance of SCM in project-based industries, especially engineering and construction, has been recognised since 1990 (Vrijhoef and Koskela, 2000; Azambuja and O'Brien, 2009; Basu, 2011; Aloini et al., 2015; Luong Le et al., 2020). SCM has been viewed as having the potential to improve project performance.

As a result of the temporariness and the 'one-off' nature of projects, especially in construction sector, project-based SCM is considered to be more problematic (Vrijhoef and Koskela, 2000). Venkataraman (2007) goes so far as to suggest that project supply chains are inherently more complex due to the multitude of actors involved. Moreover, the complexity of project-based supply chains increases with challenges, like fragmentation, adversarial relationships, project uniqueness, separation of design and production, and competitive tendering, which together result in exceeded budgets and schedules (Morledge et al., 2009; Bresnen and Marshall, 2011; Davies et al., 2016). Managing supply chains of large and complex projects can become a project in itself

(Ayers, 2010). By considering the complex and interdependent nature of project-based industries like construction it becomes clear that SCM has a critical role to play in improving overall project performance. This view of SCM has also been supported by the Project Management Institute (PMI) who recognises SCM as an important area to manage procurement processes in complex construction projects (PMI, 2017). Despite the recognised importance of SCM in successful completion of large and complex projects, many authors note that SCM practices remain less established in project-based environment (Green et al., 2005; EC Harris, 2013; Fulford and Standing, 2014; Aloini et al., 2015).

Love et al. (2004) note that the aforementioned project-based supply chain problems have long been prevalent in the construction industry; similar challenges were evident not only in the UK construction industry but in other countries too, including Australia, Finland, China, and Singapore. In response to these issues, the governments of these countries called for radical improvements. In the UK the literature highlights two government commissioned reports, Latham (1994) and Egan (1998), which are believed to have acted as a catalyst for change in the management of construction projects by sparking an interest in potential partnering arrangements for better SCI (Bresnen, 2009; Morledge et al., 2009). As Egan states (1998: 9):

> "*Partnering involves two or more organisations working together to improve performance through agreeing mutual objectives, devising a way for resolving any disputes and committing themselves to continuous improvement, measuring progress and sharing the gains.*"

Interestingly, in comparison to the construction and/or project-based SCM literature, Egan (1998) argues against the claim that the construction industry differs from manufacturing by saying that the process of construction is repeated in its essentials from project-to-project. In similarity to Egan, Towill (2009) and Basu (2011) also argue that SCM principles remain relevant to all businesses and to all operations. Therefore, some parallels can be drawn with manufacturing processes, especially in areas of construction projects like planning and design. In addition to recommendations for partnering as a tool to deliver valuable performance improvements, Egan (1998) suggests to go a step further and develop long-term alliances, arguing that long-term alliances offer an opportunity for continuous improvement and learning throughout the supply chain. Egan (1998) proposes the concept of an 'integrated project process', explaining how it is a process which utilises a full construction team and the skills of all participants to deliver value to the client, thus emphasising the importance of long-term sustainable relationships. Briscoe et al. (2004), Bresnen and Marshall (2011), as well as a more recent report by EC Harris (2013) on supply chain analysis in the construction industry, also stress the need for further integration and collaboration within project-based supply chain, arguing that integration in the supply chain, or a lack of it, has been regarded as an influencing factor affecting overall project performance.

In response, Cox (2009) argues it would be wrong to assume that partnering and long-term alliances provide the best ways of managing construction projects. Instead, he holds that it is necessary to think more strategically and to understand that partnering may not be appropriate because construction involves many one-off transactions. Creating long-term alliances, in Cox's view, would only be appropriate and effective for repeat business transactions. The distinction between one-off and long-term transactions is more greatly understood by companies in construction as CAPEX and OPEX. To clarify, CAPEX refers to the expenditure required for a project's construction and therefore tends to involve more of a one-off expenditure, whereas OPEX refers to the expenditure required for operations and maintenance after a project has been completed, which therefore tends to involve a larger number of repeated transactions. This therefore suggests that more attention needs to be paid to understanding the context and environment of the supply chain in focus and its sourcing characteristics before a decision about partnering or long-term alliances can be made. Similarly, Mouritsen et al. (2003: 694) emphasise the importance of recognising the different circumstances and environments under which the supply chain in focus operates in: "*"best practice" in SCM should only be copied and implemented if the objective situational factors are exactly the same, which is very seldom the case*". This means that there is no 'one size fits all' strategy when it comes to finding an effective way of managing the project-based supply chain. Instead, it should more simply be 'fit for purpose' (King and Pitt, 2009).

Other authors note how project-based industries like construction, shipbuilding and capital goods sectors consist of multiple supply chains of different natures, depending on product production type and customer order specifications (Azambuja and O'Brien, 2009; Gosling et al., 2017). The literature highlights six different types of supply chain structures based on the concept of the decoupling point (DP), which is otherwise known as the customer-order decoupling point (Hoekstra and Romme, 1992), the demand penetration point (Christopher, 2016), and the order penetration point (Olhager, 2003). The DP is described as the point that separates customer order fulfilment activities in the production system from production activities, which are based on forecasting and planning. Hoekstra and Romme (1992: 6) explain this further by saying that the "*customer order penetrates as far as the decoupling point, and from there the goods ordered are supplied to the customer*".

Based on the concept of DP, six different supply chain structures can be identified: engineer-to-order (ETO), buy-to-order (BTO), make-to-order (MTO), assemble-to-order (ATO), make-to-stock (MTS), and ship-to-stock (STS) (Hoekstra and Romme, 1992; Naylor et al., 1999; Gosling and Naim, 2009). As explained by Olhager (2003), each type of these supply chain structures would have different positions of DP. For example, in the STS case, the DP is placed at the shipment stage. In the MTS case, the DP is placed at the finished goods stage. In the ATO case, the DP is placed at the final assembly stage. In the MTO case, the DP is placed at the fabrication and procurement stage. In the BTO, the DP is placed at the supplier. Finally, in the ETO case, the DP is placed at the design stage. According to Gosling et al. (2017), ETO is one of the supply chain structures that is more closely associated with supply chains found in complex project environments; this is due to a high degree of customisation for each product, where almost every order is unique.

Considering that project-based supply chains are less permanent and more complex in comparison to stable manufacturing supply chains, Morledge et al. (2009) suggest using the term 'supply network' rather than 'chain' as a more accurate term to describe SCM in complex ETO environments. This has also been recognised in manufacturing and retail SCM environments (Ellram, 1991; Kim et al., 2011; Christopher, 2016). The notion of 'networks' is evident in some definitions of project-based SCM. For example, Love et al. (2004: 44), coined their own definition as follows:

> "*…the network of facilities and activities that provide customer and economic value to the functions of design development, contract management, service and material procurement, materials manufacturing and delivery, and facilities management.*"

Closely related to this definition is a definition provided by the Construction Industry Institute (CII), who say that:

> "*SCM is the practice of a group of companies and individuals working collaboratively in a network of interrelated processes structured to best satisfy end-customer needs while rewarding all members of the chain*" (Tommelein et al., 2009: Ch.6: 4).

Similarly, Formoso and Isatto (2009) recognise the need to understand project SCM in construction as a network but, importantly, the authors also emphasise human involvement in the management of a construction project by offering the following definition:

> "*A construction project supply chain can be defined as a particular human system that is set up with the purpose of delivering a construction project, organized as a network of multiple firms bound together by economic linkages*" (Formoso and Isatto, 2009: Ch. 3:2).

In line with these definitions, it is relevant to say what Pryke (2009) observed post Latham (1994) and Egan (1998) reform in the UK's construction industry, that SCM is more concerned with relationship management rather than contract management because the quality of relationships is key to the success of a project. Hence, the relevance of SCM in construction lies not in the existence of the supply chain itself, but rather in its exploitation.

This makes it clear that manufacturing and project-based supply chains are likely to share similar values, such as the importance of relationships management to improve efficiency of materials, information, and funds flow (Basu, 2011). Nonetheless, Venkataraman (2007) highlighted five value drivers that are especially important to project-based supply chains: customers, cost, flexibility, time, and quality. Value drivers, according to Venkataraman (2007), are strategic factors that add value to the supply chain and provide a distinct competitive advantage.

The most important of these five value drivers in project-based SCM, as explained by Venkataraman (2007), is the customer. The customer, or the project's client, is the final recipient of the completed project and is therefore the main actor in the supply chain determining the value driver of a project. For example, if price is the most important to a customer, then the task of all supply chain activities would be to ensure efficiencies throughout the whole supply chain. If the timely completion of the project is of the most value to the customer, then the whole supply chain should manage their activities towards achieving this goal. This would especially be the case for time sensitive projects, such as the building of Olympic stadiums (Davies, 2017).

Another important value driver of project-based supply chains is quality which, in the context of a project, means delivering project objectives that are 'fit for purpose'. In other words, a commissioned project should meet or exceed the expectations of the end customer. However, whether or not customer expectations are met or exceeded often depends on the ability of the supply chain to quickly respond to changes in customer needs or project scope; this important value driver is called flexibility. Time, cost, quality, and flexibility are value drivers, which are also considered as being major performance metrics for project-based supply chains (Demirkesen and Ozorhon, 2017; PMI, 2017). Therefore, by ensuring the right SCM approach, the strategic management of all of these value drivers can lead to overall project success and the optimisation of customer value.

In summary, based on the reviewed literature on SCM in project-based environments it can be concluded that, while project-based and retail or manufacturing supply chains known as process-based supply chains share largely similar characteristics, project-based supply chains are more complex due to their temporary nature (Dietrich et al., 2010; Davies et al., 2016). The complexity of project-based supply chains that are often composed of multiple supply chains has also led some authors to characterise them as networks rather than chains (Azambuja and O'Brien, 2009; Morledge et al., 2009).

The literature recognises the importance of integration in project-based supply chains as an influencing factor of overall project success (Egan, 1998; Briscoe et al., 2004; Basu, 2011; Bresnen and Marshall, 2011; EC Harris, 2013). However, the literature has also stressed that the extent to which SCI is required in project-based environments depends on an individual project's needs, as well as the value drivers of a project dictated by the project's clients (Venkataraman, 2007; Cox, 2009).

Based on the reviewed literature, the following characteristics can be attributed to supply chains in project-based environments:

- A temporary 'one-off' discontinuous nature (Tommelein et al., 2009; Davies et al., 2016).
- Context-dependent (Green et al., 2005; Cox, 2009; Pryke, 2009; Aloini et al., 2015).
- Associated with ETO supply chain structure that is more order driven rather than stock driven (Azambuja and O'Brien, 2009; Gosling and Naim, 2009; Gosling et al., 2015).
- A project's success may depend on a chosen strategic factor that is of the most importance to a specific project. Such strategic factors, or value drivers, include time, cost, quality, flexibility, and the customer (Venkataraman, 2007).

2.6 The Offshore Wind Supply Chain

As the OSW industry is still young in comparison to more established industries, such as oil and gas, information on the OSW industry's supply chain is still limited (Stentoft et al., 2016). Its current description derives predominantly from industry reports, but less is discussed from an academic perspective. This limitation has also been noted by Poulsen and Lema (2017) in their article assessing bottlenecks within OSW supply chains. Therefore, the aim of this section is to provide description of OSW supply chains through reference to the available SCM and project-based SCM literature.

It is acknowledged in the academic literature that OSW supply chain can be contextualised in terms of a project-based environment, and that project-based environments differ to more traditional process-based environments, such as continuous manufacturing or retail environments (Green et al., 2005; Sanderson and Cox, 2008; Martinez Neri, 2016). The most common perspective currently used to refer to the OSW supply chain involves a description of an OSW farm's lifecycle phases (Poulsen and Lema, 2017; BVG Associates, 2019).

An article by D'Amico et al. (2017), who appear to be the first to provide an academic description of the OSW supply chain, described it in reference to three phases: supply, construction, and management. These phases are based on information from the London Array OSW farm in the UK. According to the authors, the supply phase relates to the supply of the main components of OSW farms, including turbines, foundations, cables, and substations. The construction phase relates to combining these components together which involves the assembly, installation, and commissioning of a wind farm. The management phase, as the name suggests, relates to the operations and maintenance of a wind farm. The authors note that these three phases are not strictly sequential and that they often overlap due to long lead times of projects and certain resource constraints, such as the availability of vessels.

A similar description of an OSW farm supply chain was provided by Poulsen and Lema (2017), who also draw upon the wind farm's lifecycle perspective, or cradle-to-grave perspective. Although, instead of the three phases described by D'Amico et al. (2017), Poulsen and Lema (2017) distinguish four phases: the development and consent phase, installation and commissioning phase, operations and maintenance phase, and decommissioning phase. The four phase perspective is more commonly used by OSW practitioners, but with a slight difference in the name of the second phase; instead of calling it installation and commissioning, it is commonly referred to as the construction phase (Whitmarsh, 2019). This is also the name of D'Amico et al.'s (2017) second phase.

D'Amico et al. (2017) and Poulsen and Lema (2017) describe the importance of ports in the OSW supply chain. However, none of these authors consider ports as having a distinct function within the OSW supply chain. Instead, the authors consider ports as forming part of the construction phase. This view, however, ignores the fact that ports are used during all four phases of an OSW farm's lifecycle and that different ports are used to accommodate the different activities of OSW projects (Akbari et al., 2017; Irawan et al., 2017). Given this limitation, this study suggests understanding the role of ports as DPs within the OSW supply chain, especially as they decouple onshore or inland activities from activities that happen offshore or at sea. Building on D'Amico et al. (2017) and Poulsen and Lema's (2017) descriptions of the OSW supply chain, as well as industry based perspectives (BVG Associates 2019; Whitmarsh, 2019), this study provides a representation of the OSW supply chain, as shown in Figure 2.7:

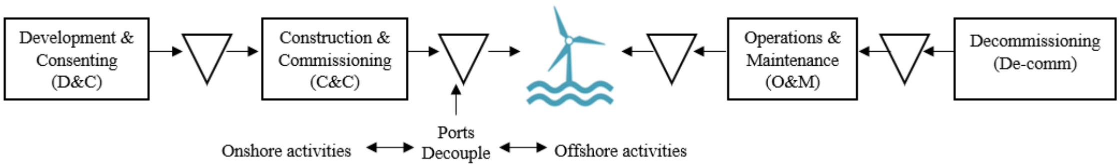

Figure 2.7: The OSW supply chain; a lifecycle perspective (Author)

This study also considers the four phases of the OSW supply chain: the development and consenting (D&C) phase, construction and commissioning (C&C) phase, operations and maintenance (O&M) phase, and decommissioning (De-comm) phase. Furthermore, it views ports as DPs; decoupling onshore activities from offshore activities. The arrows in Figure 2.7 pointing from the D&C and C&C phases towards the picture of the wind turbine represent supply chain processes that happen before OSW wind farm has been built, consequently the arrows of the O&M and De-comm phases represent those supply chain processes that happen after the OSW farm has been completed.

The D&C phase is the first step towards wind farm development and is managed by the wind farm developer. It involves all of the work needed to secure consent for building the wind farm and covers the processes up to the point of financial close before the wind farm's construction. The main activities of the D&C phase include various environmental surveys, such as the benthic studies survey, fish and shellfish surveys, ornithological surveys, sea mammal surveys, onland environmental surveys, and human impact studies. It also involves met station surveys to assess meteorological and oceanographic conditions at selected sites, as well as front-end engineering and design (FEED), which includes the development of a prototype wind farm to decide on key procurement, contracting, and construction issues. In order to receive consent, developers first need to secure a seabed lease from The Crown Estate in England, Northern Ireland, and Wales, and from The Crown Estate Scotland in Scottish Territorial Waters. Based on the Planning Inspectorate's recommendations, consent will either be granted or refused by the Secretary of State for Business, Energy and Industrial Strategy (BEIS), in England. In Wales, it is Natural Resource Wales who determines consent for OSW developments. In Northern Ireland, it is the Marine Strategy and Licencing team within the Department of Agriculture. In Scotland, consents are granted or refused by Marine Scotland and Scottish Ministers (The Crown Estate, 2010; BVG Associates, 2019).

The C&C phase is the next significant stage of the OSW farm supply chain. It involves all activities related to the construction, installation, and commissioning of the main components of an OSW farm. These components are generally divided into two parts. The first part is wind turbines, including components such as the nacelle, rotor, and tower. The second part includes all components of a wind farm, with the exception of turbines, and is referred to as the balance of plant (BOP). The main components of BOP include cables, turbine foundations, and offshore and onshore substations. To clarify, there are export cables and array cables. Export cables refer to cables that connect offshore and onshore substations. In other words, they connect wind farms to an onshore grid. Array cables connect all turbines together to an offshore substation. Turbine foundations may also vary from monopiles, jacket structures, and tripods, amongst others.

The typical processes forming the aforementioned components can be performed in the following sequence, with overlaps where possible: onshore substation and onshore export cables, foundations, offshore substation or substations (if more than one is required), followed by the installation of array cables, export cables, and finally turbines. Once all of the components are in place they are tested and the wind farm will be commissioned (D'Amico et al., 2017; Poulsen and Lema's, 2017; BVG Associates, 2019).

The O&M phase begins after a wind farm has been commissioned. The O&M phase lasts over the lifetime of a wind farm, which can be 20 to 25 years. O&M activities involve component inspection works, component servicing and repair works, and everyday condition monitoring of a wind farm and its components (Shafiee, 2015).

The De-comm phase is a relatively new practice with no established industry standards for methods or procedures regarding the removal of wind farm components

(LEANWIND, 2017). According to Smith and Lamont (2017), decommissioning will ramp up slowly, mirroring the activities needed to build an OSW farm. At the present, it is expected that the dismantling of a wind farm will be performed in reverse order of the installation procedure. Though, it is also expected that some parts of a wind farm will be unfeasible to extract, such as its foundations and cables. Therefore, to extend the life of a wind farm, other options, such as repowering or upgrading, are being considered.

Ports are perceived by this study as the main DP between onland operations and offshore processes. Ports, in general, have been viewed as interface between sea and land transportation providing different services for different supply chains (Carbone and De Martino, 2003; Mangan et al., 2008; Demirbas et al., 2014; Stevens and Vis, 2016). With the emergence of the OSW industry, as well as other marine renewable energies, ports have expanded their role to now act as staging bases to support the activities necessary for the development of a wind farm (Akbari et al., 2017; Irawan et al., 2017). Due to the size and weight of a wind farm's components, logistics processes need to be moved close to construction sites. Therefore, ports offer suitable facilities for the storing, warehousing, pre-assembly, and testing of components. This also suggests that these processes may involve more than one port because not all ports have the capacity to accommodate all of the necessary requirements for a wind farm's construction (Akbari et al., 2017). Therefore, some ports may only offer storage space, some may be used for C&C processes, and some may only be suitable for crew transfers. Nevertheless, the involvement of ports span all phases of the OSW supply chain and are becoming the focal point of local and regional development by hosting different operations centres for manufacturers, developers, and wider supply chain parties (Wind Europe, 2017).

Considering the distinct phases and activities involved in each phase, involving a large number of different actors, such as suppliers of products and services, contractors, sub-contractors and government agencies, it is important to note that each phase may be considered as a different supply chain (Stentoft et al., 2016; Adami et al., 2019). The same holds true for all the different component manufacturers; each component manufacturer has their own supply networks that they use for sourcing the parts necessary to produce wind farm components. Therefore, it suffices to say that the OSW supply chain is complex, constituting multiple levels of different supply networks (Adami et al., 2019; Johnsen et al., 2019; Adami et al., 2020). However, in order to view the OSW supply chain in terms of a network or more traditionally, this study takes Grant's (2012) supply chain representation, shown in Figure 2.6, as a basis for proposing a network perspective of the OSW supply chain, as shown in Figure 2.8 below:

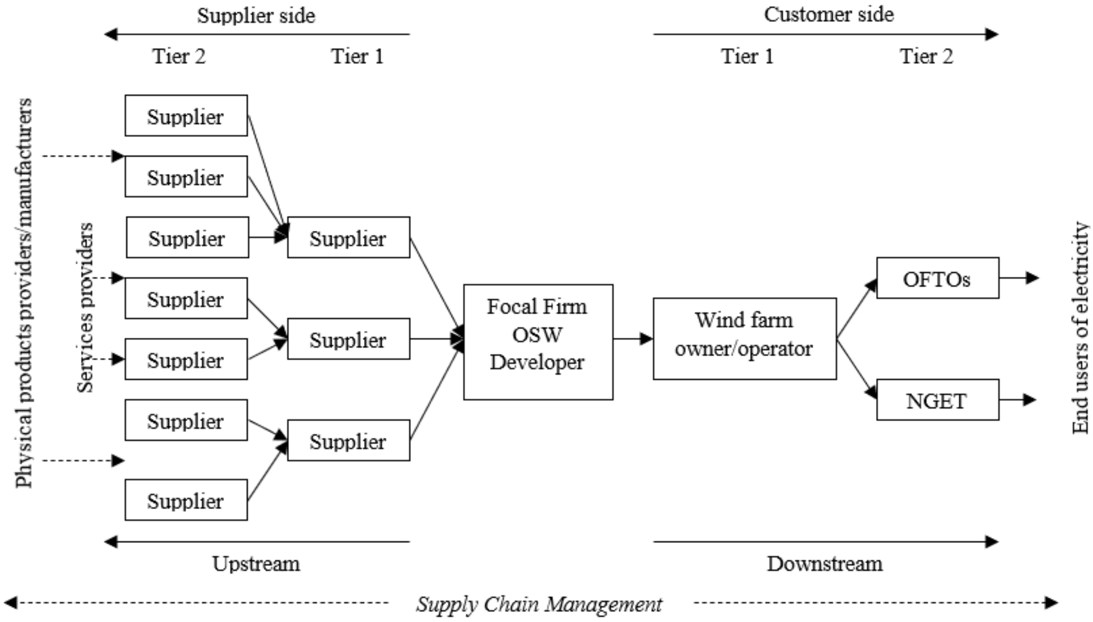

Figure 2.8: The OSW supply chain; a network perspective (Author)

The OSW supply chain in Figure 2.8 considers the focal firm which, in the case of an OSW farm's development and construction, is the developer (BVG Associates, 2019). The upstream side involves different suppliers of products and services, as well as different tiers of suppliers. Tier-one suppliers are direct suppliers to the developer. These are likely to be original equipment manufacturers (OEMs), such as the manufacturers of turbines, foundations, and substations, amongst others. Tier-two suppliers are those who supply to tier-one suppliers, and the same logic can be extended to include tier-three and lower-tier suppliers, including raw material suppliers. The downstream side involves different tiers of customers. Tier-one customers are the owners/operators of wind farms. In the OSW industry, it is common to see developers as tier-one customers. Tier-two customers include OFTOs (Offshore Transmission Owners). According to Ofgem's (The Office of Gas and Electricity Markets) regime, separate entities take responsibility for offshore wind transmission assets in the UK, thus becoming OFTOs. The physical assets of OFTOs include offshore substations, export cables, onshore substations, and related electricity equipment, although assets can vary from project-to-project (Ofgem, 2014). Another tier-two customer could be NGET (National Grid Electricity Transmission). The

National Grid collects electricity from different energy sources and distributes electricity to end consumers. This representation of the supply chain helps to provide an understanding of its network nature, as well as its main upstream and downstream flows.

2.7 Supply Chain Integration

The overview of SCM provided in Sections 2.4 and 2.5 has shown that the philosophy of SCM is predicated on concepts such as 'integration' and 'alignment'. Therefore, as argued by Pagell (2004), the importance of integration in SCM is not in doubt. The main purpose of this section is to explore the existing body of knowledge on the subject of SCI to understand its main principles and the current developments within this subject area.

The Oxford English Dictionary defines the word 'integration' as "*to be combined to make a whole*" (Soanes and Stevenson, 2008). In the context of SCM, integration is often described as encompassing variables such as cooperation, coordination, interaction, and collaboration, although they are not predefined because integration is not a formally defined construct (Pagell, 2004). Considering the broad meaning of the word integration in the context of SCM, SCI is often associated with the term 'seamless supply chain', where all actors think and act as one (O'Leary-Kelly and Flores, 2002; Childerhouse, et al., 2011; Harrison and van Hoek, 2011). SCI can be further understood in terms of the following definition:

> "*… supply chain integration is the alignment, linkage and coordination of people, processes, information, knowledge, and strategies across the supply chain between all points of contact and influence to facilitate the efficient and effective flows of material, money, information, and knowledge in response to customer needs*" (Stevens and Johnson, 2016: 22).

Other terms used in the literature which are closely related to the concept of SCI are 'extended enterprise' (EE) (Spekman and Davis, 2016) and 'virtual enterprise' (VE) (Bititci et al., 2004). Both terms have the same philosophical connotation as SCI as both terms imply collaborative relationships among strategic supply chain members. However, VE is considered as a temporary network of companies and a temporal case of an EE and is described as "*a dynamic partnership among companies that can bring together complementary competencies needed to achieve a particular business task, within a certain period of time*" (Bititci et al., 2004: 257). According to Spekman and Davis (2016), the concept of EE appeared as an evolving paradigm in supply chain theory and practice back in the early 1990s following the realisation that expanding the scope of production from an individual plant to also include suppliers, and encouraging relationships to be collaborative instead of adversarial, could bring increased gains. This resulted in a network perspective that is now widely recognised within supply chain theory and practice, appearing in more updated themes such as collaboration and integration.

Sadler (2007) adds that integration is the synergy of contributions within the design and execution of product delivery systems and argues that integration requires a systems approach taken by analysts and decision-makers to create greater customer and stakeholder value. According to Sadler, a systems view of the supply chain is concerned with the output of a whole supply chain, where emphasis is placed on the optimisation of processes which assist the performance of an entire chain rather than the optimisation of individual parts, such as travel times or inventory levels. Stevens and Johnson (2016) argue further that supply chain performance depends on the interaction of processes between the whole supply chain, rather than depending on the optimisation of isolated parts. In a similar vein, Peltz et al. (2012) recognise the value of the systems view in the context of SCM by asserting that it helps to encourage organisations to realise that everything they do interacts with the rest of the supply chain and is therefore connected.

Despite the recognition that the integration of the supply chain may lead to greater performance of the whole supply chain, the literature does not offer clear answers as to what integration involves or how it can be achieved. One of the first articles on SCI (Stevens, 1989), which is believed to have informed subsequent research in this area, posits that achieving an ‘integrated’ supply chain within a company is likely to require a bottom-up approach; where a company would progress through a number of development stages, as shown in Figure 2.9 (Stevens, 1989). Stevens suggests that there are four stages which companies move through towards achieving SCI: moving from internal integration to external integration (as the highest level of integration). The first stage describes baseline companies which, according to Stevens, have a very fragmented supply chain. Furthermore, the activities of those companies are perceived as separate departments. Baseline supply chains are therefore considered as being the least efficient and effective, and companies classified as stage one are likely to implement short-term plans based on ‘quick fix’ solutions.

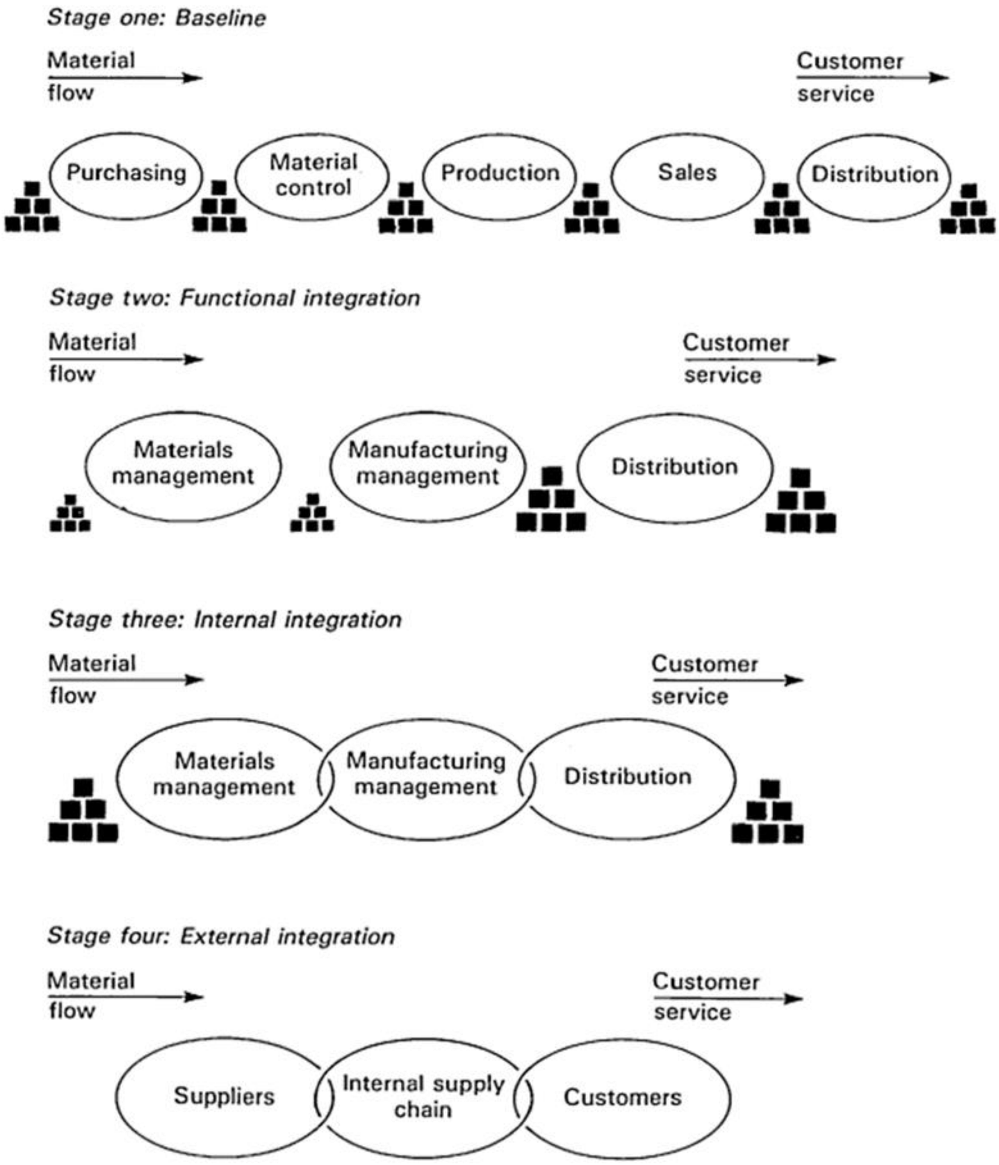

Figure 2.9: Stevens' (1989: 7) integration development stages

Stage two companies, according to Stevens (1989), typically apply materials and manufacturing planning systems, such as MRP and MRP II, with a focus on the inward flow of goods. This stage of development involves functional integration, which is characterised by an emphasis on cost reduction rather than performance improvement. According to Stevens (1989) stage two companies would hold a lot of inventory. Distribution infrastructure is likely to be decoupled from manufacturing and, as a result, stage two companies would have limited visibility of customer demand. This leads to inadequate planning and poor performance in general.

Stage three of company development is referred to as internal integration. Stage three companies recognise that solely focusing on the flow of goods into the organisation is inadequate unless the flow is well-managed. This stage embraces outward goods management and integrated supply and demand along companies' own supply chains. Stage three, or internal integration, is characterised by a comprehensive integrated planning and control system. Companies that have achieved stage three integration would, according to Stevens (1989), use a range of electronic data interchange (EDI) systems, such as DRP and MRP II for materials management, as well as just in time (JIT) manufacturing techniques where practical. When companies achieve this stage, they can begin to embrace synchronised demand management by synchronising customer demand with the flow of materials from suppliers. Stage three supply chains can be characterised as having full systems visibility from distribution through to purchasing; emphasis is placed on efficiency rather than effectiveness.

Stage four extends the scope of integration outside the firm and embraces suppliers and customers. In Stevens' (1989) view, it is considered the highest form of SCI. Stage four firms change their focus from products alone to a more customer-oriented focus in order to understand customer needs and requirements. This stage also involves changing a firm's attitude towards suppliers. In more detail, firms should move away from an adversarial attitude to one of mutual support and cooperation, where cooperation begins at the early stages of product development and encompasses the involvement of full management at all levels. This stage involves long-term commitment, which usually means the elimination of multiple sourcing.

In 2016, Stevens, together with a colleague named Johnson, revised the SCI model he originally proposed in 1989 to include additional stages of development based on changes to the business environment. Overall, two additional stages have been added. The first additional stage is a goal directed networked supply chain. By included this stage, Stevens and Johnson (2016) recognise and encourage others to view supply chains from a network perspective, rather than based on a linear sequence or chain of transactions. The second additional stage includes devolved, collaborative, supply chain clusters. By proposing this stage, the authors draw attention to the increased complexity of today's networked supply chains. By 'complexity', the authors refer to the structural differentiation, or variety, that exists within a network. The second additional stage, or model, is based on a series of self-governing clusters, where each cluster is comprised of a network of suppliers and subcontractors, associated by type, product structure, or flow.

Following Stevens' (1989) original stages of SCI, subsequent SCI studies have focused on either internal integration, external integration, or both. Internal SCI can be understood as integration within a firm's own boundaries and across its internal supply chain functions (Chen et al., 2009). Internal integration can help to break down functional barriers within a firm and facilitate real-time information sharing across key business functions in order to meet customer requirements at a lower total system cost (Wong et al., 2011). In similarity to Stevens' development stages, internal integration is often viewed as a precondition for external integration. For example, Harrison and van Hoek (2011) claim that internal integration is a key starting point for broader integration across the supply chain. Furthermore, they argue that firms with higher levels of internal integration demonstrate higher relative logistics performance in comparison to those that are less integrated. External integration, according to Wong et al. (2011), refers to supplier and customer integration, where supplier integration involves strategic collaboration between a focal firm and its suppliers and customer integration involves strategic information sharing and collaboration between a focal firm and its customers.

According to Harrison and van Hoek (2011), external integration can take several forms which can be classified as either a manual approach or electronic approach. In terms of the manual approach, the authors note that strategies such as the 'supplier-in-plant' strategy place customer and supplier processes closer together and is associated with the concept of JIT. This approach helps to eliminate the buyer and salesperson from the customer-supplier relationship, thereby facilitating communication between the parties and allowing a supplier employee to access the customer's scheduled system in order to place orders. This approach also helps material planning for the materials supplied and the production planning process, where production is planned concurrently with the supplier organisation. This form of integration is believed to streamline the supply process by removing the multi-level planner-buyer-salesperson-supplier plant process by making this the responsibility of one individual.

According to Harrison and van Hoek (2011), electronic integration is traditionally understood as including the exchange of information, including orders and delivery information by means of EDI, especially in retail environments. Today, the EDI systems that are incompatible with each other and have high development and installation costs are slowly being replaced by internet communication, which offers a relatively cheap way of integrating information systems across the supply chain. In general, information flow has been identified as one of the key elements of SCI (Cooper et al., 1997). According to Evans and Danks (2002), advances in information technology enable virtual SCI through virtual linkages.

Harrison and van Hoek (2011) distinguish three forms of electronic integration: transactional, information sharing, and collaborative planning. In more detail, transactional integration includes the automation of business transactions, such as purchase orders, invoices, orders, and advanced shipment notices, amongst others. Such electronic transactions would normally involve a fixed-format document with predefined data and information fields. Information sharing involves trading partners having joint access to a system with shared information, including product descriptions and pricing, promotional calendars, inventory levels, and shipment tracking and tracing. Uncertainty can be reduced by each partner becoming aware of the other partner's activities. Collaborative planning is the third way that trading partners can integrate electronically. This may include the use of tools such as Vendor Managed Inventory (VMI), Efficient Consumer Response (ECR), Point of Sale (POS) data sharing, and Continuous Replenishment (CR), which have together evolved into the Collaborative Planning Forecasting and Replenishment (CPFR) approach (Barratt, 2004).

There is general agreement in the literature that a well-managed supply chain is an integrated supply chain and that higher levels of SCI can lead to greater levels of supply chain performance (Cooper et al., 1997; Pagell, 2004; Flynn et al., 2010). Frohlich and Westbrook (2001) are often acknowledged as being the first to provide an empirical investigation of SCI, showing the relationship between SCI and performance. They investigate the degree and extent of supplier and customer integration strategies in manufacturing firms and characterise these strategies as 'arcs of integration'. Frohlich and Westbrook (2001) base their integration analysis on eight different types of integrative activities commonly used by manufacturing firms to integrate their operations with suppliers and customers, these activities included: 1) access to planning systems, 2) sharing production plans, 3) joint EDI access/networks, 4) knowledge of inventory mix/levels, 5) packaging customisation, 6) delivery frequencies, 7) common logistics equipment/containers, and 8) the common use of third-party logistics. Following Frohlich and Westbrook's (2001) study, many articles have since focused on the link between SCI and performance, including customer service, firm competitiveness, and financial performance (Narasimhan and Kim, 2002; Vickery et al., 2003; Droge et al., 2004; Chang et al., 2016; Wiengarten et al., 2016).

Van Donk and Van der Vaart (2016) confirm that the majority of survey-based SCI research examines integration with suppliers and its relationship with the financial performance of a focal company. The findings of these studies confirm the relationship between level of SCI and performance. However, there is little consistency between the definitions and constructs used across these studies to measure SCI and performance. Many studies also disregard the contextual differences of supply chains by studying integration as a monolithic concept (Tsinopoulos and Mena, 2015). A similar criticism was made by Evans and Danks (2002), who noticed that the proponents of integration often refer to it as a universally applicable concept. As argued by Evans and Danks (2002), this is unlikely to be the case. They argue that SCI is context-dependent and that different industries and firms within each industry are likely to develop distinct SCI strategies based on customer segments, products and services offered, and geographical location. Therefore, each organisation configures integration differently.

Sadler (2007) suggests that emphasis needs to be placed on focused efforts, rather than on an overall integration. According to Sadler, the overall aim of SCI is to create a flow of products as required by customers; responding dynamically to changes in their orders. In the context of a manufacturing environment, Sadler (2007) proposes a series of steps to help companies assess their current supply chains and adjust them to start operating in a more integrated manner. The first step includes an examination of a supply chain's boundaries by focusing on the suppliers that bring the most value to the overall supply chain. The second step involves the placement of the DP within the supply chain to better serve the customer. The third step involves identifying the physical and human resources needed to provide capability, which would confer distinctive competencies compared to competing supply chains. The fourth step suggests the need to identify order winners or, in other words, those parameters that are critical in the eyes of the customer, such as quality, speed of delivery, or price. This is similar to the aforementioned project-based supply chain value drivers proposed by Venkataraman (2007), which includes customers, cost, flexibility, time, and quality.

Sadler (2007) also considers the best type of relationship between supply chain partners, which can be regarded as a fifth step of his proposed steps. He argues that partnering forms the basis of SCI. Sadler (2007) distinguishes between transactional partnering, strategic partnering, and exclusive partnering, and argues that an important part of supply chain design involves deciding which type of partnership is the most suitable for a particular relationship. As noted by Sadler (2007) and acknowledged by the wider SCM literature, cooperation between firms belonging to the same supply chain is now recognised as a powerful source of competitive advantage. Such companies do not transfer costs along the supply chain; they cooperate to increase overall sales and reduce total costs, rather than compete for a larger share of a fixed profit. In the sixth step, Sadler (2007) suggests that decision-makers need to consider the inherent variability in demand for a product, as well as uncertainties, such as the variable nature of purchasing, provisions, and travel times. This is in order to design a robust chain that is capable of meeting expected delivery times and is responsive to changes in volume, processes, and variable orders.

Considering that SCI seeks to achieve efficiencies, the number of suppliers in the chain needs to be reduced. According to Harrison and van Hoek (2011), companies generally seek to reduce the number of suppliers they deal with by focusing instead on those with the ‘right’ set of capabilities. Indeed, it would be impractical to integrate the processes of the focal firm with the processes of a large number of inbound suppliers. Treating all suppliers in the same way, as pointed out by the authors, fails to recognise that some suppliers have different needs to others. Therefore, one of the solutions to supplier base rationalisation is to appoint a limited number of lead suppliers, with each being responsible for managing their portion of the inbound supply chain. The difficulty with this, however, is having appropriate supplier selection criteria.

The differentiation of the roles of suppliers also allows different types of relationships to be tailored to different types of products in the supply chain. Different types of relationships in the supply chain, according to Sako (1997), can be viewed in the form of a continuum. Where, on one extreme relationships are described as ‘arm’s length’ contractual relationships also known as adversarial relationships. On the other extreme there are obligational contractual relationships. In the context of SCM, arm’s length contractual relationships may refer to vertical integration, where the supply chain is owned and controlled by a single organisation (Hines, 2004). The strategy of expanding upon the supply side of the network is sometimes called ‘backward’ or ‘upstream’ vertical integration, whereas expanding upon the demand side is sometimes referred to as ‘forward’ or ‘downstream’ vertical integration (Slack et al., 2010). Other broad types of relationships that form part of the continuum between arm’s length and vertical integration include partnerships, strategic alliances, and joint ventures.

Decisions about vertical integration in today’s supply chains are rare. Vertical integration often has a negative connotation, including limiting competition, increased risk, and diseconomies of scale (Evans and Danks, 2002; Wilding and Humphries, 2006). Following the widespread outsourcing of particular business activities, especially to low-cost countries, a large proportion of direct activities are now being bought from suppliers instead of produced in-house. The outsourcing of non-value adding activities, according to Porter (2004), helps businesses to place their focus on activities that are strategically relevant, which helps businesses to gain a competitive advantage by performing strategically important activities more cost-effectively or to a higher standard than their competitors.

According to Cooper et al. (1997), an integrated supply chain of partners must be managed differently from that of a single monolithic bureaucracy. This is also supported by Cristopher (2016), who views the concept of SCM as an alternative to vertical integration. Likewise, Guan and Rehme (2012) believe that vertical integration is a precursor to SCI, where the former relates to ownership of different business activities and the latter relates to coordination mechanisms.

Considering the emphasis on collaborative thinking, working, and decision-making, SCI is generally considered to be a positive phenomenon. Among the primary benefits of SCI, the literature highlights improved process efficiencies, reduced inventories, lower operating costs, and improved customer service (Stevens and Johnson, 2016). However, there are some who question whether SCI is possible, arguing that it is difficult to achieve in practice (Barratt and Oliveira, 2001). Evans and Danks (2002) also point out that not all supply chain partners will benefit from SCI to the same degree. Therefore, as Das et al. (2006) argue, the notion of 'more is better' in the case of SCI is wrong. Das et al. (2006) discuss a range of disadvantages of SCI. For example, the possibility of integration slowing down an organisation's response to change by making the supply chain less flexible, potential cost increases as opposed to decreases, and the discouragement of independent thinking, among others. Instead, the authors suggest to look for an optimal set of integration practices; a further reminder that SCI is context-dependent. Taking Das et al.'s (2006) theory into account, Gimenez et al. (2012) interestingly find that SCI is only effective in buyer-supplier relationships characterised by high supply complexity. In other words, supply complexity determines the effectiveness of SCI.

2.8 Supply Chain Integration in Project-Based Environments

An overarching argument derived from a review of the SCI literature was that SCI is context-dependent and that it would vary from industry-to-industry and from company-to-company (Evans and Danks, 2002; Gimenez et al., 2012; Tsinopoulos and Mena, 2015). The aim of this section is therefore to conduct a more focused and structured review of the publications related to SCI in project-based environments in order to identify the key developments and emergent themes in this area. In addition, it will develop a greater understanding of the role of SCI in project-based environments.

Drawing on Denyer and Tranfield's (2009) systematic approach towards a literature review, a series of keywords were used to search for relevant publications. According to Colicchia and Strozzi (2012), applying a set of keywords to broad research areas helps to identify and select the most relevant contributions in a particular field.

The following keywords were used to create different search strings using the Boolean operators 'and' and 'or': supply chain integration, alignment, collaboration, coordination, cooperation, construction industry, project-based supply chain, engineer-to-order supply chain, make-to-order supply chain. To limit the search of these keywords to the topic of SCM, 13 journals in the logistics and SCM field were selected, including the following: *Journal of Operations Management, International Journal of Operations and Production Management*, *Production and Operations Management*, *International Journal of Production Research, Journal of Supply Chain Management*, *Supply Chain Management: An International Journal*, *Journal of Business Logistics*, *Journal of Purchasing and Supply Management*, *The International Journal of Logistics Management*, *International Journal of Logistics: Research and Applications*, *Supply Chain Forum an International Journal, Production Planning and Control, and the International Journal of Physical Distribution and Logistics Management*.

An initial search returned over 5,000 articles. Several rounds of screening were involved to reduce the number of articles to include only the most relevant. A final total of 41 articles were selected for a full paper review. Table 2.1 indicates the journal titles of the selected articles. It also indicates the journals' rankings according to the Academic Journal Guide prepared by the UK Chartered Association of Business Schools (CABS), as well as the category names under which these journals are grouped. As shown in Table 2.1, all of the journals containing the selected articles are grouped under the Ops & Tech (Operations and Technology) category in CABS.

Journal	CABS Rank (2018)	CABS Category	No. of Articles
Journal of Operations Management	4*	Ops & Tech	1
International Journal of Operations and Production Management	4	Ops & Tech	6
Production and Operations Management	4	Ops & Tech	1
Production Planning and Control	3	Ops & Tech	2
Journal of Supply Chain Management	3	Ops & Tech	1
Supply Chain Management: An International Journal	3	Ops & Tech	19
International Journal of Physical Distribution and Logistics Management	2	Ops & Tech	1
Journal of Purchasing and Supply Management	2	Ops & Tech	9
Supply Chain Forum: An International Journal	1	Ops & Tech	1
		Total:	**41**

Table 2.1: Journal titles of the selected articles, their CABS rankings, and category

Figure 2.10 shows the distribution of the selected articles published between 1998 and 2018. As it can be observed, 2010 saw the highest number of publications; ten articles out of the selected 41 were published during that year. A closer investigation revealed that five of those articles were published in the same volume and issue of the journal *Supply Chain Management: An International Journal.* A further three articles shared the same volume and issue in the *Journal of Purchasing and Supply Management*. This suggests that those publications were made in response to calls for papers in special issues concerning SCM within project-based environment. This also indicates that there is a stable and perhaps growing interest in SCI within the field of construction, which saw another increase in publications in 2015, in addition to more recent publications in 2017 and 2018.

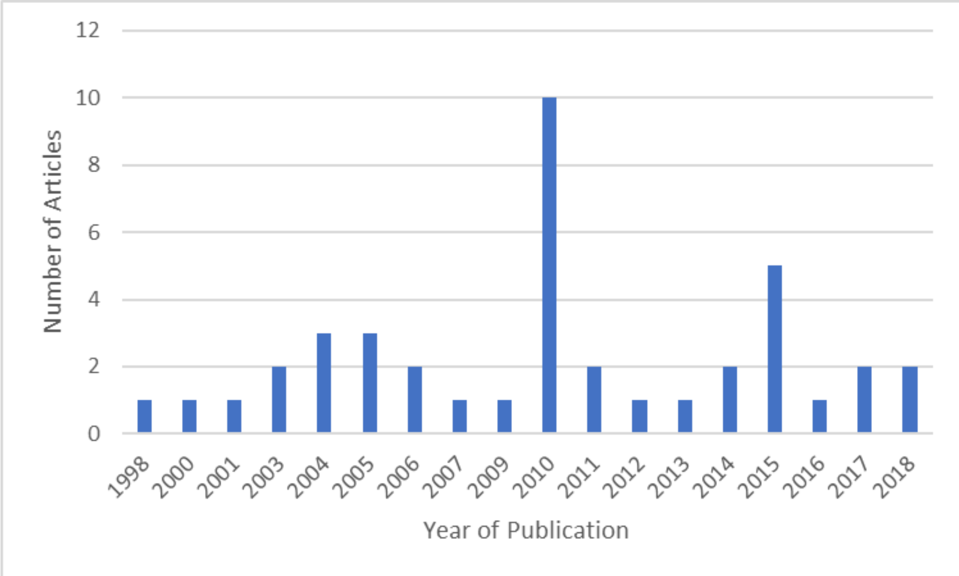

Figure 2.10: Distribution of articles published between 1998 and 2018

2.8.1 The role of SCI in project-based SCM

None of the selected articles were contextualised in terms of the OSW industry, although one article did include the wind industry as a case study (Gosling et al., 2017). Nonetheless, they have covered a good range of other project-based backgrounds, thus providing different perspectives on SCI. Some of these project-based industry backgrounds include shipbuilding, the construction of oil and gas platforms, various complex civil and structural engineering projects, and building construction: both commercial and housing. Building construction was a dominant industry discussed in 20 of the selected articles, which are focused on commercial and/or house building environment.

In similarity to the wider SCI literature, there is general agreement among these articles that the integration of a project-based supply chain is a positive phenomenon and that the extent of collaboration and coordination among supply chain partners can determine the success of a project, including whether the project was delivered on time, within budget, and to specification (Ronchi, 2006; Caniels et al., 2012). Ellegaard and Koch (2014) find that a lack of integration may lead to inter-functional conflict. However, if integration mechanisms are introduced once a conflict has already developed, an even larger conflict may occur as a result. Another study (Mello et al., 2015) argues that the poor coordination of project activities among multiple business units is a major source of delays, which increase lead times. This is a major problem for project-based or ETO supply chains, where the degree of product customisation is high.

In addition to a consensus in the literature about the need for SCI in project-based environments, there also seems to be agreement that SCI is especially challenging in the context of project-based supply chains, mainly owing to its temporary nature. Therefore, many agree that SCI is difficult to achieve in practice (Briscoe and Dainty, 2005; Eriksson, 2015). Ireland (2004) argues that, in the context of the construction industry, SCI and collaborative business relationships may not be appropriate for all players all of the time. In agreement with Ireland (2004), Caniels et al. (2012) explains that inter-firm relationships are intrinsically unstable and, after a while, the costs and benefits of relationships may change. This means that integrative supply chain relationships may cause some costs to overshadow the benefits for some parties in the supply chain, especially if initial circumstances change. This also suggests that achieving supply chain-wide integration may hamper communication and task alignment (Eriksson, 2015).

Given these challenges, a number of articles have examined the various factors and prerequisites for collaboration, coordination, and cooperation (Khalfan et al., 2007; Bankvall et al., 2010; Lehtinen and Ahola, 2010; Kim and Nguyen, 2018), as well as barriers to integration (Kornelius and Wamelink, 1998; Dainty et al., 2001; Ireland, 2004; Mello et al., 2015). However, these articles do not provide a unified view about what these factors or pre-requisites of project-based SCI should be. This could be because the majority of studies (22 out of 41) are based on case studies that examine different industry backgrounds, thus suggesting different solutions. Nonetheless, one common theme that emerged from these articles is that SCI requires both formal and informal arrangements (Caldwell et al., 2009). For example, Chakkol et al. (2018) argues that in time-finite project-based operations, collaboration itself needs to be governed. They further suggest that both contractual and relational governance mechanisms are needed, which can be supported by formal standards, such as ISO 44001. In a similar vein, Lavikka et al. (2015) argue that contractual coordination alone does not ensure enhanced project delivery. According to the authors, contractual coordination needs to be complemented with the procedural coordination of a project-based supply chain network during a project.

In addition to formal arrangements, numerous authors have highlighted things such as incentive-based and multilateral contracting (Kornelius and Wamelink, 1998; Olsen et al., 2005), the building of strategic alliances (Lonngren et al., 2010), the use of ICT technologies (Ala-Risku et al., 2010; Hadaya and Pellerin, 2010; Pala et al., 2014), formal communication and reporting structures (Dainty et al., 2001), business process reengineering (Childerhouse et al., 2003), modular construction (Voordijk et al., 2006; Doran and Giannakis, 2011), and the use of standards for collaboration; for example, BS11000/ISO44001 (Chakkol et al., 2018). In terms of 'informal' arrangements, otherwise known as procedural coordination (Lavikka et al., 2015), authors have identified working co-located (Voordijk et al., 2006), shared project goals, collaborative decision-making in inter-organisational meetings, joint IT systems, cultural change (Arantes et al., 2015), socialisation of partners, soft skills development (Dainty et al., 2001), lean construction (Eriksson, 2010), and partnering. Partnering is the most commonly used term for integration in project-based supply chains (Dainty et al., 2001). Alongside partnering, many authors highlight trust as a critical factor of the success or failure of a construction project (Latham, 1994; Egan, 1998; Khalfan et al., 2007). Caldwell et al. (2009) consider trust as the most influential safeguard against the opportunistic behaviour of supply chain partners. Caldwell et al. (2009) also find that the general opinion in the literature seems to be that trust drives other governance mechanisms too.

According to Kim and Nguyen (2018), partnership-based relationships and collaborative relationships in a project-based supply chain are often understood as being synonymous, and they are perceived as the best approach to achieving supply chain improvement. However, in similarity to the idea of achieving an integrated supply chain, partnering has been critiqued for being difficult to achieve in practice (Humphreys et al., 2003). For example, a study by Crespin-Mazet and Portier (2010) on the French construction industry finds that private construction procurement firms tend to be reluctant to build partnership-based relationships because such arrangements are perceived as a threat to existing procurement procedures. Therefore, despite its positive connotations, partnering cannot be considered as being a universally accepted project delivery method.

Bygballe et al. (2010), in their review of the literature, identify three dimensions of partnering relationships: relationship duration, relationship partners, and how relationships develop. In terms of relationship development, Bygballe et al. (2010), find discussions in the literature on the importance of the formal and informal factors that are necessary for the creation of partnerships. In terms of relationship duration, the authors find that the literature commonly distinguishes between short-term and long-term or strategic partnering. This study also shows that, while there is no dominant view as to the preferred duration of partnering, some authors hold the view that short-term or temporary partnering for the duration of a project brings more benefits because preferred supply chain partners can be especially selected to meet the specific needs of a project. This can be called ‘semi-project’ partnering (Humphreys et al., 2003). Some argue that longer-term partnership commitments can bring the benefit of economies of repetition by cross-project repeatability in terms of partners, processes, routines, and practices (Chakkol et al., 2018). However, as Bygballe et al. (2010) note, strategic partnering arrangements that span over a series of projects are unusual in both theory and practice. Furthermore, some argue that long-term partnerships can become a source of conflict (Caldwell et al., 2009). Nevertheless, as found by Ireland (2004) longer-term collaborative relationships bring better solution to manage irregular demand inherent in project-based environments.

In terms of relationship partners, which Bygballe et al. (2010) refer to as the scope of integration, the authors find that research on partnerships predominantly concerns dyadic relationships between clients and main contractors. This is also recognised by other authors in this review who note that, in spite of the importance of subcontractors in engineering projects, many partnering attempts are indeed limited to only client and main contractor relationships (Dainty et al., 2001). Others also argue that the research on partnering and SCI lacks a network perspective, which is important for knowledge building in project-based supply chains (Eriksson, 2015; Brahm and Tarzijan, 2016). The present review has identified only one paper by Mello et al. (2017) that has a network perspective on supply chain by employing one of the systems thinking approaches namely Soft Systems Methodology (SSM) (Checkland, 1999). However, SSM is recognised as a problem structuring methodology, which provides limited understanding of supply chain as a network.

Another common perspective held by the identified articles is that the integration of a project-based supply chain can be improved by aligning business relationships according to the dominant party’s working strategy (Briscoe and Dainty, 2005). A dominant party can adopt the way of working that would allow other supply chain parties to achieve their optimal performance and would allow parties to operate in the manner expected of them by the dominant party (Cox et al., 2004). This would ensure that all parties in the supply chain have knowledge of the client’s processes, which would help parties to align their systems to those of the client (Briscoe and Dainty, 2005). In this case, the literature often considers main contractors as the dominant parties who are able to drive partnering and promote SCI (Arantes et al., 2015).

In similarity to the idea of an integrated supply chain in more traditional process-based environments, this review has shown that integration in project-based environments is recognised as a positive phenomenon that can enhance overall supply chain performance. However, there is still no consensus about how to achieve it in practice. This is again consistent with the wider SCI literature, which concludes that there is no single way to achieve SCI. This leads to the view that SCI is context-dependent, not only in terms of industry background but also in terms of individual projects, which comprise many formal and informal factors that need to be considered in conjunction with each other. This review has also revealed that integration is predominantly discussed from a relationship's perspective, such as partnering and trust building, but provides less understanding in terms of the other facilitating factors necessary to progress towards integration. Many studies have emphasised the need to take a network or systems approach to understanding SCI, but there are limited amount of studies that advocate a systems perspective in their methodologies. This suggests a need for this thesis to take a systems perspective in order to further explore its merits in the study of SCI within the OSW industry. The following sections will describe the systems perspective in more detail alongside an overview of the systems approach selected by this research.

2.9 Systems Thinking

Previous sections have mentioned the terms 'systems' and 'systems thinking' numerous times as being of relevance to studies on SCM and SCI. However, they often fail to explain what exactly these terms mean both academically and practically, as well as failing to explain their relevance to the wider field of logistics and SCM. The aim of this section is therefore to explain these terms in more detail and to justify the use of the systems perspective in this research.

Many authors note that systems thinking developed as the result of a paradigm shift from a mechanistic view of the universe, based on reductionist or atomistic science with an emphasis on parts, to that of a 'systemic' which emphasises 'holism' (Capra, 1997; Jackson, 2000; Midgley, 2000). The systemic or holistic way of thinking about the world is most similar to the systems thinking approach. According to Capra (1997), the shift from thinking about the parts to a whole, can also be seen as a shift from thinking about objects to relationships. As such, it can be considered as a form of 'network thinking', where the relationships between different parts become a primary concern.

In contrast to Cartesianism, which holds that the behaviour of a whole can be analysed in terms of the properties of its parts, the systems thinking approach holds that the properties of parts can be understood only within the context of the larger whole. Thus, systems thinking is also known as 'contextual thinking' (Capra, 1997). In a similar vein, Jackson (2000) adds that systems thinking respects the profound interconnectedness of the parts in a complex problem situation and, instead of breaking it down into their parts to intervene, it concentrates on the relationships between them and their possible *emergent properties*. According to Midgley (2000: 40), "*an emergent property is one that results from the interaction of a system as a whole rather than from one or two of its parts in isolation*". Consequently, the emergent properties exhibited by the whole system cannot be reduced to individual parts (Angell and Demetis, 2010). Therefore, systems thinking is often associated with Aristotle's philosophy that 'the whole is more than the sum of its parts'. This can be further explained using the human body as an example of a living system, where the whole body is more than the sum of its parts (such as individual organs) because only the whole of the human body can show emergent property such as life (Ison, 2010).

Checkland (1990) has distinguished different types of 'systems'. He classifies systems into natural found in the origins of the universe, designed physical or man-made systems, designed abstract systems such as mathematics, poems, or philosophies, human activity systems that can vary from one man wielding a hammer to a more complex system like an international political system, and transcendental systems that are beyond natural, designed physical, or abstract systems. Checkland (1990) argues that there must be a category that includes systems beyond knowledge, and consequently he termed this category transcendental systems. Similarly, Jackson (2005) identifies physical systems such as rivers, biological systems such as living organisms, designed or man-made systems such as cars, abstract systems such as philosophies, social systems such as families, and human activity systems such as systems that ensure the quality of products. These categories can all be referred to as systems because they exhibit certain characteristics pertaining to general systems principles, including wholeness, emergent properties, and the concept of organised complexity. In addition, Espinosa and Walker (2017: 11) highlight another important characteristic of a system, which is its 'purpose'; they state that a system is "*a collection of inter-related parts that work together to create a coherent whole with a purpose*".

The main characteristics of systems thinking are said to have emerged simultaneously across several disciplines during the first half of the twentieth century. However, according to Espinosa and Walker (2017), it was through the work of the Austrian biologist Ludwig von Bertalanffy, who first distinguished between ‘open’ and ‘closed’ systems in his study of living organisms and his book *General Systems Theory*, that the ideas behind systems thinking were first defined in the 1930s. However, as the authors themselves note, many of the original ideas surrounding systems were discussed in other parts of the world some decades earlier. Nevertheless, the main ideas of systems thinking were further developed and applied in disciplines as diverse as physics, particularly quantum physics, gestalt psychology, social and ecological sciences, engineering, and management which, over time, resulted in different theories and strands of systems; some of which can be seen in Figure 2.11 below. Note, however, that this does not form a comprehensive list of different systems theories, approaches, and their development. Instead, this research uses this list as an approximate guide to different systems theories.

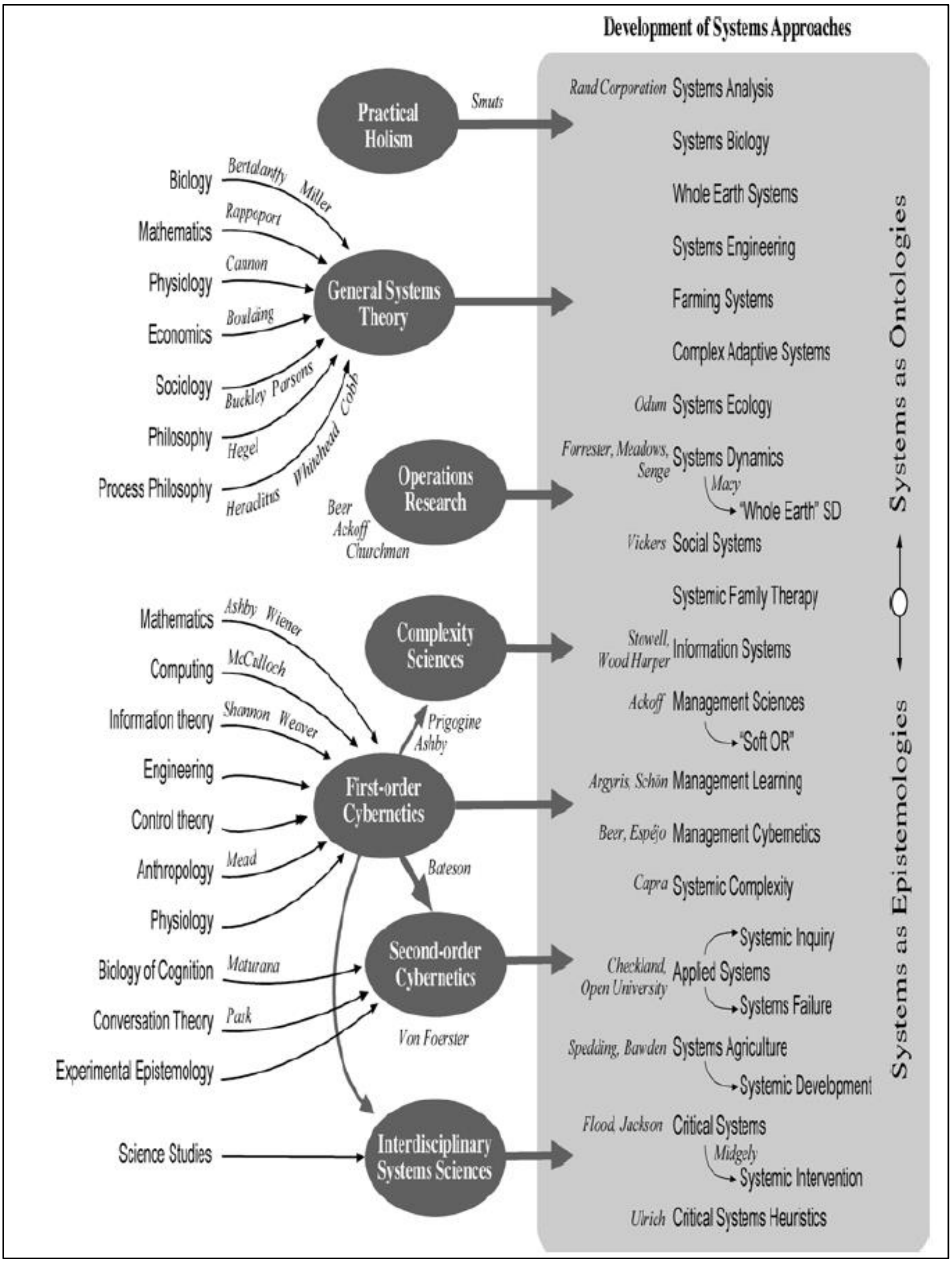

Figure 2.11: Different strands of systems theories and approaches and the lineages from which they have emerged, as illustrated by Ison (2010: 29)

The diversity of disciplines which recognise systems thinking makes it highly interdisciplinary. According to Checkland (1990), systems thinking is a subject that can discuss other subjects, and, for this reason, it can be called a meta-discipline whose subject matter can be applied to almost any other discipline. As Senge (2006) argues, the promise of the unification of knowledge across all fields is the systems perspective's greatest strength. Senge therefore referred to systems thinking as the 'fifth discipline'.

In comparison to reductionist sciences, systems thinking is often critiqued for being too vague. It is true to say that the broader a system's context, the less details are able to be included in an analysis (Hitch, 1955). According to Angell and Demetis (2010), when a particular system is chosen for a study it is artificially singled out from the rest of the complexity that surrounds it. Consequently, as argued by the authors, a system in a study can never capture the whole, meaning the choice of a system remains partial. From the perspective of epistemology, which is the branch of philosophy concerned with the theory of knowledge, it is clear that there are limitations to what a particular individual may consider as being a system. However, as it will be explained in more detail later (Section 2.9.1), there are different approaches to the study of complexity and, therefore, perspectives of the 'whole' may vary too. Moreover, according to Jackson (2000), systems thinking is generally concerned with real-life practical problems, rather than theoretical research problems. Thus, it is often associated with action research (AR) strategy in the academic world, which makes systems thinking approaches stronger in practice but somewhat weaker in theory, at least from a social sciences perspective.

It could be argued that systems thinking approaches to complex and diverse problems, such as pollution, climate change, overproduction, overconsumption, and digitalisation, allow people to understand concepts such as sustainability, ecology, and artificial intelligence. Most importantly, however, the merits of systemic thinking have allowed for a slow shift in people's mindsets from viewing these issues as 'somebody else's problem', to seeing how one's own actions can create these problems by highlighting the interconnectedness between human activities and the natural environment (Capra, 1997; Jackson, 2005; Senge, 2006; Espinosa and Walker, 2017).

In the field of logistics and SCM, and in terms of wider management practices, some evidence of holistic thinking can be noticed in particular concepts and approaches, such as total cost analysis, total quality management, the circular economy, lean production, reverse logistics or return networks, and closed-loop supply chain processes. This highlights the relevance of system thinking within this field and indicates the need to further advance systems thinking within organisational management sciences (Johannessen, 2005; Grant et al., 2017).

Various authors, including Daellenbach and McNickle (2005), argue that management sciences and operations research, have firm links with a broad systems thinking framework. Many logistics and SCM scholars (Ellram and Cooper, 1990; Choi et al., 2001; Johannessen, 2005; Grant, 2012) understand the benefits of systems thinking and the advantages that associated approaches can bring to this discipline. Bowersox and Closs (1996) go so far as to claim that logistics itself is based on the logic of systems analysis. However, in terms of the explicit use of systems approaches and theories in the logistics and SCM field, it can be concluded that systems theories are currently underused. For instance, Lindskog (2012a, 2012b) studies the extent to which systems thinking and its various theoretical approaches are applied to the field of logistics and SCM, by means of literature review, and concludes that systems theories are not well recognised and explicitly discussed in this discipline and remain to be underutilised.

This study supports the view that systems thinking is of relevance to the field of logistics and SCM and, specifically, that SCM itself implies holistic thinking by viewing the chain of supply as a single entity, thus suggesting that higher levels of SCI can lead to better supply chain performance. Considering also the need for alternative approaches to advance logistics and SCM research (Mears-Young and Jackson, 1997), this study uses a systems perspective to research SCI in project-based supply chains within the OSW industry. Hence, it views the supply chain as a system due to its integrative nature. The specific systems approach selected for this study will be discussed in more detail in Section 2.9.2.

2.9.1 Complex systems approaches

As mentioned above, there is general agreement among logistics and SCM scholars as to the relevance of systems thinking in this field. Hence, considering the supply chain as a system is not a new idea. However, as Choi et al. (2001) argue, it is not enough to simply recognise a supply chain or network as a system because there are different approaches to systems thinking. For this reason, the authors suggest complex adaptive systems (CAS) as a relevant approach to understanding supply chains, especially given their complexity. CAS refers to the systems that emerge over time into a coherent form by adapting and organising themselves without any singular entity having deliberate control over them (Holland, 1995). Similarly, Gattorna (2015) argues that it is important to treat supply chains as living organisms rather than inanimate mechanical structures in order to address the complexity of supply chains.

It is hard to disagree that supply chains can be characterised as complex systems, especially owing to changes in the business environment over recent decades. Examples of these changes include the outsourcing of none value-adding activities of firms' value chains, a move to low-cost countries, and globalisation more generally (Bowersox and Closs, 1996). All of these changes have made today's supply chains more complex as the number of nodes, through which products and associated information and finances have to pass through, have also increased (Gerschberger et al., 2017). Supply chain complexity increased overall interdependence among businesses in supply chains, emphasising the importance of more integrated and collaborative business practices.

Understanding the supply chain as a complex system does not imply looking at it solely in terms of CAS. According to Bohorquez Arevalo and Espinosa (2015), there are at least three approaches to complex systems in management sciences, of which CAS is only one approach. Other approaches include complexity sciences and organisational cybernetics. All three approaches agree that organisations are not linear systems, that they evolve over time, and that they share a basic understanding of the key characteristics of the study of complex systems, which is characterised by self-organisation, coevolution, and emergence. However, these approaches differ in their theoretical and methodological backgrounds and the types of problems and situations that they apply to (Espinosa and Walker, 2017).

CAS is described as a system composed of interacting agents, which may vary from things such as antibodies in the immune system to businesses. They are described in terms of rules, such as the stimulus-response rule, where if stimulus *S* occurs then response *R* is made. In a business context, this rule could mean that if demand for a product or service goes down then one of the responses could be to reduce prices (Holland, 1995). In terms of CAS, Holland (1995:10) argues that "*a major part of the environment of any given adaptive agent consists of other adaptive agents, so that a portion of any agent's efforts at adaptation is spent adapting to other adaptive agents*." The multiple interaction between parts creates a new order, which makes CAS an effective approach to predicting and controlling collective behaviours and their emergent properties (Bohorquez Arevalo and Espinosa, 2015). According to Espinosa and Walker (2017), proponents of CAS are typically from disciplines like chemistry, physics, biology, mathematics, and computer sciences, and are therefore more concerned with the study of natural and artificial complex systems. In management sciences, however, CAS can be recognised through tools such as a social network analysis and Cynefin, created by David Snowden, which can be understood as a decision making framework.

As the name suggests, complexity sciences incorporate different theoretical approaches, such as chaos theory, catastrophe theory, fractal geometry, non-equilibrium thermodynamics, Boolean networks, the NK model, network sciences, and collective intelligence, amongst others (Bohorquez Arevalo and Espinosa, 2015). These different approaches aim to understand systems evolution based on the breakdown of symmetries or ruptures in apparently stable systems (Espinosa and Walker, 2017). In more simplistic terms, complexity theorists are interested in the order and disorder of complex systems (Jackson, 2005). In similarity to CAS, natural and artificial systems are key areas of complexity science studies, which help to advance disciplines such as mathematics and computer sciences. In terms of management, however, sciences of complexity have yet to advance, although interest in applying complexity sciences to organisational environments in order to explain certain aspects of management, such as disorder, irregularity, and randomness, is growing (Jackson, 2005; Espinosa and Walker, 2017).

Organisational cybernetics is based on the wider science of cybernetics, which was pioneered in the Western world by the American mathematician and philosopher Norbert Wiener. Wiener introduced 'cybernetics' by defining it as the "*science of control and communication in the animal and the machine*" (Wiener, 1985). In this case, control does not refer to coercive control, but to a system's strategy for achieving its organisational purpose (Beer, 1967). In terms of cybernetics it refers to 'homeostats', which involves a system's internal mechanisms that maintain its state of dynamic stability, as well as referring to the important principle of self-regulation. To clarify, self-regulation refers to a systems' capability to adapt to a changing environment, even if it means reorganising its own structure and functions. Underlying the concepts of 'control' and 'self-regulation' is another important cybernetics concept known as 'feedback' or a causal loop. This occurs when a system makes corrective actions based on information fed back to the system. The example that is often used to explain a feedback mechanism is a room temperature thermostat, which reacts to high or low temperatures.

Such self-governing mechanisms of a system can be used to study different types of systems, including living systems, the brain, and human cognitive processes. It also has relevance to a wide-range of other disciplines, such as biology, engineering, physics, psychology, and the social sciences. Different applications of cybernetic principles in different studies have resulted in a shift from what is known as first-order cybernetics, which is sometimes compared to 'hard' systems thinking, to second-order cybernetics, which is sometimes called 'new' cybernetics that can be compared to 'soft' systems thinking (Mingers, 2014). According to Mingers, first-order cybernetics is concerned with the mechanisms of the external world, whereas second-order cybernetics is concerned with process of observation itself and is therefore otherwise known as the cybernetics of observing systems (von Foerster, 1981). The main idea behind second-order cybernetics is the recognition that peoples' perceptions of the external world are not passive reflections, but rather active constructions. Therefore, second-order cybernetics stresses the importance of the observer as forming part of the system being observed. This shift in perception of the role of the observer in systems analysis can be compared to a similar shift in the social sciences more generally, where the traditional positivist view of the social sciences was similar to the natural sciences which began to be critiqued, thus resulting in a shift towards more interpretivist and constructivist accounts of social reality. Interpretivist and constructivist accounts hold that the social world is significantly different from the material world.

Organisational cybernetics developed as a separate strand of cybernetics through the work of Stafford Beer on a theory of viable and effective organisations. As a result of his work, Beer redefined cybernetics as the "*science of effective organisation*" (Beer, 1979). As part of organisational cybernetics, Beer developed the viable system model, or the VSM in short. In brief, the VSM is based on the theory of organisational viability that includes the criteria for the structural diagnosis and design of the organisational features of a viable system, which can be explained as a system capable of independent existence within a specified environment (Beer, 1985). Given the aforementioned classification of first and second-order cybernetics, the VSM is said to be grounded in second-order cybernetics (Espejo and Reyes, 2011). Organisational cybernetics and associated VSMs therefore draw upon a wide-range of cybernetic principles, including the theory of viability, the concept of requisite variety, homeostasis, autopoiesis, and the concept of recursive organisation (Ashby, 1958). From an organisational cybernetics perspective, 'recursion' means that the organisational patterns of higher-level systems are repeated in the organisation of lower-level systems (Beer, 1979). This can also be observed in the field of SCM, where supply chains often consist of many different suppliers or businesses. These can be viewed as separate systems involved in many different interactions that take the form of a nested system or systems. They can therefore be described in terms of a system that is composed of embedded subsystems (Simon, 1962).

This study agrees with Choi et al. (2001) that supply chains, especially project-based supply chains, are complex systems due to their temporary nature, as discussed in Section 2.5. Therefore, it could be argued that all of the aforementioned complexity approaches are of relevance to logistics and SCM research. As explained by Beer (1979), systems are recognisable subjectively, the purposes of which exist only in the minds of an observer or group of observers. Angell and Demetis (2010:117) add that "*systems are products of the mind of an observer who decides what to observe, what distinctions to create, thereby designating those systems*". In comparison to Choi et al.'s (2001) theory of CAS, this study adopts an organisational cybernetics approach as pioneered by Beer (1979). This approach also involves the application of the VSM. Unlike CAS which has more prominence in the areas of natural and artificial social systems, VSM is more established in business organisation research contexts (Bohorquez Arevalo and Espinosa, 2015).

The selected organisational cybernetics and the VSM approach suggests that the system in focus is an 'organisationally closed system'. This means that, while it is open to energy and information coevolving with the environment, it remains organisationally closed. Hence, its organisational patterns and evolution are self-referential, self-organising, and self-regulated. These are therefore unlike CAS, which are open systems that exchange energy and information with the environment they coevolve with (Espinosa and Walker, 2017). Such a closed system's perspective is considered to be of more relevance to this study given that it examines the concept of integration within the system of a project-based supply chain, which can otherwise be regarded as being a closed system. Moreover, VSM approach allows to study the system in focus from management perspective. In other words, it considers different managerial functions that form the system in focus (Schwaninger, 2006b). VSM therefore allows to explore different managerial functions and strategies that can facilitate integration within OSW supply chain. In comparison, CAS would be more suited to examining a system's collective behavioural aspects and emergent properties rather than managerial functions, because CAS are viewed as systems whose behaviour is not governed by centralised mechanisms (Jagustović et al., 2019). Hence, the VSM offers a rigorous theoretical framework and approach more suited to this research. The next section will describe the VSM in greater detail.

2.9.2 The Viable System Model (VSM)

The VSM was developed by Stafford Beer as part of his work on a theory of viable and effective organisations, otherwise known as organisational cybernetics (Espinosa and

Walker, 2017). In this context, ‘viability’ does not refer to economic viability, as people might often think when considering a viable business. Instead, viability refers to a system’s ability to independently exist within a specified environment (Beer, 1985). The human organism is an example of a viable system, which served as the basis for the VSM’s development. Beer developed the VSM based on the organisation of the brain and human organs as a neural network. Both the neural network type of organisation, as well as its implicit principles of self-organisation and other cybernetic principles, appear to be of equal relevance to social organisations of all shapes and sizes (Jackson, 2005). Therefore, the VSM can be described as a model of the organisational features within any viable system (Jackson, 1991).

The VSM suggests that the dynamic structure determining the adaptive connectivity of a system’s parts is central to organisational viability (Beer, 1985). What this means is that some businesses may be unable to survive, even once all of their financial constraints have been addressed. For example, a company running a profitable business could be regarded as being a viable system, but if it depends on one customer who decides to switch companies its viability will be at stake. The VSM therefore helps to design an organisational structure that can be deemed as being viable, as well as being used to diagnose faulty ones.

Viability, in VSM terms, should not be confused with the concept of sustainability. This concept is said to have changed existing business management practices largely because of the work of John Elkington, who argues that a business is sustainable when it lives up to the ‘triple bottom line’ (Elkington, 1997). According to Elkington (1997), everyone would benefit if businesses adopted their practices to three interrelated and interdependent bottom lines, which include economic prosperity, environmental quality, and social justice. However, as Espinosa and Walker (2017) argue, environmental management (forming part of sustainability) requires further actions and new responsibilities to be added to existing business practices and organisational systems. Therefore, ‘viability’ can and should be regarded as a precondition for sustainability. By expanding upon this notion of viability as a precondition for sustainability, the authors propose a theory of viability and sustainability (V&S), which emphasises the importance of sustainable governance as opposed to environmental management only.

2.9.2.1 VSM constituent parts

The VSM consists of three main elements: a set of operations (O), consisting of a system's basic activities, which is embedded within a meta-system (managerial context) (M) and an environment (E), in which all of that is embedded. The operations and the meta-system can be further subdivided into five interacting systems: called Systems One, Two, Three, Four, and Five. These can be understood as typologies of functions, similar to those performed by the human body, its organs, nervous system, and the brain (Espinosa and Walker, 2017).

System One (S1) is referred to as a collection of operational elements of a system in focus which form the primary activities that are responsible for implementing the purpose of the system in focus. For example, if the system's purpose is milk production, S1 would consist of the various parts of the organisation concerned with carrying out the tasks directly related to milk production (Espinosa and Walker, 2017).

System Two (S2) acts as a service for S1 to ensure that S1's parts act cohesively. It provides coordination function and is referred to as an anti-oscillatory function. According to Beer (1979), S1 may experience an uncontrolled oscillation unless a sufficient element of 'damping' is introduced. Therefore, S2 exists to damp oscillation. The most often used example of an S2 is a school timetable. In the context of a manufacturing firm, an example of S2 would be a production protocol. Note, however, that normally there would be several S2s in place. As noted by Espinosa and Walker (2017), a lack of effective S2 mechanisms may lead to 'oscillatory disease', resulting in conflict within a system rather than collaboration and harmony.

System Three (S3) refers to the day-to-day management of S1. S3 is concerned with firm's internal operations at present; it has direct links with all managerial units of S1s, which exist simultaneously and in real-time. S3 transmits policies and special instructions to divisions. Therefore, S3 functions are managerial functions at a corporate level, which relate to the continuous activity of a firm's internal operations. S3's function is primarily to govern the stability of a firm or network's internal environment by ensuring the synergy of S1 through three channels: resource bargaining, the accountability channel, and the legal and corporate requirements channel. In a business environment the responsibility to fulfil the S3 function is usually that of corporate directors (Beer, 1986).

System Three star (S3*) is part of S3, which fulfils an auditing role to ensure that S3's specified targets, rules, and regulations are being adhered to (Jackson, 2005). Therefore, the function of S3*, which can include internal as well as external audits, is triggered by S3 as and when required.

System Four (S4) is focused on the larger environment. Beer (1985) called this function ‘outside’ and ‘then’, by explaining how every viable system is involved in an environment that is wider than the sum of S1’s environments. While Systems One, Two, and Three are considered the ‘inside and now’, S4 is responsible for the ‘outside and then’. S4 therefore performs ‘environmental scanning’ by searching for and capturing information about anything happening in the outside world that may potentially either benefit or threaten an organisation (Espinosa and Walker, 2017). Things such as R&D, market research, corporate planning, economic forecasting, management development, and other activities necessary to maintain a business’s competitiveness all count as S4 activities. Organisations need to be responsive to changes in the environment and remain up to date with information and new innovations within the market. However, Beer (1985) argues that simply being up to date with information is not enough because this information also needs to be used. Therefore, whoever is responsible for performing S4 activities within an organisation must communicate their gathered information with S3 which, depending on the system in focus, can be organised either formally or informally. Beer (1985) called the interaction between S3 and S4 an ‘adaptation mechanism’.

System Five (S5) is responsible for an organisation’s closure, identity, ethos, and policies. In a more autocratic organisation, S5 may involve corporate directors, whereas S5 in a more democratic organisation could consist of many people, including the heads of S1 and S3. According to Beer (1985), in order to ensure a system’s viability, it is vital to achieve a continuous interaction between S3 and S4. Therefore, one of the main tasks of S5 is to ensure balance between S3 and S4. It is important to note that all of these systems are functions of one unified system, where S2, S3, S4, and S5 are meta-systemic to S1’s main operations.

Figure 2.12 provides a graphical representation of the VSM, where S1 includes multiple operations and operational management (1a, 1b, 1c), which are represented as (O). The meta-system (M) encompasses all support roles of S2, S3, S4, S5, as well as the environment (E) in which the system operates. The environment includes organisation’s or network’s external stakeholders which lie outside of the organisation’s or network’s boundaries, such as its customers, suppliers, competitors, and other related parties.

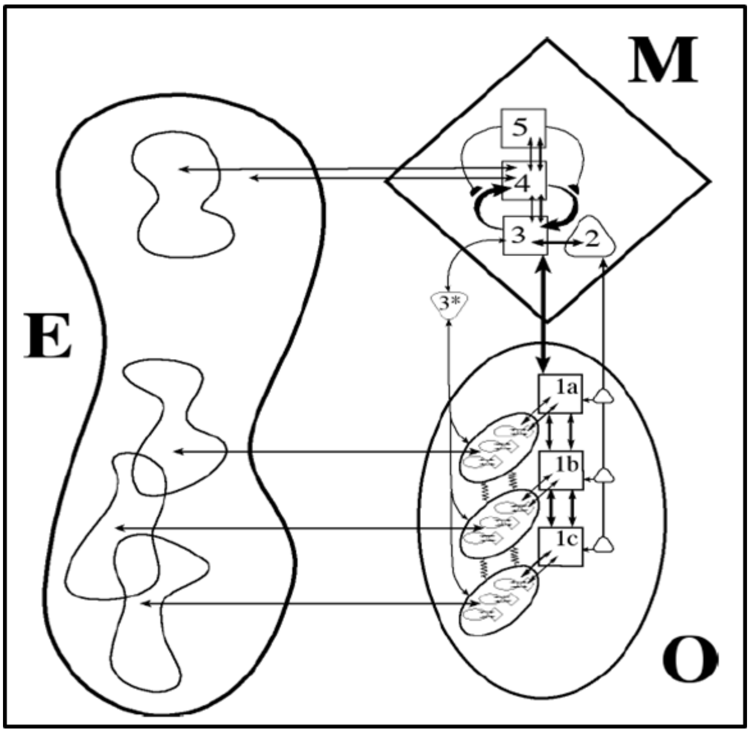

Figure 2.12: The Viable System Model (Espinosa and Walker, 2017: 127)

A key VSM concept is 'recursion', as briefly mentioned in Section 2.9.1 and shown in Figure 2.12. Recursion occurs when each operation repeats the same graphical representation of a viable system, and each operation can be considered as a viable system in its own right. This concept of recursion refers to Beer's 'Recursive System Theorem', where "*in a recursive organisational structure, any viable system contains, and is contained in, a viable system*" (Beer, 1979: 118). This means that the viable system is organised recursively and maintains its independent existence at each level of recursion. In other words, recursiveness can be described in terms of organisational and interactional invariance because, to a cybernetician, all organisations appear identical as they are all underwritten by the same laws of an 'organisation' (Espinosa and Walker, 2017). Therefore, even though viable systems can vary in size and form, all viable systems exhibit the same organisational characteristics (Beer, 1979). This means that a higher level of recursion of the system can be found repeated in the lower-level of recursion of the system, and vice versa (Jackson, 2005). This also suggests that there is no basic level of recursion upon which one should place their focus. Instead, this choice is made by the observer depending on the recursive level of interest. This makes the VSM a powerful and unique model for the study of complex systems, which helps to identify the different interactions between viable systems and their relevant environments at different levels of recursion (Espinosa and Walker, 2017).

Another important VSM concept is ‘variety’, which is a measure of complexity. This concept is based on Ashby’s (1958) Law of Requisite Variety. The principles of requisite variety served as the basis for Beer’s subsequent laws and axioms of variety management, which explain the structural conditions for viability when dealing with organisational tasks. In Beer’s theory (1979), a meta-system (M) has lower variety than the operations because no management team can possibly know every operational thing that occurs within their organisation, and nor should they. Similarly, the operational system (O) has lower variety than the environment (E) because, like in the example of a single shirt manufacturing business, it is impossible to accommodate all potential demand for different shapes and sizes of shirts. Therefore, as argued by Beer (1979), a manager’s job is to act as variety engineers by employing mechanisms such as variety ‘attenuators’ or variety reducers, and variety ‘amplifiers’ or variety enhancers, to achieve the necessary balance. A lack of variety within operations could restrict an organisation’s capacity to adapt to changes in the environment. In contrast, too much variety could slow an organisation’s ability to react to changes in the environment. Therefore, in VSM language the system in focus needs to maintain a state of stability called ‘homeostasis’, described as the “*stability of a system’s internal environment, despite the system’s having to cope with an unpredictable external environment*” (Beer, 1985: 17). An example of a homeostat within the human body is body temperature, which remains approximately 36.6 ^{o}C despite the weather conditions.

The VSM represents a model of a viable system, where all of its parts or systems depend on each other to ensure the system’s internal balance and external interaction with its environment. This makes it an ideal approach for studying SCI, which also aims for cohesion among all relevant supply chain partners for the benefit of the whole supply chain. The following sections will provide a structured review of the publications related to VSM applications in the wider research environment and specifically in the logistics and SCM field to identify key publications and explore the usage of the VSM across different studies.

2.10 VSM Applications in Research

The primary aim of the following sections is to explore the use of the VSM in the wider research environment in order to identify its main research areas and applications and to explore its use as a methodology by identifying key publications. Another aim is to review current logistics and SCM publications which utilise the VSM to explore its main methodological aspects in SCM research.

In similarity to Section 2.8, a structured review was performed by drawing on Denyer and Tranfield's (2009) idea of a systematic literature review. It facilitates finding, selecting, and evaluating key articles of relevance to the inquiry by following a systematic way of reviewing the literature. In this context, being systematic means working in an ordered or methodical way (Jesson et al., 2011).

2.10.1 Overview of VSM applications in the wider research environment

Five databases of academic journal articles containing the largest number of papers on VSM were used as a source to obtain publications for further review, these included: Emerald, Science Direct, Springer, Wiley, and Taylor and Francis. Only two keywords were used to perform database search: 'viable system model' OR 'VSM'. There were also no time period limitations as it was important to capture all articles that could be of importance to this research. The initial search returned a total of 8,785 articles. This total was limited to include only those articles relevant to management sciences. All open access journals were also excluded from the search based on a lack of quality. After screening the titles and abstracts and eliminating papers using a 'VSM' abbreviation unrelated to the viable system model, such as the vector space model, value stream mapping, and vibrating sample magnetometer, a new total of 132 articles was obtained. Table 2.2 below shows the most popular journal titles and their rankings in this search, as well as their CABS rankings and categories. Journals that contained only one article were grouped in the category called 'Other', which comprises 23 different journal titles.

Journal	**CABS Rank (2018)**	**CABS Category**	**No of Articles**	**%**
Kybernetes	1	Or & Man Sci	48	36.36
Systemic Practice and Action Research	2	Org Stud	26	19.70
Systems Research and Behavioral Science	2	Or & Man Sci	17	12.88
European Journal of Operational Research	4	Or & Man Sci	8	6.06
Journal of the Operational Research Society	3	Or & Man Sci	5	3.79
The Learning Organization	1	Org Stud	3	2.27
Knowledge Management Research and Practice	1	Info Man	2	1.52
Other			23	17.42
Total articles: 132				

Table 2.2: Journal titles based on a search of articles on the VSM

This search involved a diverse range of journals from different categories according to the category names found in the CABS journal guide. These included information management, psychology, accounting and general management, ethics, and social responsibility. The two categories that formed the largest number of journals used in this search were ‘operations research and management science’ and ‘organisation studies’. This observation can be explained by the VSM’s theoretical background given that it forms part of organisational cybernetics. This also explains the title of the journal *Kybernetes*, where the majority of publications about the VSM were found in this search (as shown in Table 2.2). Three journals that also contained a large number of papers on the VSM included *Systemic Practice and Action Research*, *Systems Research and Behavioral Science* and, of a higher rank, *The European Journal of Operational Research*. These indicate that the VSM is more popular among operational research society and systems studies. This also confirms its relevance to the field of logistics and SCM as it falls under the umbrella of operational research.

Another positive finding is that the number of articles involving the VSM increased in the last several years. Figure 2.13 below shows the distribution of the analysed articles published between 1992, which is the year of the earliest published article, and 2017, which is the year of the latest one found. It shows that although the number of publications related to the VSM vary each year, the overall number of articles have increased from 1 article published in 1992 to 10 published 2017, and year 2015 saw the highest number of publications, that is 16 articles. This shows a positive and growing trend of publications within operations and management sciences, which also signals increasing interest in the VSM.

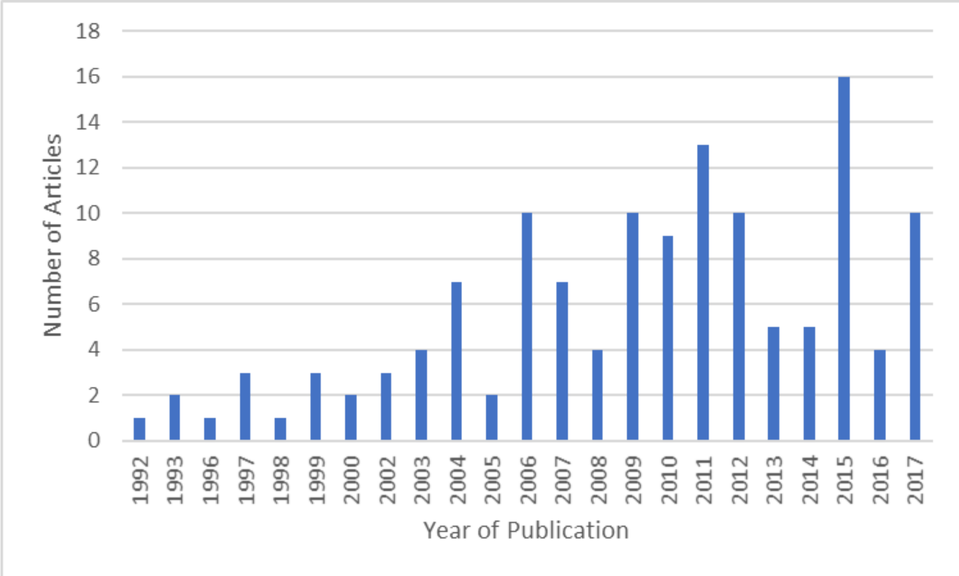

Figure 2.13: Distribution of articles published between 1992 and 2017

As demonstrated in Figure 2.14, more than half of the identified publications are conceptual or descriptive, where authors predominantly discuss conceptual VSM frameworks in various scenarios, as well as proposing changes to the model. For example, Bititci et al. (1997a and 1997b) propose a framework for assessing the integrity of the performance measurement system based on the VSM. A study by Morlidge (2009) incorporates a financial regulation system into the VSM. Another interesting study by Johnson (2011) explores the experience of music and memory, and presented a model of memory based on cybernetic principles including the VSM, in addition to Luhmann's model of social systems and Harre's 'Positioning Theory'.

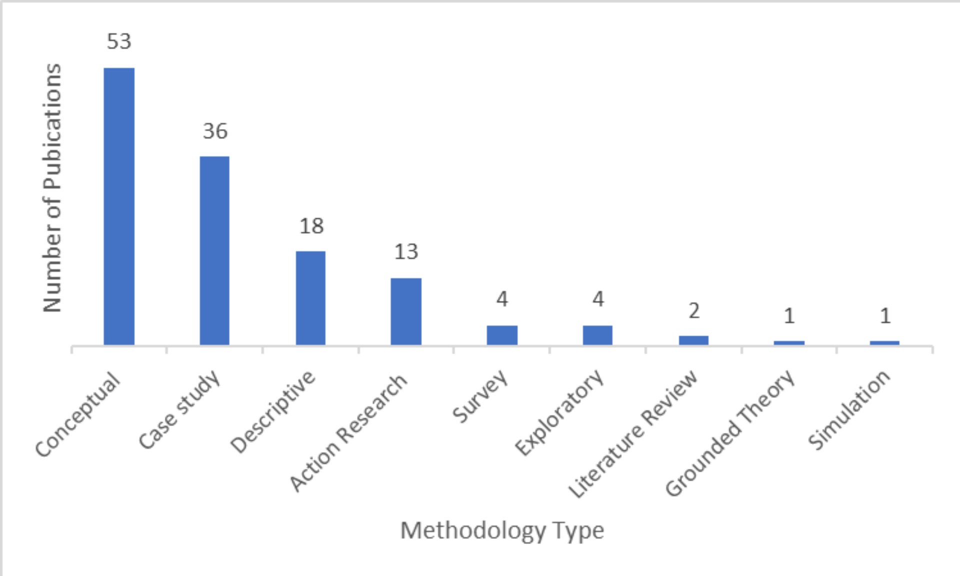

Figure 2.14: Methodology types of 132 reviewed articles on VSM

Based on a review of the conceptual papers in the collected sample of publications and with the exception of the more obvious applications of VSM, such as those in complexity management (Espinosa and Harnden, 2007), organisational viability, and organisational structures assessments (Leonard, 2009; Donaires et al., 2010; Burgess and Wake, 2012), it can be said that the VSM is applicable to a wide-range of other research areas. Some authors link the VSM to the concept of sustainability by proposing different frameworks based on the VSM (Espinosa et al., 2008; Leonard, 2008; Barile et al., 2014; Panagiotakopoulos et al., 2015; Schwaninger, 2015). Other areas of VSM applications include knowledge management (Leonard, 2000; Achterbergh and Vriens, 2002; Yang and Yen, 2007; Paucar-Caceres and Pagano, 2009), policy making (Espejo, 2007), information management (Donaires, 2010; Puche-Regaliza, 2014), and safety management (Kontogiannis and Malakis, 2012).

In relation to descriptive papers, authors often share their experiences or reflections of the application of the VSM in their consulting work to highlight its merits as a tool for the diagnosis and design of organisations (Brocklesby and Cummings, 1996; Schuhmann, 2004; Schwaninger, 2006a). However, this has become a reason for some to critique the model by saying that it requires expert knowledge in order to apply it. In other words, the model is difficult to understand and apply, and is therefore still considered as a niche product (Orengo, 2018). A similar observation is made by Hildbrand and Bodhanya (2015), who note that there are few studies which advise novice users about the implementation of the VSM. The authors therefore suggest that more examples alongside detailed explanations of the VSM's usage are required. This may also partly explain the lack of empirical applications of the VSM in the academic realm.

In relation to this critique, one AR-based study (Tavella and Papadopoulos, 2015) compared the roles of novice and expert facilitators during a facilitated modelling workshop using the VSM in the context of the UK's local food network. They found no large differences between the novice and expert in facilitating the workshop, although novices may be more outcome-driven, whereas experts may be more concerned with the acceptability of the model itself (Tavella and Papadopoulos, 2015). This partly suggests that the VSM is accessible to all, although some background knowledge of the model is required given its heavy theory.

All systemic methodologies are associated with AR strategies in the academic world and often imply interventions in problem situations with the aim to enhance the system in focus (Checkland, 1990). Therefore, academic articles on the VSM often involve publications reporting on intervention-based approaches involving consultancy work. This is partly evident in this literature review, which included 13 AR-based articles and 36 case studies that included instances of consultancy-based work. These articles include Ben-Ali's (2011) work on information systems for the newly created ministerial information centre in Libya, Espinosa and Walker's (2013) work facilitating self-organisation process in an Irish eco-village using the VSM, Espejo's (2011) retrospective report on a company that had undergone changes following an intervention using the VSM, and an article by Adams et al. (1993) reporting on an analysis of the Manchester Business School performed by Beer (1970).

By considering these examples it could be fair to say that the VSM is more highly recognised among systems practitioners and the systems thinking community, whereas it is less widespread within other academic communities. However, this does not limit its applicability to different contexts and research areas, as it has been made evident in the conceptual papers, AR studies, and case studies included in this search. These show that the VSM is predominantly applied to a business environment with different objectives, varying from a viability analysis (Burgess and Wake, 2012) and business management assistance (Christopher, 2011; O'Grady et al., 2016), to assisting self-transformation (Espinosa et al., 2015). It has also been applied to other contexts. Interesting examples include the UK police force (Kinloch et al., 2009; Preece et al., 2013), local government sectors (Preece et al., 2015; Walker, 2017), the defence industry (Batista et al., 2017), the social community in the Amazon jungle (Espinosa and Duque, 2018), the alternative food network community (Tavella and Papadopoulos, 2017), and pharmaceutical enterprises (Vidgen, 1998). This suggests that there is no limitation to the use of the VSM in the chosen context of this thesis, which concerns development and construction supply chains in the UK OSW industry.

Table 2.3 indicates the top ten articles out of the chosen 132 that are most cited by other authors. This calculation is based on the papers' citation values and a ratio of individual citations of a paper to the total citations in the collected sample (Backhause et al., 2011). An article by Bititci et al. (1997a) was found to be the most cited. In their conceptual paper, the authors propose a performance measurement system based on the VSM in a manufacturing environment. Their findings are of relevance to this thesis because the authors discuss the importance of promoting integration between various areas of the business where VSM could be of value. As shown in Table 2.3, these authors provide a similar discussion in another article published in the same year but in a different journal.

Authors	Year	Journal	Citation Count	Citation Value
1. Bititci, Carrie, and McDevitt	1997a	International Journal of Operations and Production Management	847	23.56%
2. Espinosa, Harnden, and Walker	2008	European Journal of Operational Research	138	3.84%
3. Bititci, Carrie, and McDevitt	1997b	The TQM Magazine	137	3.81%
4. Schwaninger	2000	Systemic Practice and Action Research	107	2.98%
5. Espinosa and Porter	2011	The Learning Organization	100	2.78%
6. Brocklesby and Cummings	1996	Long Range Planning	93	2.59%
7. Schwaninger	2006a	Kybernetes	83	2.31%
8. Espejo, Bowling, and Hoverstadt	1999	Kybernetes	83	2.31%
9. Achterbergh and Vriens	2002	Systems Research and Behavioral Science	83	2.31%
10. Bititci, Turner, and Ball	1999	International Journal of Agile Management Systems	68	1.89%
Total citations: 3595				

Table 2.3: Top ten most cited scholars out of 132 articles, according to citation value

The second most frequently cited article by Espinosa et al. (2008) offers an argument for the usefulness of the VSM in support of sustainability management compared to more traditional management approaches. They explain that a cybernetics approach, which includes the VSM, views sustainability as an ongoing process that is constituted through the dynamic relationships between viable organisations. Most importantly, they point out that the VSM helps to create more effective organisations by engaging autonomous organisations at every recursive level, which will individually produce sustainability. The emphasis on structural coupling through the conscious interaction between parts is an important idea that is also relevant to the concept of SCI in this thesis. In similarity to sustainability, it may be argued that achieving an integrated supply chain requires emphasis to be placed on the structure of the system, rather than just the relationships between parts.

A similar idea is discussed by Schwaninger (2000), who authored the fourth most cited paper where he presents the concept of the 'intelligent organization' alongside a framework linking three organisational cybernetic models, including the Model for Systemic Control, the VSM, and the Team Syntegrity model. Schwaninger (2000) argues that the intelligence of an organisation manifests itself in certain behaviours, which depend on structural prerequisites that enable and generate such behaviours. Another article by the same author was ranked seventh in Table 2.3. It documents five case studies of VSM applications, emphasising its power as a diagnostic and design tool of organisations (Schwaninger, 2006a). However, this paper does not provide any details on the use of the VSM in these case studies. Instead, it only discusses the positive outcomes of its application.

The theme of sustainability is mentioned by Espinosa and Porter (2011), whose article ranked fifth in Table 2.3. The authors compare two different approaches to complexity management in organisations aiming to improve their sustainability. This comparison involves the VSM and CAS, which was briefly discussed in Section 2.9.1 of this thesis. Another frequently appearing theme in the VSM literature is knowledge management, which is discussed in an article by Achterbergh and Vriens (2002) that ranked ninth in Table 2.3. This paper provides an informative theoretical perspective on system-wide knowledge management. The authors argued that, in order to be viable, organisations require knowledge which allows the functions required for viability to assess signals and perform actions in a way that contributes to the viability of the whole.

Another interesting paper is presented by Espejo et al. (1999), which ranked eighth in Table 2.3. In this article the authors describe their developed learning system software known as The Viplan, which acts as an aid to teach Beer's VSM and its application. The authors acknowledge that the VSM is sometimes perceived of as being difficult to apply in practice and, in response to this difficulty, Espejo developed The Viplan method

(Espejo, 1989). This method is based on their personal involvement with the VSM and its extensive application in many organisations. Espejo et al. (1999) provide their interpretation of the VSM by introducing names to the VSM's systems. For example, S1 is referred to as implementation, S3 as cohesion, S4 as intelligence and S5 as policy.

There are two remaining papers listed in Table 2.3: Brocklesby and Cummings' (1996) article ranked sixth and Bititci et al.'s (1999) article ranked tenth. Both papers discuss the usefulness of the VSM in business process reengineering (BPR). Bititci et al. (1999) share their experience of using the VSM to facilitate BPR and propose their viable business structure framework with a focus on the strategic analysis, planning, and agility management of a business. Brocklesby and Cummings (1996) describe the use of the VSM within a New Zealand telecom company as part of their research and consultancy intervention with Telecom (NZ) Ltd during a period of the company's extensive reorganisation and downsizing. The authors find some similarities between BPR and VSM, but the main difference lies in their approach to organisations themselves. According to the authors, the VSM builds upon the idea that an organisation may be conceptualised as an organism with an advanced brain capacity. On the other hand, BPR seeks to manage change as though organisations are machines. This is a good reminder of the 'organism' metaphor that the VSM implies.

A review of 132 selected articles also identified 11 publications directly related to the subject of logistics and SCM. Table 2.4 summarises their relevance to the field based on the focus areas of these articles, two of which relate their studies to VE (Assimakopoulos and Dimitriou, 2006; Pollalis and Dimitriou, 2008) which, as explained earlier, share the same philosophical idea as SCI. This provides some confidence in the relevance of the VSM to logistics and SCM studies, but also in its applicability to this research. However, a study by Pollalis and Dimitriou (2008) uses additional methodologies other than the VSM, which gives only a partial perspective on the model's use. This was found to be the case in the majority of publications; six articles use more than just the VSM in their studies. In addition to the VSM, some of these approaches include artificial neural networks (ANNs), system dynamics (SD), data flow diagrams (DFD), the viable systems approach (VSA), SSM, total systems intervention (TSI), strategic assumption surfacing and testing (SAST), and problem structuring methodology (PSM); nearly all of which are classified as systemic methodologies. The remaining five articles that use only the VSM are limited by conceptual or descriptive research strategies, which again do not provide a full perspective of the VSM's application in practice.

Authors/Journal Titles	Research Strategy	Relevance to Log & SCM	Focus of the Article	Context
1. Assimakopoulos and Dimitriou (2006) *Kybernetes*	Conceptual	Virtual Enterprise (VE)	VE framework based on the VSM.	Business
2. Azadeh, Darivandi Shoushtari, Saberi ,and Teimoury (2014) *Systems Research and Behavioral Science*	Case study	Broiler industry's supply chain	Intelligence against environmental turbulences. Use of the VSM to map broiler industry's supply chain. The VSM is complemented by ANNs, and SD simulation.	Agricultural industry
3. Azadeh, Darivandi, and Fathi (2012) *Systems Research and Behavioral Science*	Simulation	Purchasing process	Improvement of purchasing process using cybernetic law and the VSM through computer simulation and DFD.	Business
4. Dominici and Palumbo (2013) *Systemic Practice and Action Research*	Conceptual	Lean production system	Lean production system analysis using the VSM and the VSA of Gaetano Golinelli (2010).	Business
5. Hildbrand and Bodhanya (2014) *British Food Journal*	Descriptive	Sugarcane supply chain	VSM diagnosis of one sugarcane milling area in South Africa.	Food industry
6. Hildbrand and Bodhanya (2017) *Kybernetes*	Exploratory	Sugarcane supply chain	Analysis of two sugarcane production and supply systems using the VSM and SSM.	Food industry
7. Mugurusi and de Boer (2014) *Strategic Outsourcing: An International Journal*	Conceptual	Production offshoring	Conceptual model of an offshoring organisation to anticipate internal changes to the organisation and its response to new environments using the VSM.	Business
8. Pollalis and Dimitriou (2008) *International Journal of Information Management*	Case study	VE	Knowledge management in VE using TSI, SAST, VSM, and PSM.	Consulting business

9. Sagalovsky (2015) *Kybernetes*	Conceptual	Lean deployment	Recursive organisation design with autonomous organisational units using the VSM.	Business
10. Shoushtari (2013) *Systemic Practice and Action Research*	Case study	Broiler industry's supply chain	Redesign of the managerial system of the chicken meat supply chain using the VSM, SSM, and SCOR models.	Agricultural industry
11. Tejeida-Padilla, Badillo-Pina, and Morales-Matamoros (2010) *Systems Research and Behavioral Science*	Conceptual	The enterprise resource planning system (ERP)	Conceptual model of a production system based on ERP modules using the VSM.	Production business

Table 2.4: 11 articles related to the subject of logistics and SCM

One of the reasons for adopting a multimethodology approach in these articles was owing to the common criticism that the VSM disregards the social aspects of an organisation (Hildbrand and Bodhanya, 2014). Other authors, such as Azadeh et al. (2014), went so far as to claim that the VSM is too generic, which might point to authors' incompetence in the VSM. Even though VSM requires some degree of imagination and takes time to grasp its basics, there are books that provide guidance on how to implement the VSM, including *Diagnosing the system for organisations* (Beer, 1985). *Organizational systems: managing complexity with the Viable System Model* (Espejo and Reyes, 2011), and *A complexity approach to sustainability: theory and application* (Espinosa and Walker, 2011; 2017). Based on a review of these articles, the VSM may not always be used according to its purpose of a structural diagnosis or design of an organisation based on cybernetic principles. As a result, this disadvantages the model in relation to other systemic methodologies.

Nevertheless, considering the justifications for the use of the VSM in these articles, it is recognised for its diagnostic competency and holistic approach to complex systems, such as supply chains (Hildbrand and Bodhanya, 2017). Other justifications for the use of the VSM are based on its ability to help balance the variety, or a number of possible states, of a system (Ashby, 1958). One example includes the problem of bureaucracy in the demand management of certain purchasing departments (Azadeh et al., 2012). Another justification is based on the VSM's systems interaction with the external environment. For example, a study by Dominici and Palumbo (2013) uses the VSM to identify the similarities that the Japanese lean production system has with the business environment in order to enable the system to be exported beyond Japan.

Due to their generic approaches and descriptions of research concepts and the model itself, none of the 11 articles provide a fully developed example of the VSM in relation to SCM or SCI. Nevertheless, their ideas are still important to consider in this thesis. For example, Assimakopoulos and Dimitriou (2006) indicate the clear roles that every organisation needs in order to form VE. As the authors argue, the VSM provides a good approach towards helping to understand and reorganise these roles. A study by Azadeh et al. (2014) reveals two prerequisites for the viability of systems including SCM: intelligence against environmental changes and intelligence in maintaining internal stability. These can be organised through Systems three and four of the VSM. According to Dominici and Palumbo (2013), interaction with the environment normally occurs through the exchange of information, resources, and raw materials. In relation to this, Pollalis and Dimitriou (2008) argue that information management and its flow within and between VE is perhaps the most important aspect of viability to ensure an organisation responds to environmental changes; where different decision-making levels of an organisation should be concerned, connected, and interactive with the external environment. To achieve this, the authors suggest forming key performance indicators (KPIs), which serve as ‘corporate sensors’ that can trigger certain alert signals, known as ‘algedonics’ in VSM language.

Hildbrand and Bodhanya (2014, 2017) give another perspective on the coordination between supply chain participants. They suggest that both hard and soft aspects need to be considered, which shares similarities with the aforementioned formal and informal aspects of SCI in project-based supply chains. The authors suggest that hard issues involving technical and operational matters can be managed through formal EDI systems, which should be considered in System Two of the VSM analysis. In comparison, soft issues refer to relationship matters, which are often an underlying cause of inefficiencies; these should be considered in System Three. In similarity to the literature on SCI, Hildbrand and Bodhanya (2017) discuss the soft issue of trust which, as argued by the authors, can be improved through a shift in mindset. These similarities to discussions of SCM point to the relevance of the VSM in the context of SCM, which is a significant finding in this thesis.

2.10.2 An overview of VSM applications in the field of logistics and SCM

In order to explore the use of the VSM and its similarity to other systemic methodologies in the logistics and SCM field, this literature review involved searching for articles specifically related to this field. Table 2.5 summarises the selected journal titles and their CABS rankings, which contained articles related to key search words. The key words involved 'viable system model' OR 'VSM', 'organisational cybernetics', and 'systems thinking' in order to establish the current state of research involving systemic methodologies besides the VSM. This is because, as found in Section 2.10.1, VSM is not currently a widespread approach outside of systems studies.

A search of the key words was performed in each individual periodical related to logistics and SCM including all time periods. The initial search resulted in 11,851 articles. This total was refined to include only those articles that used the relevant VSM and other systemic methodologies or aforementioned systems theories. A new total of 37 articles was obtained, but only two involved the VSM in their studies, namely the articles by Puche et al. (2016) and Chan (2011). This suggests that the full potential of the model has not yet been explored and recognised in the field. It also indicates a potential area of future interest within logistics and SCM research.

Journal	CABS Rank (2018)	CABS Category	No of Articles	%
International Journal of Operations and Production Management	4	Ops & Teck	9	24.32
Supply Chain Management: An International Journal	3	Ops & Teck	5	13.51
International Journal of Production Research	3	Ops & Teck	4	10.81
The International Journal of Logistics Management	1	Ops & Teck	4	10.81
International Journal of Physical Distribution and Logistics Management	2	Ops & Teck	4	10.81
Journal of Operations Management	4*	Ops & Teck	3	8.11
Production and Operations Management	4	Ops & Teck	3	8.11
International Journal of Logistics: Research and Applications	1	Ops & Teck	1	2.70
Journal of Supply Chain Management	3	Ops & Teck	1	2.70
Benchmarking: An International Journal	1	Ops & Teck	1	2.70
Journal of Business Research	3	Ethics-CSR-Man	1	2.70
European Journal of Purchasing and Supply Management	1	Ops & Teck	1	2.70
Total articles: 37				

Table 2.5: Journal titles related to the field of logistics and SCM based on the key word search

Puche et al.'s (2016) study recognises how SCM practices can benefit from more holistic and collaborative approaches, and they propose an integrative framework for supply chain collaboration based on Beer's VSM and Goldratt's Theory of Constraints (TOC). The authors justify why they have used the VSM, which was specifically chosen for its ability to help to implement collaboration within the supply chain. This is closely related to the objective in this thesis. However, the authors built their integrative framework for supply chain collaboration primarily on ideas related to TOC, which is described as a production management philosophy that views any system as being constrained by whichever resource is the most limited. It is also perceived of as being an optimised production technique. The main idea behind TOC is to identify a system's bottleneck and to optimise a system's processes and flows by maximising processing at the bottleneck and making all other resources subservient to the needs of the bottleneck (Goldratt, 1997). According to Goldratt, a bottleneck helps to regulate flow and is therefore viewed as a positive phenomenon. TOC also holds that a system which is constrained is the most practical way to reliably manage a complex system. It is an interesting philosophy that shares similarities with Ashby's law of requisite variety, which is used as a measure of complexity implied in the VSM. However, Puche et al. (2016) do not draw any parallels and instead use ideas related to the VSM to design a conceptual supply chain based on TOC which, according to organisational cybernetics, is the theory that could limit the whole viability of a system. In addition, the authors do not provide any further discussion on collaboration, which renders the discussion in the article relatively generic. Moreover, this article is purely conceptual in nature as the authors base their framework upon a hypothetical case study, which limits its application to wider research.

An article by Chan (2011) uses the VSM together with another approach to enhance organisational resilience. In addition to the VSM, which is used as a diagnostic tool to identify viability criteria within the case study company situated in Hong Kong, the author also uses a quantitative tool known as a multi-criteria decision aid to help choose the preferred structural arrangement options. However, this paper does not provide any details of those options or what kind of preferred options were selected, nor does it provide any details on the VSM analysis apart from a general overview of the model's purpose, which is of limited use to this research.

In terms of the use of other systemic methodologies, this review has identified one article that uses the SSM, which involves a benchmarking study analysing battery recycling logistics practices in China (Zhou et al., 2007). SSM, developed by Peter Checkland (1999), is known as a problem structuring methodology that is designed to explore 'messy' managerial situations, or so called 'soft' systems situations, by considering and exploring diverse viewpoints related to decision-making and intervention processes (Flood and Jackson, 1991). Another article involved the fitness landscape theory and use of the associated NK model as complex systems approaches (as briefly mentioned in Section 2.9.1) to analyse manufacturing competitiveness and to establish its fitness (McCarthy, 2004). McCarthy explained how fitness in manufacturing concerns its capability to survive based on its demonstratable adaptability and durability to the changing environment.

Based on this review, the most applied systems methodology is the SD simulation modelling technique. 14 out of 37 articles applied simulation modelling techniques based on SD concepts. Originally developed by Forrester (1958), SD involves causal loop mapping, known as feedback loops, and is often used to model, analyse, and interpret the dynamics of a complex system (Forrester, 1958). The reviewed articles which involve simulation modelling predominantly focus on manufacturing systems and management decision-making processes, studying issues such as the postponement strategy in a global supply network (Choi et al., 2012), business process reengineering (Ashayeri et al., 1998;

Burgess, 1998), supply chain risk management (Ghadge et al., 2013), and product sustainability (Brockhaus et al., 2016). Größler et al. (2008) speaks specifically about the usefulness of SD in operations management studies and found that SD is often applied 'just' as a suitable method without any theoretical considerations pertaining to its usage in research. A similar observation is made by Nilsson and Gammelgaard (2012), who note that those who use systems approaches rarely explain the grounds, theories, and definitions that these approaches are derived from. This review has also found that the systems perspective, despite being recognised by many as a valuable tool for a holistic understanding of SCM, is hardly applied in methodologies (Peck, 2005; Koh et al., 2017).

In relation to the systems view of SCM, this review has shown how most articles hold that supply chains are complex systems, which are often referred to as CAS. Furthermore, thinking of supply chains or networks as CAS allows researchers and managers to interpret supply chain behaviours and their dynamics in a more complete manner (Choi et al., 2001). For example, a study by Fawcett et al. (2010) proposes a collaborative inventory management framework by drawing on systems theory and referring to inventory management programs as CAS. An article by Holweg and Pil (2008) finds that the perspective of CAS, in addition to the resource-based view and adaptive structuration theory, helped them to identify unnecessary buffer stocks in automotive supply chains as a result of information deficiencies within the system. However, in the majority of these articles CAS has been used as a background philosophy rather than as a guiding methodology (Ellram et al., 2007; Fawcett et al., 2012; Saghiri et al., 2017). A similar concern is raised by Nilsson and Darley (2006), who argue that there is a need to transform CAS-based ideas into tangible and understandable results. In response, they propose agent-based modelling influenced by the complexity paradigm which, in some studies, forms part of a separate research phenomenon. For instance, Größler et al. (2006) studies complexity within manufacturing firms and their adaptation processes to increased external complexity, thus distinguishing between the complexity of products and complexity of customers. The authors' main argument is that firms must be able to react to external complexity based on their own internal capacity, which is similar to Ashby's law of requisite variety. Another study proposed a generic model of complexity to advance research into industrial collaborations by drawing on various complexity related sciences, including cybernetics management (Schuh et al. 2008). In similarity to Größler et al. (2006), Schuh et al. (2008) refer to Ashby's law of requisite variety by arguing that, in order to design a collaborative system, both internal and external aspects of complexity need to be considered.

This review has shown that there is general agreement among logistics and SCM scholars that supply chains can be referred to as systems or, more specifically, as complex systems and even as CAS. However, as it was established in Section 2.9.1 CAS is not the only approach to complex systems; there are at least three other approaches. For instance, organisational cybernetics is associated with the VSM and offers a more structured perspective on SCM in terms of it being a complex system. Given the scarcity of articles involving the VSM or other discussions of organisational cybernetics, it is reasonable to suggest that this is still an unfamiliar area in the field. Hence, this provides an opportunity for this study to help fill this gap in the literature. It is also clear that the benefits of more holistic systems theories are being recognised in the field of logistics and SCM. However, the systemic approaches that are currently used are often limited to SD. This finding therefore supports Lindskog's (2012a, 2012b) finding that systems theories and their different approaches are uncommon in the logistics and SCM domain. Nonetheless, general support for holistic perspectives voiced by a number of scholars in this review, shows that more research involving different systemic approaches is needed.

2.11 Summary

This chapter has reviewed the literature on the five main research areas of this study, including the OSW industry, SCM, SCI, systems thinking, and the VSM. This review has shown that relationship among these subject areas is currently not well established, from either a theoretical or empirical perspective. This therefore presents an opportunity to contribute to the body of knowledge in relation to these areas.

A review of the UK OSW industry has shown that emphasis is placed on its supply chain. This is primarily due to the vested interest of the UK government to build capable and competitive domestic supply chains, which are able to support OSW developments around UK coasts. The need to reduce LCOE has further emphasised the importance of supply chains and the importance of making supply chains more integrated. OSW supply chain presents an area to seek efficiencies and integration that would allow OSW parties to address OSW industry issues in a more collaborative manner. The emphasis on supply chains has been reflected in many industry reports and related conferences. However, despite the widespread use of the terms 'supply chain' and 'SCI' in the OSW industry, there has been no unified definition of an OSW supply chain or how it should be examined. At the time of writing this thesis only three academic articles provide partial description of the OSW supply chain: D'Amico et al. (2017), Poulsen and Lema (2017), and Irawan et al. (2017). Moreover, little has been done to explain SCI in the context of OSW or how it can be achieved. Only one article that mentions SCI in the OSW industry became available at the time of writing this thesis; it was written by Martinez Neri (2016). However, the article only provides a review of the literature on SCI without a further explanation of SCI in the OSW industry.

A review of SCM and project-based SCM has shown that there has been little research available on SCM in project-based environments, of which the OSW industry is a part. SCM is predominantly discussed in terms of more traditional supply chains, such as retail or manufacturing process-based supply chains. The difference is that project-based supply chains are temporary in nature and are therefore described as being more complex. However, what is common to both is the underlying philosophy of integration, upon which the entire concept of SCM is built. The general agreement is that a more integrated supply chain leads to greater overall supply chain performance (Frohlich and Westbrook, 2001). However, while integration has been viewed as a positive phenomenon in both process and project-based environments, there is no consensus on what constitutes SCI and how best to achieve it. The difficulty lies in the fact that it is context-dependent, which suggests that SCI conditions are likely to vary between industries, companies, and projects.

Another common philosophy underlying SCM and SCI is the need for the 'end-to-end' management of supply chain processes, in addition to the idea of viewing the supply chain as a single entity. For this reason, many logistics and SCM scholars recognise the relevance of systems thinking as being valuable in terms of providing a holistic understanding of SCM processes (Grant et al., 2017; Koh et al., 2017). Though, despite the relevance and diversity of systems thinking approaches, they remain underutilised in this field (Lindskog, 2012a; Lindskog, 2012b). There is some acceptance in the literature on SCM that, due to the complexity of supply chains, they can be viewed as CAS (Choi et al., 2001). A further review revealed that CAS is only one of many potential systems approaches that can enhance our understanding of SCM. Yet, other approaches could be of greater use, especially in the study of SCI. For example, the VSM that was developed by Stafford Beer (1979) in his work on a theory of viable and effective organisations, otherwise known as organisational cybernetics. The VSM offers a systemic framework to explore different systems from the viable system's perspective, including supply chains. Given that viability from the VSM perspective implies coherent interaction of system's parts, it thus provides a useful framework to apply in the study of SCI; the aim of which is also to achieve coherence among supply chain parties.

A review of the literature on the use of the VSM has shown that the model is more greatly recognised among consultancy practitioners, but is less adapted in the academic world. However, there is a growing trend in publications related to the VSM, which suggests that interest in the VSM within academia is growing. The review of VSM publications has also identified articles related to the field of logistics and SCM, as well as identifying two articles which specifically apply the VSM to the study of SCM (Chan, 2011; Puche et al., 2016). This provides some confidence in the VSM's relevance to the field of logistics and SCM, as well as to its applicability in this research.

The identified shortcomings of the existing research into the OSW SCI, which represents project-based supply chain environment, and a lack of existing studies applying systems thinking approaches, such as VSM to SCI and SCM research, inform the following research problem:

How can a systems thinking approach; VSM help to understand the current state of SCI in the OSW industry and reveal potential areas for improvement in order to facilitate greater performance of the whole supply chain?

The main research problem further informs the following research questions:

RQ1. *What is the nature of SCI in the development and construction phases of UK OSW farms*?

RQ2. *What are the current factors that facilitate or constrain integration in the development and construction phases of UK OSW farms*?

RQ3. *How can VSM principles help to analyse and improve integration in the development and construction phases of UK OSW farms*?

RQ4. *What potential improvements can be made to achieve a more integrated supply chain based on VSM principles*?

Chapter Three

Methodology

3.1 Introduction

The literature review revealed that the subject of SCI is heavily context-dependent. Furthermore, there is no single approach for achieving an integrated supply chain, and neither is there a single methodology that is best suited to studying integration within a supply chain. The literature review has also shown that SCI often implies systemic thinking because it is recognised that the performance of a whole supply chain often depends on the joint interactions and processes of all relevant parties (Sadler, 2007; Childerhouse, et al., 2011). This perspective has long encouraged certain academics to suggest that logistics and SCM subject could benefit from systems thinking approaches to better understand SCM processes (Choi et al., 2001; Johannessen, 2005; Grant, 2012; Koh et al., 2017). However, a further review of the literature has shown that systems methodologies are not commonly applied in logistics and SCM research (Lindskog, 2012a, 2012b). Chapter Two highlighted a gap in the literature concerning the use of systems thinking approaches within SCM and SCI. As a result, this research will contribute to the literature by applying the VSM to the study of SCI within the OSW industry; where SCM and its integration remains an underexplored area.

This chapter will proceed by describing the methodology employed in this research, beginning with an overview of the philosophical approaches used to guide this research. This includes a discussion of ontology, epistemology, and axiology more generally, as well as a more specific discussion in relation to systems thinking. It will then proceed by outlining the subsequent choices of a research paradigm and research approach. The following section will discuss quality criteria in qualitative research, in comparison to quality criteria in quantitative research, to ensure the validity and reliability of this study. Then, the research strategy adopted in this thesis will be described. The methodology chapter will be followed by the research design chapter, which will provide more detail on the data collection strategy and methods of analysis.

3.2 Research Philosophy

A researcher's approach to a particular study is believed to be underpinned by the research philosophy that has been adopted (Robson and McCartan, 2016). A research philosophy explains the worldview of a person, or their understanding of the way the world works, what constitutes knowledge, and how personal values might influence a research outcome. These philosophical considerations are related to particular strands of research philosophy, such as ontology, epistemology, and axiology (Easterby-Smith et al., 2015).

Morgan (1980) explains that people often approach research based on commonly accepted assumptions about the universe. Therefore, understanding the origins of different strands of ancient philosophy and uncovering personal philosophical assumptions is an important task. In turn, this can influence the research strategy and methods used to answer research questions. This section provides an overview of the important philosophical considerations that lay the foundations for the design of this research.

3.2.1 Understanding ontology, epistemology, and axiology

In the past, the terms 'philosophy' and 'science' were used almost interchangeably. For example, Aristotle believed that philosophy was equivalent to science. This understanding is also evident in some later definitions of 'philosophy', including phrases such as "rational knowledge from concepts" (Kant 1724-1804), the "science of knowledge" (J. G. Fichte 1762-1814), and the "science of principles" (Kulpe, 1927). However, in the early 1600s the terms 'philosophy' and 'science' started to be differentiated. Today, the most relevant philosophical concepts related to business management studies include ontology, epistemology, and axiology.

According to Whiteley (1966), ontology is a branch of metaphysics that refers to the theory of being, and of the kind of beings. In other words, it is associated with a discussion of the most general concepts surrounding a person's understanding or general beliefs about reality (Kulpe, 1927). Fleetwood (2004) goes so far as to suggest that to have an ontology is to hold a theory about what exists. Translating this into research, ontology refers to the assumptions that researchers make about the world (Burrell and Morgan, 1987). An important ontological consideration in business management research concerns whether social entities are objective entities, meaning that entities have a reality external to social actors, or whether social entities are subjective or socially constructed, such as being based on the perceptions and actions of social actors (Bryman and Bell, 2015).

The same distinction can be made between objectivity and subjectivity in relation to the theory of knowledge, which is otherwise known as epistemology. Epistemology concerns researchers' assumptions regarding the best way to study the world (Bhattacherjee, 2012). Understanding the duality between subjectivity and objectivity helps to provide an understanding of what should constitute as acceptable knowledge within a field of study (Robson and McCartan, 2016). For example, Chalmers (2013) believes that the perceptual experiences of individuals and the consequences of their beliefs relates to subjective knowledge, whereas objective knowledge involves observation statements made by those individuals. Consequently, Chalmers (2013) thinks that objective knowledge is publicly testable and debatable, whereas subjective knowledge is not. However, according to Cunliffe (2011), making such a clear distinction between objectivism and subjectivism may no longer hold true. This is especially owing to recent developments in organisation and management studies, which have resulted in more pluralistic perspectives and approaches.

The radical separation between objectivism and subjectivism that is evident in mechanistic or reductionist sciences is also opposed by systems thinkers who argue that separating the subject from the object, or the observer from the observed, would lead to the illusion of perfect objectivity, which in turn would marginalise the importance of values and subjectivity in knowledge production (Midgley, 2000; Boulton et al., 2015). Even though, as noted by Midgley (2000), systems theories do not break free of subject and object dualism by accepting the possibility of independent observation and universal knowledge, most systems theories hold that the universe is a continually unfolding, interconnected entity, which points to the acceptance of both subjects and objects as being important for knowledge creation.

Tashakkori and Teddlie (2003) argue that subjectivism and objectivism should be understood as a continuum rather than as opposite positions. Cunliffe (2011) then extended this debate by introducing the term 'intersubjectivity'. According to Cunliffe (2011), this continuum can be understood in the form of three knowledge problematics: intersubjectivism, subjectivism, and objectivism; where the intersubjectivism problematic relates to the creation of interrelational knowledge. It differs from subjectivism by implying a more participative approach towards generating knowledge; suggesting that 'togetherness' is key to intersubjectivity. This view is closely associated with certain systems approaches that imply systemic interventions or AR strategies performed by researchers or agents (Midgley, 2000; Checkland and Winter, 2006).

Another important branch of philosophy to be considered is ethics. Ethics is closely related to axiology, which is otherwise known as the theory of values. Axiology is concerned with the study of worthwhileness or counterworthwhileness, as well as an analysis of these (Findlay, 1970). Robson and McCartan (2016) argue that by establishing the main value principles that define our existence, such as ethics, culture, and humanism, it becomes possible to make our own value judgements. However, the main difficulty with general value principles is that there is no unified theory of values. Values differ not only between countries in terms of culture, religion, and aesthetics, but they also differ on a personal level. Therefore, the choice of research questions and philosophical assumptions behind a research reflects one's own values and background (Robson and McCartan, 2016). As a consequence, the choice of methodology and data collection methods used in this research are based on personal values and beliefs, in addition to particular ontological and epistemological perspectives. The summary of ontological, epistemological and axiological perspectives taken in this research will be provided in Table 3.1 in the next section.

3.2.2 Ontology, epistemology, and axiology in relation to systems thinking

As mentioned above, this research applies a systems thinking approach to the study of SCI. Therefore, it is important to consider key ontological, epistemological, and axiological concerns in relation to systems philosophy, which arguably has a different outlook on the world in comparison to traditional science perspectives (Checkland, 1990). According to Checkland (1990), a traditional outlook of science assumes that the world is characterised by natural phenomena, which are ordered and regular. This has effectively led to the discoveries known as the 'laws of nature'. In comparison, the systems outlook accepts the basic propositions of science and assumes that the world contains structured wholes, which can maintain their identities under a certain range of conditions and which exhibit certain general principles of 'wholeness'. Therefore, one of the key aspects of systems philosophy is 'holism' (Jackson, 2019). Holism is the opposite of reductionism and tries to ensure the comprehensiveness of an analysis. However, such 'comprehensiveness' is limited as it is unfeasible that any analysis could be fully comprehensive. Therefore, the application of systems thinking in practice often implies the use of problem structuring methodologies that help to identify boundaries of a system for intervention or study purposes. For example, SSM (Checkland, 1999), the theory of boundary critique, which helps to determine what should be included or excluded in an analysis (Ulrich, 2002; Midgley and Pinzón, 2011), and other methods pertaining to specific theories. One such method is the process of defining the system in focus implied in the use of the VSM, according to the methodology to support self-transformation, which is discussed in more detail in Section 4.3. Such problem structuring methodologies help to refine a system in focus, which indicates that systems are observer dependent whose boundaries are comprised of personal or social constructs (Espejo and Reyes, 2011).

The way that systems are described often implies an element of objectivity. However, as argued by Espejo and Reyes (2011), what one person identifies as a system remains abstract because it is impossible to physically touch the system. Nevertheless, it may be possible to touch parts of the system, depending on the type of system in focus. However, system’s wholeness or ‘systemicity’ remains abstract as it emerges from the interrelationships of those parts, thus creating emergent properties of the system. This therefore shows that systems thinking accepts a plurality of perspectives as opposed to a purely subjectivist or objectivist perspective. This also suggests that a systems view of reality is unlikely to be value-free. As argued by Midgley (2000), it would rather be value-full given the importance of subjectivity and intersubjectivity to knowledge creation. Therefore, determining the boundaries of a system in focus would likely be directed by person’s own values, as well as the world view of the person observing the system, also known as Weltanschauung (Jackson, 2005).

According to Espejo and Reyes (2011), an identified system may lead to two complementary system descriptions, thus leading to different epistemologies depending on the issue at hand. One description constitutes a system as a black-box that takes an external view of the system, including its interactions with its environment, whereas another description is concerned with the internal view of the system, where the focus lies on the nature of the system’s internal coherence that emerges from the interconnectedness of its constituent parts. This type of description is called an operational description. Consequently, it can be said that the black-box description is more of an objective or functionalist way of understanding the system and the aforementioned first-order cybernetics (explained in Section 2.9.1), whereas the operational description relates more closely to the subjective or interpretive perspective of deriving knowledge about the system, which is more closely related to second-order cybernetics that emphasises the importance of observers as part of the observed system (Umpleby, 2014).

Given both ways of describing systems: a black-box type description and operational description, it can be determined that this study is most concerned with an internal or operational view, of the system in focus. This is because its focus is on SCI potential amongst businesses constituting a supply chain. Hence, businesses forming part of a supply chain, which is viewed as a system, are considered as being parts of that system. As a result, taking an operational view of the system, in addition to a subjective and intersubjective approach to access the different perspectives of business representatives on SCI potential, is most valuable to this research. Table 3.1 below provides the summary of the research perspectives concerning ontology, epistemology, and axiology.

Philosophical Perspectives of the Research		
Ontology Theory of Being	**Epistemology** Theory of Knowledge	**Axiology** Theory of Values
▪ There are multiple realities. ▪ World contains structured wholes. ▪ Supply chains can be viewed as structured wholes and therefore as systems.	▪ This study is most concerned with internal or operational view of supply chain as a system as opposed to external view or black-box view of the system. ▪ Knowledge of the system is derived through subjective and intersubjective approach. ▪ This study views chosen VSM as an epistemological tool because it helps to study OSW supply chain as a system and helps to derive and generate knowledge about SCI.	▪ Systems are observer dependent. ▪ In this research system's boundaries are directed by the researcher for research purposes. ▪ Thus, values of both the researcher and research participants are important for this research.

Table 3.1: Summary of ontology, epistemology, and axiology of the research (Author)

3.3 Research Paradigm Considerations

Thomas Kuhn is believed to have been the first to introduce the term 'paradigm' through his analysis of revolutions in the sciences (Kuhn, 1970). By the term 'paradigm', Kuhn (1970) broadly refers to scientific achievements that share two characteristics: namely those achievements that are sufficiently unprecedented to attract followers and make them change their perspectives from competing modes of scientific activity, and those achievements that were sufficiently open-ended to allow an understanding and resolution to different problems. Kuhn's (1970) conceptualisation of a paradigm can be understood as a school of thought, which is shared by a particular scientific community who follow recognised examples of scientific practices based on laws, theory, application, and the relevant tools to provide models that give rise to particular traditions in scientific research. Shared practices within a scientific community implies the sharing of a particular paradigm. However, Kuhn (1970) stated that a shared paradigm does not determine shared rules. Indeed, if paradigms were to prescribe rules and procedures there would be no scientific revolutions because members of a scientific community would consistently follow the same traditions and approaches. Instead, it can be argued that a paradigm provides a basis upon which subsequent arguments and new theories can be developed.

In similarity to Kuhn (1970), Burrell and Morgan (1987) also identify a paradigm as a term that emphasises the commonality of perspectives across a group of theorists. Likewise, they note that a shared perspective does not imply a unity of thought. The acceptance of different views within a discipline gave rise to Burrell and Morgan’s (1987) four paradigms, as shown in Figure 3.1 below:

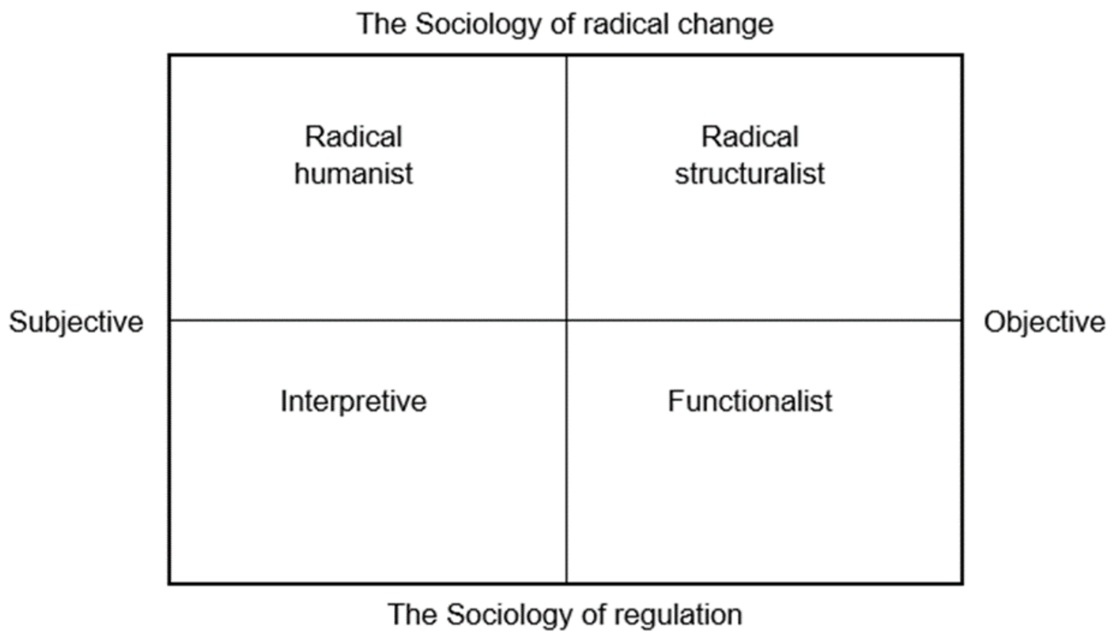

Figure 3.1: Burrell and Morgan's (1987: 22) four paradigms for social and organisation theory analysis

Burrell and Morgan (1987) differentiated four sets of assumptions, or four paradigms, about social reality: radical humanism, radical structuralism, interpretivism, and functionalism. According to the authors, these paradigms provide different ways of observing the nature of society. Although distinct, they are based on a common set of assumptions about the theory of society (vertical axis) and the philosophy of science (horizontal axis). The vertical axis is based on the order-conflict debate, which can be understood as a regulation and radical change. The sociology of regulation condones supporting the unity and cohesiveness of society. In comparison, the sociology of radical change explains radical change, structural conflicts, and contradictions, as well as modes of domination. The horizontal axis represents the nature of science, focusing on the subjective and objective aspects of ontology, epistemology, human nature, and methodology.

According to Burrell and Morgan (1987), the functionalist paradigm has been the dominant framework for organisational studies for the past several decades. The functionalist paradigm takes an objectivist approach to a subject and is closely associated with the positivist standpoint. The latter of which approaches the social world in the same way as the natural sciences, where the nature of things is viewed as material and concrete, and prone to measurement (Donaldson, 2005). Thus, the functionalist paradigm views the world as being relatively stable and organised, whereas the social world is viewed as being regulated. The functionalist paradigm takes a positivist and quantitative approach to research; it is said to prevail in logistics and SCM studies, and in operational research fields more generally (Mentzer and Kahn, 1995; Mears-Young and Jackson, 1997; Burgess, et al., 2006). However, some authors note that, over recent years, the field of logistics and SCM has experienced an increase in the use of qualitative methods, particularly due to the need to use qualitative approaches to enrich research on logistics and SCM (Johannessen, 2005; Trautrims et al., 2012).

With regards to a subjectivist approach towards the sociology of regulation, there is the interpretive paradigm. This paradigm shares similarities with functionalism and views the world as regulated and relatively stable. Also, in similarity to functionalism, interpretivism is interested in understanding social reality by viewing it as cohesive, ordered, and integrated. However, the interpretive paradigm tries to understand reality at the level of individual subjective experiences, and it therefore accepts the notion of a socially constructed reality, as opposed to an objective reality.

Another paradigm based on the idea of a subjective social reality is known as radical humanism. In similarity to interpretivists, radical humanists value the subjective experience of individuals as well as human consciousness. However, radical humanists are more concerned with trying to change the social world by altering the thinking patterns of individuals who they believe are influenced by the dominant ideologies of powerful societal structures. The radical humanist paradigm therefore seeks ways to release human beings from the constraints imposed upon them by current social settings (Burrell and Morgan, 1987).

The fourth paradigm is known as radical structuralism, which is similar to radical humanism as it is also concerned with radical change. Though, it focuses on structural relationships within a realist social world, as opposed to human consciousness as a subject for critique. Radical structuralists are therefore concerned with the objective reality of social structures by examining things such as changes in laws, and economic, political, government, institutional, and organisational policies.

3.3.1 Research paradigm

Based on the above discussion, this study adopts the interpretivist paradigm. This paradigm is believed to have been developed in response to the positivist paradigm which seeks universal laws of the natural and physical world. The interpretivists argue that the social world cannot be understood in the same way as the natural world (Hatch and Yanow, 2005). Interpretivism holds that knowledge of the social world is derived from the interpretation of sense perceptions and the realisation that different people may have different interpretations of social reality. Interpretivists therefore accept that there could be multiple realities, rather than the positivistic understanding of an external singular reality.

As this study aims to gain an operational understanding of the system in focus, or an ‘internal’ understanding of the system involving existing and potential SCI processes, it values subjective and intersubjective knowledge creation more than the objective, value-free observations supported by functionalists and positivists. In order to access the internal view of the system in focus to explore its current SCI processes, an understanding of the experiences and interpretations of key actors within the OSW industry, such as supply chain representatives, is required. Therefore, a subjective approach will best fit the purpose of this research. Hence, interpretivism is the appropriate paradigm to guide this study as it allows for an exploration of the OSW industry’s supply chains from the perspective of different actors, thereby emphasising the possibility of multiple realities that can together constitute a system.

3.4 Understanding Research Approaches and Differences in Reasoning

The exploratory nature of this study lends itself to the interpretivist paradigm. Subjective and intersubjective knowledge will be sought by collecting qualitative data, including acknowledging the multiple perspectives of research participants on SCI processes in the context of OSW farm development and construction supply chains. Hence, this research is qualitative in nature, rather than quantitative. Qualitative research, as explained by Bryman and Bell (2015), emphasises words rather than the quantification of data collection and analysis, which is the concern of quantitative research approaches.

By taking a qualitative approach to research, this study is less concerned with deductive reasoning. To clarify, deductive reasoning is typically associated with quantitative research as it is a process of deriving scientific truths based on logic (Chalmers, 2013). Deduction is normally compared to hypothesis building based on *a priory* established facts or statements about a subject of concern. Instead, this study adopts inductive and abductive reasoning methods.

Induction refers to the process of deriving scientific knowledge, made up of laws and theories, from experiences and observations of phenomena. Induction is traditionally understood as theory building scientific reasoning (Chalmers, 2013). The inductive reasoning process is commonly associated with qualitative research, especially when insufficient understanding of a topic does not allow for hypothesis building and testing, which is the case in this research (Eaterby-Smith et al., 2015). However, while deduction and induction are considered as being the two basic forms of scientific reasoning, some authors have distinguished another form of reasoning, known as abduction.

Abductive reasoning is viewed by some as an alternative approach that helps to overcome some of the limitations associated with deduction and induction (Bryman and Bell, 2015). For example, deduction is often criticised for its strict process of theory testing and hypothesis falsification, which could lead to false conclusions when an initial theory is unclear. A limitation of induction is that it cannot provide universally valid generalisations (Chalmers, 2013). Abductive reasoning, on the other hand, is described as a dialectical process of moving back and forth between data, experience, and wider concepts (Mason, 2002). It is an iterative approach that is closely associated with the aforementioned intersubjective problematic, thus implying a more participative approach to knowledge generation (Cunliffe, 2011). In a broader sense, it involves pragmatically seeking the best explanation across a range of competing explanations or interpretations, and is associated with the work of philosopher Charles Pierce (Bryman and Bell, 2015). Due to its pragmatic approach to reasoning, some authors argue that abduction is one of the primary reasoning tools used in everyday decisions and, as such, in scientific enquiry also (Mantere and Ketokivi, 2013). However, as noted by Mason (2002), this reasoning process is not always explicitly recognised by researchers as part of their research strategy and, more often than not, research strategies in practice draw on a combination of all three approaches.

Considering that this research seeks to explore and apply a systemic analysis in the study of the potential of SCI in the OSW industry using VSM as an epistemological tool, a combination of induction and deduction is required. According to Bhattacherjee (2012), induction and deduction go hand in hand in model building processes. More broadly, this study draws upon abductive reasoning as an iterative and dialectical process of using theory, generating data, and analysing it, instead of using theory to measure data as implied by deduction, or developing theoretical propositions based on data as implied by induction. This study values the subjective and intersubjective process of creating knowledge about the nature and potential of SCI in the OSW industry. This implies consulting with, and gathering the opinions of different stakeholders within the OSW industry, regarding SCI's practical potential. This leads to a more participative approach to knowledge creation, thus suggesting that abductive reasoning is more appropriate for this research.

3.4.1 Research approach

Given that this study examines areas that have previously received little attention, such as OSW SCM, and SCI in project-based environments, as well as the use of VSM in the field of logistics and SCM, a more exploratory approach to research is required. One of the primary aims of this research is to explore how a systemic analysis using the VSM can help to understand current levels of SCI within the development and construction phases of UK OSW farms and help to reveal potential areas for improvement within the whole supply chain.

According to Stebbins (2001: 3), social science exploration can be defined as follows:

> "*Social science exploration is a broad-ranging, purposive, systematic, prearranged undertaking designed to maximize the discovery of generalizations leading to description and understanding of an area of social or psychological life*."

This definition highlights the importance of systematically and purposefully exploring social groups or processes of interest. It also implies a more formal approach to exploration, rather than the random discovery of new ideas in the form of serendipity. The definition also suggests that there might be several forms of exploration. Stebbins (2001) made a distinction between investigative exploration, innovative exploration, exploration for discovery, and limited exploration. As the name suggests, investigative exploration aims to examine something; it is one of the most common forms of exploration in the social sciences. The goal of innovative exploration is to become familiar with something by testing or experimenting with it until the desired effect is achieved. Another form of exploration is exploration for discovery. The main difference between exploration for discovery and innovative exploration is that the latter is more concerned with achieving a desired outcome, whereas exploration for discovery is interested in the process of discovery and in gathering details for understanding and describing the area of study, thus making it a broader type of exploration. The fourth type of exploration is limited exploration, which occurs when a researcher is already aware of what to explore and investigate, and as such tries to systematically search for it.

Based on these different forms of exploration, this research is mostly concerned with exploration for discovery, but it will also draw upon aspects of investigative exploration. This is because this study seeks to adopt the VSM and a related methodology as its chosen systemic approach. It will also provide novel insights by applying the principles of the VSM to the supply chain, or to a network of interconnected businesses involved in the OSW industry. Applying the VSM to SCM can be classed as being a methodological exploration or investigation because it explores the feasibility of the VSM as an epistemological tool in the study of SCI potential. At the same time, this research values any new information that might emerge as a result of the exploratory processes.

Exploratory studies are often associated with qualitative research. However, as argued by Stebbins (2001) and Yin (2014), ‘exploration’ is not the same as ‘qualitative research’. As it has been explained above, the process of exploration could take different forms and approaches may vary between qualitative and quantitative methods. However, a qualitative research approach has the most value to this research because it allows for a more in-depth exploration. It also provides more flexibility in developing an appropriate research strategy and data collection method for the purpose of developing a greater understanding of the complexity and context of the research problem. A qualitative approach is especially of value to under-researched study areas, such as aforementioned underexplored research areas of this study. Moreover, a qualitative approach allows the researcher to study the system in focus through 'the eyes of research participants', which is sometimes referred to as the 'actor approach' (Jonker and Pennink, 2010). In this sense, a qualitative approach allows for a more 'holistic' form of analysis and description, which may otherwise have been limited under more standardised forms of quantitative research (Mason, 2002). Table 3.2 below provides the summary of the adopted research paradigm, the research approach taken and the overall nature of the research.

Research Paradigm	Research Approach	Research Nature
Interpretivism	**Abductive**	**Qualitative and Exploratory**
▪ Values subjective experiences of individuals. ▪ Accepts that there can be multiple realities.	▪ Using existing systems thinking approach; VSM and adopting it to SCI study by identifying relevant themes through literature review and interviews with research participants. Evaluating data and building explanations against VSM, dialectically moving between theory and data, and data to theory.	▪ Due to lack of previous research of SCI in project-based environments, specifically in OSW industry. ▪ And due to application of the VSM in the study of SCI, which has not been done previously. ▪ Allows for more in-depth and holistic approach to research.

Table 3.2: Summary of the research paradigm, the research approach, and the nature of the research (Author)

3.5 Understanding Research Quality Criteria in Qualitative Research

The absence of numerical and statistical data in qualitative research sometimes results in increased attention to its quality because it makes it harder to evaluate qualitative research. The issue of quality in qualitative studies can be traced back to times when the positivist paradigm, with its lawlike approach to the social sciences, prevailed. The dominance of positivism limited the understanding of quality criteria in qualitative research (Denzin and Lincoln, 2000). As a result, qualitative research remains prone to criticisms about rigour and reliability when compared to quantitative studies (Bryman and Bell, 2015). It is therefore important to address quality criteria in qualitative research to help reduce common concerns about the rigour and reliability of exploratory qualitative studies.

The quality of quantitative research has been traditionally evaluated using reliability and validity criteria. Reliability refers to the repeatability of the results of a study or the consistency of measures devised for measuring business and management concepts, whereas validity is concerned with the integrity of a study's findings (Halldorsson and Aastrup, 2003). With regards to qualitative research, applying the same quality criteria of reliability and validity varies amongst different scholars. For example, Guba and Lincoln (1994) hold the view that qualitative research requires different quality evaluation criteria from quantitative studies because they object to the view that social scientists can find absolute truths about the social world in the way that quantitative research suggests. Therefore, the authors' proposed two sets of criteria for assessing qualitative studies: trustworthiness and authenticity.

Trustworthiness incorporates four additional criteria. First, the credibility of findings, or how believable the findings are; paralleling internal validity. Second, transferability, which parallels external validity, or the generalisability of a study's results beyond the specific research context. Third, there is dependability, which parallels reliability. Finally, there is confirmability, which parallels objectivity, or the degree to which a researcher has allowed their own values to affect the results. Another criterion is ontological authenticity, which concerns authenticity as it is related to fairness, such as whether the right people were included in the research or whether the research helps its participants to arrive at a better understanding of their personal constructions. Educative authenticity concerns whether the research helps its participants to better understand other perspectives. Catalytic authenticity concerns whether a study was able to stimulate any change and, finally, tactical authenticity concerns whether research encouraged its participants to take any actions for improvement. These concepts of authenticity share certain parallels with AR, which can be explained in terms of a participative approach. In comparison, practice-based research occurs when an action researcher or consultant helps organisations to learn and make changes or improvements (Coghlan and Brannik, 2005). This suggests that authenticity cannot be commonly applied to all qualitative research studies as an evaluation criterion. Trustworthiness, on the other hand, can be applicable to all qualitative research.

However, as identified by Guba and Lincoln (1994), trustworthiness shares too many parallels with the reliability and validity criteria of quantitative studies. This led Kirk and Miller (1986) to suggest that reliability and validity apply equally well to both qualitative and quantitative research, particularly as qualitative research can be conducted as a science that can complement non-qualitative science. However, these concepts only gain meaning in qualitative studies by reference to a theory or experience of the researcher. In other words, it is almost impossible to be certain of the accuracy of researcher's understanding of the observed, as well as the accuracy of the methods used to draw particular conclusions. Therefore, it is important to acknowledge that there might be some limitations to achieving 'accuracy' in research (Kirk and Miller, 1986). However, this does not mean that qualitative researchers are limited in terms of ensuring the rigour of their research. In fact, the opposite is true as it is essential to seek rigour in any type of research but, due to the unique approaches often found in qualitative research, the validity and reliability of each study could vary (Mentzer and Flint, 1997).

Kirk and Miller (1986) distinguished three types of validity: apparent validity, instrumental validity, and theoretical validity, as well as three types of reliability: quixotic reliability, diachronic reliability, and synchronic reliability. These types of validity can be broadly defined in reference to the accuracy of measuring a phenomenon under observation. Different types of reliability refer to the accuracy of a study's findings. For example, quixotic reliability is related to the consistency of a single method of observation and whether it yields consistent results. Diachronic reliability refers to the similarity of measurements taken at different times, whereas synchronic reliability refers to the similarity of observations within the same time frame. One example given by Kirk and Miller (1986) concerns quixotic reliability in the context of trying to establish how people feel by asking the simple question: 'How are you?'. Responses are likely to yield only 'fine' as an answer, which cannot be considered as reliable data. Therefore, the author's argued that the best way to ensure validity and reliability is to use one's own sensitivity and intelligence during research, as well as a good theoretical orientation to eliminate instances of quixotic reliability. It is also important to provide explicit descriptions of observational procedures.

Following the arguments of Kirk and Miller (1986) and Guba and Lincoln (1994) on the quality of qualitative research, it is clear that there is no standardised set of assessment criteria due to the non-standardised and context-dependent nature of qualitative research. Nevertheless, the evaluation of qualitative research still relies upon common assessment criteria, such as validity and reliability. However, Easterby-Smith et al. (2015) argue that validity and reliability in qualitative research may depend upon the philosophical context of studies. The authors' suggest that different criteria of validity and reliability can be used depending on whether the philosophical approach concerns positivism or constructionism, for instance. Positivist studies may focus more on the validity and reliability of the measurements of their constructs and their relationship to reality, whereas constructivist studies may be more concerned with the credibility of their observations and the transparency of their data collection and interpretations.

Mason (2002) agrees that conventional quality measures used in quantitative research, such as validity, reliability, and generalisability, are also useful for qualitative research, but in a different way. She argues that it is important for qualitative research to ensure and demonstrate to others that the approach is thorough, careful, honest, and accurate, as well as to identify the appropriateness of the data generation and analysis to the research questions. This is supported by Silverman and Marvasti (2008: 258), who argue that: "*unless you can show your audience the procedures you used to ensure that your methods were reliable and your conclusions valid, there is little point in aiming to conclude a research dissertation*".

It follows that even though the meaning of validity and reliability in qualitative research could vary, these concepts still play an important role for assessing the quality and rigour of these studies. Even in exploratory research, which tends to be more open-ended in its research design than confirmatory research, it is important to maintain sensitivity towards the accuracy of data collection methods and the process of interpreting results. For this reason, a reflexive account of the research process and transparency of these processes can enhance the quality of qualitative research and make it accessible to fellow researchers adopting similar philosophies, as well as to quantitative researchers (Easterby-Smith et al., 2015).

3.6 Research Strategy

In comparison to more traditional approaches in the social sciences, such as surveys, systems thinking approaches are better placed to deal with real-world, complex, 'messy', ill-defined, or unstructured problems found in the natural and social world (Flood and Jackson, 1991). Therefore, many systems thinking approaches have been developed to deal with the practical problems that exist within organisations, especially where the source of complexity derives from the human interactions that mechanistic science approaches struggle to address (Jackson, 2019). For this reason, systems thinking approaches to research in business context are often characterised as intervention-based approaches that aim to address management problems and improve organisational performance (Midgley, 2000). In this case, intervention is described as a "*purposeful* *action by a human agent to create change*" (Midgley, 2000: 113). Such types of intervention-based approaches to management research often take the form of AR strategies.

According to Coghlan and Brannick (2005), AR is research in action rather than research about action. AR uses organisational problems as a unit of analysis to develop solutions, which often involves changes. Therefore, the researcher undertaking the research tends to be referred to as the 'change agent', given that they would facilitate that change (Rapoport, 1970). The emphasis on change promotion or action within an organisation, along with research within organisation, makes AR different to other research strategies, including experiments, surveys, ethnographies, or case studies.

A review of the VSM articles discussed in Chapter Two have shown that VSM is predominantly used as an intervention-based methodology (Schwaninger, 2000; Espejo, 2011; Espinosa and Walker, 2013). However, this research does not seek to use the VSM in an intervention-based approach because it does not seek to make changes within the system in focus. Instead, this research uses VSM to create greater understanding of the possibility of achieving a more integrated supply chain. In other words, this research seeks to gain more context-dependent knowledge about the nature and potential of SCI in the OSW industry. For this reason, a case study research strategy is appropriate owing to the possibility of gaining rich and in-depth insights about a research phenomenon (Yin, 2014). This possibility to gain more context dependent knowledge makes case study research strategy appropriate in applying systems thinking because it is also considered as being 'contextual' thinking (Capra, 1997).

Based on the findings of reviewed articles on the use of the VSM in research studies, discussed in Section 2.10.1, a case study approach was the second most often used research strategy for VSM applications, with conceptual papers being the first (as shown in Figure 2.14). This also supports the use of a case study approach in this research, which takes two case study examples to inform the development of this study's research design. The examples include a case study by Espinosa and Duque (2018) focusing on complexity management within an Amazonian indigenous association, and a case study of the Mexican sustainable supply programme, as reported by Espinosa and Walker (2017: 249-312). Both case studies are examples of the VSM analysis in a network context, which is relevant given that this research explores the supply chain, which can be considered as a network (Tommelein et al., 2009).

3.6.1 Understanding case study research

Yin (2014: 16) defines a case study as "*an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident*". In business and management studies, a case study is understood as a choice of what is to be studied (Stake, 2005). Thus, the term 'case' is commonly referred to as a unit of analysis, which could include a person, organisation, process, programme, neighbourhood, institution, or event (Yin, 2014). While there are no prescribed steps for performing case study research, it is useful to know that there are different case study designs.

Yin (2014) broadly distinguishes four types of case study research designs, including single holistic, multiple holistic, single embedded, and multiple embedded, as shown in Figure 3.2, thus allowing for context-dependent learning and knowledge building in each type of case study. A single case study might represent a critical or unique case, though, it could also represent a typical case to allow for an objective study of the conditions common to a situation. Another rationale for choosing a single case study design could be to study a revelatory case, which provides an opportunity to study something that has not been studied before. Yin (2014) also mentioned longitudinal cases as another rationale for choosing a single case study design. Longitudinal cases involve studying the same individual case at two or more points in time.

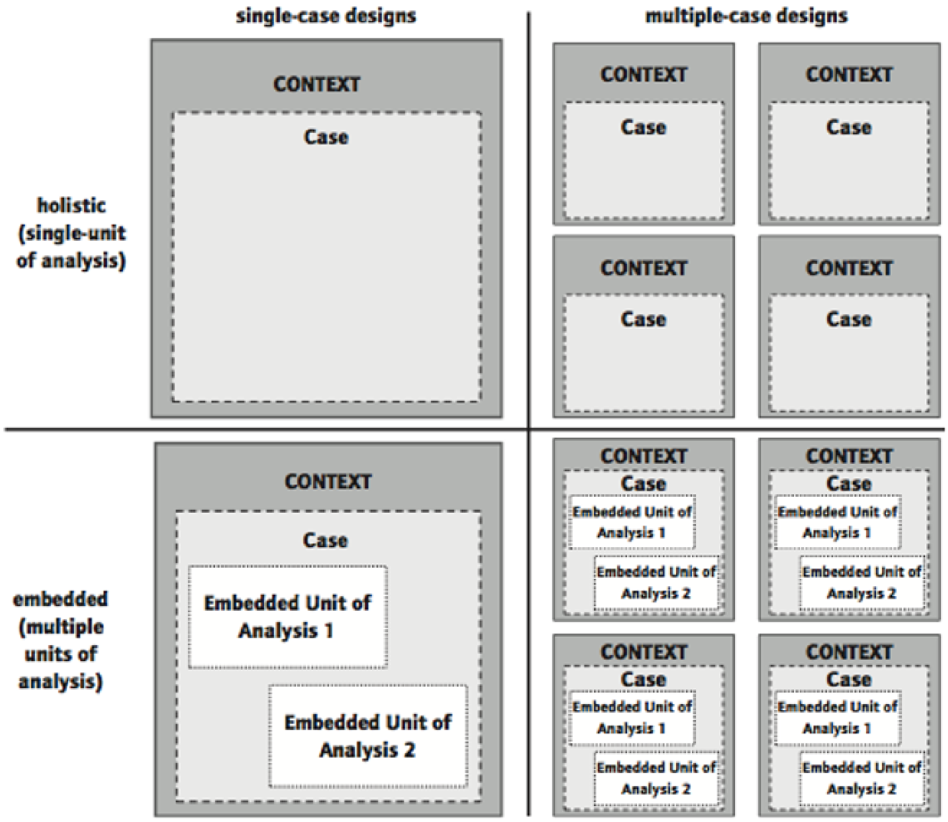

Figure 3.2: Types of case study research design (COSMOS Corporation, cited in Yin (2014: 50))

A single study can examine more than one case, which would be referred to as a multiple case study research design. This type of research design is well-placed for comparative studies. Every case study design, either single or multiple, may also be holistic or embedded. A holistic case study refers to the study of the case as a whole, whereas the focus of an embedded case study would be on the unit or units of analysis that cases of interest might involve.

In similarity to Yin (2014), Stake (2005) distinguishes between single and multiple case studies, referring to them as individual and collective case studies, and also makes a further distinction of individual case studies: intrinsic case studies and instrumental case studies. Stake (2005) understands an intrinsic case study as one that is interested in a particular case in all of its particularity or ordinariness. In other words, the case itself is of interest. By an instrumental case study Stake (2005) refers to a study in which a case is mainly examined to provide insights into an issue or to draw generalisations. Instrumental case studies play a supportive role to facilitate our understanding of something else. Stake (2005) notes, however, that there is no clear distinction between intrinsic and instrumental case studies because a researcher is likely to have an interest in both. However, researcher's interest in either intrinsic or instrumental case is likely to be refined by purpose of a study. Drawing a fine line between intrinsic and instrumental cases also suggests that a case is likely to involve a number of contexts or environments in which it operates. However, for case researchers the complexity surrounding cases is not a concern. Instead, it becomes the subject of attention and interest.

According to Yin (2014), the choice of case study design can be shaped by the purpose of a study, thus making a case study either exploratory, descriptive, or explanatory. An exploratory case study is normally used when the study requires an investigation into the feasibility of previously unestablished research procedures. A descriptive case study aims to provide a complete description of a phenomenon within its context, whereas an explanatory case study aims to explain events based on the cause-effect relationship. Eisenhardt (1989) adds that case studies can be used to test and generate theories. This makes a case study research strategy versatile and adaptable to the various contexts of research studies. Following Yin's (2014) description of different case study research designs, this research takes the form of a single embedded case study research strategy, as shown in Figure 3.3. The system in focus forms the main unit of analysis. It was defined using methodology to support self-transformation, which forms part of subsequent VSM analysis (Espinosa and Walker, 2017). Further details of the design of the case study and the use of the methodology to support self-transformation will be provided in Chapter Four.

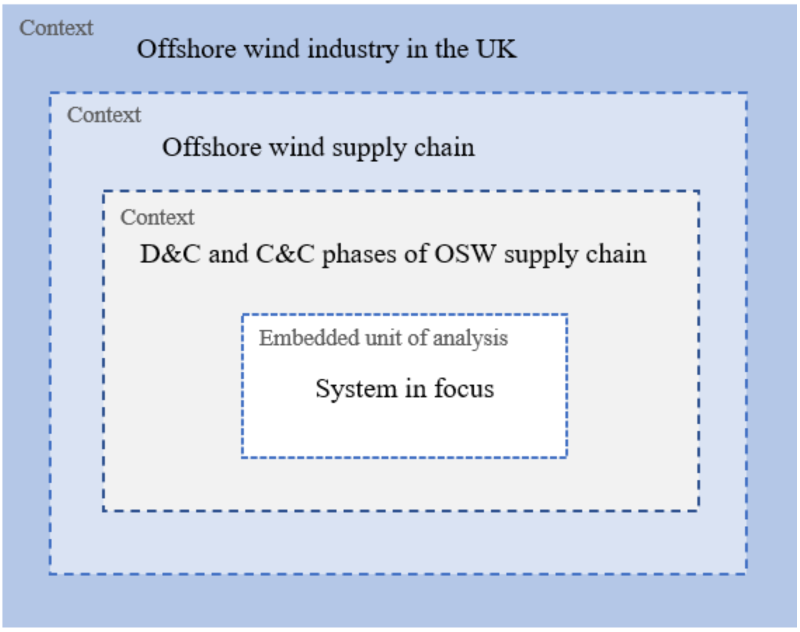

Figure 3.3: The chosen research strategy (Author)

3.6.2 Criticisms of a case study research strategy

Even though a case study is a recognised research strategy in the social sciences, including in the field of logistics and SCM, it is prone to criticism (Ellram, 1996; Seuring, 2005, Eisenhardt and Graebner, 2007). It seems as though a case study's ability to generate context-dependent knowledge is considered as being one of its biggest strengths, as well as its biggest criticism. In relation to this, Flyvbjerg (2011) identified five common criticisms or misunderstandings about the nature of case study research, which are summarised as follows:

1. Context-dependent case studies are less valuable in the search for predictive theories and universal truths.

2. It is difficult to form generalisations on the basis of an individual case.

3. Case studies are more useful as pilot studies to help generate hypotheses, but not to test hypotheses.

4. Case studies are biased towards verification, that is, a tendency to confirm the researcher's preconceived notions.

5. The results of case studies are difficult to summarise and develop into general propositions and theories.

To challenge the first misunderstanding, Flyvbjerg (2011) argues that in the social sciences there appears to be only context-dependent knowledge, and that context-dependent learning is necessary to enable people to become experts in their fields. In contrast, context-independent learning comprises of facts and rules, which would bring students to a beginner level only. Nonetheless, both approaches are necessary to advance the level of expertise within a subject.

In addition to the benefit of developing expertise through context-dependent knowledge, case study research can help to retain a holistic and real-life perspective of a case, which tends to have set boundaries of interest like, for example, an organisation or a particular industry or operation (Ellram, 1996). This allows some authors to draw certain parallels with the notion of a 'system'. Stake (2005), for example, mentions that a case can be compared to a 'bounded system', paralleling description of a closed system (Jackson, 2019). This helps to evidence the relevance of adopting a case study research strategy in this study as it takes a systems perspective to understand SCI in the context of the OSW industry. Case study research methods that take systems approaches are also encouraged in the field of logistics and SCM (Gammelgaard, 2004).

Nevertheless, this type of contextual research often raises questions about the generalisability of such studies. This forms the second common misconception surrounding case studies. According to Flyvbjerg (2011), the question of generalisability largely depends upon the strategic choices of a case and how it can provide important examples and a deeper understanding of the problem being studied. This type of in-depth approach makes case studies well-suited for so called 'black swan' identification, which occurs when a single case can refute or falsify an established theory or hypothesis, such as Galileo's rejection of Aristotle's law of gravity. This makes it clear that generalisations are possible even on the basis of a single case (Ellram, 1996). However, this is not the usual purpose of a case study; it is more common to employ case studies to expand and contribute to a theory, thereby making theoretical generalisations rather than statistical ones (Stake, 2005; Yin, 2014). Case studies are therefore more problem-driven rather than methodology-driven. This also shows that case studies can be useful for generating and testing hypotheses, thus responding to the claim that case studies are only useful as pilot studies. This is the third misconception about case studies and again depends on the strategic choice of case. As some cases become a platform to test a hypothesis, these may prove the preconceived views of some researchers wrong.

The fourth misunderstanding is that case studies contain bias towards the verification of a researcher's preconceived notions. According to Flyvbjerg (2011), case studies are mostly biased towards falsification rather than verification. This is due to the greater emphasis on a contextual understanding of the case, in addition to study participants that can help to change researcher's preconceived views. Though, general issues of verification and subjectivism bias can be attributed to all methods of enquiry, not just case studies.

A similar response can be made in relation to the fifth criticism of the case study research strategy, concerning the view that the results generated by specific case studies are difficult to summarise or develop into general propositions and theories (Flyvbjerg, 2011). Though, this criticism can also be levelled against other qualitative methods. In response, Flyvbjerg's (2011) view is that the 'thick' and difficult to summarise narratives of case studies should be regarded as an advantage rather than a drawback. This is because it could mean that the study has uncovered something deep and complex. On the other hand, Yin (2014) argues that such criticism may stem from the fact that people often confuse case studies with ethnographic research, which is associated with participant observations and is usually time consuming and detailed in terms of observational and interview evidence. Case studies, in Yin's (2014) view, should not necessarily result in lengthy narratives depending on the topic being explored. Instead, Yin (2014) suggests to link case studies with theory as part of the research design process; by articulating a theory about what is being studied and learned prior to data collection. This also serves as a point of difference between case study research and other qualitative methods, such as grounded theory and ethnography. Yin (2014) adds that a well-designed case study can become an important communication device that is able to raise awareness and bring attention to those issues that would have otherwise remained in the shadows. The next chapter will provide details on how case study research is implemented in this thesis.

Chapter Four

Research Design

4.1 Introduction

This chapter describes the process of developing a research design and describes its implementation in practice. It can be noted that the research design of this study followed a lengthy process of refinement to fit the purpose of this research. One of the main challenges of developing this research design was to find a way to link the theory of organisational cybernetics and associated VSM analysis to the study of SCI potential in the OSW industry, particularly in terms of the supply chain as a network as opposed to a focal company perspective.

The aforementioned reviewed literature analysing the use of the VSM in the field of logistics and SCM (Section 2.10.2) presented limited examples. More precisely, the literature review identified two articles only: one by Puche et al. (2016) and another by Chan (2001), both of which mentioned the use of the VSM along with other theories, but which lacked details on methodological considerations pertaining to the VSM application. Another example came later in 2019 in fellow PhD researcher's Ricardo Valenzuela Gonzalez research into the automotive supply chain in Mexico (Valenzuela Gonzalez, 2019). However, like the previous two articles he presented a slightly different VSM outlook. Another challenge related to the research design of this study concerned how to link the VSM analysis with an exploratory case study. A case study research strategy is believed to provide a better fit in this research when compared to an AR strategy, the latter of which is commonly used in systems methodologies, including the VSM (Jackson, 2019). This section therefore provides details on the analytical processes behind the development of the research design and how it has been used in practice.

4.2 Case Study Design

Based on earlier considerations of different types of case studies, including single versus multiple and holistic versus embedded, this research fits Yin's (2014) description of a single embedded case study research design (Figure 3.3). According to Yin (2014), one of the main tasks of a case study research design is to define the unit of analysis. While the process of defining the 'case' may be more straightforward in holistic case studies, which focus on the case as a whole, it is more challenging when the focus is embedded, like in the example of this research. The main challenge of defining the unit of analysis in this research was that it attempted to focus on the supply chain by taking a systems perspective. However, this did not fit the common definition of a case study, which is commonly associated with examples involving an individual or firm. A further challenge was to link the subject of supply chains to the VSM, which implies its own methodology and a view of a system based on cybernetic principles that is not traditionally applied in the field of logistics and SCM. The process of defining the unit of analysis therefore required a traditional way of looking at the case study by trying to distil its context, as well as using the 'methodology to support self-transformation' suggested by Espinosa and Walker's (2017), which will be discussed in the next section.

From a traditional perspective, this case study has several contexts, as shown in Figure 3.3. The most obvious concerns the industry and country examined in this research; the UK OSW industry. Hence, this study is interested in different initiatives and projects within this industry specifically in the UK, which is the largest country in the world in terms of installed OSW capacity. Another context includes the supply chain of the UK OSW industry. It was established in the literature review that the OSW industry's supply chain is related to the project-based environment. The main difference of project-based supply chains compared to process-based supply chains or retail supply chains is their temporary nature. This means that projects have both a beginning and end time (Tommelein et al., 2009). Thus, the OSW supply chain can be described as following several phases, starting from D&C phase of a wind farm, to C&C, to O&M, and then finishing with the De-comm phase of a wind farm. These phases also define a wind farm's lifecycle. This study is specifically interested in the D&C and C&C phases of a wind farm because they closely relate to SCM processes that can be characterised as project-based supply chain environment. The D&C and C&C phases also play an important role in the delivery of a successful project overall (BVD Associates, 2019). The O&M and the De-comm phases come post construction of the OSW farm, involving other actors, therefore they are not included in this research, as mentioned in Section 1.2. The supply chain phases of interest in this research are shown in Figure 4.1 below, highlighted with a dotted line:

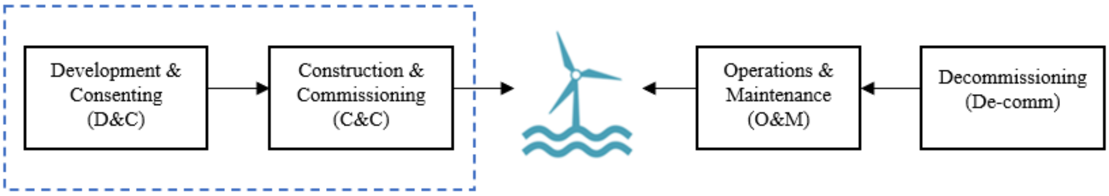

Figure 4.1: OSW supply chain phases of interest in this research (Author)

The reason it is important to specify the context of this study is because supply chains in general are commonly described in terms of traditional supply chains, such as in the context of manufacturing or retail sectors where there are continuous flows of products, services, information, and finances exchanged amongst supply chain partners. As mentioned previously, project-based supply chains include flows of exchanges of goods, information, and finances that are not continuous. This means that continuous customer demand is limited in project-based supply chains. It was important to make this distinction between the two different supply chains in order to more closely describe the unit of analysis in this study. Another important reason for specifying project-based supply chains in the OSW industry was because supply chain contexts vary between industries, especially in project-based environments (Mouritsen et al., 2003; King and Pitt, 2009).

By stipulating these contexts, it becomes possible to link them to the systems perspective adopted in this study. As mentioned previously, this study views the development and construction supply chain of an OSW farm as a system because it fits the certain characteristics of a system; where there are interconnected parts working together to create a coherent whole with a purpose (Espinosa and Walker, 2017). This therefore makes it the main case of the research. However, in order to apply the VSM it is important to further specify the unit of analysis and identify its level because systems can be nested within other systems (Jackson, 2019). This study therefore follows Espinosa and Walker's (2017) suggestion to use 'methodology to support self-transformation', which was designed as a guideline for the use of the VSM within organisational design or diagnosis in order to define the system in focus as the main unit of analysis.

4.3 Defining the System in Focus

Considering that the VSM is recognised as a design and diagnostic tool which can help organisations to improve their viability, it is sometimes regarded as a meta-language. In other words, it can enable members of organisations and networks to engage in the joint mapping of their complex interactions to identify any issues pertaining to organisational viability, which can then be acted upon (Espinosa and Walker, 2017). To help facilitate this process of collective organisational learning, Espinosa and Walker (2017) propose their 'methodology to support self-transformation'. Figure 4.2 below shows the steps that this methodology involves:

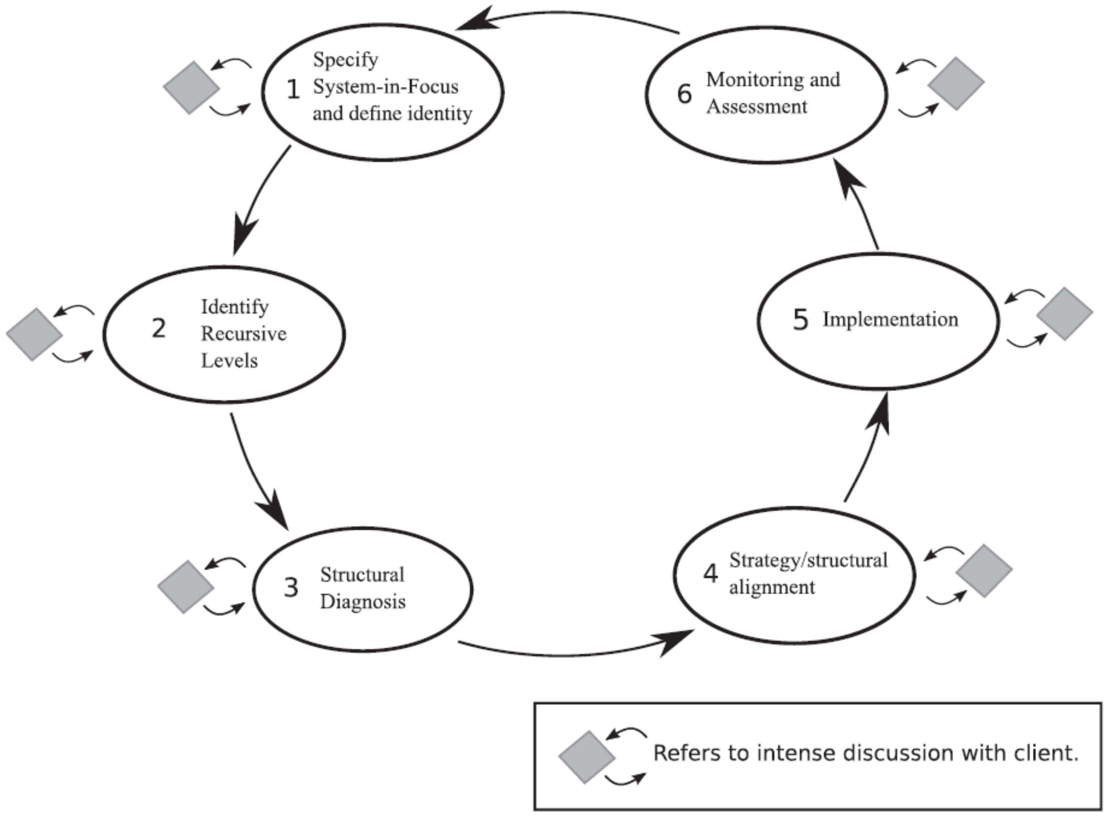

Figure 4.2: Methodology to support self-transformation (Espinosa and Walker (2017: 97))

One of the first steps of this methodology is to understand 'system in focus' in relation to its identity and purpose. Since this methodology implies a participative approach, the process usually requires a joint input from all participants where the VSM analysis is implemented. According to Espinosa and Walker (2017), this would normally take the form of a workshop with representatives of an organisation using rich pictures; cartoon like representations of a studied problem. This process allows a researcher or an agent to capture the main issues and opportunities people may experience in the studied system. In addition to this, Espinosa and Walker (2017) suggest using Espejo's TASCOI mnemonic, which stands for Transformation, Actors, Suppliers, Customers, Owners, and

Interveners, and is an adaptation of Checkland's (1990) CATWOE (Espejo and Reyes, 2011).

The second step of the methodology involves a recursive analysis. The concept of 'recursion' refers to Beer's 'Recursive System Theorem', which holds that "*in a recursive organisational structure, any viable system contains, and is contained in, a viable system*" (Beer, 1979: 118). The purpose of this analysis is to identify and map the relevant recursion levels of the system by distinguishing its primary and support activities. The third step involves a structural diagnosis using the VSM itself. The fourth step involves aligning organisational strategy and structure, based on identified diagnostic issues. The fifth step involves securing an agreement about the necessary changes needed to achieve desired improvements and their implementation, and the final step involves monitoring and assessing the implemented changes.

For the purpose of this research, only the first three steps were adopted of the methodology to support self-transformation. This is considering that the purpose of the research is to explore, rather than to intervene. This also means that the first steps did not involve a joint consultation with representatives of the system in focus because, at that stage, its boundaries were not clearly evident. Instead, the first steps of the methodology to support self-transformation were used to determine the system's boundaries, which then served as a framework for the study participants' selection. Therefore, the first steps of defining the identity of the system in focus and identifying its recursive level were performed prior to data collection to set the system's boundaries for subsequent data collection and analysis. The VSM analysis was used as an epistemological tool following the data collection to gain a greater knowledge and understanding of the potential of OSW SCI based on the participants' responses. Figure 4.3 below shows the process flow of the steps taken by drawing on the methodology to support self-transformation:

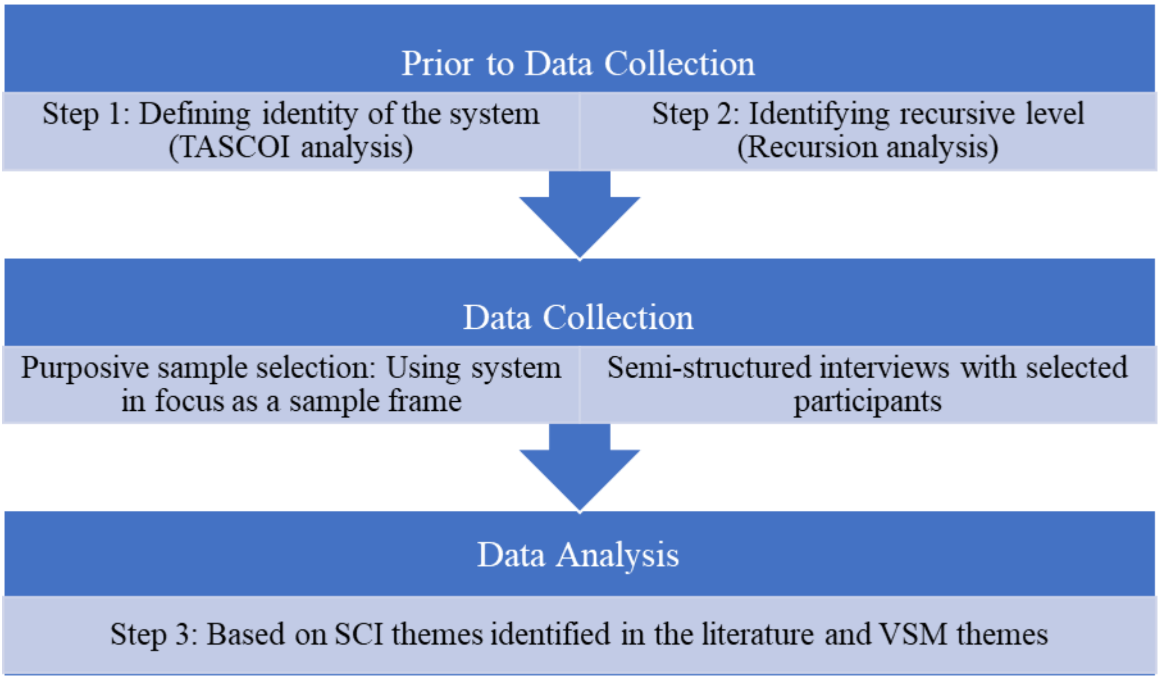

Figure 4.3: Process flow of the steps taken based on the methodology to support-self transformation (Author)

The initial process of defining the system in focus was based on a research plan that aimed to look at a single OSW farm construction project in the North Sea off the East coast of England at the time of writing this thesis. The initial plan aimed to apply the VSM analysis to the single project's supply chain. However, this research plan necessitated revision following a consultation with a developer at the targeted OSW farm project. The developer raised concerns about a potential breach of confidentiality in the event of an individual project's supply chain being disclosed and information about its current processes becoming publicly available. As a result, the research plan was viewed as being a direct threat to the developer's unique selling point (USP), because a supply chain is rightly perceived as being a competitive advantage. This resulted in a slight change to the focus of the research; from targeting a single project's development and construction supply chain to looking at the industry's supply chain in a more general sense. This study therefore explores the experiences of different OSW industry players in relation to working on different OSW projects, rather than in relation to a single OSW farm.

Despite this challenge, the initial steps in the process of defining the system remained almost unchanged. This study followed the suggested TASCOI mnemonic in specifying and naming the system of interest and identifying its main purpose related to the development and construction supply chains of OSW farms. The TASCOI process helps to name a system of interest and subsequently helps to envision its identity. However, it is important to note that the identity of the system is likely to be viewed differently by different people depending on their position in relation to the system (Espejo and Reyes, 2011). Therefore, it is worth mentioning that the system identity of the present research has been defined from the researcher's perspective as an observer of the system.

As mentioned earlier, TASCOI stands for Transformation, Actors, Suppliers, Customers, Owners, and Interveners. Transformation relates to the process of transforming certain inputs into certain outputs performed by a system. In the case of this research, the main output of the transformation process in a development and construction supply chain is considered to be a completed OSW farm; using all of the necessary products and services as an input. Actors refer to those who perform the transformation. In this research the actors include businesses that are directly involved in different supply chain tasks. The meaning of 'actors' in a supply chain context would be similar to the next letter of the TASCOI mnemonic, which stands for suppliers. Thus, the actors in this research can also be referred to as suppliers of different products and services. In terms of customers, there are several tiers of those; beginning from the owners and operators of a completed wind farm and ending with the end users of electricity. This is shown in Figure 2.8, which depicts a network perspective of the OSW industry's supply chain. The role of the owners is described as those agents that have an overview of the transformation, or those that 'own' the transformation (Espejo and Reyes, 2011). With regards to this research, the role of owner can be attributed to the organisations that build OSW farms, who are also referred to as developers. Their role involves developing wind farms, beginning with the initial stages of receiving consent to the project management of all the tasks leading to a completed OSW farm. Finally, interveners, or external agents that could affect the performance of the transformation process of a given system, are considered as being those parties that grant consents to OSW projects, as well as interested parties that might affect the permissions to build the farms. Table 4.1 summarises the results of the TASCOI analysis:

Transformation	Using all of the necessary products and services to develop, build, and construct OSW farms.
Actors/Suppliers	OSW farm development and construction supply chain members. In other words, businesses that are involved in providing and supplying their products and services for the development and construction of OSW farms. Examples include consultancy firms that perform various survey tasks of potential locations for wind farms, such as environmental surveys. A further example includes the suppliers of resources or main component manufacturers, such as manufacturers of wind turbines, foundations, and power cables. A final example includes the providers of offshore substations, onshore substations, and various other suppliers of components and services.
Customers	Wind farm owners/operators (in the case of the OSW industry, this role is usually fulfilled by wind farm developers), OFTOs who act as owners and operators of electricity transmission assets, NGET, and end consumers of electricity.
Owners	Developers of OSW farms. Usually these are utility companies that project manage development, construction, and in some instances the operations of a wind farm after it has been built. Some examples of UK developers include EDF Renewables, Orsted, SSE, Vattenfall, and Innogy, amongst others.
Interveners	The Crown Estate or Crown Estate Scotland (which grant leases of sea beds for OSW development); The Planning Inspectorate (which examines applications for nationally significant infrastructure projects (NSIP) and grants a Development Consent Order; in the case of OSW farms, projects involve a greater capacity than 100MW); BEIS (which grants or refuses consent for OSW development based on Planning Inspectorate recommendations); In Wales - Natural Resources Wales (which determines marine licences); In Scotland – Marine Scotland (which examines applications for offshore works); Scottish Ministers (who grant or refuse consent); In Northern Ireland – the Marine Strategy and Licencing team within the Department of Agriculture, Environment and Rural Affairs (DAERA) (which reviews applications and makes decisions about consent); Local Planning Authority (LPA) (which grants consent for onshore transmission cable landfall for smaller projects, not including NSIPs); Marine Management Organisation (MMO) (which grants consents for projects that are 1MW, but less than or equal to 100MW); The Environment Agency (which may influence decisions about consent); Statutory consultees; local authorities, local communities, and other interested parties (BVG Associates, 2019).

Table 4.1: Summary of TASCOI analysis (Author)

Based on the TASCOI analysis (Espejo and Reyes, 2011), the working identity of the system in focus for this research is defined as follows:

> "*Offshore wind supply chain is a temporary system comprising businesses that by providing their products and services are engaged in the process of developing and building OSW farms that once completed produce clean electricity that is supplied to the ultimate consumers of electricity*" (Author).

4.3.1 Identifying recursion levels

Following the TASCOI analysis undertaken to name the system in focus, the next step involved a recursive analysis. The main purpose of this analysis is to identify primary activities of a system in focus. This step of the analysis is based on the identification of the primary activities of the system, which are aligned to its transformation process. As explained by Espinosa and Walker (2017), primary activities are directly related to a system's purpose, which transform certain inputs into certain outputs for customers. According to Espinosa and Walker (2017), primary activities usually have clear boundaries or clearly defined tasks, and each of those tasks can potentially become independent units that can be considered as being independent viable systems. Primary activities also include support activities. However, this analysis focuses solely on primary activities. As a result, this process can help to distinguish a system's primary activities from its support activities.

This exercise is important because it helps to uncover the complex interactions and relationships amongst different organisational units, which might reside in different recursion levels. Recursions, in the context of VSM, can be explained as occurrences with the same structural patterns of a viable system that is embedded within another viable system, which is also embedded within another viable system (Beer, 1985). With regards to the example of a transportation system, which can be considered as being a viable system on its own, there would be various elements, including a railway system, road system, water way transportation systems, airways, and so forth. Each element can also be considered as being separate viable systems, which are embedded at a lower level of recursion within the transportation system. Each of those can be broken down further to more recursion levels. The extent to which a researcher should extend its focus on recursion levels should ideally depend on the needs of a studied problem (Espinosa and Walker, 2017).

When recursive mapping is used in intervention-based studies of a single organisation, it becomes a powerful tool to enable the identification of a viable system, within the organisation which requires the most attention. In addition, recursion analysis helps to place the right focus on a particular problem in relation to the system in focus (Espinosa and Walker, 2011). According to Espinosa and Walker (2011), in some instances a recursion analysis may become the solution to a problem itself, without the need for further action. In this research, however, the recursion analysis was less aimed at identifying the depth or height of recursion levels in a search of a viable system that needs attention, but instead focused on the width of the system in focus based on its primary tasks. The reason for this is because this research explores supply chain within the OSW industry. In other words, this research explores a network that serves as a temporary viable system, which is composed of many different organisations that offer different products and services. These organisations are likely to have many different layers of recursions, as they themselves can be considered as viable systems. What is more, these products and services are provided at different stages or phases of a wind farm's development and construction process, which means there is a time difference between when the primary activities happen. Therefore, in this research a recursion analysis has primarily been used to determine the width of the system in focus by identifying the tasks that play an important role within the development and construction phases of an OSW farm.

The process of a recursive analysis has revealed the system in focus, which is shown in Figure 4.4 below. The main primary tasks highlighted in Figure 4.4 were identified using industry reports, such as the '*Guide to an offshore wind farm*' (BVG Associates, 2019), *UK offshore wind supply chain: capabilities and opportunities* (BVG Associates, 2014), and one of the offshore wind sectors leading consultancies and market research organisations' website: *4C Offshore* (2018). It can be observed that the supply chains of OSW farm projects can be broken down into two main activities: development and project management, and construction and project management. Each of these can be further broken down into additional tasks. For example, the development and subsequent project management of a wind farm consists of three main sub-tasks: securing consent for the wind farm, wind farm design and engineering, and procurement of the necessary components.

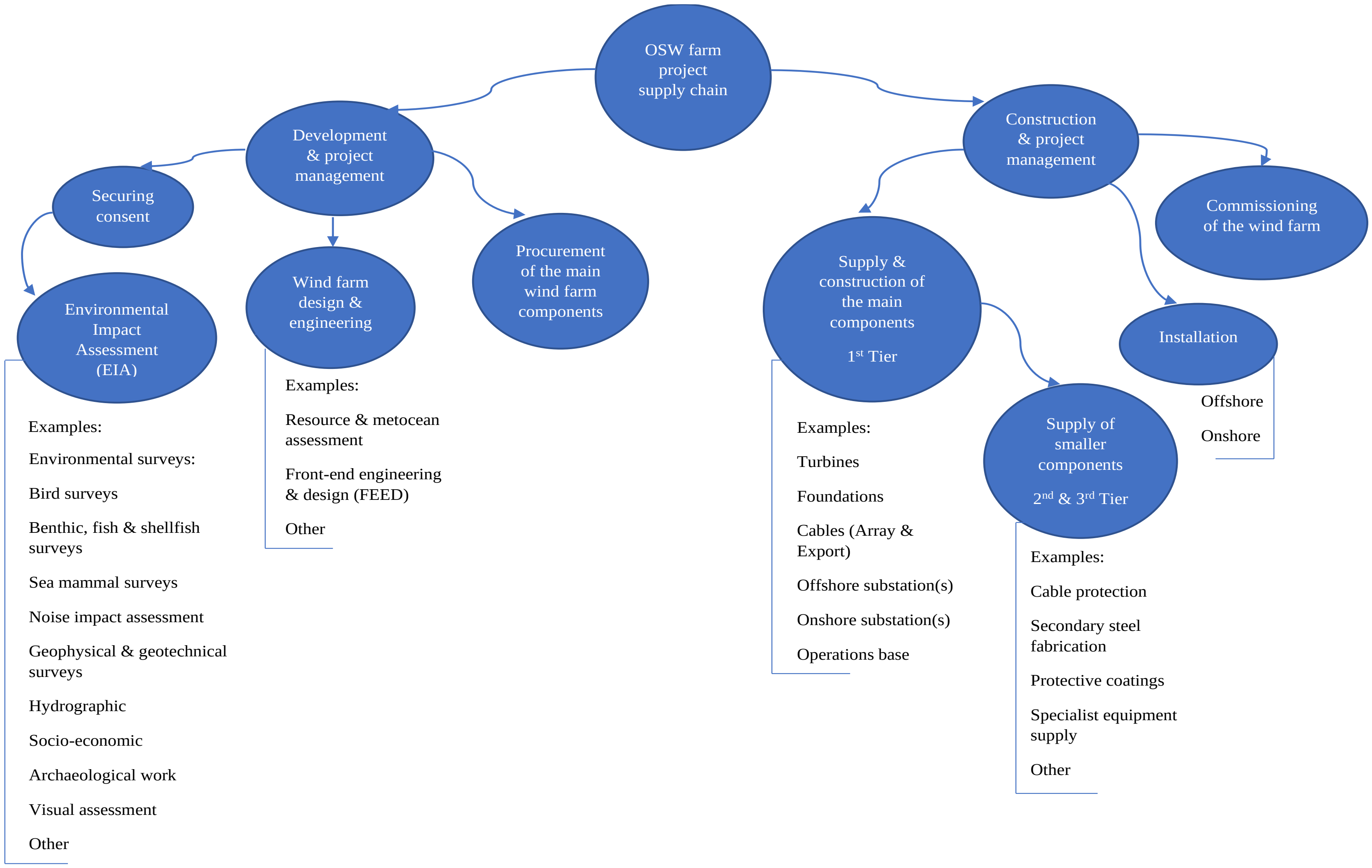

Figure 4.4: The initial system in focus (Author)

Given that receiving consent to build a wind farm is the most important task, the activity of securing consent can be subdivided into specialist consultancy works, such as a range of environmental survey tasks. Each consultancy would provide their assessments and, working towards an EIA, they would describe the potential impact of the proposed wind farm project on the physical, biological, and human environment during different stages of its lifecycle (BVG Associates, 2019).

In addition to the different environmental survey tasks that are needed to secure consent to build a wind farm, this process involves careful wind farm design and engineering involving FEED. This is in addition to resource and metocean assessment activities to produce a conceptualisation of a wind farm and determine its potential energy production capacity. FEED details which size of turbines will be used, which types of foundations are required, the layout of the wind farm, substation design, electrical systems, and connection method to the grid. All design and engineering tasks are done in advance of the procurement process of all necessary components. Resource and metocean assessments measure wind speeds and overall wind farm operating conditions. Once all of the planning, design, and engineering tasks are complete, the procurement of the key wind farm components begins. Procurement normally involves a tendering process, where a developing company sends out invitations to tender as part of a competitive bidding process for potential suppliers.

The process of construction and project management of all construction tasks begins once suitable suppliers and/or contractors have been selected. The main task of construction and project management can be divided into four sub-tasks: the supply and construction of the main components, the supply of smaller components, the installation, and the commissioning of the wind farm. The main components of the wind farm include turbines, foundations, cables (array and export), offshore and onshore substations, and an operations base. Suppliers or contractors of the main components are classified as first-tier suppliers or contractors in this research. The construction of an OSW farm also involves smaller components, ranging from things like cable protection, secondary steel fabrication, specialist equipment supply, and a range of other smaller components. The suppliers of smaller components are classified as second and third-tier suppliers. The installation tasks involve installation works offshore and installation works onshore, and finally, there is the commissioning of the wind farm. Together, all of these activities form a system that is the focus of this research.

All of the identified primary tasks can be considered as being autonomous units of the system in focus. These may or may not be performed by separate organisations, which can subsequently be considered as individual viable systems. This also means that each of these primary tasks can be broken down into more recursion levels because each task most likely belongs to separate organisations with their own networks of operation. However, this research will not analyse each task separately. Instead, it is concerned with gaining a greater understanding of the interaction amongst businesses representing these primary activities; viewed as primary activities of the OSW supply chain. It is also concerned with understanding how well integrated these interactions currently are amongst different organisations performing these primary activities, and whether there are any aspects that could be improved.

4.4 Data Collection Strategy

Using a recursion analysis together with the TASCOI analysis helped to define the system in focus as well as specifying the boundaries of the system in this research for data collection purposes. According to Midgley and Pinzón (2011), the concept of a ‘boundary’ is central to systems thinking because it clarifies the level of comprehensive understanding that systems thinking aspires to reach. Boundary judgement helps to identify those aspects that need to be included or excluded from the analysis based on personal or social constructs.

4.4.1 Research participants selection strategy

There are different types of strategies for selecting research participants, which are also known as sampling strategies (Easterby-Smith et al., 2015). Those can vary from probability sampling techniques, such as simple random sampling, stratified random sampling or cluster sampling, to non-probability sampling techniques, including: convenience sampling, quota sampling, snowball sampling, and purposive sampling, amongst others.

In this research, determining the system in focus and thereby specifying its boundaries has allowed for a purposive sampling of potential participants. This form of sampling is common in case studies and qualitative research. Purposive sampling is sometimes referred to as theoretical sampling, which is when a sample selection has relevance to the theoretical position of the research or, in other words, is meaningful theoretically because it has certain characteristics or criteria that can help to test or explore a theory, like in the case of this research (Silverman, 2017). It is important to note that purposive sampling should not be confused with convenience sampling. According to Bryman and Bell (2015), convenience sample refers to a sample which is simply available to researcher for its accessibility. In purposive sampling, however, sample is selected with specific research goals in mind. In this research, the previously defined system in focus shown in Figure 4.4 served as a sampling framework to seek suitable participants for this research.

In accordance with the system in focus, this study specifically targeted companies that have supplied their products and/or services to the UK OSW industry as well as having participated in the development and construction phases of UK OSW farms. It can be observed that the system in focus does not include ports, considered by this study as DPs in the OSW supply chain. The reason for that is because the system in focus has been defined based on its identified primary activities. Ports are considered to provide support activities in the OSW supply chain. Therefore, ports and other businesses providing support activities have been excluded from the sampling frame. Table 4.2 below lists the types of companies and examples of company names that were considered in this research, including the reasons for their consideration in relation to the system in focus:

Company Type	**Relevance in Relation to the System in Focus**	**Examples of Companies**
Developers	Development and project management; Securing consent; Wind farm design & engineering; Procurement of main wind farm components; Construction & project management, Commissioning of the wind farm	Orsted, Innogy, Vattenfall
EIA specialist consultants	Environmental Impact Assessment	GoBe Consultants, ABP Marine Environmental Research Ltd (ABPmer), RPS Group, Wessex Archaeology, RSK Environment, NIRAS A/S
Wind farm design & engineering consultants	Wind farm design & engineering	DNV-GL, Arup, Atkins
Turbine manufacturer/supplier	Supply & construction of the main components 1ST tier	Siemens Gamesa Renewable Energy, MHI Vestas Offshore Wind (MVOW), GE Renewable Energy
Turbine foundations manufacturers/suppliers	Supply & construction of the main components 1ST tier	BiFab, Bladt Industries, Smulders, EEW OSB
Cable (array & export) manufacturers/suppliers	Supply & construction of the main components 1ST tier	JDR Cable Systems, Nexans, Prysmian, NKT

Company Type	Relevance in Relation to the System in Focus	Examples of Companies
Offshore substations fabricators and contractors	Supply & construction of the main components 1ST tier	Babcock, Bladt Industries, Sif/Smulders (substation structures fabrication), Semco Maritime, Engie Fabricom (EPCI contractors)
Onshore substations contractors	Supply & construction of the main components 1ST tier, Installation onshore	Balfour Beatty, J. Murphy & Sons, Siemens Transmission and Distribution, Jones Bros (onshore substation infrastructure construction)
Operations base contractors	Supply & construction of the main components 1ST tier, Installation onshore	Tolent, NRS Group, Hobson & Porter (onshore operations base construction)
Smaller component manufacturers/suppliers	Supply of smaller components 2nd & 3rd tier	Tekmar, Seaproof Solutions, Subsea Protection Systems, Terram, Wilton Engineering, Hutchinson Engineering
Wind turbine installation contractors (vessel operators)	Offshore installation, commissioning	A2SEA/GeoSea (DEME Group), Van Oord, Jan de Nul, Fred. Olsen WindCarrier
Turbine foundations installation contractors (vessel operators)	Installation offshore	Boskalis, GeoSea, Van Oord, Jan de Nul, Saipem, Seaway Heavy Lifting (Subsea 7)
Cable installation contractors (vessel operators)	Installation offshore, commissioning	Seaway Offshore Cables (Subsea 7), Tideway (DEME Group), DeepOcean, Boskalis
Other OSW industry organisations	General	The Crown Estate, ORE Catapult, Team Humber Marine Alliance; Other

Table 4.2: Examples of companies considered for the purposes of this research

In addition to purposive sampling, this research has involved some aspects of snowball sampling in earlier stages of the research design. Snowball sampling is described as a sampling technique when someone who meets the criteria for inclusion helps to identify further contacts, who are then also asked to identify further contacts, and so on. It is in this way that a sample snowballs (Saunders et al., 2016). This technique was used to identify potential contacts for this research by asking a number of OSW industry representatives to help identify further participants relevant to this study.

Initial contact with potential research participants was made during OSW industry related conferences, such as the ‘Wind Europe Conference and Exhibition 2017’ in Amsterdam, which was organised by Wind Europe; the association for wind energy in Europe. Also, the ‘Offshore Wind Energy 2017’ conference in London, which was co-organised by Wind Europe and RenewableUK; the leading renewable energy trade association in the

UK. Similar industry conferences were also attended throughout 2017 and 2018. Industry conferences served as a platform to create awareness about this research and to send initial invitations to relevant companies regarding their participation in this research.

Although participation in industry conferences allowed for the identification and invitation of various contacts, for the purpose of this research subsequent searches and invitations for relevant participants involved Google search, LinkedIn, and OSW related news websites, such as 4Coffshore.com, OffshoreWIND.biz, Renews.biz, and Windpowermonthly.com, amongst others. This search enabled the purposeful selection of relevant contacts so that they could provide their perspectives on their scope of work related to the system in focus of this research. The identified research participants were invited to take part in this research using personalised emails. An example invitation email is provided in Appendix A.

Every email contained information about the research using a project information sheet; an example of which is provided in Appendix B. The project information sheet outlined the project's aims and objectives, as well as information about participation. Specifically, it noted that participation would involve an interview that was expected to last approximately 30 to 45 minutes. In addition, every participant was provided with a list of interview questions, which was also attached to the invitation email. This was necessary to make the process more open, keeping the aforementioned confidentiality concerns in mind about disclosing project's supply chain, as well as to show participants the type of information that this research was looking to collect for analysis. This also helped to determine whether the participants could answer the interview questions, as well as helping to refine the interview guide before each interview to ensure that it was relevant to each participant. An example of the interview guide is given in Appendix C. The development of the interview guide is also discussed further in Section 4.6.1.

More than 50 personalised emails were distributed to the potential participants of this research. In total, 15 companies (16 participants, two participants represented one company) agreed to take part in this research to provide their perspectives. Even though there are no strict rules in terms of the required sample size in qualitative research, there is a general recommendation that the size of the sample, or the number of interviews, should reach some saturation in data. As explained by Bryman and Bell (2015), data saturation is reached when any additional data collected provides few new insights. While it is understood that reaching certain levels of data saturation is desirable in any qualitative, as well as quantitative study, it was not the primary aim of the data collection in this research. Instead, it was more important to obtain a diverse range of perspectives from companies that play different roles within the development and construction supply chains of OSW farms. This is to gain an in-depth understanding of the feasibility of the systemic analysis for the potential of supply chain wide integration. In addition, ensuring diversity of perspectives allows to reduce researcher potential biases by being open to alternative points of view and thereby increasing reliability of findings (Brennan et al., 2015). This study was able to reach this diversity by performing interviews with participants whose companies represent different roles within the OSW supply chain, and by interviewing company representatives in senior positions with extensive experience in the OSW industry. The following section provides more details on the participants of this research.

4.5 Description of Research Participants

Table 4.3 provides details of the participants who have taken part in formal interviews for this research. It lists the participants' job roles, the types of companies they represent, and company or participant descriptions (given that two participants were involved in a personal capacity). For confidentiality and anonymity, neither the company names nor the names of participants are given in this research.

Participants' Job Roles	Company Type	Company/Participant Description
Senior Supply Chain Development Manager (1); Project Manager (2)	Developer	One of Northern Europe's leading energy groups. Develops, constructs, and operates OSW farms, bioenergy plants, innovative waste-to-energy solutions, and provides smart energy products to customers.
Project Manager, Director	Personal capacity	Project managing the development and construction of OSW farms in the UK.
Chief Technology Officer	Subsea cables manufacturer	Manufacturer, designer, and engineering company of subsea power cables, production umbilicals, intervention workover control systems and end termination and accessories (predominantly inter-array cables).
Senior Account Manager/Sales Manager	High voltage cable manufacturer	Turnkey AC/DC cable systems provider (predominantly export cables).
Commissioning Project Manager	Wind turbine manufacturer	Manufacturer, seller, installer, and servicer of wind turbines.
Regional Manager, UK	Offshore turbines and foundations installer	A market leader of the transportation and installation of OSW farms, offering integrated installation and service solutions for the OSW industry (vessels operator).

Participants' Job Roles	Company Type	Company/Participant Description
Corporate Projects Manager	Subsea cables installer	Company specialising in the design, route planning, installation, trenching, and termination of inter-array cables, export and interlink cables, and HVAC & HVDC interconnector cables (vessels operator).
Sales Engineer	Subsea cables protection manufacturer	Market leading provider of subsea cable, umbilical, and flexible pipe protection systems.
Business Development Manager	Secondary steel fabricator	Secondary steelwork component manufacturer, such as J-tubes, boat landings, anode cages, platforms, ladders, secondary steel, and other items.
Director, Business Development	Offshore substations contractor	International project engineering company offering full turnkey engineering, procurement, construction, and installation of offshore substations within the OSW market.
Project Manager	Onshore substations contractor	International infrastructure group. Develops, finances, and maintains various infrastructure assets.
Principal Acoustic Consultant	Acoustic advice and measurement services provider	Scientific and engineering consultancy offering specialist consultancy services, specialising in underwater noise modelling and surveying.
Geoservices Director	Archaeological and heritage services provider	Market leader in the provision of quality marine archaeological and cultural heritage services.
CEO and Chairman	Business development organisation	Business development, membership organisation. Driving force in the development of the marine and OSW sectors in the Humber region and beyond.
Senior Originator, Sales and Originations Business Area Markets	Personal capacity	Financial adviser, currently focusing on the Power Purchase Agreement market (PPA).

Table 4.3: Description of study participants

4.6 Primary Data Collection Approach

In order to hear the representatives about SCI's potential within the system in focus, semi-structured interviews were employed as the primary data collection means. Interviews can be categorised into three main types: structured interviews, semi-structured interviews, and unstructured or in-depth interviews (Bryman and Bell, 2015). Structured interviews are similar to questionnaires, and use questionnaires to collect quantifiable data; these are sometimes referred to as quantitative research interviews. On the other hand, semi-structured and in-depth interviews are often referred to as qualitative research interviews.

The difference between semi-structured and in-depth interviews is that semi-structured interviews involve a list of interview questions regarding specific themes to be addressed. Bryman and Bell (2015) call this list of questions an interview guide. In comparison, an in-depth or unstructured interview is unlikely to use an interview guide because these types of interviews often take the form of a conversation, and may only include one question to be asked. In-depth interviews are therefore more informal, whereas semi-structured interviews have a greater structure and more formality. However, the reason they are known as semi-structured rather than structured interviews is because they allow for some degree of flexibility given that the flow of interview questions is flexible. This means that some questions can be amended, changed, or omitted depending on the interview context. This structure, and the flexibility of interview questions, was necessary for this research given the diversity of the research participants. Therefore, semi-structured interviews were chosen as the primary means of data collection.

4.6.1 Interview guide development

A semi-structured interview guide was developed by combining themes related to SCI, which were previously identified in the literature, as well as themes related to the VSM, specifically the five systems that constitute the VSM. Both sets of themes were placed together to create the interview guide; an example of which is available in Appendix C. It is important to note, however, that some of the questions in the copy of the interview guide needed to be revised before each interview to make them relevant to the participants' backgrounds, which varied from manufacturing and services to project management backgrounds.

Table 4.4 shows the themes related to SCI that were considered in the development of the interview guide, including the rationale behind these themes as discussed in the literature. Based on the previously reviewed literature, five key themes were identified as important facilitators of SCI: relationship type, relationship scope, relationship management, value drivers/order winners, and information flow. These five themes were further broken down into sub-themes.

In terms of the type of relationship, the literature has highlighted partnerships and subsequent long-term relationships as important aspects that facilitate integration. Therefore, partnerships and long-term relationships were included as important sub-themes. In terms of the scope of the relationship, this study considered only external business-to-business relationships and the extent to which all supply chain partners are important to the creation of an integrated supply chain. This is because the literature has clearly identified that not all supply chain partners play an equal role (Cox, 2009). In terms of relationship management, both formal arrangements, such as contracts, standards, and regulations, as well as informal arrangements, such as trust building through various initiatives, were highlighted as important SCI facilitators and were therefore included as sub-themes in this research. With regards to value drivers/order winners, this study has taken into consideration the extent to which OSW industry players share the same value drivers when participating in particular OSW supply chains. This study has considered value drivers like cost, time, and quality and the extent of their importance in the OSW industry. According to Venkataraman (2007), shared value drivers help to align supply chains towards meeting the same goal, thus helping to achieve a more integrated supply chain. Finally, with regards to information flow, this study considered the extent and means of information sharing amongst supply chain participants as it plays an important role in creating a more integrated supply chain (Frohlich and Westbrook, 2001).

Interview questions were formed around these themes, which acted as checkpoints to explore the nature of the SCI that exists within the OSW industry, specifically during the development and construction phases of wind farms. Nevertheless, the questions were open enough to allow themes that had not been previously considered to emerge from conversations.

Supply Chain Integration Themes		
Theme	**Sub-theme**	**Rationale based on the literature**
Relationship type	Partnerships	A partnership type of relationship arrangement is considered to form the basis of SCI (Sadler, 2007).
	Long-term	Long-term alliances offer an opportunity for continuous improvement and learning throughout the supply chain (Egan, 1998).
Relationship scope	External relationships	Construction involves many one-off transactions, meaning that forming longer-term relationships with all supply chain participants would not make sense (Cox, 2009). Not all supply chain partners may benefit from SCI to the same degree (Evans and Danks, 2002). SCI and collaborative business relationships may not be appropriate for all players in a supply chain all of the time (Ireland, 2004).
Relationship management	Formal	Contractual and relational governance mechanisms supported by standards may help to achieve collaboration in time-finite project constructions (Chakkol et al., 2018).

	Informal	Contractual coordination alone does not ensure enhanced project delivery, it needs to be complemented with procedural coordination (Lavikka et al. 2015). This often includes things such as shared project goals, collaborative decision making, inter-organisational meetings, socialisation of partners, and trust building (Caldwell et al., 2009).
Value drivers/order winners	Shared value drivers	Shared values or order winners as expected by the customer helps to align supply chains to customer needs (Venkataraman, 2007; Sadler, 2007).
Information flow	Information sharing	A shared EDI helps to integrate supply chain operations (Frohlich and Westbrook, 2001).

Table 4.4: Interview themes regarding SCI (Author)

Since this study implies the use of the VSM analysis, it was important to include themes related to the VSM in order to allow for a subsequent analysis of SCI's potential. Table 4.5 identifies the themes that were created in relation to the five systems of the VSM, along with a description of each.

Viable System Model Themes		
Systems	**Theme**	**Description**
One	Primary activities	Primary activities or tasks of an organisation in relation to the OSW development and construction supply chain.
Two	Order/task fulfilment procedure. Communication. Standards. Conflict/issues management	The process and means of order/task management by different organisations within the system in focus. Day-to-day communication process. Use of standards.
Three	Contractual arrangements. Change management	Affiliation among supply chain members. Contractual relationship management. Ease or difficulties of the change management of original orders or delivery schedules.
Three*	Inspections/Auditing formal and/or informal	Customer inspections or auditing instances of organisations within the system in focus.
Four	Adaptability to changes in the wider OSW environment	Impact of changing OSW environment on supplier abilities to adapt to these changes.
Five	Developers' roles as ultimate decision makers	Developers' roles as the ultimate decision makers within the OSW supply chain in relation to SCI.

Table 4.5: Interview themes of the VSM (Author)

System One (S1), concerns the operations of the system in focus. This study considered the roles of organisations, represented by the participants, within system in focus as S1. System Two (S2), is considered as being a coordination mechanism of S1. This study has taken into account things such as customer order/tasks fulfilment procedures, day-to-day communication amongst supply chain members, conflict/issue management procedures, and the use of ISO standards or similar guidelines. System Three (S3), is regarded as a day-to-day management system. This study considered things such as contractual arrangements among supply chain members, and the management of change related to the original orders of customers. S3*, is a subsystem of S3 and can be regarded as being an informal auditing system. This study was interested to find out about existing formal and informal customer inspections and auditing procedures experienced by the participants. System Four (S4), referred to as an outlook to the outside environment. It can also be referred to as system's adaptability mechanisms to the competitive market forces. This study considered the adaptability of each organisation represented by the participants within the system in focus to changes in the OSW environment, such as technological, political, social, legal, and environmental changes. System Five (S5), is the ultimate authority over any viable system of interest. This study explored the roles of developers in making their supply chains more integrated.

The interview guide was piloted and refined following discussions with three of the OSW industry supply chain players who initially raised a concern about potential confidentiality issues that some of the questions may have raised, as mentioned above in Section 4.3. The resultant interview guide was then further reviewed before and after each interview to address any comments or suggestions. For example, the definition of SCI used in this study was included to facilitate a discussion of the way participants understand the term. In addition, question 19 of the interview guide concerning other industry sector examples that could benefit the OSW industry was added as the result of a suggestion by some of the study participants. This progressive trialling, as Gillham (2000) phrased it, allowed for a more engaged approach towards the interview process.

4.6.2 Additional sources of data

In case study research interviews are considered to provide essential sources of evidence because they allow a researcher to gain in-depth insights about a phenomenon through guided conversations. What is more, there is also the possibility to ask additional questions or to 'probe' for clarification (Yin, 2014). However, interviews are not the only sources of evidence that could be used in case studies, or in qualitative research more generally. According to Yin (2014), other sources of evidence might include documents, archival records, observations, and physical artefacts. In addition to these, photographs, videos, and films could form data sources depending on the informative capacity of these data sources and the study's objectives.

The use of multiple sources of evidence in one study is commonly referred to as data triangulation (Bryman and Bell, 2015). The benefit of triangulation in qualitative case studies is commonly associated with the process of accessing multiple ways the phenomenon can be viewed from to seek clarification about meanings and interpretations about it (Stake, 2005). In addition, Denzin and Lincoln (2000) understand triangulation in a more general sense, particularly in terms of helping to secure an in-depth understanding of the phenomenon in question. Therefore, the use of multiple sources of evidence and other triangulation techniques could enhance the quality of case study research (Yin, 2014). Figure 4.5 below describes all of the data sources that have been employed in this research:

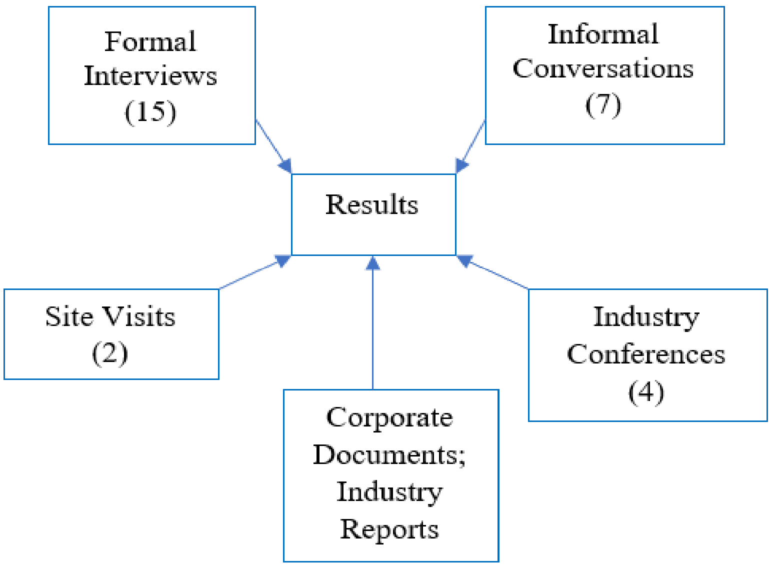

Figure 4.5: Summary of data sources used in this research

In addition to formal interviews, which were the key source of primary data, this study involved a number of informal conversations with different OSW industry players during the initial stages of the research design. These conversations are considered as being informal because they did not involve the use of an interview guide. Nonetheless, the primary objective of the conversations was to seek opinions and views on SCI. These conversations not only helped to validate the study's interest in this subject area, but also helped to develop the subsequent research design.

Additional sources of evidence have also included participation in various industry conferences, including the 'Global Offshore Wind 2018' conference in Manchester, which was organised by RenewableUK; a leading renewable energy trade association in the UK. The 'Offshore Wind Connections 2018' in Hull, organised by the Team Humber Marine Alliance; a local trade association and 'powerhouse' of businesses working in the marine and offshore sectors. The 'Wind Europe Conference and Exhibition 2017' in Amsterdam, organised by Wind Europe; an association for wind energy in Europe, as well as the 'Offshore Wind Energy 2017' in London, which was co-organised by Wind Europe and RenewableUK. Participation in these conferences involved active listening and note-taking, as well as observing industry players in action. This shares some similarities with participant-observation, which is described as a qualitative research method where a researcher observes research participants and engages in their community (Bryman and Bell, 2015). Industry conferences also served as a platform to make initial contact with potential research participants.

Alternative important sources of evidence included corporate documents and industry reports, some of which were shared by the research participants. Others were found through the internet or via OSW industry related organisations, such as Wind Europe. Furthermore, the primary research involved two site visits: a visit to the operations base of a wind farms located off the UK's East coast and a visit to the ongoing construction of an onshore substation at a different wind farm also located off the UK's East coast. These were important sources of evidence that helped to gain a better understanding of supply chain processes in the OSW, whilst also providing the opportunity to observe examples of SCI based on the day-to-day operations of particular companies.

4.7 Research Ethics

Research ethics approval had to be sought from the Research Ethics Committee at the University of Hull's Faculty of Business, Law and Politics before the data collection process could commence. In accordance with the ethical principles outlined in the University Code of Practice and Faculty Ethics Procedures, all research participants had to formally agree to participate in this research by signing an informed consent form. The form also asked for permission to record conversations using an audio recorder. The informed consent is available to view in Appendix D.

All participants were offered the right to withdraw from the study at any time without consequence. Further to this, the study ensured the anonymity of participants and the confidentiality of information by not sharing interview data with other parties. Participants were also informed of their right to decline to answer any of the questions during the interview. Following the interview, all participants were offered to review and comment upon the interview transcript to ensure the accuracy of the conversation. This also helped the researcher to validate their own understanding of the information. Bearing confidentiality in mind, all of the information shared by the participants was processed only by the researcher of this study.

4.8 Data Analysis Strategy

As mentioned by Sergi and Hallin (2011), qualitative research textbooks often form an impression of a linear sequence of the key research processes, such as thinking, reading, writing, collecting data, and analysis, whereas in practice it is more comparable to an iterative process which goes ‘back and forth’ between these processes. Therefore, it is often advised that qualitative research data analysis should be concurrent with data collection (Gibbs, 2012; Miles et al., 2014). This has also been the case in this research, where information has continuously been gathered by taking notes, keeping a log of events, and recording memos, which helped to generate and refine research ideas throughout the process. However, a more formal strategy was required to analyse the collected data. This section therefore explains the data analysis strategy employed by this study.

There are diverse possible data sources in qualitative research, such as a variety of textual data, visual data, and verbal data obtained in a variety of ways, including interviews, observations, video recordings, documents, images, audio recordings, and research diaries, amongst others. This suggests that there is also a variety of analytic approaches to analysing the data, including the grounded theory approach, which Bryman and Bell (2015) argue is the most widely used analytical strategy for analysing qualitative data. The process involves data coding or a categorisation technique where data is broken down into component parts and compared, ideally resulting in the development of a new theory or new concepts (Glaser and Strauss, 2006). Another data analysis technique includes aspects of phenomenology, sometimes referred to as the ‘science’ of phenomena, where ‘the things themselves’ and how we perceive and conceive of them are of concern. Phenomenology helps to understand a person’s ‘lived experiences’, therefore a phenomenological analysis take place in the here-and-now, rather than on recorded data (Eberle, 2014). Other strategies may include narrative approaches, which are concerned with people's stories about their lives. Though, this places the emphasis on a full account of stories for analysis, rather than fragmenting them through coding or categorisation processes (Esin et al., 2014). There is also a discourse analysis, where language itself becomes of interest to the researcher (Willig, 2014). Furthermore, a content analysis is a quantitative approach that provides a systematic process of describing the meaning of qualitative data using a coding frame (Schreier, 2014). Finally, a thematic analysis can be understood as a process of identifying themes and patterns in data that help to explain a research phenomenon (Willig, 2014).

According to Ellram (1996), data analysis processes in case study research largely depend on the type of data collected; whether qualitative or quantitative. In addition, it is guided by the particular method used to gather information; surveys or interviews, for example (Yin, 2014). Considering that this research is qualitative in nature, including the use of interviews and observations, the data analysis process also utilises a qualitative data analysis technique.

Based on the aforementioned analytic approaches to analysing qualitative data, this study employed a thematic analysis owing to its interest in exploring theory-related themes, as well as any emergent themes related to SCI and the VSM. A thematic analysis is often described as a general approach to analysing qualitative data (Bryman and Bell, 2015). For this reason, authors such as Boyatzis (1998) consider a thematic analysis as a tool that can be used across different methods, rather than as a specific method in its own right. To the contrary, Braun and Clarke (2006) argue that it should be considered as a method in its own right and, more specifically, that it should be viewed as a foundational method for qualitative analysis. Braun and Clarke (2006) go on to say that a thematic analysis should be the first qualitative method of analysis that researchers learn because it provides a range of core skills that can be useful for conducting other forms of qualitative analysis. The authors note that the main benefit of a thematic analysis is its flexibility, especially because it is not tied to any specific research philosophy and can be used in either deductive, inductive, or abductive approaches to study.

In addition to flexibility, a thematic analysis offers a systematic and logical way to analyse data (Aronson, 1995). In this research, the thematic analysis involved searching for existing themes related to the VSM and SCI, as detailed in Tables 4.4 and 4.5 detailing interviews and related data sources. These themes were then explored and expanded upon using the emergent information derived from primary sources. In addition to the thematic analysis, the data analysis process of this research involved the use of the VSM, which was in accordance with step three of the methodology to support self-transformation (as discussed in Section 4.3). Together, these approaches helped to derive rich descriptions and explanations related to the study's objectives, which will be discussed in the results and findings Chapter Five.

4.8.1 Data analysis process

There is general agreement amongst qualitative researchers that the process of qualitative data analysis involves two aspects: data handling and subsequent interpretation (Gibbs, 2012; Mason, 2002). To prepare the data for analysis in this research, all interviews were audio recorded with permission from the research participants. All of the interviews were then transcribed by converting audio recordings into text and producing verbatim accounts of the conversations. According to Gibbs (2012), text remains the most common form of qualitative data used in analysis as it makes it more convenient to sort, retrieve, index, and handle data. Transcripts were prepared following each interview and were offered for review to each participant. Any interesting ideas or thoughts that emerged during each transcription process were recorded in a separate file entitled 'preliminary thoughts and results'. Keeping records of these notes was an important aspect of the data analysis process as it helped the researcher to keep track of their thought processes following each interview. This information was also used to help interpret the results. The use of notes and memos during the data analysis process is sometimes referred to as the use of analytical aids (Miles et al., 2014).

After all of the interviews had been transcribed and reviewed by the research participants, they were printed for familiarisation along with their content and subsequent analysis. As suggested by Yin (2014), a good starting point in data analysis is to 'play' with data first. The initial step of this research involved reading through several transcripts for familiarisation purposes and to help establish a more specific form or technique of analysis. The familiarisation process also helped the researcher to realise that the entire data analysis process would need to be based on a 'pen and paper' approach, rather than using computer-assisted tools such as NVivo software; a qualitative analysis computer software package.

Although it is recognised for its ability to assist with project management, data organisation, and with providing a structured approach to data analysis (Gibbs, 2012), it can be concluded that the use of NVivo for analysis in this research would provide little benefit. A key advantage of NVivo is that it can help to keep information in one place in a digital format. In terms of data analysis, though, it should be treated as a blank page because the process of data analysis would still be the same as on paper, guided by specific analytic procedures. As Gibbs (2012) and Yin (2014) warn, computer assisted tools will not perform any thinking or analyses on their own; these would still need to be performed by the researcher. The process of identifying themes and patterns in the interview data using NVivo appears to be fragmented as it requires grouping and categorising data sets into nodes or cases, thus making it difficult to maintain the context of an interview conversation, which was important in this research. In addition, the use of the VSM diagram in drawing form would not be possible using NVivo. Therefore, it was not used in this research. Nevertheless, it is recognised that NVivo may be helpful in locating and matching words and phrases with codes or themes defined by the researcher, as well as counting their occurrences using the 'Queries' function.

Following the familiarisation process, this research broadly applied two steps: a within-case analysis and cross-case analysis (Eisenhardt, 1989). The purpose of a within-case analysis is to become familiar with each case as an individual entity, which allows for unique patterns pertaining to each case to emerge. This exercise then allows for comparisons to be made across cases. Given that this case study research design is embedded, meaning that the OSW supply chain is treated as a unit of analysis embedded within a single case study of the UK OSW industry, a within-case analysis was applied to each interview. The reason is because each participant represented a different organisation of the supply chain in focus or the system in focus, where different organisations play different roles in terms of their scope of work in relation to OSW farm projects. Therefore, each interview was first analysed as an individual 'case'. This process also involved aggregating all of the relevant information from other data sources and assigning it to each interview.

The next step of a within-case analysis involved analysing each interview using the VSM diagram for VSM diagnostic purposes, as well as themes and pattern matching related to SCI. This included a pen and paper approach by drawing a VSM diagram for every interview and scrutinising interview conversations for any themes or patterns related to the VSM and SCI. The focus was placed on aspects that may facilitate SCI and on those that may constrain integration. Any identified issues were identified as diagnostic points within the VSM diagram and highlighted in red, whereas anything that was considered as being positive was highlighted in green. Picture, providing example, of how this process has been performed is shown in Appendix E.

This process of identifying interesting aspects of the data relating to previously generated themes or, alternatively, if the process is more inductive in nature, identifying aspects of the data that may form the basis for themes or patterns, is sometimes described as a coding process (Bryman and Bell, 2015). Some authors use the terms ‘codes’, ‘themes’, ‘indexes’, and ‘categories’ interchangeably to describe the process of assigning names to pieces of interview text that represent the same meaning (Braun and Clarke, 2006; Gibbs, 2012). In comparison, others prefer to view these terms as separate components (Saldaña, 2016). This study follows Saldaña (2016) by understanding a ‘theme’ as something broader than a code, index, or category. However, it is understood that the process of linking ideas to pieces of text could be the same in relation to all of these terms.

After the first step of the within-case analysis was applied to individual interviews, the second step involved searching for patterns across all of the interviews, which shares similarities to a cross-case analysis. The main emphasis of a cross-case analysis is to look for similarities and differences across cases by examining data in different ways (Eisenhardt, 1989). This step also involved comparing, contrasting, and consolidating answers on a question-by-question basis to identify any patterns and relationships across the interview data. The resultant findings were placed together and interpreted in relation to the study’s main research objectives and research questions. The following chapters will provide details of the results and findings of this research, in addition to a subsequent discussion.

Chapter Five

Research Results and Findings

5.1 Introduction

This chapter will present the results and findings of the data analysis, which involved themes and pattern matching as the primary analytic approach. This study followed an embedded case study research design focusing on the D&C and the C&C phases of the UK OSW supply chain as the unit of analysis or the system in focus (Yin, 2014; Espinosa and Walker, 2017). The following results present the aggregated findings from interviews with the study participants. The results are broadly divided into three main parts, as shown in Figure 5.1. The first part provides further details on the participants who have taken part in this research and formed the final system in focus. The second part presents the findings of SCI related themes, and the third part presents the findings related to the VSM analysis. The results of all analyses will be used to propose SCI strategies, which are based on the VSM framework outlined in Chapter Six.

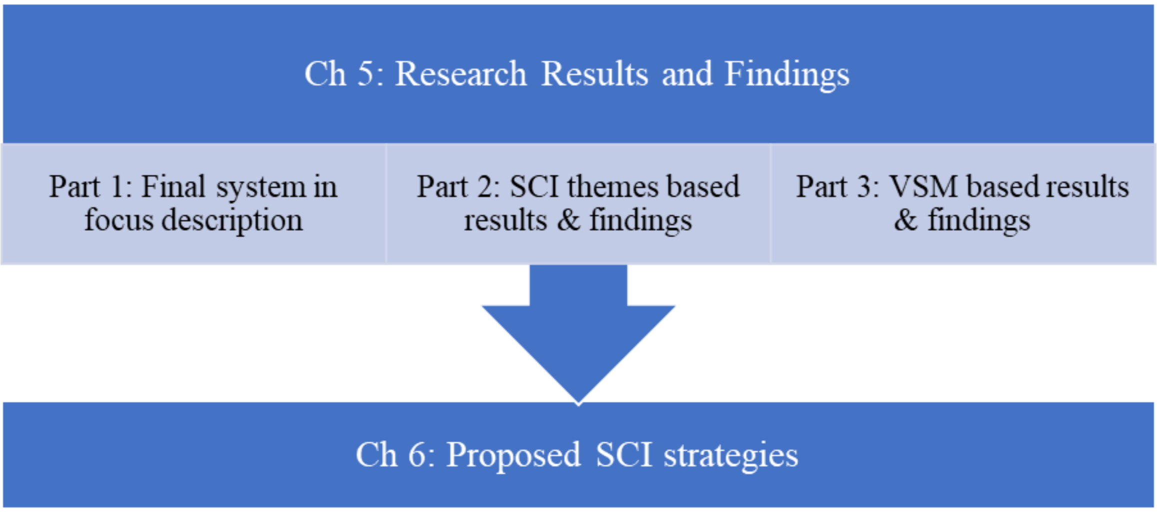

Figure 5.1: Outline of Chapters Five and Six

Part One

5.2 The Final System in Focus Description

As part of the research design process, this study defined the initial system in focus shown in Figure 4.4, discussed in Sections 4.3 and 4.3.1. The process of defining the system in focus included TASCOI analysis (Table 4.1) and recursive analysis. These analyses helped to delineate boundaries of the system in focus for the research by identifying its primary activities or value adding activities and by identifying the main actors performing those activities. The system in focus, as shown in Figure 4.4, served as the sampling frame for the selection of study participants. The examples of company types considered in this research are provided in Table 4.2. Based on this sampling frame, 15 companies representing different primary activities of the D&C and C&C phases of the OSW supply chain have taken part in this research, thus forming the final system in focus and final unit of analysis, as shown in Figure 5.2 below.

There were 16 interviewees (two participants represented one company), which were purposively selected from each type of company that forms a primary activity of the system in focus. Each interviewee was coded using different letters. As mentioned above, this study was not examining a particular supply chain of an OSW farm project because such information was considered to be confidential. Instead, this study invited research participants, active in the OSW industry, to discuss their experiences of working on different OSW projects in the UK to understand their experiences in relation to the existing SCI conditions. The research design of this study also sought to include varied and diverse perspectives to ensure a rich analysis and greater understanding of SCI's nature and potential.

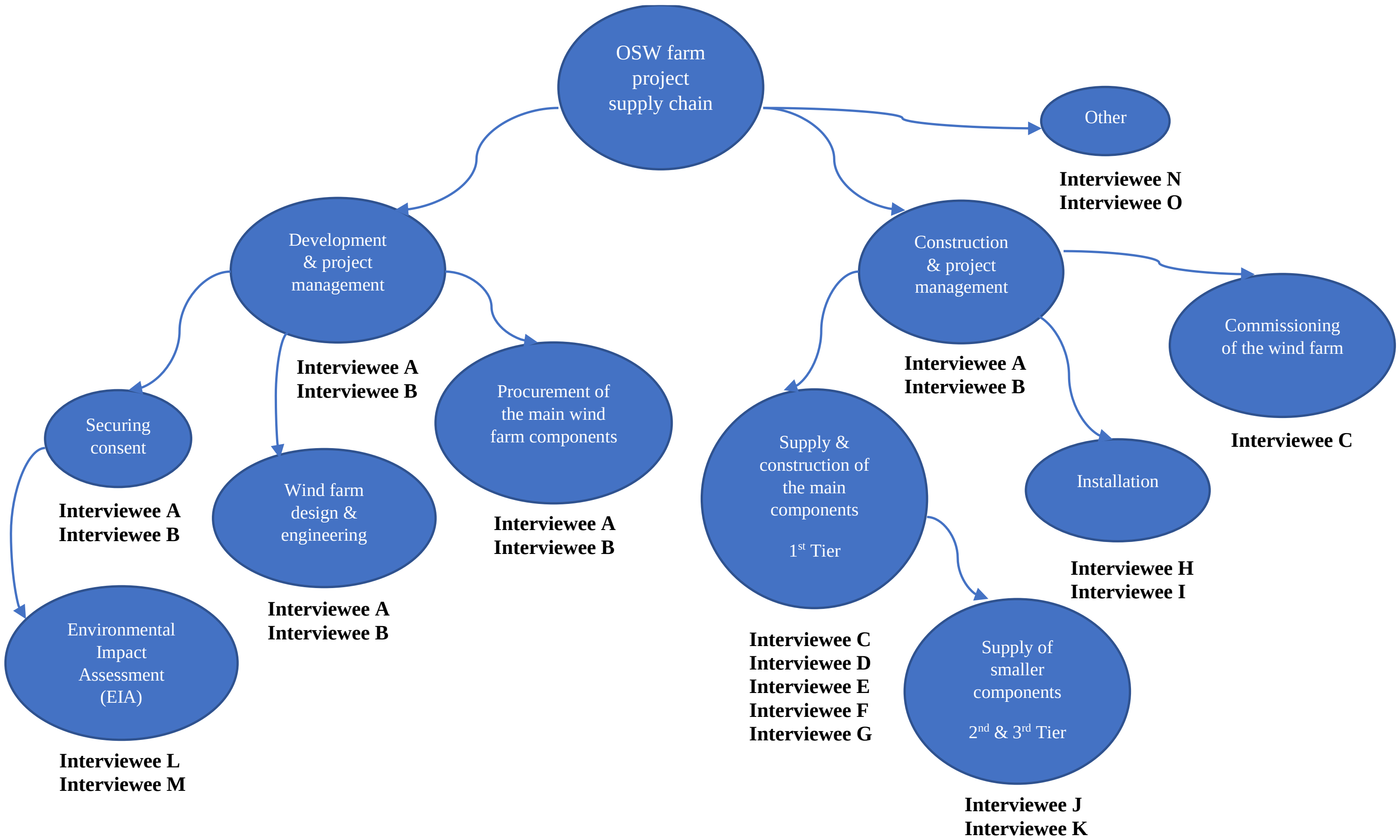

Figure 5.2: The final system in focus (Author)

Table 5.1 provides a summary of the interviewees' backgrounds and company roles in the system in focus, represented by each interviewee. More details about each participants' job roles and the company descriptions were provided in Table 4.3 (Section 4.5).

Interviewees' Backgrounds		
Interviewees	**Company type**	**Company role in the system in focus**
Interviewee A (two participants)	OSW farms developer	Wind farm development and project management. This includes securing consent for development through an EIA. Develop initial design of the wind farm (FEED), secure a grid agreement. Procurement of components, securing suppliers/contractors of components. Project management of onshore construction activities. Project management of offshore construction activities.
Interviewee B	OSW farm project director	Participated in a personal capacity but provided an overview of a role of the developer. Similar role as Interviewee A.
Interviewee C	Turbine manufacturer	Wind turbine assembly, installation, and commissioning.
Interviewee D	Power cables manufacturer (array)	Subsea power cables manufacturing and supply. Intra-array cables (connecting all wind turbines to offshore substations).
Interviewee E	Power cables manufacturer (export & array)	Subsea power cable manufacturing and supply. Export cables (connecting OSW farms to the grid by connecting offshore substations with onshore substations).
Interviewee F	Onshore substation contractor	Build and construct onshore substations for high-voltage equipment, which transforms the power received from wind farms to grid voltage.
Interviewee G	Offshore substation contractor	EPCI (Engineer, procure, construct, and install) contractor; offshore substations, including the steel structures that house necessary equipment for stabilising power generated by wind turbines for transmission of this power to shore.
Interviewee H	Installation services provider/vessels operator (turbines & foundations)	Collect turbine components or foundation components from the quayside, load them onto a vessel, and transport them to site. Using various equipment onboard a vessel, install them on-site.
Interviewee I	Installation services provider/vessels operator (power cables)	Perform pre-installation surveys and Pre-Lay Grapnel Run (PLGR). Collect cable from cable manufacturers and install (trench or post-lay burial).
Interviewee J	Cable protection manufacturer	Cable protection manufacturing and supply. Support component providing protection to cables during cable installation processes and operations.
Interviewee K	Secondary steel fabricator	Secondary steel component fabrication to make part of primary steel components, like turbines, substations, and foundations. Such components may

		include boat landings, J-tubes, anode cages, platforms, ladders, and other items.
Interviewee L	EIA provider (underwater noise impact)	Providing specialist consultancy (modelling and measurement of underwater noise impact) services at different stages of OSW farm development; during the consent stage for the EIA and during offshore construction and the O&M phase.
Interviewee M	EIA provider (archaeological services)	Providing archaeological consultancy services at different stages of OSW farm development, including the scoping phase, and consenting through EIA during and after the construction phase.
Interviewee N	Business development & trade association	Provide OSW related information to interested businesses. Identifying opportunities for member organisations to take part in OSW. Various events organiser, for example, 'OSW Connections'.
Interviewee O	Financial adviser focusing on PPAs	Participated in a personal capacity, provided a perspective on working for the developers.

Table 5.1: Interviewees' backgrounds

It can be observed in Figure 5.2 that Interviewees A and B appear under several primary activities; this can be explained by their roles in the OSW industry. Interviewee A is one of the largest OSW developing companies in Europe, which is also active in the US and Taiwan. The general role of a developing company is to build OSW farms and, for this reason, developers are also often the owners and operators of wind farms (Thomsen, 2012). Developers' primary roles include development and project management. This involves various activities, such as securing consent for development through relevant regulatory authorities, environmental impact assessments of the proposed site, engineering and design of proposed wind farms, procurement of the main components, organisation of the supply chain or, in other words, inviting suppliers or contractors to supply necessary components and services for the project's execution, as well as project managing all activities related to the development and construction phases of the wind farm. Project management is often extended to include the O&M phase after wind farms have been built. Developers are typically private or public utility companies or a consortium of several companies. Interviewee B participated in a personal capacity but, in similarity to Interviewee A, Interviewee B's discussion was based on the perspective of a developing company. This was owing to Interviewee B's role as a director of an OSW farm project, which was under construction at the time of writing this thesis.

Since developing companies oversee OSW farm projects, the extent of their involvement in each primary activity largely depends on their project execution strategies and in-house capabilities. This means that the activities necessary to secure consent for development, such as the initial design of the wind farm, can be performed using in-house resources or can be outsourced to specialist consultancy companies. In relation to consent activities, which includes preparing an EIA that normally require specialist knowledge, EIAs are often performed by specialist consultancies. Two participants - Interviewees L and M provided a perspective related to EIA activities.

Other key players include suppliers or contractors of the main components of wind farms. This study considers these as first-tier suppliers/contractors. They include Interviewee C who works for a turbine manufacturer and Interviewee D who works for an array power cables manufacturer. Array cables, intra-array, or infield cables are cables that connect all wind turbines to offshore substations. Interviewee E works for an export power cables manufacturer. Export cables connect wind farms to the shore by connecting offshore substations with onshore substations. Interviewee F works for an onshore substation contractor and Interviewee G works for an offshore substation contractor. Interviewee C also provided a perspective on the wind farm commissioning process. Given that wind turbines form the main parts of wind farms, and can thus be considered as one of their main assets, turbine manufacturers oversee not only the manufacturing and assembly of turbines, but also turbine installation processes and their subsequent commissioning.

Various vessel operators provide installation services for the main components, such as wind turbines, foundations, offshore substations, and cables. Interviewees H and I provided their views from installation services perspective. In order to gain a more in-depth understanding of the OSW supply chain, it was important to include the perspectives of suppliers of smaller components, considered as second and third-tier suppliers. Interviewees J and K provided an overview from smaller suppliers' perspective.

In addition, this study involved Interviewees N and O who, owing to their experience in the industry, provided different perspectives on the overall OSW industry and its supply chain. Interviewee N represents a business development organisation active in the OSW and maritime industries. Interviewee N has also been involved in OSW since its inception in the UK's Humber region nearly ten years ago. Interviewee O participated in a personal capacity as a financial adviser with experience in the banking and finance sector working in Power Purchase Agreement (PPA) markets.

Part Two

5.3 Supply Chain Integration Themes-Based Results and Findings

5.3.1 Understanding the term 'SCI'

During visits to various OSW industry related conferences prior to and during this research, it was observed that SCI was often mentioned in relation to OSW. However, it was unclear what exactly was meant by SCI and whether this term was understood in the same way by different OSW industry players. Therefore, it was important to determine the participants' understanding of this term in order to see whether any of their perspectives shared commonalities. Table 5.2 below shows what this term means to each interviewee and provides evaluation of what kind of SCI these perspectives refer to, according to established view of SCI in the literature.

Understanding of the term 'Supply chain integration'		
Interviewee	**Perspective**	**Evaluation**
Interviewee A OSW farms developer	Use of strategic suppliers and creating a high trust environment. Project suppliers are called project partners.	External integration (with suppliers)
Interviewee B OSW farm project director	Involvement with supply chain companies at different stages like design, forward planning, building, and operating wind farms to ensure the most efficient and best outcome of the OSW project.	External integration (with suppliers)
Interviewee C Turbine manufacturer	Working closely with suppliers and subcontractors and the customers to achieve the goal that has been set out in the contract or in the KPIs, in a given time scale.	Internal and external integration (internal with own suppliers, subcontractors and external with customers)
Interviewee D Power cables manufacturer (array)	Forming and maintaining good relationships and interactions between contracting parties. For example, wind farm developers, installation contractors, and cable manufacturers, subcontractors, and cable manufacturers. SCI means that parties are aligned with the same purpose and work together for mutual benefit.	Internal and external integration (internal with own subcontractors and external with customers)
Interviewee E Power cables manufacturer (export)	Organisation of own procedures and processes to ensure the smooth production of cables. An example includes CPFR.	Internal integration (with own suppliers of raw materials to the point of automatic interaction).

Interviewee F Onshore substation contractor	Operates on three different levels: Level 1: own supply chain – working with own approved suppliers. Level 2: OSW client – working for client. Level 3: client's supply chain members – working alongside other supply chain members of the project.	Internal and external integration (internal with own suppliers and external with client and other supply chain members)
Interviewee G Offshore substation contractor	Involving potential/new suppliers with OSW development. A prerequisite is that potential suppliers understand OSW operations and the environment as they differ between onshore operations.	External integration (attracting potential suppliers)
Interviewee H Installation services provider/vessels operator (turbines & foundations)	Forming and maintaining a relationship with own supply chain and the client's supply chain members to optimise the delivery of own services or the client's project.	Internal and external integration (internal with own suppliers and subcontractors, and external with customers)
Interviewee I Installation services provider/vessels operator (power cables)	Particular parts of the country that can provide a wider range of services or operations for a particular project. Building on rather relatively smaller sizes to deliver bigger projects.	External integration (with local suppliers)
Interviewee J Cable protection manufacturer	Integrating own suppliers into the business. Getting suppliers on company approved supplier vendor lists to support internal business processes and supply of the product to customers.	Internal integration (with own suppliers)
Interviewee K Secondary steel fabricator	Integration of tier-one suppliers with tier-two and tier-three. In addition, becoming preferred supplier.	External integration (tier-one suppliers with lower-tier suppliers)
Interviewee L Environmental Impact Assessment provider (underwater noise impact)	Operating effectively between the other companies that Interviewee L's company has to coordinate with. Improved understanding of requirements between the client and supplier.	External integration (with other supply chain members and with client)
Interviewee M Environmental Impact Assessment provider (archaeological services)	The term SCI itself is a link between all of the different competencies or components of a supply chain and by integrating them resulting in a more efficient or cost-effective outcome.	External integration (of supply chain members)
Interviewee N Trade association and business development organisation	Making sure there are close relationships between organisations to successfully complete OSW projects. Understanding where everybody fits into the supply chain.	External integration (of supply chain members)
Interviewee O Financial adviser	Including both physical (component suppliers) and virtual aspects (external factors) of the supply chain.	External integration (of supply chain members)

Table 5.2: Summary perspectives of the term 'SCI'

The results show that the participants' understanding of 'SCI' varies. Whilst there is no right or wrong perspective, it can be seen that SCI means slightly different things to different people depending on their roles within the OSW supply chain. Participants' perspectives can be broadly divided into three categories: external integration, internal integration, and both internal and external integration.

To remind, according to logistics and SCM literature, external integration refers to the integration between a focal firm and its suppliers and/or customers (Wong et al., 2011). The responses of interviewees in this research have broadly referred to external integration as explained above, including examples from Interviewees A, B, C, D, F, and H. In addition to integration with suppliers and/or customers few more meanings of external integration emerged. For example, Interviewees F and L also referred to integration with other supply chain members of a project, thus highlighting the importance of coordination when working alongside other supply chain members on a project. Similar responses were given by Interviewees M, N, and O, who held more holistic perspectives by mentioning the integration of supply chain members. However, Interviewee O included another interesting aspect of SCI, which was that SCI should include both physical aspects, such as seeking the right suppliers of components, and virtual aspects. In terms of virtual aspects, Interviewee O explained how they refer to any external factors that can affect overall SCI. For example, changes in political conditions, changes in companies' internal policies, health and safety (H&S) changes, and human factors, amongst others.

More specific responses were given by Interviewees I and K. Interviewee K, given their role as a second or third-tier supplier within the system in focus, understandably talked about integration between tier-one suppliers/contractors and lower-tier suppliers. Interestingly, Interviewee I discussed group integration, where companies with different competencies in a specific geographical location may be grouped together to be able to provide a wider range of products and services for the OSW projects. A similar idea was raised by Interviewee N, who suggested that forming specialist partnerships could help smaller suppliers to get involved in the OSW industry. This idea led to a different understanding of external SCI from the participants, involving accessing the supply chain or attracting potential suppliers. Interviewees G, N, K, I, and J all referred to this idea.

Other understandings of SCI by the study participants referred specifically to internal SCI. Within logistics and SCM literature, internal SCI refers to the activities and processes within a firm, or inter-functional integration (Stevens, 1989; Cooper et al., 1997; Trkman et al., 2007; Chen et al., 2009). However, in this research internal SCI is used in reference to a firm's integration with its own suppliers or subcontractors. This is in order to differentiate between the perspectives related to firms' own supply chains and those related to OSW project supply chains, of which the participants are a part. Interviewees E and J talked exclusively about their firms' supply chains in relation to the term SCI. Interviewee E provided an example of how they organised their processes and procedures to make their manufacturing "as smooth as possible" (Interviewee E). In their case, SCI refers to framework agreements with raw material suppliers across various parts of Europe. A framework agreement can be understood as an agreement with suppliers to establish the terms governing contracts, which may be awarded during the period of an agreement. It can be broadly divided into two types: a framework contract and a framework agreement. A framework contract involves an up-front payment by the buying organisation to the supplier in order to create a contract based on the supplier's terms and conditions. This means that a framework contract commits a company to buying a certain volume of particular goods or services from the supplier over a specified period. A framework agreement is similar to a framework contract, but it does not involve an up-front payment, thus making it an agreement between two parties for the supply of an unspecified amount of product or service over a specified period (CIPS, n.d). Framework agreements may be referred to as 'period contracts', 'trade agreements', 'frames', and 'memorandums of understanding'.

Interviewee E's raw material suppliers can be notified once stock levels reach a certain level and once they know when to supply more raw materials to interviewee E. This practice is known as CPFR. CPFR is defined as "*a business practice that combines the intelligence of multiple partners in the planning and fulfilment of customer demand*" (defined by VICS – The Voluntary Interindustry Commerce Standards Association, cited in Chopra and Meindl, 2016).

In the case of Interviewee J, SCI means integrating their suppliers into the business or seeking suppliers from an approved supplier vendor list in order to improve their business processes and supply of products to customers. For this reason, Interviewee J employed a head of supply to align suppliers and help deliver products at the expected price within the OSW industry.

A combined understanding of internal and external SCI were provided by Interviewees C, D, F, and H, who discussed working closely with their own suppliers, subcontractors, and customers, as well as discussing the importance of good relationships and interactions between contracting parties. Interviewee F provided the most detailed understanding of SCI, which summarised the different perspectives raised by other participants of this research. Interviewee F identified three different levels of possible SCI within the context of a project-based supply chain:

- First level: Own supply chain; working with own approved suppliers.
- Second level: Working with a client (in the case of Interviewee F, this involved OSW farm developers).
- Third level: Working alongside a client's other supply chain members.

Interviewee D provided the following definition of SCI, which is close to the definition supported by this research:

> "*Supply chain integration involves those parties that are aligned with the same purpose and who seek to work together for mutual benefit*" (Interviewee D).

Interviewee D's response can be compared to the definition of SCI advocated by this research:

> *"…supply chain integration is the alignment, linkage and cooperation of people, processes, information, knowledge, and strategies across the supply chain between all points of contact and influence to facilitate the efficient and effective flows of material, money, information, and knowledge in response to customer needs*" (Stevens and Johnson, 2016: 22).

Whilst different participants provided slightly different understandings of SCI, all answers appeared to accord with definitions of SCI cited in the literature. More specifically, that SCI refers to alignment of different supply chain parties, it involves collaboration or good working relationships among supply chain parties and that it can refer to different types of SCI. Those include internal integration, external integration, and the combination of both. More importantly, however, participants' answers relate integration to likely performance improvements in the supply chain. This is closely related to an established perspective held in the literature that better SCI leads to improved supply chain performance (Gimenez et al., 2012).

5.3.2 Attitudes towards SCI

The concept of SCM includes coordination and collaboration between channel partners, such as suppliers, intermediaries, third party services providers, and customers (Grant, 2012). Hence, SCI is often viewed as being a key part of a well-managed supply chain (Pagell, 2004). The literature therefore views SCI largely positively (Wong et al., 2011). A positive view is also held by this study. However, the literature on project-based supply chains has argued that partnerships and long-term relationships, as implied by SCI, may not be relevant in all phases of the project supply chain (Cox, 2009). Therefore, this study has tried to understand the overall sentiments of the research participants in relation to SCI by evaluating their responses to understand if the same positive outlook on SCI is maintained by the interviewees.

The results show that all interviewees generally acknowledged the importance of increased collaborative relationships within the supply chain and, due to the uniqueness of each OSW project, integration is viewed by some as a necessity. For example, Interviewee A, viewed supply chain as a competitive advantage and its integration as a strategy for interface management in areas of high importance to a project's success. In the context of OSW, 'interface' refers to "*the point where one contract party takes over or hands over parts of or the entire work scope to either another contractor or to the wind farm owner*" (Thomsen, 2012: 109). It can also be described as the point where responsibilities for products or services are passed from one contractor or work package to another (Thomsen, 2012). Examples of work packages may include onshore storage and preassembly, offshore installation, onshore installation, and commissioning tasks. Those who are responsible for overseeing these work packages will largely depend on the interface management strategy employed by the developers. Developers have an option to either contract this responsibility to an Engineer, Procure, Construct (EPC) or Engineer, Procure, Construct, Install (EPCI) contractor, or manage it themselves. Interviewee A tends to manage different interfaces themselves, which is considered as being an extreme and uncommon approach within the OSW sector. Interviewee A justified their reasons as follows:

> "*By managing the interfaces, we can optimise programme and avoid multiple layers of risk contingencies on the project*" (Interviewee A).

Interviewee A emphasises the development of collaborative working environments amongst supply chain partners. Some examples include calling suppliers and contracting partners or project partners, especially as Interviewee A recognised that all parties succeed or fail depending on the success of a project. Emphasis is also placed on developing 'high trust' environments and creating trusting, open relationships. This is explained as follows:

> "*We need our suppliers to be successful; if they're not successful we're not successful. So, we have a vested interest in helping them fix issues or develop them, and that's our general attitude to things*" (Interviewee A).

A similar attitude towards working with suppliers was made evident by Interviewee C. Creating a collaborative working environment through partnerships is amongst the company's Interviewee C works for main objectives, or so called 'creeds', towards the sustainable growth of the company and industry. It was mentioned by Interviewee C that once relationships are established between first-tier suppliers/contractors and lower-tier suppliers, it is "*hard to break that bond*" (Interviewee C). An interesting explanation was provided by Interviewee G who described how OSW farms cannot be operated like onshore factories, and so closer relationships between suppliers and customers are needed to better manage any issues that may occur.

Interviewee F has experienced partnership development with their OSW client, which resulted in a range of improvements to subsequent projects that they have been involved in. For this reason, Interviewee F was confident about the positive impact of forming a more integrated supply chain. Interviewee B took the supply chain to be essential and characterised it as an overly complex issue that is important to get right. Close interaction with suppliers was also perceived to be important for a project's success. Interviewee B explained this as follows:

> "*[…] if you don't get involved with supply chain companies, then you will not end up with the best offshore wind farm that could be built at the time*" (Interviewee B).

Whilst the general sentiment of participants towards SCI was positive, there was some degree of scepticism and doubt towards experiencing more integration in practice, or towards the need for integration altogether. For example, Interviewee E explained how every project is treated in isolation and that the relationships created during one project do not necessarily continue into the next project. For this reason, Interviewee E believed that supply chain collaboration and integration are more talked about than experienced in practice:

> "*It is a very overused term and in practice I would say we are a bunch of suppliers working on the same projects in parallel, rather than necessarily collaborating*" (Interviewee E).

In similarity to Interviewee E, Interviewee J described how SCI is often mentioned in industry talks, and that the industry is aware that SCI may improve issues related to OSW costs. For example, reducing the LCOE (explained in Section 2.2), if addressed collectively. Though, Interviewee J also mentioned the following:

> *"[…] everyone's kind of aware of what it takes and the improvements that can be made, but I just don't see it happening physically. I don't see that kind of integration level engaged. I don't see anyone kind of driving that at the moment*" (Interviewee J).

There has also been some agreement amongst participants that SCI is something which can be improved. For example, Interviewee D has experienced many transactional relationships in their scope of work and described these relationships as being wasteful on resources. Hence, a more partnership-based approach would be welcomed by Interviewee D. A more integrated supply chain was also viewed as having the potential for achieving the commonality and standardisation of product designs (Interviewee K). Furthermore, information sharing across different clients for contract purposes is believed to save administration time (Interviewee L). Although some feel as though SCI has advantages, a lack of visibility in terms of a project's supply chain, especially in areas of specialist consultancy work, makes it difficult to understand exactly what those advantages would be:

> "*My gut feeling would be that more integration would be of benefit, but it is hard to know where that would be without understanding a particular supply chain, and that's something that we just don't get to see*" (Interviewee M).

However, there also appears to be areas where SCI is perceived as being of less importance. For example, it is viewed as being less important by one of the specialist consultancy services focused on EIA, especially those specialising in underwater noise measurements (Interviewee L). Due to the nature of Interviewee L's company services, coordination with other supply chain participants is less required. This is because it is a task-based role, meaning that long-term relationships are not as important. Although for different reasons, Interviewees H and I also viewed integration as being of less value because work scopes of companies that they work for, within OSW project supply chains, are already well-organised. Given that the roles of companies represented by Interviewees L, H, and I are specialist services providers related to EIAs and offshore installation works, close collaboration with project supply chain participants might not be as important for service-based companies than for product-based companies like component manufacturing companies, whose product design, manufacturing, fabrication, and delivery could be more greatly affected by supply chain partners.

5.3.3 The advantages and disadvantages of SCI

As it can be seen, the study's participants held mixed attitudes towards SCI based on their experiences of working on different OSW projects. Likewise, the participants also provided information about the advantages and disadvantages of close collaboration and long-term relationships. Table 5.3 below indicates the negative aspects of a more integrated supply chain, as identified by the participants.

Disadvantages of SCI	
Disadvantages	**Support descriptions/quotes**
It might create a high dependency on suppliers	"*We don't have a lot of key strategic suppliers because that implies we have a high dependency on them*" (Interviewee A).
Long-term agreements may become obsolete or outdated and may disadvantage the parties	"*It is a very dynamic and changing supply chain, so you may think that you've reached a framework agreement with the market leader and the framework agreement was planning to go over seven years, but two years later your market leader is not the market leader anymore*" (Interviewee B).
Informal collaboration tools (ICT tools) may blur the boundaries of commercial agreements	"*Big construction contracts are quite formal and there are major risks apportioned between parties and if you have an informal collaboration tool, it can blur the boundaries of those commercial agreements, which can be a problem*" (Interviewee B).
It may create awkward situations between parties in cases of discrepancies and conflicts	In the O&M phase after a wind farm has been completed, turbine manufacturers often work together with their client, sharing facilities, vessels, manpower, warehouses, and equipment. When issues arise between parties at a local level it creates an awkward situation and unpleasant working atmosphere (Interviewee C).
It might obstruct competition	▪ When teams of suppliers working for specific clients (developers or main contractors) become established, it closes the opportunity for other suppliers to get in. ▪ As OSW projects get bigger, it is harder for smaller companies to get in (Interviewee E; I; N; G).
It might expose pricing structures	Close collaboration between contractors and clients may make contractors' pricing structures, used in relation to their subcontractors, visible to the client (Interviewee F).

Table 5.3: The identified disadvantages associated with SCI

A potential disadvantage of SCI is that it might create a high dependency on suppliers. As Interviewee A explained, project supply chains tend to be highly integrated by facilitating the development of collaborative working environments amongst selected project partners. When it comes to creating long-term partnerships with the suppliers of products and services, Interviewee A has limited partnerships which only include key strategic suppliers. According to Interviewee A, having many key strategic suppliers leads to a high dependency on them, which they considered to be a limitation.

Another problem is that long-term agreements may become obsolete or outdated and could disadvantage parties. Interviewee B explained how there can be a lot of value in working with the same suppliers or resource providers because they understand their client's drivers, which gives the client confidence that they will deliver on the task. For developers who prefer to use EPCI contractors, especially for OSW construction tasks, there is value in forming long-term multiple project partnerships between the developing company and EPCI contractor using framework agreements. However, such partnerships may become less successful in the long-term. According to Interviewee B, one of the reasons is that the OSW supply chain is dynamic and changes regularly:

> "*You may think that you've reached a framework agreement with the market leader and the framework agreement was planning to go over seven years, but two years later your market leader is not the market leader anymore*" (Interviewee B).

Given that the OSW environment is dynamic, like many business environments in today's world, framework or long-term agreements may become obsolete or outdated, or could simply cease to be beneficial for parties over time. As explained by Interviewee B, another issue that could impact commercial agreements is the use of information sharing systems during the OSW farm construction stage. Informal collaboration tools (ICT tools) may blur the boundaries of commercial agreements. In general, the use of different ICT tools to share information between parties is welcomed and is necessary to keep track of important documentation and other related information. There is normally a spectrum of various ICT tools used in large projects, such as OSW farm projects. This also involves the use of some systems that allow for more informal communications between parties to encourage a collaborative working environment. However, such informal communications could become uncontrolled, which would be risky during the construction phase of a wind farm as it requires rigid controls. It is important to understand that there are substantial and formal contracts in place. As major risks are apportioned between parties, informal communication tools may blur the boundaries of these commercial agreements, thus potentially causing problems.

Interviewee C described a different problem that may occur when the development of a wind farm is complete and enters an O&M phase. O&M activities involve ensuring the safe operation of wind farm assets during their lifetime, which could be up to 25 years (BVG Associates, 2019). Wind farm assets include wind turbines, BOP (cables, turbine foundations, offshore substation, onshore substation), and associated transmission assets. O&M is generally overseen by a wind farm's owner. Separate components, such as wind turbines, would normally be covered by a wind turbine manufacturers' warranty for between five and ten years. This means that the maintenance and service of wind turbines would be performed by the wind turbine suppliers during the warranty period.

Furthermore, the O&M phase often involves close partnerships between wind farm owners and wind turbine suppliers, including shared facilities on the operations base, vessels, manpower, warehouses, and equipment. Whilst such close partnerships normally work well, it may create awkward situations between parties in cases of discrepancies and conflicts.

The most frequently mentioned problem associated with SCI was that it might obstruct competition. Various participants acknowledged that established groups of suppliers working with a particular developer on various projects sounds promising for all parties, especially as time can be saved on the tendering process and more understanding can be established among parties involved. However, this means that companies who were unsuccessful in the first tendering process would effectively be obstructed from any further work by that particular developer or contractor (Interviewees E and I). For this reason, allowing everyone a fair chance to tender could be an attractive option and so, more generally, the tendering process has been described as an area that needs improving (see Section 5.3.9).

Another observation was provided by Interviewees N and G who mentioned that OSW projects have become increasingly larger in terms of the size of their capacity, thus requiring more resources and rendering the tender processes for these projects more time consuming and expensive. As projects become larger, supply chains become more established. This creates a barrier for smaller suppliers due to their lack of resources. Nonetheless, according to Interviewee G, larger companies can also struggle depending on whether the OSW project is derived from the private or public sector:

> "*In the public sector it is very difficult for smaller companies to be suppliers and in the private sector it is quite hard for a huge company to enter because the private utility owners focus very much on cost and don't care about what we can deliver on certainty and transparency, they care a lot about the price*" (Interviewee G).

Another disadvantage of close partnerships was identified by Interviewee F, which is that it might expose pricing structures. Even though this had not been mentioned in a negative context by Interviewee F, it poses a concern about a potential risk. Therefore, it is important to mention that close collaborations between contractors and clients may make contractors' pricing structures, used in relation to their subcontractors, visible to clients.

Despite these potential disadvantages, opinions on SCI remain largely positive. Table 5.4 below lists the advantages of SCI identified by the participants. One positive aspect is that it facilitates the management of issues and conflicts. All participants have mentioned that large projects, such as OSW farm projects, face inevitable issues and conflicts; often on a daily basis. One even said that projects, by definition, always go wrong (Interviewee E). Though, some have argued that the words ‘conflicts’ and ‘issues’ are too strong, and that in practice they are frictions or frustrations (Interviewees M, G, and C), which, most of the time, are manageable (Interviewees H, I, and K). In relation to this, Interviewees A, D, F, and G stated that a collaborative working environment helps to overcome issues more effectively and efficiently.

Advantages of SCI	
Advantages	**Support description/quotes**
Facilitates management of issues and conflicts	▪ “*Creating really good collaboration and communication with our supply chain allows us to be open and transparent with our suppliers when issues go wrong*” (Interviewee A). ▪ Developing trusting open relationships helps people volunteer when they hit problems and it helps to come up with solutions together, as a team, rather than try and hide them (Interviewee A). ▪ Formal collaboration agreements help to resolve issues much earlier and often reduce any transactional costs between parties. It helps to prevent issues. (Interviewee D). ▪ Partnership type relationships between contractor and the client help to resolve any issues informally rather than formally (Interviewee F). ▪ Purposively created rooms for joined meetings for all parties present on-site that facilitate collaboration, encourage parties involved to be open about any issues. This helps to address any project related issues early on and jointly as a team (Interviewee F). ▪ Partnership type relationships or close relationships help to foresee potential challenges and help to overcome them (Interviewee G).

Continuous improvement/development	▪ Collaboration agreements with clients give opportunities for cost reduction e.g. through innovation and design levers. Opportunities for various levers to improve e.g. commercial, financial guarantees, standard terms, and conditions (Interviewee D). ▪ Closer integration with own key suppliers brings benefits of reduced transactional costs, innovation, standard terms and conditions, better credit solutions, better delivery dates, and packaging and supply (Interviewee D). ▪ Continuous relationship between client and contractor from one project to the next, fosters understanding between parties (Interviewee F). ▪ Framework agreements between supplier and key clients help to develop things in conjunction with each other. Clients develop supplier, helping reduce costs, streamline systems, and processes (Interviewee J).
Early engagement	▪ Early engagement of the same contractor in the next project by the developer helps to address any lessons learned based on previous projects at the early stages of the new project. It also helps to improve the design of the onshore substation (Interviewee F). ▪ Early engagement of the principal contractor and chosen suppliers of the developer helps to reduce interface challenges (Interviewee F).
Streamlined manufacturing processes	▪ In relation to internal integration (company's own SCI), framework agreements with key raw material suppliers and CPFR practices, when raw material suppliers are notified of customer stock levels automatically, it helps to streamline and smooth production procedures and processes (Interviewee E).
Establishes familiarity between parties	▪ Repeat business helps to establish familiarity between client and supplier and helps to improve channels of communication (Interviewee E). ▪ There is often repeat business because the client becomes familiar with the supplier's systems and outputs of analysis (Interviewee L).
Knowledge and resource sharing	▪ In O&M phase after wind farm has been completed, the turbine manufacturer often works together with their client, sharing facilities, vessels, sharing manpower, warehouse, and equipment (Interviewee C). ▪ Interviewee F had access to client's design team and were able to suggest things for the next project (Interviewee F). ▪ Close partnership between contractor and the client helps to jointly purchase any software tools for the project (Interviewee F). ▪ One example of collaboration facilitation of all parties on the site is the creation of ROC room – rehearsal of concept, for joined meetings (Interviewee F).

Pre-agreed contract terms & prices	As part of framework agreements between parties that last for a specified period of time, there will be pre-agreed contract terms and pre-agreed prices, which reduces contract negotiation time and streamlines processes overall (Interviewee J).
De-risking potential	▪ Partnerships are sometimes used by some developers as a de-risking exercise for potential problems by having a more collegiate approach (Interviewee M).
Efficiencies in processes	▪ Closer collaboration with project development team gives opportunity to be part of the whole and "*you get more chance to input and more chance to see where you can see efficiencies between what we do and what the geologists do and what the ecologists do*" (Interviewee M).

Table 5.4: The identified advantages associated with SCI

For example, as Interviewee A mentioned, a lot of effort is placed into creating collaborative and trusting relationships amongst supply chain partners so that any issues can be openly discussed and resolved together as a team. In support of this, Interviewee A stated the following:

> "*We are trying to create really good positive relationships throughout the supply chain from engineering right through to senior management [...], so we encourage our teams to work with each other, communicate properly, and try and deal with any conflicts and issues at the execution level collaboratively*" (Interviewee A).

Interviewee D specifically highlighted the benefits of having a formal collaboration agreement, which is that it provides structure around how to work together, helps to address any issues early on, reduces transactional costs, or helps to prevent issues altogether. Similar observations were highlighted by Interviewees F and G, who also mentioned that partnerships help to address any issues early on and, by knowing those issues early, solutions can be collectively developed as a team. In addition, Interviewee F noted that collaboration and partnerships help to resolve issues informally rather than necessitating formal procedures. Interviewee F described one example of issue resolution as: "*it's a chat over a cup of coffee now, most of the time*".

Interviewee F's partnership with their client may serve as a separate case study that highlights different positive examples. Continuous improvement/development is one such example. Interviewee F works together with one client over multiple projects, which has allowed them to understand each other and continuously improve projects by addressing the lessons learned. Interviewee D also views partnerships over multiple projects as an opportunity for continuous development, as well as cost reduction based on innovation and design levers. According to Interviewee D, partnerships provide opportunities for various other levers to improve, such as commercial, financial guarantees, and standard terms and conditions. Based on Interviewee D's perspective, the opportunities for continuous development apply equally to different levels of SCI, either internally based on a company's own supply chain or externally with clients. Moreover, Interviewee J provided their perspective of working for a company which has been able to secure framework agreements with leading companies across different sectors, such as development, cable installation, and cable manufacturing:

> "*They are developing us as a supplier, helping us to reduce our costs or streamline our systems and processes getting things preapproved to really reduce costs when we supply to those customers*" (Interviewee J).

In similarity to continuous improvement and development, early engagement has been identified as another positive aspect of SCI in the context of projects. It has been highlighted by Interviewee F that, since they had been chosen as the preferred contractor to continue working with the same client on a subsequent project, they are able to start engaging with different project tasks related to their scope of work early on in the project. This helps to address any lessons learned early in the process and helps to achieve an efficient design of onshore substations. Interviewee F explained how the design of onshore substations must consider the different sizes of high-voltage equipment to be installed on the substation. High-voltage equipment suppliers are procured by the OSW farm developer, who is a client of Interviewee F. In the past, Interviewee F had not been able to access information on the suppliers of high-voltage equipment and lacked access to information on equipment sizes. Therefore, the onshore substation was designed using educated guesswork as to the size of the equipment needed.

In addition, for the preparation of the onshore substation, including earth works, below ground infrastructure, and reinforced concrete structures installation, Interviewee F is also responsible for managing the H&S of all suppliers of high-voltage equipment. Through early engagement in workshops, Interviewee F can brief their clients' equipment suppliers regarding H&S procedures:

> "*Because it is our site and we're the principle contractor, they have to comply with our health and safety requirements, and they can be quite different to other organisations' health and safety requirements, so the earlier we can tell them what we need them to do the better and there's no surprises later on, which causes delays and relationship issues, so that's much better than it was and it is purely down to early engagement and these early workshops*" (Interviewee F).

Early engagement also provides an opportunity to access information about equipment sizes early on, which allows for a fully integrated design of the onshore substation, thus improving efficiency.

For manufacturing companies such as company represented by Interviewee E, internal SCI or integration of their own supply chain using the CPFR tool helps to achieve streamlined manufacturing processes. It allows for an automated raw materials supply to manufacturing facilities, thereby rendering internal manufacturing processes more efficient.

In relation to external SCI, Interviewee B described how there is a lot of value in working with the same suppliers or resource providers on consecutive projects. One benefit is that it establishes familiarity between parties. This helps to improve communication between parties (Interviewee E), and in some instances it can help suppliers to win work due to established familiarity with their work outputs (Interviewee L).

Knowledge and resource sharing is another important advantage of SCI. It is especially evident during the O&M phase where, as previously mentioned by Interviewee C, a lot of resources and knowledge is shared between turbine suppliers and wind farm owners. Additional examples were provided by Interviewee F, whose partnership with their client allowed them to gain access to their client's design team. This allowed Interviewee F to suggest a range of improvements for the next project. Through shared resources, Interviewee F and the client were able to purchase special software for joint use.

An example of Interviewee F's partnership raises an interesting concept related to knowledge and resource sharing, called the rehearsal of concept room (ROC room). The ROC room is a physical space that is open for use by all parties present on-site. Its main purpose is to facilitate collaboration between all parties where, during joint meetings, parties are able to raise any issues that could affect time, cost, quality, and safety. This helps all parties to collectively find solutions to problems as a team. In addition, the room has a scale model of the entire project and, during the meetings, parties gather around this model to state where they would be working each day. This exercise ultimately helps to align the work processes of all parties.

The benefits of long-term agreements between parties, and framework agreements more specifically, were highlighted by Interviewee J as including pre-agreed contract terms and prices. Framework agreements that last over a specified period of time do not give exclusive rights to suppliers, but do give suppliers a preferential position in terms of future contracts. This allows suppliers to fix their prices over several years, depending on the duration of the framework agreement. It also allows them to pre-agree contract terms. This means that contract negotiations are unnecessary as the terms have already been pre-agreed, which streamlines the contract negotiation process.

Another positive aspect of SCI concerns its de-risking potential. Interviewee M observed that some developers use partnerships as a risk exercise, including de-risking potential problems within certain supply chain areas by taking a more collegiate approach. Interviewee M also identified how external SCI may lead to more efficient processes. While the word 'efficiency' has been mentioned several times in relation to partnerships, collaboration, and overall SCI, in this case Interviewee M emphasised how collaboration makes efficiencies more visible. Interviewee M explained how some developers work closely with consultancies and subcontractors to almost form a project team. This makes parties feel as though they are part of the whole, rather than being responsible for simply transmitting information:

> "*You get more chance to input and more chance to see where you can see efficiencies between what we do and what the geologists do and what the ecologists do, so it gives you that opportunity to be a little bit more efficient*" (Interviewee M).

Based on these findings, it is possible to say that the study participants view SCI as largely positive, which can bring benefits to supply chain parties during the development and construction of OSW projects.

5.3.4 Participants' preferences for collaboration

The study participants were asked to provide information about who they would prefer to form more collaborative relationships with, in terms of other companies in the OSW supply chain, or which company would provide the most benefit from forming more collaborative relationships with. Table 5.5 shows the participants' preferences and provides details of the reasons for their answers.

Participants	Collaboration Preference	Reason
Interviewee A OSW farms developer	Wind turbines manufacturer.	Considered strategic supplier.
Interviewee B OSW farm project director	Cable designers, cable installers, turbine designers (with electrical interfaces), foundation designers and installers, and offshore substation platform designers.	Opportunity for co-development in technology or methodology and reduced risk.
Interviewee C (Turbine manufacturer)	First-tier turbine component manufacturers (gear boxes, blades, generators). Vessel providers (SOVs, jack-up vessels).	Key suppliers.
Interviewee D Power cables manufacturer (array)	Developers.	Working directly with developers is considered to be more effective.
Interviewee E Power cables manufacturer (export)	Developers and/or clients company has done business with before.	Possibility for efficiencies in work.
Interviewee F Onshore substation contractor	Developers.	Main customers.
Interviewee G Offshore substation contractor	Local partners.	For efficient logistics.
Interviewee H Installation services provider/vessels operator (turbines & foundations)	Developers.	Pipeline of work.
Interviewee I Installation services provider/vessels operator (Power cables)	Developers. Cable manufacturers.	Key customers.
Interviewee J Cable protection manufacturer	Offshore installation contractors: cable installers.	Key customers who handle this supplementary product.
Interviewee K Secondary steel fabricator	Turbine manufacturers, primary steel fabricators (foundations, transition pieces, substations).	Main customers.
Interviewee L Environmental Impact Assessment provider (underwater noise impact)	Not required.	
Interviewee M Environmental Impact Assessment provider (archaeological services)	Developers.	Possibility for greater work efficiency.
Interviewee N Trade association and business development organisation	In O&M phase.	Because O&M phase is more long-term, it lasts up to 25 years.
Interviewee O Financial adviser	-	-

Table 5.5: Participants' preferences for collaboration

Since Interviewee N's company is not directly involved in the development and construction process of OSW farms, the interviewee was instead asked to provide their perspective on the areas of the supply chain that would require more partnership-based relationships or alliances. In response, Interviewee N stated that, due to timescales, partnerships would be required in the O&M phase because it lasts for up to 25 years. In comparison, construction phase lasts for up to three to five years. This is also an area that experiences ongoing cost reductions. Therefore, the O&M phase naturally requires strong partnerships, which would also provide opportunities for some companies to offer different services. For example, turbine inspection technologies such as drones.

Almost half of the participants expressed a preference for greater collaboration with project developers (Interviewees D, E, F, H, I, and M). According to Interviewee D, business growth within the OSW industry has shown that working directly with wind farm developers is better for them, than working with EPC or EPCI contractors as intermediaries:

> "*It allows us to work much more closely and solve the problems much earlier on*" (Interviewee D).

According to Interviewee E, it is important to maintain relationships with previous clients, including developers and offshore and onshore cable installation contractors. This is due to the established familiarity between parties. Nonetheless, established familiarity does not necessarily provide Interviewee E with an advantage as a supplier as they are still required to go through long tendering processes. For this reason, Interviewee E described how it would be nice to have the opportunity to be a preferred supplier for subsequent projects without having to go through long tendering processes, especially when an original job had been done well. Closer collaboration with developers could have provided this opportunity. Though, Interviewee E acknowledged that this would limit opportunities for other suppliers.

Interviewee F's experience of working with OSW farm developers on multiple projects gave them grounds to say that there can be long-term gains when opportunities to continue working with the same client arise.

For Interviewee H, closer collaboration with developers would be welcomed because developers are the ones who can ensure large pipelines of work. Likewise, developers are considered key customers for Interviewee I, along with cable manufacturers who Interviewee I would also like to have a closer relationship with. Interviewee M similarly expressed a wish to have closer relationships with developers. In Interviewee M's case, it is uncommon to work directly for developers, but, based on Interviewee M's previous experience of working directly for developer, Interviewee M said that it gives a sense of being part of a whole. Furthermore, working directly for developer provides greater visibility of work processes of other members of supply chain, which allows to see potential areas to improve work efficiency and gives visibility for potential efficiencies.

Smaller suppliers, such as Interviewees J and K, prefer to have closer relationships with their existing customers. For Interviewee K, these include turbine manufacturers and primary steel fabricators (foundations, transition pieces, substations). For Interviewee J, it would be of more benefit to further collaborate with offshore cable installation contractors because Interviewee J's manufactured cable protection is a supplementary product that attaches to cables during installation. Interviewee J would also benefit from feedback by offshore cable installation contractors owing to their knowledge and experience regarding their products and ideas on how to improve by working together.

For Interviewee A, collaborations involving partnerships tend to be formed with strategic suppliers. Turbine manufacturers form one type of strategic supplier, and it is important for Interviewee A to maintain close relationships with these. From Interviewee A's perspective, 'strategic suppliers' tend to involve certain obligations, including things such as collaborative development and forward planning. For this reason, Interviewee A does not have many strategic suppliers. Strategic partnerships could also be formed when Interviewee A's company enters new markets. When new markets lack a developed supply chain, and when there are rigid local content requirements, then Interviewee A would look at entering into strategic partnerships in those areas.

For similar reasons, Interviewee G would prefer to partner with local suppliers when entering new markets. As Interviewee G explained, it increases the efficiency of logistics tasks. However, when companies move from existing OSW markets into new markets, they would be considered first because they have previously acted as established suppliers. Interviewee G prefers to form partnerships on a project-by-project basis. This allows parties to learn about each other on a project basis, rather than focusing on joint ventures from the start.

Interestingly, Interviewee B felt that greater collaboration would be beneficial with those companies that have less developed technologies or methodologies, including cable designers, cable installers, turbine designers (especially with electrical interfaces), foundation designers and installers, and offshore substation platform designers. Early collaboration in these areas would allow Interviewee B to gain knowledge of the way technologies are developing and, if necessary, influence research and development (R&D). This would help Interviewee B to learn about the latest developments. Another reason concerns offshore cables and foundations installation, which are areas associated with a lot of risk. Hence, early collaboration could reduce and mitigate risk more effectively.

For Interviewee C, it is important to maintain good relationships with key suppliers. These are described as ‘A tier’ suppliers who can affect Interviewee C’s capability to deliver their product to the client. These products include turbine components, such as gear boxes, blades, and generators. As explained by Interviewee C, it is a small industry, and it is costly to lose key suppliers because it limits one’s own business capabilities. A similar situation arises with service vessel suppliers (SOVs), SOVs and jack-up vessels, who are considered key vessel service providers that enable Interviewee C’s business to offer their products to the OSW market.

For Interviewee L, forming a close collaboration with any OSW players is unrequired due to the nature of their services. To clarify, Interviewee L specialises in underwater noise impact measurements and their services are commissioned as and when required. For example, when conducting EIAs. For this reason, there is no need for them to form long-term partnerships.

5.3.5 Participants’ evaluation of SCI levels

In order to understand the participants’ overall perspectives on SCI within the UK’s OSW industry, they were asked to evaluate the current SCI levels based on their experiences. Table 5.6 below summarises their answers and shows that the overall responses are generally positive. Furthermore, many responses suggested that current SCI levels are better than they have been previously.

Interviewees B, C, D, F, J, K, M and N all agreed that current SCI levels are better than they were before, but they also agreed that there is still room for improvement. However, Interviewee J was more critical by saying that many improvements were still required. According to Interviewee J, nobody is currently driving SCI and it is unclear who should command and drive that. Interviewee J also mentioned that a lot of people are saying the right things, but are not really doing the right things at this stage.

In partial response to Interviewee J's concern, Interviewee B referred to organisations and initiatives like The Carbon Trust, The Carbon Trust Scotland, OSW Accelerator, and the Catapult, who all work to provide advisory services to the government and businesses through various research and development projects. Interviewee B mentioned that these organisations play an important role in OSW in terms of new developments and innovations in technology and other aspects. These other aspects also include questions about the supply chain and its integration. Therefore, as mentioned by Interviewee B, the industry is not starting from zero point when considering SCI.

Participants	**Level of SCI Evaluation**	**Reason**
Interviewee A	Extremely integrated.	In relation to own project supply chain: "*That's what we do as a project, we buy a lot of bits and pieces and we stick them all together*".
Interviewee B	Moderate.	In general: "*I would say it is better than it was, but I'm sure it can be improved*".
Interviewee C	Good.	In general: "*It is a very young industry everyone is still getting into it*".
Interviewee D	5/10.	In general: "*There's better integration that could occur*".
Interviewee E	Integrated just for the project.	In general: "*Every project is treated in isolation*".
Interviewee F	Getting better.	In general: "*There's always room for improvement*".
Interviewee G	Every project is different.	
Interviewee H	Well-established.	For Inter. H scope: "*It's operating quite well at the moment*".
Interviewee I	Good.	For Inter. I scope: "*It's quite a small market [...] we know our supply chain quite well*".
Interviewee J	Needs improving.	"*I think there's a lot of improvements required*".
Interviewee K	6 or 7/10, getting better.	
Interviewee L	It works well.	For Inter. L scope: "*Happy with the way it works*".
Interviewee M	Perhaps more integration would be of benefit.	In general: "*My gut feeling would be that more integration would be of benefit*".
Interviewee N	Better than it was.	In general: "*I think they are a lot better than they were, but I think there's room to do more*".
Interviewee O	Well-established.	In general: "*In the UK and on the European continent project supply chains are well-established*".

Table 5.6: SCI evaluation by participants

Interviewee C mentioned that the industry is still growing and that it is still young. Although some areas have already formed established bonds between buyers and suppliers that are hard to break, opportunities for growth and improvements still exist. However, to achieve more integration a lot of companies would need to increase their working practices and standards to the level of first-tier suppliers, such as turbine manufacturers.

Interviewee F mentioned that they understand how difficult it would be to achieve a more integrated supply chain because people have such different scopes and specialisms. Nonetheless, their own positive experiences related to collaborative client relationships made Interviewee F feel certain that more could be done. Based on Interviewee K's experience of working with clients, the interviewee was also positive about current SCI levels.

Interviewee D was less optimistic about the current SCI levels, but felt optimistic about potential integration. In particular, Interviewee D believes that better integration can occur if current transactional relationships are changed through increased collaboration and framework agreements. In similarity, Interviewee N thinks that improvements can be made by creating additional partnerships.

In similarity to Interviewee F, Interviewee M perceived the supply chain as a complex system that they felt could benefit from being more integrated. However, as explained by Interviewee M, without understanding the supply chain fully, it is difficult to see where changes can be made. Interviewee M mentioned that they work predominantly in isolation and only see the parts of the supply chain that directly impact them, but "*that is only a small part of the whole*".

Interviewees H, I, and L were satisfied with the current SCI levels as they relate to their scope of work. For example, they said it is quite well-established (Interviewee H), works well (Interviewee L), and that everyone knows each other because it is a small market (Interviewee I). Similarly, Interviewee O thinks that OSW supply chains in the UK and on the European continent are well-established.

Interviewees E and G were less satisfied. Interviewee E was sceptical about achieving a more integrated supply chain; they said that it would be nice to think that there was a way of doing it without leaving some businesses in a "desert":

"*In an ideal world every supplier manufacturer and contractor would love it where they got really friendly with a couple of developers and did all of the projects with those guys for the next 10 years, then you would have quite a nice guaranteed pipeline of work you could then invest in R&D because you'd know you're going to get projects coming through and you wouldn't have to worry about going through the tender process, it would be surety of supply. But if you weren't the chosen one, you'd be in a desert for those 10 years*" (Interviewee E).

For Interviewee G, levels of SCI vary from project to project depending on the developers' style of building OSW farms. As explained by Interviewee G, in many development projects there is a percentage of employees working as consultants, which can reach up to 75%. They are only there for the duration of the project. While Interviewee G fully acknowledged the effectiveness of employing consultants to address supply chain issues during the project, it could create difficulties when attempting to create a more integrated supply chain. The problem is that it is difficult to build long-term relationships with temporary staff. Complications are added when supply chain principles or philosophies are based on the consultant's own principles, rather than on the principles of the company. Given this challenge and the fact that all projects are unique, it is difficult to achieve synergies (Interviewee G).

A different picture of SCI levels was provided by Interviewee A. However, it is important to note that Interviewee A provided their evaluation in relation to their own supply chains that they create as a developer. Interviewee A evaluated their own project supply chains as being extremely integrated. This was also evident in Interviewee A's previous responses, emphasising the importance of collaborative working environments.

5.3.6 Researcher's evaluation of SCI levels

As explained in Section 4.6.1, the interview questions were broadly developed based on two set of themes: SCI themes as identified in the logistics and SCM literature, as well as themes related to the VSM to allow for a VSM analysis. This section provides an evaluation of the SCI levels based on these SCI themes. Table 5.7 provides details of the evaluation criteria used to evaluate answers in relation to each theme.

Evaluated SCI themes		
Theme	**Subtheme**	**Evaluation Criteria**
Relationship type	Partnerships	Dominant relationship type (transactional or partnership).
	Long-term	How easy or difficult it is to form long-term relationships and the need for long-term relationships.
Relationship scope	External/internal relationships	Downstream and upstream connections.
Collaborative relationship management	Formal	Use of ISO44001 or other formal collaboration management. Dominant management type: formal or informal.
	Informal	
Value drivers/order winners	Shared value drivers	Alignment of participants to dominant industry value drivers.
Information flow	Information sharing	Use of shared ICT systems and extent of information sharing.

Table 5.7: SCI evaluation criteria (Author)

5.3.6.1 Relationship type

Based on the interviewees' answers related to dominant relationship types within the OSW industry, it appears that their opinions vary, as summarised in Table 5.8 below. Relationships largely depend on the developers' approaches to building projects and managing their supply chains; creating a spectrum between transactional relationships and partnership relationships. From the developers' point of view, their approaches to project management and SCM depend on their in-house capability, as well as each project's needs (Interviewees A and B). Interviewee A tends to have a large in-house capability, which allows them to create more partnership relationships with key suppliers by working with them directly. However, Interviewee B said that this approach is uncommon. It is more common for developers to use EPCI contractors to manage major interfaces or work packages on behalf of developers. Considering that EPCI contractors act as intermediaries between developers and suppliers, relationships with EPCI contractors tend to be more transactional and contractual, rather than partnership based (Interviewee D).

Participants	Relationship Type	
	Partnerships/Transactional	**Duration of relationships**
Interviewee A	Partnerships on a project basis.	Long-term only with strategic suppliers.
Interviewee B	More commonly transactional, but partnerships do exist.	There is an interest to form long-term multiple project partnerships using framework agreements with EPCI contractors.
Interviewee C	More transaction/contractual during projects. Partnerships in O&M.	There are long-term established relationships with key suppliers, subcontractors.
Interviewee D	More transactional/contractual with EPCI contractors. More collaborative with developers.	More long-term structure with developers. Building long-term multi-project collaborative relationships with own suppliers. Sector deal in the UK helps to form longer-term relationships.
Interviewee E	More transactional, more of a partnership only with some developers.	Difficult to achieve continuity of relationships due to use of contracted staff.
Interviewee F	Partnership-based with client. Work scope dependent in relation to own subcontractors.	Based on trust, which is hard to earn but easy to lose.
Interviewee G	More partnerships in O&M.	Long-term partnerships are needed to increase company competence.
Interviewee H	Depends on customer. Some more transactional, some more of a partnership. This creates a spectrum between the two.	Vessel services market has become more commoditised, creating a need for further strategic alliances with developers rather than long-term relationships.
Interviewee I	More transactional with clients, it is formal, but also depends on the value of the contract.	Generally formed long-term relationships work well, but it is more difficult to maintain relationships with the same team of people as the same teams are unlikely to work together again.
Interviewee J	Depends on customer. Some more transactional, some more of a partnership.	Company's experience and competence gives it a preferential position, helping to form some partnerships with customers and get repeat business.
Interviewee K	Combination of the two.	Relationships mature over a long period of time. For urgent orders, this becomes less consistent.
Interviewee L	Difficult to say because the nature of this service does not require partnerships.	Long-term relationships are not required.
Interviewee M	Depends on the consultancy and the developer. Different companies work in different ways.	Good personal relationships tend to be formed because these are long standing projects that take months to complete. Those personal relationships are maintained even when people transfer to different companies.

Interviewee N	Seem more transactional. More partnership-based in O&M.	From a smaller supplier's perspective, there is a willingness to form longer-term relationships and partnerships, but there is limited knowledge on what terms to do this upon.
Interviewee O	There is a combination of relationships, but mostly cooperative.	-

Table 5.8: Summary of relationship types dominant in the OSW industry

The participants' answers suggest that relationships are project dependent and, in some respects, project phase dependent. More partnership type relationships are formed in the O&M phase, which lasts for the duration of an OSW farm's lifecycle, up to 25 years, as explained by Interviewees C, G and N.

In relation to forming longer-term relationships, long-term relationships are generally valued, and some participants tend to form long-term relationships with their own key suppliers (Interviewees C, D, E, and G). However, not every area of a project supply chain requires long-term relationships. For example, they are not needed in specialist consultancy services, like in the case of Interviewee L. It is also evident that long-term relationship formation involves a strategic approach, where relationships are formed only with strategic partners (Interviewees, A, B, and H).

Furthermore, it seems as though strategic partner status does not guarantee a long-term relationship. One of the reasons is that long-term relationships are built on trust, which is hard to earn and easy to lose if something goes wrong (Interviewees F and E). Another reason is that the OSW supply chain is dynamic and regular changes make relationships more fragile (Interviewee B). In addition, there seems to be a lot of movement of people within the industry, which makes it difficult to achieve a continuity of relationships (Interviewees E and I). Although, for some, the movement of people does not pose a concern (Interviewee M).

Those who are market leaders find it easier to form long-term relationships with their customers (Interviewees J and I), but it seems more difficult for smaller suppliers who lack knowledge of what is required in terms of risk and reward, as well as general work sharing (Interviewee N). As explained by Interviewee K, relationships mature "*on the back of a successful delivery*" of work within a project. To form longer-term relationships, as explained by Interviewee K it is classically about human relationships and whether teams get along well.

5.3.6.2 Relationship scope

To further evaluate current SCI levels, this study looked at the current and potential scope of relationships between project supply chain members, based on the participants' responses. The results show that the scope of the relationship is not wide. Table 5.9 summarises the participants' answers in relation to the scope of internal relationships (with interviewee companies' own suppliers) and external relationships (with OSW project suppliers/partners). In terms of external supply chain relationships (such as project supply chain relationships), product and service suppliers tend to work closely with immediate project clients. There seems to be no need to coordinate with other supply chain members on a project, with the exception of Interviewee F who, due to their onshore substation contractor role, needs to coordinate with other supply chain members. Despite a lack of certainty, the results suggest that relationship scope could depend on the work scope of each supplier/contractor.

Participants	Relationship Scope	
	Internal	**External**
Interviewee A	Only few strategic suppliers and use of key suppliers.	Project partners.
Interviewee B	Project and developer dependent.	Project and developer dependent.
Interviewee C	Ties with key turbine component suppliers.	In areas of limited markets in key supplies. For example, labour and vessels.
Interviewee D	Increasingly building frame agreements with key suppliers, critical suppliers.	Collaborative working approach with client on a project basis, in product design.
Interviewee E	Integrated with own suppliers.	Project and developer dependent.
Interviewee F	Use of key subcontractors.	With client and client's other supply chain members.
Interviewee G	Use of core suppliers if they can also work in different locations.	Partnering with local suppliers where possible.
Interviewee H	Framework agreements with port services. For specialist equipment use of prequalified supplier list.	With clients (developers and turbine manufacturers).
Interviewee I	Project-dependent.	With clients (developers, cable installation contractors, and cable manufacturers).
Interviewee J	Use of approved vendor list.	With key customers (cable installation contractors, cable manufacturers, and exclusively with one developer).
Interviewee K	Established team of own suppliers.	With clients (turbine manufacturers, primary steel fabricators).
Interviewee L		Depends on the project and the developer. Some developers prefer to work directly.
Interviewee M		With project clients. Work tends to be completed in isolation.
Interviewee N		Supply chains become more established. Usually the preferred supplier route.
Interviewee O		Developers often have established teams of preferred suppliers.

Table 5.9: Summary of internal and external relationship scope

For some, relationship scope is defined by the market capacity of required suppliers or staff for OSW project tasks. Interviewee C explained how, in order to maintain their own capability to perform their job and deliver their product, they would form certain long-term agreements in areas of limited supply. This includes the labour market for turbine technicians and vessels market, especially jackup vessels for turbine installation and SOVs for O&M tasks.

Interviewee G noted a similar situation; they would seek to form partnerships with local suppliers to provide materials and competencies for O&M purposes from a local OSW base. This is due to high logistics costs that occur when suppliers are brought from abroad.

Based on Interviewee A and B's answers, the relationship scope of developers is project dependent, which means that suppliers and contractors are largely determined on a project basis. However, according to Interviewee O, project developers often have a team of preferred suppliers. This was also mentioned by Interviewee N, who also noticed a likely trend for more continuous relationships in upcoming projects; where some suppliers might follow some developers in their projects, even to other countries.

In relation to internal supply chains or the participants' own supply chains, relationship scope varies depending on whether it is a product manufacturing company or services company. Product manufacturing companies tend to have more established supply chains with a move towards forming a more integrated supply chain (Interviewees C, D, E, J, and K). As explained by Interviewee J, it is necessary in order to withstand industry pressures on cost reduction. Another reason is that it helps to streamline supply chain processes to make them more efficient (Interviewee D). On the other hand, the relationship scope for service providers depends more on the project, which usually do not require high levels of integration and instead require a list of approved suppliers (Interviewees H and I).

5.3.6.3 Collaborative relationship management

As it has been noted by Chakkol et al. (2018), in time-finite projects collaboration itself might have to be managed and formally governed to be effective, suggesting the use of ISO44001 as a formal collaboration management standard. For this reason, this study has evaluated the participants' responses to determine whether they are aware and/or use the ISO44001 standard. In addition to this, the responses were evaluated to determine whether there are any informal incentives that encourage collaboration among supply chain participants. Table 5.10 summarises the responses:

Participants	Collaborative Relationship Management	
	Formal	**Informal**
Interviewee A	No ISO44001, but use of framework agreements.	Informal collaboration 'barometer' with key suppliers.
Interviewee B	No ISO44001, but use of framework agreements.	
Interviewee C	No ISO44001, but company follows own established creeds.	
Interviewee D	Cannot answer about ISO, but use of framework agreements.	
Interviewee E	No ISO44001, but use of framework agreements and contract terms.	
Interviewee F	No ISO44001.	ROC room.
Interviewee G	Aware of ISO44001, increased use of other ISO standards.	Customer surveys with new customers.
Interviewee H	No ISO44001, but use of framework agreements.	
Interviewee I	No ISO44001.	
Interviewee J	No ISO44001, but use of framework agreements.	
Interviewee K	Aware of ISO44001, use of other ISO standards.	
Interviewee L	No ISO44001.	
Interviewee M	No ISO44001.	
Interviewee N	Worked closely with people who tried to set up ISO44001, which was not an accreditation back then. Over time it became BS11000 and then ISO44001.	
Interviewee O	-	-

Table 5.10: Summary of formal and informal collaborative relationship management

It is important to note that the purpose of questioning the use of ISO44001 was not to promote it, but rather to check whether there are any formal collaboration management systems in place. As it can be seen in Table 5.10, ISO44001 is not used by participants, although several are aware of it (Interviewees E, F, G, J, K, and N). In the cases of Interviewees G and K, there might have been confusion with ISO14001; an environmental management standard, which is widely used in the OSW industry.

One interesting finding was provided by Interviewee N, who had been personally involved with the team who established the ISO44001 criteria. As Interviewee N explained, the initial focus was on encouraging collaborative working, especially within big companies. Over time it developed into BS11000, the British Standard, and only later was it developed into an ISO standard. However, according to Interviewee N it has not been used in the OSW industry, but it is an area that could be looked at because the process of enabling companies to work together is as important as the right technologies.

Despite not finding support for use of ISO44001 as a formal collaboration management system, it was found that the participants use framework agreements. It has been identified that framework agreements act as formal collaboration agreements, that provide structure for collaborative working.

There has been less information provided on any informal incentives to encourage collaboration, which might suggest that there are not a lot of informal incentives in place. However, a key point was provided by Interviewee F, who mentioned the positive aspects of SCI earlier in the findings. More specifically, this involved the concept of the ROC room, or rehearsal of concept room, which is a physical space for project partners present on-site to use for joint meetings.

Interviewees A and G use informal surveys. In Interviewee A's case, surveys are used to see how supplier teams and developer teams work collaboratively. In Interviewee G's case, surveys are used to follow-up with new customers in order to understand their terms and needs. Furthermore, they are used to find out if Interviewee G's company is on target and whether they meet customer requirements.

5.3.6.4 Dominant value drivers

Participants were asked to provide answers in relation to the most important industry value drivers to see whether there were any shared commonalities. Time, cost, and quality were used during interviews as three prompts of potential value drivers. Participants were asked whether it is more important to deliver the project/task on time to the lowest possible cost or to the highest possible quality. Table 5.11 provides a summary of the responses and shows emergent value drivers that have not been previously considered in this study.

It has been found that an overarching industry-wide value driver is the overall cost of energy or electricity reduction. This is typically understood as the drive to reduce LCOE, (explained in Section 2.2).

Participants	Value Drivers	
	Predefined: time, cost, quality	**Emergent**
Interviewee A	Industry-wide: cost of energy reduction. Quality comes first.	H&S and focus on value creation.
Interviewee B	Time, cost, and quality are interrelated.	Use of critical success factors that include time, cost, quality, but also H&S, wellbeing of staff, contractors, communities & the public.
Interviewee C	Time, cost, and quality are interrelated.	Use of own KPIs. H&S.
Interviewee D	Big drive on cost, reducing LCOE. Quality important.	Big drive on H&S.
Interviewee E	Reducing LCOE and quality.	Reliability of delivery.
Interviewee F	Time, cost, and quality in equal measure.	H&S is number one.
Interviewee G	Cost of energy reduction.	
Interviewee H	Previously quality, but with increased quality overall it has become time and cost based now.	
Interviewee I	Reducing overall cost of the installation.	
Interviewee J	Reducing overall cost of energy.	
Interviewee K	Reducing overall cost of energy. Time and budget are in equal measure but timing is often more important.	
Interviewee L	Depends on the client. Time, cost, quality, and H&S would have different priorities.	H&S.
Interviewee M	Depends on the developer. Time, cost, and quality would have different priorities.	Reliability of delivery.
Interviewee N	Time, cost, and quality on equal level.	H&S number one.
Interviewee O	-	-

Table 5.11: Summary of dominant value drivers

In order to make OSW more competitive within the energy market, which has historically been more expensive than onshore wind, there is an overall industry objective to reduce LCOE. According to a LEANWIND (2017) study, there are potential cost reductions in many areas throughout the lifecycle of an OSW farm. This has therefore created a big push for all industry players to reduce their costs, which has been felt by all of the study participants who have highlighted cost reduction as the biggest drive (Interviewees D, E, G, I, and K).

In terms of study prompts, particularly time, cost, and quality, almost all participants said that all three are equally important, but that they would be prioritised differently depending on the project and the developer. Some developers are more focused on price, some are more focused on quality, and some are focused on all three. This study also found that the participants view H&S as the number one driver, above time, cost, and quality. This extends to the wellbeing of staff, contractors, communities, and public

(Interviewee B). As explained by Interviewee B, if a project was finished on time and on budget but there was a record of a safety issue, then the project would not be considered a success. What is more, OSW farms are built as part of a portfolio, and for this reason companies are mindful of the long-term implications of the project.

In addition to the aforementioned industry value drivers, another interesting finding concerns product and service providers; where it is also important to maintain a company's reliability of delivery (Interviewees E and M). This refers to a company's ability to be responsive to a project's needs while maintaining high product and service quality. It can also be explained in terms of a company's in-house capacity and capability.

5.3.6.5 Information sharing

Table 5.12 provides the participants' responses in relation to the use of shared ICT systems during OSW farm development and construction and during the O&M stage (Interviewee G). Table 5.12 also provides the emergent findings regarding information flow among supply chain members in general.

Participants	**Information flow**	
	Shared ICT	**General**
Interviewee A	Various shared formal commercial & technical communication platforms mainly for main technical packages. Outside that largely emails.	
Interviewee B	A spectrum of ICT from informal to formal.	Lessons learned sessions internal to company and with contractors.
Interviewee C	Use of SharePoint with customer. Documentation registers. SeaPlanner for marine coordination.	On a personal level, regular feedback and briefings.
Interviewee D	Project-based document sharing systems and standard emails.	
Interviewee E	Project portals to share tender information. Document management systems. Emails.	
Interviewee F	Aconex for contract drawings.	
Interviewee G	Access to clients' O&M systems for information sharing.	Lessons learned sessions at the start of the project to agree joint targets and after the project for review of the performance.
Interviewee H	Emails. Shared system for marine coordination.	
Interviewee I	Documents management system.	General communication happens through industry trade bodies. News sites.

Interviewee J	More informal, face-to-face meetings, presentations.	
Interviewee K	Emails. Video conferencing.	
Interviewee L	Varies from client to client. Microsoft SharePoint used internally & externally. Often clients have internal shared IT systems for collaborative communication.	Lessons learned at the beginning of the project to discuss experience of previous projects.
Interviewee M	Microsoft SharePoint and emails.	Some self-organisation in relation to communication with other environmental consultancies for technical information sharing.
Interviewee N		Through different events and organisations like OSW Innovation Hub, Innovate UK, Catapult knowledge transfer network, and similar.
Interviewee O	-	-

Table 5.12: Summary of responses concerning the use of shared ICT systems

In similarity to many of the other responses discussed previously, the extent to which participants use shared ICT systems and the extent to which information is shared varies from project to project and from developer to developer. Those who have experience of working with developers directly explained how developers usually have project portals that they use to publish tender information on, where suppliers/contractors can submit tenders. In addition, there are document management systems that suppliers can interact with to upload and revise documents. These are used for tracking documents, tracking progress, and for making comments. Participants mentioned the use of systems such as Microsoft SharePoint and Aconex and, with the exception of these formal ICT systems, the most common form of communication is via email.

Those who are connected to offshore work mentioned the use of SeaPlanner for marine coordination, which tracks the movements of vessels within a set parameter and provides information about personnel, including whether they are fully qualified and equipped to go offshore (Interviewees C and H).

An interesting observation was made by Interviewees J and K, who can be classed as smaller suppliers. In both cases, information sharing happens predominantly via less formal means, such as emails, face-to-face meetings, presentations, and video conferencing.

Interviewee G provided information in relation to the O&M phase of a wind farm and mentioned that, in some cases, they would have a direct access to a client's O&M system where they could share information and make orders without the need for formal permission from the client. This example shows that there is often closer collaboration between parties during the O&M phase.

Participants were also asked to discuss information sharing more generally and, as a probe, participants were asked whether it is common practice to discuss 'lessons learned' to share project experiences among project supply chain members. Considering all of the responses, it was found that there is no common practice to discuss information among all supply chain members of a project. For some, there is a company internal practice (Interviewee C), and for others this occurs at the beginning of a project rather than at the end (Interviewee L), or at the beginning and the end to establish project targets at the beginning and then to review company performance after (Interviewee G).

5.3.6.6 Summary

Based on the above findings on the existing relationship types in the OSW industry, especially those findings on the scope of relationships, formal and informal collaboration management, dominant value drivers, and the use of shared information technology systems, it can be summarised that SCI levels differ from project to project, largely due to the different approaches taken by OSW project developers to implement SCM.

There are notably higher SCI levels when there is a direct interaction with project developers, and slightly lower SCI levels when interaction is through EPCI contractors. A lack of continuity in project supply chains between projects also suggests that SCI levels are currently rather limited. However, the consistency of the participants' answers in relation to dominant value drivers within the industry shows that there is a high level of alignment in relation to the industry's overall objective to reduce LCOE, as well as high levels of understanding about the changing nature of each project's value drivers. The use of framework agreements, or collaboration agreements, also give grounds to suggest that there would be greater integration in some supply chain areas compared to others and, as previously mentioned by Interviewee B, this suggests that the industry is not starting from zero.

5.3.7 Identified inhibiting factors of SCI

In order to understand how to achieve a more integrated supply chain, it was important to first determine the complexities associated with OSW SCI. Table 5.13 shows the identified inhibiting factors based on conversations with the participants.

Inhibiting Factors of SCI	
Inhibiting factors	**Description**
Unique nature of projects	Every project could require different parties to be involved, which limits standardisation of product designs.
Irregular demand	It is difficult to invest in facilities and staff with irregular demand.
Uncertainty of future pipeline of projects	It makes it difficult to invest in any long-term relationships without the certainty of the future projects in the pipeline.
Temporary contract staff	It is difficult to form any long-term relationships with contracted staff who leave as soon as the project finishes.
Unreliability of individual supply chains	Unreliable third parties might affect companies in fulfilling their deliveries, leading to delays of the whole project supply chain, affecting longer-term relationships.
Dishonesty of suppliers	Some suppliers may underbid the job to win the job without understanding the full demand of the work. Some suppliers may be dishonest about their capability to fulfil the role and may start to involve other parties to help meet demand. This creates a lot of risk in the supply chain and limits its integration potential.

Table 5.13: Identified inhibiting factors of SCI

One factor concerns the unique nature of projects. While it implies a lot of challenges in itself, it makes it difficult to achieve greater integration among supply chain members because every project could necessitate different suppliers. The fact that every project is unique inhibits the standardisation of products. This means that it requires plenty of bespoke and ETO solutions.

Irregular demand is another factor inhibiting collaboration and thus inhibiting a more integrated supply chain. Some have described the nature of the OSW industry as highly cyclical (Interviewees K and D). This means that sometimes there are peaks of work followed by periods of no work, and then further peaks. Such volatility in demand makes it difficult to form long-term plans and therefore makes it difficult to form long-term relationships.

Irregular demand often results from not knowing how many projects will be in the pipeline, therefore, the uncertainty of future pipeline of projects has been identified as a separate inhibiting factor. While cases of irregular demand mainly affect lower-tier suppliers, the uncertainty of future work in the pipeline is an industry-wide problem affecting not only lower-tier suppliers, but also developers. This makes it difficult for collaborations to form. The visibility of project pipelines normally depends on the intentions of governments to invest in renewable energy. In the UK, this problem has largely been improved by the sector deal, which was secured between the UK government and the OSW industry in 2019. The UK government has committed to a pipeline of projects every two years by running regular auction rounds for contract for difference

(CfD), which is a subsidy mechanism created to support the growing industry (HM Government, 2019).

Another identified inhibiting factor is the use of temporary contract staff. This problem has been identified on several levels, including one at the development phase of wind farms and another concerning other supply chain areas. Some developers may hire contracted consultants to build project supply chains. As it was mentioned above around 75% of project employees are contracted staff. This constrains the formation of more collaborative relationships because some consultants may be more concerned about their own successes instead of focusing on the job as a whole. A similar problem exists at other supply chain levels. For instance, some relationships between project suppliers might be formed in one project, but these will not necessarily continue into the next project due to the frequent movement of people. This creates a limited continuity of relationships from one project to the next.

A less obvious inhibiting factor concerns the unreliability of individual supply chains. It has been mentioned before that even those relationships which can be considered as strategic partnerships remain fragile. For example, if project suppliers' or contractors' own suppliers face problems and are unable to keep up with demand, this may place a strain on existing buyer-supplier relationships. In turn, this could affect the whole project supply chain by creating delays.

The experiences of some participants (Interviewees B, C, and G) suggests that some suppliers may simply be dishonest about their capabilities to deliver by overstating their capabilities to win contracts. Therefore, the dishonesty of suppliers has been identified as another inhibiting factor affecting the ability to create long-term relationships. As explained by interviewee C, "*there are not a lot of companies in the industry that can match the supply and demand*". What sometimes happens is that some companies, especially new companies just starting in the industry, fulfil all the requirements at the pre-qualification stage, but during the project they could begin to fail. In such cases, they might start to involve other subcontractors to help them meet demand, but this is unacceptable within the industry because it creates a range of quality risks that may result in expensive repairs during a project's lifecycle. For this reason, Interviewee G described how suppliers are expected to be open about their capabilities and, if they are open, then many companies would be happy to work with them to teach them new things about the industry. To the contrary, if suppliers are unwilling to learn or act dishonestly, then companies would typically show no interest in building long-term relationships with these types of suppliers.

5.3.8 Identified facilitating factors of SCI

Following the inhibiting factors described above, Table 5.14 lists the identified facilitating factors of SCI.

Facilitating Factors of SCI	
Facilitating Factors	**Description**
Framework agreements	Provide structure for collaboration.
Strategic alliances/partnerships	Provide structure for collaboration and give visibility of plans.
European ISO standards/other guidelines	Help to align understanding between parties about different standards of work processes and procedures.
Compliance with client requirements	Helps to streamline supply chain processes.
Joint project targets/goals	Facilitate alignment of project partners towards joint targets/goals.
Standardisation of communication/product design/other	Standardisation facilitates the flow of supply chain processes.
Formal/informal incentives	Monetary and other incentives with an objective to facilitate collaboration.
Organisational culture	Collaboratively oriented organisations facilitate SCI.
Industry trade bodies	Facilitate communication among supply chain parties through industry events, meetings, presentations.
Personalities	Human factor.

Table 5.14: Identified facilitating factors of SCI

As mentioned previously, the study participants often mentioned framework agreements as a formal way of managing collaborations between parties. They allow people to pre-agree contract terms and prices, which could last for several projects to provide structure for collaboration. Therefore, framework agreements, or long-term collaboration agreements, act as facilitators of SCI.

Strategic alliances and strategic partnerships are closely related to framework agreements, which also provide structure for collaboration over several projects as well as visibility for suppliers in terms of their customers' plans over following years. This allows suppliers to enter into a strategic alliance with their customers in order to provide the right services or products to deliver on planned projects.

The European ISO standards and various other guidelines related to specific project tasks help to align understanding between parties about different standards of work processes and procedures, such as vessel operations. One example was provided by Interviewee H, who explained that, apart from specific vessel operation manuals and set procedures preapproved by the vessel classification society, there are other OSW vessel guides that advise the industry to ensure consistency between different vessel providers. Interviewee G mentioned that they use European ISO standards to achieve a shared understanding between parties about things like the quality of deliverables, the supply chain, and reporting standards. Interviewee G explained that ISO standards provide a good framework for understanding whether other parties have the same general understanding of terminologies like SCM.

Another important identified factor is compliance with client requirements. This helps to streamline supply chain processes more generally, but also helps to keep client-supplier relationships in good order. What this means is that, even though some suppliers may have their own opinions about how to do things or what they can do instead, it is better to comply with project targets or task targets as requested by the client when dealing with time-finite projects. Therefore, setting up joint project targets or goals at the beginning of a project has been identified as a facilitating factor to align project partners towards the same goal.

Project participants often mentioned that they would like to see further standardisation across project developers, product design/engineering and across wind farms. The standardisation of communication/product design/other is therefore listed as a factor facilitating SCI because it facilitates product/services, information, and financial flows related to the supply chain.

Conversations with the study participants suggest that there are few incentives to facilitate project or multi-project collaboration. It seems that there are difficult punishments in place for when things do not go well. In such instances, relationships quickly become strained. When, however, things have been done well, suppliers deliver their product and services as required, there are few rewards. For this reason, formal/informal incentives have been noted as facilitators that can help to integrate supply chains.

A less obvious SCI facilitator, but one that seems to work successfully, is the organisational culture. Based on examples from the study participants about their own approaches towards working with project partners and suppliers, it seems that companies which are collaboratively oriented tend to view collaborative relationships as beneficial for all. They therefore strive to form, or have no objections to forming, more collaborative relationships.

Another way of attracting the interest of suppliers and industry players over the past eight to ten years has involved industry trade bodies. These are more effective in terms of accessing the supply chain or becoming a supplier to the OSW industry by facilitating conversations between parties through various industry events. They can further facilitate the SCI of specific projects by giving grounds for more informal incentives by providing networking and meeting opportunities.

Another important more general factor is personalities. It sounds simple, but as Interviewee E explained, when it comes to forming trade relationships it is as much about personalities and whether the supplier team can ‘gel’ with a buyer team. A similar comment was made by Interviewee K, who mentioned that it is still classically about human relationships.

5.3.9 Improvements participants would like to see happen

It should be noted that there is a general sense of satisfaction with the way things currently work. All participants acknowledge that the OSW supply chain is complex and, therefore, some found it difficult to suggest any improvements. However, there are still things that could be improved. Table 5.15 provides a summary of improvements the participants would like to see happen in relation to their scopes of work, or in relation to the OSW industry in general.

One of the things most commonly mentioned was standardisation and commonality. This includes standardisation or commonality in contracts or terms and conditions (Interviewees D, E, and F), in information requests from developers (Interviewee L), in cable designs (Interviewee J), in other product engineering areas like primary and secondary steel components (Interviewee K), across developers in their approaches to practical technical solutions offshore (Interviewee G), and across the supply chain overall (Interviewee B).

Participants	Suggested Improvements
Interviewee A OSW farms developer	More realistic government expectations.
Interviewee B OSW farm project director	Improvements in IT tools. Improvements in contracts in dealing with change. More long-term investment by both suppliers and government for future projects. More standardisation across the supply chain.
Interviewee C (turbine manufacturer)	Better match of supply and demand. Training of turbine technicians.
Interviewee D Power cables manufacturer (array)	Better standardisation of contract terms and conditions.
Interviewee E Power cables manufacturer (export)	Consistency in project teams. Better visibility of available local companies for tier-one suppliers/contractors in different areas of expertise. Pain and gain share contracts. Standardisation in contracts. Improvements in ICT systems.
Interviewee F Onshore substation contractor	Use of NEC (Engineering and Construction Contract) suite of contracts instead of FIDIC (The International Federation of Consulting Engineers). Lessons learned sessions among supply chain parties. Unification/standardisation of contracts.
Interviewee G Offshore substation contractor	Standardised solutions/approaches to main component designs.
Interviewee H Installation services provider/vessels operator(turbines & foundations)	Multi-project contracts.
Interviewee I Installation services provider/vessels operator (power cables)	Improvements to the tender process.
Interviewee J Cable protection manufacturer	More collaborative approach and more knowledge sharing between different customers and suppliers. Improved standardisation of cable designs.
Interviewee K Secondary steel fabricator	Standardisation across clients, across designers and across wind farms. More commonality of product engineering approaches.
Interviewee L Environmental Impact Assessment provider (underwater noise impact)	Standardisation of information requests from clients.
Interviewee M Environmental Impact Assessment provider (archaeological services)	Smoothing of timelines. More visibility of potential delays affecting other parts of supply chain. NEC4 contracts could be used in the OSW industry.
Interviewee N Trade association and business development organisation	More collaboration to facilitate potential supplier participation in the OSW industry.
Interviewee O Financial adviser	-

Table 5.15: Summary of improvements the participants would like to see happen

As mentioned by Interviewee G, every developer tends to have their own solutions to OSW farm development and opinions about the way things should work. However, developers' unique approaches to OSW project management makes it more challenging to reduce LCOE. Interviewee G suggested that it would be more effective to learn from examples in the automotive industry. For instance, where companies began to share car components whilst retaining their own designs. Interviewee G believes that there is the potential to keep costs down if developers shared ideas in relation to key OSW components.

Similar issues were raised by Interviewees K and J, who mentioned that there is a high variance and difference between products, such as cables and primary steel products, which makes the production of secondary components to those more challenging because it requires a high degree of ETO approaches rather than ETS or MTS. While Interviewees K and J fully understand that this occurs due to the uniqueness of projects, they strongly believe that improvements to product standardisation can be made to keep overall costs down.

Another area for standardisation concerns contracts and their terms and conditions. It has been mentioned by Interviewees E, F, and D that more can be done to standardise these without having to negotiate contract terms for every new project. Interviewee F suggested that, instead of having separate FIDIC contracts, which are commonly used between developers and each of their suppliers/contractors (this is discussed further in section 5.4.4), there could be one contract for all, with shared risks or incentive structures or penalty structures and risk management. Similarly, Interviewee E suggested a single contract approach between developers and suppliers, where suppliers would know in advance what the contract will look like when working for a particular developer. Interviewee E believes that the oil and gas industry takes a similar approach.

Interviewee D explained that, when there are framework agreements in place, 80-90% of different terms would be pre-agreed for one or multiple projects, and 10 or 20% would be negotiated on a project-by-project basis. This makes the process highly efficient and makes it easier for parties to be more agile in their response to customer needs. However, even with framework agreements in place, terms and conditions still tend to be seen as onerous. Better standardisation of terms and conditions is believed to improve competitive tensions between customers and suppliers especially for one-off orders, which usually result in a vicious circle of price penalties (Interviewee D).

Differences in developers' approaches also seem to increase administration tasks for suppliers when establishing a new contract. As explained by Interviewee L, clients who could be main contactors would normally request to fill in the forms and ask many company related questions. As mentioned by Interviewee L, these forms sometimes take hours or days to complete, especially with regards to accessing all of the appropriate information. Most information is already stored on third-party systems, and it would be much easier if clients could access these systems to view the information. Unfortunately, suppliers and customers often use different systems. Standardisation in this area would help to avoid lengthy processes of filling in forms based on information that already exists elsewhere.

The IT systems currently used by industry players to share information is also an area that could be improved (Interviewees B and E). Some tools that are currently used during the construction phase for formal information sharing have been described as "not brilliant" (Interviewee B). This suggests that there is room for more effective collaboration tools. The project portals used by developers to publish tender information have also been described as "clunky" and non-user friendly (Interviewee E). This means that suppliers use emails as an alternative. In addition to Interviewee E's observations about project portals, Interviewee D mentioned that some project portals act as ebidding systems, which are similar to eBay, where suppliers can bid for work. Such ebidding systems might be set up to attract the lowest cost without considering the quality or complexity of offshore projects. Such systems have meant that Interviewee D refuses to participate in these types of bidding processes. Likewise, other participants raised similar concerns by saying that it is more important to maintain the quality of their work, to ensure the longevity of their products/services, and to maintain the company's reputation, rather than offering anything to a low standard just to meet the lowest cost bid (Interviewees E, L, and M). In a more general sense regarding information sharing, Interviewees F and J would like to see a more collaborative approach towards knowledge sharing between relevant suppliers and customers, including increased joint learning sessions to receive feedback on the performance of certain products or services.

Another area for potential improvement concerns the contracts between supply chain parties. Aside from further standardisation, as mentioned above, some participants suggested that existing contract frameworks used in the OSW industry could be updated to form more collaborative types of contracts. The participants explained that the FIDIC suite of contracts are the most often used contract types within the OSW industry. However, as mentioned by Interviewee F, FIDIC is quite an “old-fashioned” contract, which could be changed to a more collaborative type, such as the NEC suite of contracts. This opinion was supported by Interviewee M, who mentioned that the NEC4 contract could have the potential for use in the OSW industry. Another suggestion regarding contract types was given by Interviewee E, who suggested that pain and gain share types of contracts could also be considered. According to Interviewee E, they are more ‘open book’. This means that contract parties have a target price where, if parties come below the target price, they get a share of the savings. However, if they go over, they get a share of the pain. Such contracts are believed to change the approach taken by parties to a more collaborative one.

The desire to improve current contracts and tender processes in general were also expressed by Interviewees B, H, and I. Interviewee I explained that current tender processes are time consuming and expensive, and therefore hoped for improvements in this area. Interviewee H believes that their scope of work is operating well but that, if there was an opportunity for developers to sign a multi-project contract with a particular supplier over several years and several projects, supplier confidence would be given for investments. Interviewee B expressed a will to seek improvements to existing contracts in relation to dealing with any changes.

Other areas for improvement relate to each participant’s area of concern. For example, in terms of developers and project management, Interviewees A and B discussed how government expectations could be more realistic in terms of involving local suppliers as much as possible. Often, the capabilities of local suppliers do not match the requirements of developers, thus requiring developers to invest in suppliers to develop them to the required standards. This requires trade-offs to be made between the government and developers, necessitating both sides to make investments for the growth of the industry. Potential suppliers are also required to take steps towards development initiatives, which is where industry trade organisations like Interviewee N’s could bring value. They provide a point of contact that can help to identify smaller suppliers for potential work within the industry. Therefore, Interviewee N would like to see further collaborations between different industry players to facilitate potential supplier participation in the OSW industry.

In relation to the local industry trade bodies, Interviewee E provided perspective as an onshore cable EPCI contractor. Interviewee E explained how, in their EPCI scope of work in the UK, they often do not have visibility of those potential suppliers that can help them with their work on onshore cable installation. The local industry trade bodies that try and match local companies with developers and tier-one suppliers tend to focus on turbines. However, Interviewee E typically requires different kinds of suppliers. Therefore, this could be improved by making local companies within other OSW supply chain areas, like onshore cable installation works, more visible.

Another issue surrounding greater visibility was raised by Interviewee M. The biggest problem that Interviewee M encounters in their work scope, given their position in the supply chain, is that everything from the tendering process right the way through to the completed project seems rushed, for reasons that Interviewee M is unaware of. This constant pressure on time could be caused by things that might happen far up the supply chain or in one particular part of it. However, these reasons that create time pressure for other supply chain member of the project are not visible. Improvements to these issues that cause time pressure would therefore be beneficial.

From a turbine manufacturing perspective, there are many difficulties associated with matching supply and demand. As explained by Interviewee C, one difficulty is that there is a lot of available work, but there are few companies that can provide the level of quality expected. The same applies to turbine technicians; there is a lot of temporary work for them, but this work requires them to be trained on specific turbine makes and models as general training is inadequate. Another difficulty is that demand for work is temporary. Therefore, even though Interviewee C would like to see some improvements to the training standards of turbine technicians and to the quality of suppliers to increase availability of supply, they acknowledge that the improvements would be difficult to achieve given the temporary nature of projects.

5.3.10 Industries to learn from

Some potential improvements suggested by participants regarding current OSW supply chain processes were based on other industry practices. Table 5.16 provides information on the industries that the OSW industry could learn from.

Industries to Learn From	
Industry	**Reason**
Automotive	▪ Sharing components/approaches (Interviewees G). ▪ Lean techniques (Interviewees G and D). ▪ Competing supply chains (Interviewee D).
Oil & Gas	▪ Each developer has a set standard contract to use with their suppliers (Interviewee E). ▪ Alliancing model (Interviewee B). ▪ Operations interface management. Companies work together to perform general operations of their assets (Interviewee I).
Aerospace	▪ Product engineering to optimise safety factors. Batch manufacturing. Materials use (Interviewee D). ▪ H&S regulations (Interviewee N).
Civil Engineering	▪ Use of NEC suite of contracts (Interviewee F). ▪ NEC4 contracts (Interviewee N). ▪ Pain and gain share contracts (Interviewee E).
Other Views	
Oil & Gas	▪ Standards brought from oil & gas increasing costs of OSW instead of decreasing (Interviewee J).
OSW	▪ Setting up own standards (Interviewee L). ▪ OSW itself defines some sectors (Interviewee M). ▪ Learning from one another (Interviewee F).

Table 5.16: Summary of industries that the OSW industry could learn from

The automotive industry provides potential ideas regarding the sharing of components and approaches, as discussed previously by Interviewee G. This industry is also famous for its lean techniques, which could be applied to the OSW industry. Another observation was made by Interviewee D, who believes that the OSW industry is moving towards the direction of competing supply chains, which is similar to the automotive industry. Competing supply chains refer to the idea of new rules of competition. According to logistics and SCM scholars (Christopher, 2016) organisations can no longer act in isolation in competition with other organisations. Instead, there is a need to recognise that organisations are interconnected in supply chains that create value for the end customer. This change in perspective emphasises that there is new era of ‘supply chain competition’ (Christopher, 2016).

The oil and gas industry can provide ideas in terms of the use of standardised contracts and alliances between parties. Interviewee I discussed an idea related to the interface management of operations by describing how oil and gas companies come together to perform their general operations, whereas in the OSW industry operations and the maintenance of assets are fragmented. However, the idea of learning from the oil and gas industry was slightly controversial. Interviewee J, who also has experience of working with oil and gas clients, provided an alternative opinion about taking ideas from oil and gas. More specifically, Interviewee J mentioned that many oil and gas standards are being brought into the OSW industry because OSW staff have experience of oil and gas, but that this is driving up costs. People are bringing unique bespoke oil and gas products that are expensive alongside a mentality that is more stringent on quality control standards. These quality control requirements are starting to filter into the OSW industry, thus resulting in unnecessary amounts of product testing and verification.

The aerospace industry could provide ideas in terms of how to engineer products to optimise safety. Ideas in relation to batch manufacturing could also be useful given that some of the materials used for wing sections are similar to those used for turbine blades. The aerospace industry is also extremely H&S conscious and highly regulated, which might provide examples for the OSW industry. The civil engineering industry provides examples of the NEC suite of contracts, which are considered as being more collaborative, as well as providing examples of pain and gain share contracts.

An alternative view is that OSW itself provides directions for some specialisms, for example, archaeological services. As explained by Interviewee M, OSW industry has had more impact in certain archaeological tasks and the ways those tasks are carried that have been applied to other industries, rather than another way around. A similar view is held by Interviewee L, who sets their own standards due to the uniqueness of OSW requirements. Finally, Interviewee F believes that there are opportunities for project partners to learn from each other by exchanging ideas on how to improve business processes, including collaboration.

5.3.11 A cloud summary of frequently used words

As mentioned above, this study did not use NVivo software for its main data analysis process due to complications surrounding data fragmentation. However, NVivo offers a data query function called word frequency. This function collects the most frequently used words within a data set and was the only function of NVivo used in this study. This function was used to create a word cloud of the most frequently used words by participants, shown in Figure 5.3. The word cloud is limited to one hundred most frequently mentioned words by study participants, excluding anything that was asked or stated by the researcher of this study.

Figure 5.3: A word cloud of the 100 most frequently mentioned words by the interview participants

In terms of the top ten most frequently mentioned words, ‘think’ was mentioned 288 times. This shows that each participant has given their thoughts and personal viewpoints on each interview question. Following on from this, the word ‘project’ was mentioned 235 times, ‘supply’ was mentioned 225 times, ‘offshore’ was mentioned 176 times, ‘chain’ was mentioned 167 times, ‘contract’ was mentioned 156 times, ‘really’ was mentioned 146 times, ‘things’ was mentioned 144 times, ‘quite’ was mentioned 139 times, and ‘different’ was mentioned 135 times.

While words such as ‘project’, ‘supply’, ‘offshore’, and ‘chain’ are relatively self-explanatory given that this study concerns OSW project supply chains, it is interesting to note that the words ‘quite’ and ‘different’ were amongst the most frequently mentioned. This partly demonstrates the overall participants’ discourse in relation to OSW project supply chains, and how, more specifically, projects differ from each other in terms of their supply chains. Another interesting finding concerns the word ‘contract’. Contract types and contractual arrangements currently used within the OSW industry appears to be an area requiring attention. This will be discussed in more detail in the following sections.

Part Three

5.4 VSM Based Results and Findings

As explained in Chapter Four, Section 4.3, the VSM analysis for this study followed the first three steps of the methodology to support self-transformation (Espinosa and Walker, 2017). The first two steps were performed prior to the data collection and the third step, which involved the use of the VSM, was applied in the data analysis stage (as shown in Figure 4.3). This section provides the results of the VSM analysis.

As mentioned above, the VSM analysis was first undertaken using a pen and paper approach to analyses of the individual interviews. This was done by analysing the interviewees' responses to the interview questions related to the VSM themes, as outlined in Table 4.4 of Chapter Four. Table 5.17 below provides further details on the criteria used to evaluate participants' answers in relation to the VSM themes. The study participants' responses were mapped according to a diagrammatic representation of the VSM. This was followed by a cross-case analysis (Eisenhardt, 1989), which allowed for an aggregated interpretation of the viability of the supply chain network, as well as the potential for further integration.

The following sections are structured based on VSM subsystems in order to first describe and evaluate each subsystem individually and highlight any identified issues pertaining to each subsystem, which are outlined as diagnostic points. The descriptions and evaluations of individual subsystems are then followed by a summary evaluation of the system as a whole. An evaluation of the whole system helps to provide a systemic understanding of the current interconnections between subsystems and to highlight any imbalances that could possibly affect the viability of the system in focus and its potential for integration.

Viable System Model based themes analysis criteria		
Systems	**Theme**	**Evaluation criteria**
Environment	OSW environment	Description of the environment and environmental variety evaluation.
One	Primary activities	Assessment of any issues related to the primary activities or tasks of an organisation in relation to OSW. Assessment of the overall operations of OSW supply chains and operational variety evaluation.
Two	Order/task fulfilment procedure. Communication. Standards. Conflicts/issues management	Assessment of the existing tasks management systems/mechanisms and effectiveness of those.
Three	Contractual arrangements. Change management	Assessment of three managerial channels: accountability, resource bargain, and legal and corporate requirements between buyer and supplier. Managerial variety evaluation.
Three*	Inspections/auditing formal and/or informal	Assessment of the effectiveness of inspections/auditing of suppliers, whether formal or informal.
Four	Adaptability to changes in the wider OSW environment	Assessment of any implications of the changing OSW environment on the suppliers' adaptability to changes in the environment.
Five	Ultimate decision maker roles	Assessment of the developers' roles as the ultimate decision makers within OSW supply chains in relation to SCI.

Table 5.17: The VSM analysis criteria used to analyse the interviews (Author)

5.4.1 Description and evaluation of the OSW environment

Description

The OSW environment is a project-based environment, which requires plenty of bespoke engineering and designing of products and services. OSW projects are of a temporary nature, and all project supply chain members are expected to work to a specified project programme to execute that programme. OSW has been described as a young industry that is still growing and developing, which makes its supply chain dynamic and open to change. At the same time, it has been noted that there is more experience in the industry now than ten years ago, which led participants to agree that the OSW sector is maturing, alongside its supply chain. However, it has been mentioned that there are still many challenges that need to be addressed before OSW can be termed a 'mature market'.

OSW projects are often described as unique, and their operations are incomparable to the operations of onshore projects. Their uniqueness partly derives from the seabed conditions that can vary in different parts, but largely it derives from the weather conditions and things such as water depth, wave heights, wave currents, and the speed of currents, which all create unique project conditions. In addition, the industry itself is still developing and OSW farms are getting bigger. Consequently, the components are getting bigger, which adds to the uniqueness of the projects, especially as every project brings new issues, which renders it "*one long development process*" (Interviewee G).

In the UK, OSW projects depend on the UK government's CfD auction process. CfD is known as the feed-in tariff with contract for difference subsidy mechanism, which is offered to the developers of various renewable energy projects. According to the study participants, this subsidy mechanism is welcome, but it does create continuous trade-offs between governments and OSW developers. For governments, including in the UK, it is important to secure investments into the domestic infrastructure and to involve domestic businesses, which is known as the local content requirement. For developers, it is important to receive permission to build OSW farms and to secure PPA, which is commonly known as the route to market (Interviewee O). In other words, developers need to know who would buy the power and assets generated by a wind farm before they decide to build it. To receive permission to build OSW farms and to receive government help, developers need to contribute to the UK economy. In cases where either developers or the government do not provide what was expected of them in terms of subsidies or a contribution to the local economy, certain trade-offs would be made between them. This, however, might be changed in the future because there are projects that are being built with zero subsidies. Though, building OSW projects without government support is still considered advanced and it is expected to be advanced for some years yet.

Another current trend that is developing is floating OSW. As the name suggests, floating OSW does not require turbine foundations to be fixed to the seabed. Instead, they will float on the sea's surface. This would require new approaches to OSW development and construction. In addition, many markets are opening around the world, which has been described as both an opportunity and challenge in terms of OSW supply chains.

Diagnostics

Table 5.18 outlines the identified diagnostics or issues pertaining to the current OSW environmental conditions, based on the participants' responses.

Diagnostics Environment	
Issue	**Description**
Ad hoc nature of projects	This creates fluctuations in the availability of people and resources (Interviewees B, C).
Lack of visibility of project pipelines	There has been poor visibility of planned projects, which makes it difficult for businesses to invest in people, facilities, skills, but it has improved with the sector deal (described in Section 5.3.7) (Interviewees B, C, D, E, H, K).
Big drive to reduce LCOE	This puts pressure on all parts of OSW supply chain (Interviewees D, I, J, K).
Issue in definition of quality and price	There is an overall demand to reduce cost, but at the same time to keep quality standards high. It is difficult to deliver high quality with a low price (Interviewee G, D, E, L).
Rising competition from Asian markets	More suppliers are entering the OSW market with little experience, which poses risks to OSW projects (Interviewees A, G).
Expected shortages in products/services	With the rise of OSW in Asia, US, and parts of Europe, there might be shortages of e.g. installation vessels. A similar concern arises with new generation turbines that will be bigger in size (Interviewee B).
Subsidies are less likely in the future	This will likely put even bigger pressure on the supply chain to drive down costs (Interviewee I, O).
Supply chain capacity issues	If companies bid for every project in CfD auction rounds, they risk creating shortages in the supply chain because suppliers and factories are limited to certain outputs they can produce (Interviewee C).
Projects affecting other projects	If one project runs late then it can affect the other project, which can cause contractual and commercial problems (Interviewees B, C).
Clients provide unclear job specifications	Clients may be unclear in their message about the task due to poorly drafted specifications of contracts, potentially affecting the whole project (Interviewee B).
Underestimating risks	Some unlikely risks sometimes happen because they were underestimated or deemed unlikely (Interviewee B).
Shortage in labour market (turbine technicians)	Different makes of turbines require different skills, knowledge, and experience. The current labour market is limited in what it can provide, creating shortages of qualified turbine technicians (Interviewee C).
More contracted staff than full-time employees	Creates difficulty in forming long-term relationships between supply chain members (Interviewee G).
Supplier/contractor underperformance	Some suppliers/contractors fail to deliver the job on time due to miscalculations of getting the right resources in the right place. Suppliers/contractors underbid the job to win, which causes project issues (Interviewees B, C).

Table 5.18: Identified diagnostics related to the OSW environment

Perhaps the biggest issue voiced by the participants is the *ad hoc* nature of OSW projects. This creates ‘feast or famine’ conditions that make it difficult for businesses to invest, creating fluctuations in the availability of people and resources. This also explains another issue; that in OSW there are more contracted staff than full-time employees. As a result, there is little continuity of project teams, which makes it difficult to develop longer-term relationships between supply chain parties.

Another closely related issue concerns the lack of visibility regarding planned projects in the pipeline, which again affects businesses' abilities to invest. This problem has been partly stabilised by the recently launched sector deal between the UK government and the OSW industry. As explained by Interviewees D and K, it provides more certainty about future projects.

The drive to reduce LCOE places pressure on the whole supply chain. This sometimes creates unrealistic product/services quality expectations in light of the need to reduce costs (Interviewee G). Resource and service providers refuse to compromise on quality. Thus, even bigger pressure to drive down costs is expected, given that more projects will be built with less subsidies (Interviewee I).

Another significant issue that has been raised is related to the current or expected limitations within the suppliers' markets. It has been mentioned before that there are shortages of suppliers and skilled workforces who can match demand and supply. Shortages in products and services impacts different OSW projects (Interviewee C). This means that if one project runs late, a different project could be impacted. In addition, this may create further shortages of available resources owing to other OSW markets opening across the globe (Interviewee B). A similar concern was raised in relation to the development of wind turbine technologies, which has meant that components are becoming larger in size. This will require certain suppliers, such as vessel providers, to invest and update their vessels to accommodate this change, thus creating a potential short-term shortage (Interviewee B). Shortages in the supply chain and the problem of the ability of suppliers to meet the demand of multiple projects, can be created by developers and first-tier suppliers who may bid for every project in CfD auction rounds. It is important to remember that supply chains could be limited to what they can provide and produce at a given time (Interviewee C).

It is important to note that some areas of the supply chain may have more availability than others. Therefore, existing or potential shortages may only pertain to specific parts of the supply chain. In addition, more availability in terms of various resources is coming from Asian markets. Though, a lot of new companies entering the OSW market have little experience in OSW, which creates further issues. For instance, some companies transfer staff from oil and gas to the OSW industry, but their knowledge gained in oil and gas is different to what is required in OSW (Interviewee G).

Other problems related to suppliers and contractors are associated with underperformance, either due to miscalculations of resources and logistics, or simply owing to underestimating demand and misleading clients about their capabilities (Interviewee C). However, clients themselves often cause issues due to unclear job specifications provided to suppliers. Another concern that is associated with developers and which may affect the whole supply chain is the underestimation of unlikely risks (Interviewee B).

Evaluation

Since the viability or survivability of an organisation or any other system is assessed in relation to the environment where that system exists (Beer, 1985), it is important to understand the OSW industry's environmental conditions to enable a further analysis. An environmental evaluation has been based on the availability of resource providers to fulfil the demands of OSW projects. Based on the OSW environment, it can be suggested that there is limited environmental variety in terms of available suppliers. However, there are OSW supply chain areas or supplier markets that are more competitive than others. Supplier variety seems to naturally increase with ongoing OSW development across the world, as well as an ongoing transition from the oil and gas industry to the renewables sector (Interviewee O). Nevertheless, there are stringent requirements to enter the OSW industry. The identified thresholds for potential suppliers are listed as follows:

- High levels of standards to meet (H&S standards, quality standards, various other compliance standards).
- Knowledge and understanding of the OSW environment/operations.
- In-house capability/capacity to be able to fulfil ETO requests (bespoke production).

Based on industry pressures, such as the reduction of LCOE and decreasing subsidies, the attractiveness of the OSW market for potential suppliers may decrease. However, the OSW market's attractiveness is growing on the whole due to the ongoing move from the oil and gas industry to renewable energy (Interviewee O).

5.4.2 System One description and evaluation

Description

In the language of VSM, System One (S1) refers to a collection of operational elements of a system in focus. As this research looks at the project supply chains of OSW farm projects as a network system, it considers its suppliers/contractors as S1 because they form a collection of operations necessary to build a wind farm. Descriptions of the roles of each participant and thus their primary operations were provided in Table 5.1. The primary operations considered in this research were also shown in Figures 4.4 and 5.2 of the system in focus.

The development, construction, and operations of OSW farm projects normally occur in stages. The industry has typically distinguished four phases, namely the development phase, construction phase, O&M phase, and decommissioning phase (BVG Associates, 2019). These phases also define an OSW farm's lifecycle. An OSW farm project's supply chain is therefore formed based on these phases. Each phase involves different suppliers of products and services. This means that each phase can be understood as a separate supply chain or network. While distinct, these phases can overlap in certain ways. For example, some O&M tasks can be decided at the development phase, and some on-land construction tasks may begin at the development phase. In addition, if there are any strategic framework agreements or strategic alliances in place, then some manufacturing and construction contracts can be decided at an earlier stage. However, as Interviewee B explained, the point at which the development phase stops and the construction phase begins occurs when a final investment decision is made.

A final investment decision (FID) can be understood as the point at which a developer secures financial commitments from all relevant parties to finance the construction of a wind farm (BVG Associates, 2019). FID is therefore a key milestone that project developers need to achieve before construction can commence. The key milestones can be summarised as follows: securing consent for the project, deciding on a route to market, and achieving an FID (Interviewee B). The timing of the project would thus be determined based on these milestones.

The project would then be executed based on the developer's chosen strategy. There are two broad strategies. First, by outsourcing work (covering different work packages) to EPC or EPCI contractors. Second, by managing different work packages as a do-it-yourself or multi-contracting strategy. This strategy involves a developer choosing to manage different work packages themselves by awarding a number of contracts related to the main tasks involved with developing a wind farm. As explained by Interviewee A, project tasks are divided into different work packages, examples could include a turbine package, foundations package, cables package, offshore substation(s) package, and onshore substation package; where a turbine package forms the largest part of the CAPEX. The division of tasks within these work packages largely depends on the capabilities that a developer has in-house, versus the capabilities a contracted party can offer.

Diagnostics

Table 5.19 outlines the identified diagnostic points related to S1 based on the interview findings.

Diagnostics S1	
Issues	**Description**
Suppliers/contractors are determined on a project-by-project basis unless there are framework agreements or strategic alliances in place	Teams of suppliers/contractors are formed on a project-by-project basis. This means there would be a new team of suppliers/contractors every time a new project starts. This reduces the opportunity for continuous development and therefore for achieving further integration among supply chain parties. However, if there are multi-project framework agreements or strategic alliances, then some suppliers may be contracted again (Interviewees A, B, E, D).
Supply chain configuration depends on the developer's procurement strategy	The configuration of supply chains largely depends on each developer's interface management strategy, including whether they will manage different work packages themselves or via EPCI contractors. This means suppliers would need to adapt to developers' project execution style every time they work with a new developer (Interviewees D, E, J).
The project procurement strategy is based on the developers' in-house capability	OSW projects require a range of different skills to manage different and complex tasks. One company is unlikely to possess expertise in all areas, thus requiring a number of third parties to be involved. However, some developers may have large in-house capabilities, making them vertically integrated (Interviewees A, B).
A high variety of project conditions create a high variety of products and services	Every project is unique, which creates high variances and differences in product designs. In turn, this makes manufacturing complicated and limits the standardisation of manufacturing processes (Interviewees D, J, K).
Long product engineering & design process	Unique project conditions that require unique product designs make product engineering & design tasks time consuming (Interviewee E).

Some component production or transportation is geographically limited	OSW farms consist of heavy components that are expensive to be shipped from different countries. Locally-based production facilities make logistical tasks more efficient. However, some components, like for example certain types of foundations, would still need to be shipped from overseas due to their complex fabrication, which is difficult to replicate (Interviewee G).

Table 5.19: Identified diagnostics related to System One

As mentioned above, there is limited continuity of project team suppliers from one project to another because suppliers/contractors are determined on a project-by-project basis. However, when framework agreements or strategic alliances between parties are in place, some teams may continue in subsequent projects (Interviewees A and E).

The way that project supply chains will be formed and managed depends on the developers' procurement and interface management strategy, which varies from direct interface management through to a multi-contracting strategy, or indirect interface management via EPCI contractors. Whether EPCI contractors would be involved, and their numbers, would depend on the developers' in-house capability or level of expertise to manage different tasks. Given the complexity of different project tasks and the wide-range of skills required to manage them, it is unlikely that one company could manage all project tasks (Interviewees A and B).

The uniqueness of projects creates a high variety of product designs and service needs. This complicates the manufacturing and fabrication processes of components, making it difficult to standardise production (Interviewees J and K). This complication leads to a further issue, which is that product design and engineering becomes increasingly time-consuming.

Another identified issue, or condition of OSW farm development, is that the production of certain components can be geographically limited. This especially relates to heavy components, such as foundations. In turn, this makes logistical tasks related to transporting these components to OSW construction sites both challenging and expensive. Further complications are added with the capacity limitations of seaports; not all ports are able to handle heavy components, which means that deliveries may not arrive at the ports closest to OSW construction sites (Interviewee C).

Evaluation

All subsystems of the VSM should be considered as being interconnected because they form one unit (or one 'organism' or system). Therefore, to evaluate S1 of the system in focus, it has been assessed in relation to the OSW environment and in relation to the managerial context of the system in focus. More specifically, each primary operation or task of the participants forming part of S1 has been evaluated in relation to the OSW environment and in relation to the participants' connections with their clients or management according to the VSM.

Given the uniqueness of OSW environmental conditions, a high variety of products and services are created to fulfil project operations. This means that every project requires slightly different products in terms of size and variance. Thus, companies need to be flexible in their product designs, engineering, and production. As mentioned by Interviewee G, it is difficult to have continuous or line manufacturing/production in OSW. Although some line production could occur for turbine components and steel structures such as foundations, most wind farm components need to be designed and engineered based on an individual project's needs. Some strategies to help respond to these project-based conditions include the following:

- Postponement strategy, which is explained as "*the ability of a supply chain to delay product differentiation or customization until closer to the time the product is sold*" (Chopra and Meindl, 2010: 329).
- Batch manufacturing.
- Modular manufacturing.

5.4.3 System Two description and evaluation

Description

System Two (S2) refers to a regulatory centre or mechanism of the system in focus. Its main function is to ensure that parts of the system, specifically its operations or S1s, do not interfere with each other when performing their tasks. In the language of the VSM, when such instances occur they are called 'oscillations'. Oscillation is a key issue, or "sickness" of S2, as it is referred to by the VSM. Therefore, the main task of S2 is to dampen these oscillations (Beer, 1979; Espinosa and Walker, 2017).

In the context of SCM, an example of oscillation can be found in the concept of the 'bullwhip effect', which is also known as the Forrester effect. The bullwhip effect occurs when information about customer demand travels through different tiers of the supply chain and becomes distorted or delayed, therefore amplifying order variations and making suppliers buy more than they need. This, in turn, results in too much inventory stock that does not materialise (Grant, 2012). The further up the supply chain from customer demand a company is, the larger the forecasted error of demand and thus the larger the bullwhip effect (Chopra and Meindl, 2016). This suggests that appropriate mechanisms and plans need to be in place to ensure supply chain coordination and to minimise the bullwhip effect. Existing examples of such mechanisms in the context of process-based supply chains involve MRP, MRP II, DRP, ERP, and various CPFR methods.

In the context of the development and construction of OSW farms, there are several supply chain coordination mechanisms in place. It has been identified that, at a project level, there would be a project execution plan or programme. As explained by Thomsen (2012), a project execution plan is a script outlining how an OSW farm project is going to be orchestrated, covering all aspects of the project. It can also be perceived of as a road map covering all project tasks, detailing the sequence of these tasks.

At the level of individual suppliers of products and services, each supplier will have their own project management and production plans that would align with the overall project execution plan. Other identified mechanisms, based on the participants' responses, include the following S2 mechanisms:

- The use of approved vendor lists.
- The use of ERP, CPFR, and other systems in product manufacturing/fabrication.
- ISO standards: ISO9001 or equivalent system for quality management, ISO14001 or equivalent for environmental management, and ISO18001 or equivalent for H&S management.
- DNV rules and standards for project management.
- Other specifications/instructions provided by OEMs to vessel operators outlining how they need to protect components during the transit from quayside to offshore works.
- Vessel operation manuals and sets of procedures that govern the capability and limitations of the vessel, pre-approved by the ship industry classification society.
- Other OSW vessel guides. For example, from Renewable UK.
- SeaPlanner for marine coordination.
- ROC room.

Diagnostics

Table 5.20 lists the identified diagnostic points related to S2. These are the points considered to have an effect on the overall project execution programme or plan, considered as the ultimate S2 in the system in focus.

Diagnostics S2	
Issues	**Description**
Annual production & installation capacity of suppliers	Every resource provider has their own annual capacity as to how many units they can produce, or what they can provide, in a given time. Some supplier capacities (like for example cable manufacturers) need to be booked in advance to ensure timely delivery of the product. Supplier capacity limitations can affect project execution plans (Interviewee C).
Port facility limitations	Similar to product and service suppliers, ports have limitations. Some may only be able to accommodate a certain number of components at one time, creating delivery and installation problems. Ports also have a limited permissible draft capacity, which means that there are limited number of ports that can handle large vessels. Port limitations may impact project delivery timelines (Thomsen, 2012).
Suppliers overstatement of supply capacity (dishonesty of suppliers)	Some suppliers may underestimate demand and provide incorrect details about their capacity to meet demand. This creates complications and delays as a result (Interviewees B, C).
Weather conditions	OSW installation tasks depend on weather conditions, which are difficult to accurately predict in advance. Installations cannot happen when waves are too high, or winds are too strong. This, in turn, affects project execution plans and deadlines (Interviewees E, C).
Delays at individual supplier levels create a knock-on effect	Failures of individual production plans or the supply chains of individual suppliers create delays for the overall project execution plan (Interviewee J).
Late projects create a knock-on effect	If one project is delayed it may affect other project timelines (Interviewee C).
Quality issues of components and staff	Any defects in components or any issues with work force creates delays in the overall project plan (Interviewee C).
Changes to work scope	If the work scope of suppliers changes during the project, it can potentially impact the overall project programme (Interviewee M).

Table 5.20: Identified diagnostics related to System Two

According to Thomsen (2012), the timings of a project largely depend on the individual suppliers' capacity; their capacity for what they can produce in a given period of time. Every supplier has their own limitations as to what they can produce, which in turn impacts project schedules. Similar capacity constraints can be found in ports; some ports may only accommodate a certain number of components at one time, and not all ports provide the deep water berths that are required for large vessels. This may create complications, or even delays, in project schedules. Another problem concerns an overall project schedule, which can be affected by dishonest suppliers who may, at the tendering stage, overstate their ability to deliver on a particular job. As explained by Interviewee C, such instances place an entire project at risk, resulting in conflicts and delays.

Interestingly, all of the suppliers/contractors involved in offshore installation processes must contend with weather conditions. Poor weather conditions can place a project on hold, thus potentially impacting a specific project as well as subsequent projects. Hence, a knock-on effect occurs when one project is late.

Other problems affecting a project's schedule may be caused by project suppliers. These problems may be caused directly, when project plans fail due to problems in a supplier's own factory or company, or they may be caused by their supply chains, such as when suppliers fail to deliver on tasks. A related issue concerns product and service quality; when physical products are defective or there are problems associated with work force complications affecting the overall project programme may occur.

A slightly less critical issue, but one that could nevertheless impact the execution of a project's plan, is associated with change to the original scope of work. Some suppliers may begin with one work scope, but then the goalposts may move slightly during the execution of the original order (Interviewee M). This may also impact the overall project's schedule.

Evaluation

Considering all of the aforementioned issues, S2's biggest problem in the context of OSW involves delays. As shown in Table 5.20, delays can be caused for various reasons. The identified S2 mechanisms outlined above as bullet points suggest that there are various mechanisms in place to facilitate the coordination of parties and to minimise oscillations. However, based on the identified diagnostic points of S2, the issues affecting the execution of overall project plans are inevitable in large projects, such as OSW farms. In relation to this, Interviewee C gave an example of stringent supplier pre-qualification questionnaires and pre-qualification audits that are in place for new suppliers. Yet, the interviewee described how it could still be difficult to identify any issues that might appear later in a project. This suggests that there is a need for further visibility of supply chains of OSW project suppliers/contractors in order to ensure that all parts of the supply chain are reliable and can withstand challenging OSW environmental conditions.

5.4.4 System Three description and evaluation

Description

System Three (S3) is known as the management function of daily operations of the system in focus. Depending on the system in focus, this function in a single organisation can be represented by senior management tasks or management tasks at various operational levels. It is important to consider three ‘channels’ through which interactions between senior management and the management of operational units can occur, these include: legal and corporate requirements channel, resource bargain channel, and accountability channel. The legal and corporate requirements channel signifies the affiliation between parties. The resource bargain channel ensures that there are mechanisms in place for resource allocation. The accountability channel can also be understood as the governing mode of management, which ensures all parties deliver on their tasks (Beer, 1985).

According to Beer (1985), these channels pertain to day-to-day management and can ensure the consistent organisation of management tasks. There are, however, business areas and tasks that do not require constant management and observation, but rather require *ad hoc* checks. According to Beer (1985), such procedures may generically be called ‘audits’. Some businesses may require more formal auditing procedures, whereas others will only require informal procedures. In terms of the VSM, such ‘audits’ are represented as System Three* (S3*).

Considering the different backgrounds of the study participants, representing different work scopes or areas of the OSW supply chain, different interactions between the participants forming S1 and the management forming S3 and S3* were explored. Table 5.21 highlights the different interactions that were explored and shows the findings related to S3 and S3* and the three channels of S3. The main interactions that have been explored include those between developers and the UK government, those between developers and suppliers, those between individual suppliers and their clients (such as developers) and, in some instances, those between individual suppliers and their own suppliers.

The interactions between developers and the UK government have revealed that the main legal and corporate requirements include local content requirements. This can be explained in terms of a policy that requires foreign investors or other companies involved in the industry to contribute to the national economy by purchasing local goods and/or services (OECD, 2016). Another requirement is known as the OFTO regime (mentioned in Section 2.6), which ensures that all OSW electricity capacity is connected and distributed to customers, and it also provides opportunities for investment.

Levels of Interaction	**S3**			**S3***
	Legal & Corporate Requirements	**Resource Bargain**	**Accountability**	
Developers & government	▪Local content requirement ▪OFTO regime ▪Leasing Terms of the Crown Estate UK	▪CfD auction rounds ▪Sector deal ▪ PPA	Supply Chain Plan (investment in local economy)	
Developers & suppliers	▪FIDIC based contracts ▪LOGIC suite of contracts	Tender process or direct award	▪Defined specifications & timing for suppliers ▪Framework agreements ▪A team of dedicated contract managers, together with a project manager looking after the scope that the supplier is delivering ▪Contract management ICT tools ▪Contractual terms (liquidated damages, performance volumes, structuring payments) ▪Informal supply chain relationships ▪Critical project success factors ▪Lessons learned sessions (company internal & external with contractors)	▪People permanently located at the suppliers' facilities for the duration of a contract ▪Audits of suppliers during a contract ▪Informal collaboration barometer with key suppliers (a survey three times a year)

Levels of Interaction	S3			S3*
	Legal & Corporate Requirements	**Resource Bargain**	**Accountability**	
Turbine manufacturer & OSW owners		Tender Process	A client representative on a vessel during commissioning	▪Regular audits & presence on-site ▪Quality inspection visits during turbine installation & commissioning
Turbine manufacturer & suppliers	▪Supplier agreement ▪Service provider agreement		▪Set supplier requirements & standards (depending on the contract value) ▪Set KPIs ▪Supplier/technicians briefings ▪Sea Planner for offshore works staff compliance with HS&E PPE	▪Quality inspections both upstream and downstream ▪Audits of suppliers & labour companies
Cable manufacturers (array & export) & developers	FIDIC type contract	▪Concept phase (FEED) ▪Tender process ▪Purchase order	▪Framework agreements ▪Customer schedules ▪Cost penalties for delays	▪Client representatives or inspectors witnessing key parts of the manufacturing and testing of the product ▪A marine warranty surveyor supervising cable load out onto the vessel ▪Client representative on vessel to witness installation
Cable manufacturers (array & export) & suppliers		▪Tender process ▪Purchase order	▪Engaging supply chain early ▪Framework agreements with raw material suppliers	

Levels of Interaction	S3			S3*
	Legal & Corporate Requirements	Resource Bargain	Accountability	
Onshore substation contractor & developer	FIDIC based (modified)	▪Tender process before ▪Now direct award	▪Client's team based on-site for the duration of construction to monitor the process ▪Set KPIs ▪Progress monitoring through critical path activities on the schedule ▪Use of iPads by project teams ▪ROC room-rehearsal of concept	Client's team based on-site for the duration of construction to monitor the process
Onshore substation contractor & suppliers & other supply chain members		Tender process	▪Interface management for HS&E ▪Early engagement with suppliers	
Offshore substation contractor & developer	Service agreement for O&M part	▪European tender rules (if developer is a public organisation) ▪General tender rules (if the customer is a private organisation) ▪Contract negotiations	Set KPIs	▪Customer surveys, initiated by offshore substation contractors, to follow up with new customers ▪Following up with new customers in person ▪Safety walks by customer
Offshore substation contractor & suppliers			▪Use of local suppliers/native speakers where possible ▪Direct supervision and management of processes ▪Set standards & certifications ▪Setting up common project targets	

Levels of Interaction	S3			S3*
	Legal & Corporate Requirements	**Resource Bargain**	**Accountability**	
Turbine/foundations installation supplier & clients	▪BIMCO contracts ▪Customer contracts (charter party or construction lump sum)	Tender	▪Own project management ▪Own HS&E management ▪Specifications from developer & turbine manufacturer for component transit ▪Turbine manufacturers' own installation crew looking after turbine components during installation & commissioning	▪Client representative on board the vessel at all times ▪Component checks before and after installation
Cable installation supplier & clients	▪FIDIC based ▪LOGIC (mostly for vessel hire) ▪BIMCO (for vessel charter)	▪Tender (different in the UK & Europe) ▪Contract negotiations	▪Own project management procedures based on DNV standards ▪Master Document Register (MDR) agreed with the client ▪Regular progress meeting & updates	▪Audits before contract award or after ▪Client representative checking procedures ▪Marine warranty surveyor reviews & approves procedures ▪Regular progress reviews & meetings
Cable installation supplier & suppliers			A set schedule agreed between parties for performance monitoring	▪Audits before contract is awarded ▪ Agreed inspection & test plan of products
Cable protection supplier & clients	FIDIC based or LOGIC terms	▪Tender ▪Contract negotiation	▪Internal project schedule ▪Project management processes ▪Client project plan	Agreed client inspections

Levels of Interaction	S3			S3*
	Legal & Corporate Requirements	Resource Bargain	Accountability	
Secondary steel fabricator & clients	Subcontract agreement (bespoke contract)	▪Tender ▪Contract negotiation	▪Internal project schedule ▪Project management processes ▪Client project plan	▪Daily in-house inspection at a shop floor level ▪Weekly at inspector level
Underwater noise measurement supplier & clients	Consultancy agreement	▪Tender ▪Contract negotiation	▪H&S risk assessment ▪Internal firm processes	Vessel used is subject to a series of inspections
Archaeology services supplier & clients	Subcontract agreement	▪Tender ▪Contract negotiation	▪Depends on client & client expectations ▪Internal firm processes	Regular progress meetings

Table 5.21: System Three and System Three findings*

Other rules and regulations for OSW developers would be subject to the terms of the Crown Estate leases of the UK seabed. The Crown Estate also runs CfD auction rounds to allocate CfD contracts to new low-carbon electricity generation projects. These auctions can be considered as the main resource bargain mechanism between the UK government and OSW developers because it acts as a version of PPA, as explained by Interviewee O. The aforementioned sector deal between the UK government and OSW industry also forms part of the resource bargain mechanism because it outlines the government's intentions in relation to future OSW projects, thus providing more clarity for developers. To ensure that OSW developers adhere to local content requirements, the government requires all developers to outline their investment plans via the supply chain plan, which needs to be submitted as part of their CfD application. The supply chain plan is therefore considered as being an example of how the government seeks accountability from OSW developers.

In relation to other interactions, the way legal and corporate norms are established between parties is through contractual arrangements, which vary from company to company. The most common type of contract used between developers and first-tier suppliers/contractors is the FIDIC suite of contracts. There are various types of FIDIC, which are categorised using different colours. For example, the FIDIC Yellow Book and FIDIC Silver Book. FIDIC type contracts provide a general framework that is often modified according to developers' preferences, as it has been explained by the participants. Subcontractor agreements, consultancy agreements, or service agreements are used for lower-tier suppliers.

Contractual agreements also define the work specifications of suppliers, including the work's execution. Any necessary changes needed to be made by suppliers in relation to their work would be dealt with based on these contractual terms. Contractual agreements therefore act as a key resource bargain mechanism between parties. A resource bargain would normally occur via a competitive tender process, after which detailed contract negotiations would take place where parties agree on the main terms of a project. When framework agreements or strategic alliances are in place, some contracts may be awarded directly without a competitive tender process.

Following detailed contract negotiations, each supplier is responsible for delivering their jobs as per the contract using their own expertise. Companies often have their own internal project teams that produce a work plan to follow. Individual work plans need to adhere to the client's project plan, and suppliers often set their own KPIs to monitor their progress. When working directly with developers, developers may define critical project success factors that need to be followed and may closely supervise progress themselves. For instance, by exerting a permanent physical presence throughout the duration of the project in construction or installation sites. Similar supervision levels could be exercised by OEMs. For example, turbine manufacturers and OSW substation contractors.

Given that OSW farms are high-risk and high-value environments, OSW farms are normally £2 billion projects, and so any mistakes made onshore in terms of components or processes can be costly once offshore. Mistakes can even cost people their lives during the installation process. This makes developers to take additional care in their supplier auditing procedures, reflected in the findings related to S3*. According to the VSM, S3* should be sporadic in nature rather than implemented as a permanent routine. However, given the high-risk nature of OSW, there are high levels of control. Based on the participants' responses, suppliers are audited before and after the contract agreement and, depending on the importance of the supplier, some require close monitoring throughout a project; with regular quality inspections and progress meetings. As explained by the participants, any quality inspections or safety walks should be pre-agreed and pre-planned, this means that there would be no "*surprise visits*" (Interviewee A).

Such levels of control may cause a hindrance for some, such as cable manufacturers or other component manufacturers who would need to halt their processes until all inspections and tests have been approved. In general, though, all participants accept it is a necessity as it provides reassurance and peace of mind to clients. In relation to installation processes, the client's representatives, together with marine warranty surveyors, will be on board the vessels at all times. This is considered to be helpful because it provides a different 'set of eyes' (Interviewee C). It is also critical, as Interviewee H explains:

"*It is critical because it not only protects the client, it also protects us*".

It also makes it easier to track issues and find who is responsible for them.

Diagnostics

Table 5.22 lists the identified diagnostic issues related to S3. As mentioned previously, all study participants held positive sentiments about the current processes in the OSW industry, but they accept that there are some areas with the potential for improvement. The main issues identified in relation to S3 revolve around CfD auctions and FIDIC contracts, as well as other contractual issues. Other identified issues have been pertaining to each participants' work scopes or roles within the OSW supply chains.

Diagnostics S3	
Issues	**Description**
CfD auctions are "double-edged swords"	It increases the competitiveness of domestic suppliers, but it also increases uncertainty for OSW developers. Developers find it difficult to make long-term investments into the domestic supply chain without knowledge of which renewable energy project will get awarded CfD (Interviewee B).
Companies bidding for every wind farm at CfD auctions could create supply chain capacity problems	If one company (such as a turbine manufacturer) bids for every wind farm project at CfD auctions and gets awarded every project, it would create a lot of demand for the suppliers, which they might not be able to fulfil (Interviewee C).
Local supplier competitiveness on a buy-local basis is not enough	Local content requirement helps local companies to become more competitive in the domestic market, but it is not enough for developers. Companies need to be competitive in the global marketplace to be able to form longer-term relationships (Interviewee A).
Delays caused by weather conditions impact contractual agreements with resource providers	If contracts do not have special clauses allowing some delays due to weather conditions, it results in additional costs (Interviewee C).

Lack of visibility of OSW farm’s system design	Information about the overall OSW farm’s system design is not easily accessible for all supply chain members. Suppliers of products cannot assess themselves if their products would function as required in the designed system’s conditions (Interviewee D).
Ebidding type tender systems do not consider quality	Ebidding type tender systems used in some jurisdictions are set up to award for the lowest costs. Such systems do not consider quality and discourages some suppliers to participate (Interviewees D, E).
Marine warranty surveyors might be difficult to work with	Marine warranty surveyors might have personal preferences about how things should be done, resulting in process delays (Interviewees C, E, G).
FIDIC based contracts are heavily modified	The FIDIC suite of contracts are used as a general framework, but they are heavily modified, thus reducing standardisation and resulting in a long contract negotiation process (Interviewees D, E).
FIDIC based contracts are “employer friendly and contractor unfriendly”	FIDIC based contracts burden contractors with the highest risks. (Interviewees D, I).
Lack of standardisation in contract terms lead to long contract negotiations	There will be negotiations about a set of contract terms every time a new project begins. Negotiations can take up to a year, making them “long-winded” (Interviewees E, K).
The FIDIC suite of contracts is considered as being old-fashioned	The commonly used FIDIC suite of contracts is considered as being old-fashioned. The NEC suite of contracts is considered as being more updated and collaborative, but they are not widely used in OSW at the present (Interviewees B, E, M).
Contract negotiations can be more difficult for smaller suppliers	EPCI contractors may pass on terms to smaller suppliers, which the developer is passing on to them. But smaller suppliers will have smaller contracts, which creates some difficulties during contract negotiations (Interviewees J, K).
Contractual discrepancies between construction elements and non-construction elements	Some contract terms are construction based; this creates difficulties for non-construction companies (Interviewees J, M).
Contractual discrepancies between onshore activities and offshore activities	Some manufacturing/fabrication companies need to negotiate offshore liabilities because their scope of work does not include work offshore (Interviewees J, K).
Difficult to form alliances	There is a willingness to form more alliances in the UK OSW industry, but it is difficult to achieve because companies are too small to take the risk of an alliance (Interviewee B).
Lack of incentives to appreciate positive supplier performance	There are cost penalties in place for any delays, but there are no incentives to reward the positive performance of suppliers (Interviewees E, J).
No formal feedback to company sales teams on any issues	Any lessons learned or feedback about product performance is not passed down to the sales team, who would find this information useful (Interviewee E).
Interface management issue regarding onshore substation works	The lead contractor of onshore substations has no contractual arrangement with other supply chain parties present on-site who are procured by the developer and need to be managed by the lead contractor’s HS&E terms (Interviewee F).
Issue defining quality and price among developers	Developers take different approaches towards paying for supplier capabilities and competencies. Often, high expectations for quality are not reflected in their readiness to pay for quality (Interviewee G).

Potential developer accountability issues	Sometimes suppliers raise issues to developers, which are not appropriately addressed by the developer (Interviewee L).

Table 5.22: Identified diagnostics related to System Three

It has been mentioned how CfD auctions are "double-edged swords". Both Interviewees A and B provided their perspectives as developers and project managers, and agreed that CfD auctions help to improve the competitiveness of local suppliers because developers are required to make their inputs into the domestic supply chain before they receive CfD. However, it is difficult for developers to make long-term commitments to the local economy when they do not know which low carbon project from which industry sector will be successful at auction. This therefore creates uncertainty for developers. Overall certainty and visibility of the UK government's intentions with regards to the OSW projects would make it easier for developers to invest.

CfDs also require careful consideration from developers and OEMs to avoid supply chain capacity problems. If companies bid for every project and are awarded them all, then that would inevitably create a surge in demand for resources and services, which suppliers might not be able to satisfy. Another related issue is that the capabilities of suppliers are assessed not only on a buy-local basis (what they can provide locally), but also on whether they are able to compete in the global marketplace. For developers who invest in the local economy based on the local content requirement, it is not enough for suppliers to be developed for the domestic market only as they also need to be able to compete in the global marketplace (Interviewee A). This is because it would provide both local suppliers and developers with opportunities to build more long-term relationships.

In terms of FIDIC contracts, several issues have been raised. According to the participants, the FIDIC suite of contracts are the most common types of contracts used in the OSW industry. They were designed by The International Federation of Consulting Engineers to help parties avoid lengthy negotiation processes by providing a standard set of terms. However, in the OSW industry it is common practice for developers to modify FIDIC's terms to suit their project needs. In turn, the contracts become more bespoke and, instead of minimising contract negotiation times, they often make them lengthier. What is more, some participants mentioned another reason why contract negotiation times are lengthened, which is because these contracts appear strict for suppliers; some called them "*employer friendly and contractor unfriendly*" (Interviewees E and I). This means that a lot of contractual risk is passed on to suppliers which they then try to negotiate out, thus making contract negotiation times longer. Another interesting observation about FIDIC contracts is that they are considered by some as being old-fashioned (Interviewee F). It has been mentioned before that few customers in the UK use FIDIC, especially in the civil engineering and construction sectors. Instead, the NEC suite of contracts are considered to be more popular and collaborative (Interviewees F and M).

In terms of contractual issues, some contractors may reuse the same terms from their developers with smaller suppliers, which makes it more difficult for smaller suppliers and increases contract negotiation times (Interviewees J and K). Complications with contract negotiation can also be created by discrepancies between onshore liabilities of a supplier and offshore liabilities. Contracts often include both, but some companies only operate onshore without the capability to extend their liabilities for their products offshore (Interviewees J and K). This means that some suppliers will have to negotiate in order to remove irrelevant offshore liabilities from contracts. A similar situation occurs with regards to contractual discrepancies between construction parts and non-construction parts. Given that OSW projects are construction projects, contracts are often based on construction terms. However, some manufacturing companies are unrelated to construction (Interviewees J and M). Again, this means that suppliers need to revise the details in contracts and negotiate the removal of anything that is unrelated to them.

In addition to contractual issues, a further complication was raised by Interviewee F. As a lead onshore substation contractor within the OSW project, Interviewee F is in charge of the H&S rules that must be followed by anyone entering an onshore substation site during its construction. Considering that onshore substations house different high-voltage equipment procured by the developer, all high-voltage equipment suppliers need to be present on-site to install their equipment. This means that Interviewee F must manage all of the suppliers present on-site from a H&S standpoint, despite there being no contractual relationship between Interviewee F and the suppliers.

Further contractual issues can be caused by poor weather conditions, which impact OSW installation processes. In general, contracts are designed to allow for some delays due to poor weather conditions by including special clauses. However, these clauses are often breached when delays are longer than anticipated, thus resulting in higher costs (Interviewee C).

Another issue concerns damage to products as they travel through the supply chain, such as damaged cables. Such problems may arise during the installation and construction phases in particular. Interviewee D experienced this problem when cables were not connected properly by third parties, or when cables have suffered an electrical overload. Such problems may be caused by mistakes in the overall OSW system design. This is further complicated by the fact that information about system designs is not readily available to all supply chain members as it could be considered as being competitive intelligence. Hence, suppliers may be unable to know whether their products could continue to operate in those designed conditions.

Another issue relates to the lack of information sharing, which was raised by Interviewee E from a sales perspective. Interviewee E mentioned that company sales teams do not receive information about lessons learned in relation to their products or work scope following a project, but that this information would be useful to consider for future sales tasks. According to Interviewee E, this information may be circulated between project teams, but it is not formally or regularly passed down to sales teams. Instead, the sharing of information happens on an *ad hoc* basis in cases of repeat business. Even though this problem is an internal company issue, a similar point was made by Interviewee J, who would also prefer to form closer relationships with their customers and to receive feedback about their experiences of using Interviewee's J product. This information would then allow the company to improve their existing products. It has also been found that there are usually stringent and formal contracts in place with penalty mechanisms for delays. However, it is less clear as to whether there are any formal or informal incentives in place to reward project performance at an individual or project level.

Evaluation

Based on S3's related findings outlined in Tables 5.21 and 5.22, it is evident that there are formal contractual relationships in place that provide a high degree of control over supply chain processes. Though, the findings suggest that there is not much trust developed between OSW companies. Nonetheless, given that OSW is a high-risk and high-value environment with difficult to predict time schedules and weather conditions, a high level of control is important to ensure project safety and quality. A high degree of control does not cause problems at the level of individual suppliers, and is understood as being necessary.

Finally, the current contracting strategy has also been criticised. This has predominantly been based on the FIDIC suite of contracts. A lack of standardisation with regard to contract terms, along with high contractual risks for smaller suppliers, make contract negotiation process time and resource consuming. A lack of knowledge and resources necessary for contract negotiations means that some may be hit hard in dispute situations. However, all of the participants believe that such situations are unwelcome and that everybody is keen to avoid dispute situations by quickly resolving issues in a collaborative manner.

5.4.5 System Four description and evaluation

Description

System Four (S4) is explained in terms of an adaptation to the future. In the context of business management, it is important for businesses to remain competitive given the changing business environment. Therefore, S4 can be understood as an adaptability function to the competitive market forces (Espinosa and Walker, 2017). According to Beer (1985), it is important to be aware of the wider business environment and to have the right capabilities to make the right decisions in order to respond to the changing environment. There are many examples of businesses that have lost their market positions by failing to respond to the changing environment in time. One example is Nokia, who lost their global leadership position in the mobile phone market due to the arrival of smartphones. Although it would not be possible to react to any kind of change all of the time, Beer (1985) argues that businesses need to have mechanisms in place that would alert decision-makers to the need to react and adjust strategies, policies, and/or action plans in real-time.

Overall, this study has examined the participants' answers to determine whether there are any future trends that could pose a concern. It has also explored how easy or difficult it is for companies to adapt to the changing OSW environment. These are the following future trends identified by this research:

- Projects are getting bigger.
- Projects are being built further from the shore.
- Wind turbines are getting larger.
- Upcoming development of floating OSW (floating OSW refers to the new types of foundations that do not require to be fixed to the seabed, IRENA (2019)).
- More partnerships or acquisitions to maintain or build company competencies.
- Less dependence on government support for subsidies.
- A greater push on price reduction in cases of zero subsidies.
- New OSW markets opening globally (especially in Asia and the US).

- Investor interest for OSW is growing.

It can be said that OSW is a politically motivated industry because most wind projects depend on government support. This means that major industry trends have been based on political drivers, notably the reduction of LCOE. Based on the participants' responses, every supplier has their own internal company strategies to respond to the changing OSW environment. Some prefer to wait to see trends develop and for the market to move in a particular direction before deciding whether to pursue that trend or not, whereas others prefer to react quickly to maintain their competitiveness. It is evident that companies who successfully compete in the OSW market have high internal company capabilities in terms of R&D and engineering. For example, as subsea power cable manufacturers, Interviewees D and E have their own FEED services to complement the installation and connection of those cables. Interviewee J's company has an in-house design and engineering team that allows the company to offer bespoke products based on different project needs. Interviewee L's underwater noise measurement company also relies on its internal R&D capabilities to constantly update their underwater noise measurement methods by taking empirical measurements of new turbine installations.

Interviewee A's development company performs most of the engineering and design activities of different OSW components internally owing to their large in-house RD&E capability. This suggests that Interviewee A's company is vertically integrated. In other words, it owns a large number of capabilities which other developers may need to outsource to different resources providers or EPCI contractors.

In terms of the organisations that provide information on industry developments, the following examples were provided by the study participants:

- The Catapult (OWiX -The Offshore Wind Innovation Hub).
- ORE Catapult.
- The Offshore Wind Growth Partnership (sponsored by the government for the sector deal).
- The Carbon Trust (OWA-Offshore Wind Accelerator).
- Innovate UK.
- Aura Innovation Centre.
- Local industry trade organisations and business development organisations.
- OSW industry news websites.

These examples show there is a range of different organisations and innovation centres across the UK that offer R&D expertise and other support related to the OSW market. For example, they provide information about the latest technological developments and various other industry developments, which can help businesses to make their own R&D decisions. These organisations also work in partnership with industry, allowing companies to participate in various R&D projects to contribute towards their knowledge and experience. In addition to these organisations, a range of consultancy companies offer their intelligence by publishing reports on latest industry trends and innovations. These organisations can be considered as forming part of S4 in the OSW industry, helping businesses to keep up-to-date with the latest developments. Some larger organisations also partner with different UK universities for industry related research.

Diagnostics

Table 5.23 provides the diagnostics in relation to S4.

Diagnostics S4	
Issues	**Description**
Dissonance between industry-wide value drivers & company internal value drivers	Industry-wide drivers to reduce LCOE pushes companies to offer products at a lower cost while maintaining the same levels of quality standards. Some suppliers refuse to compete on the lowest cost because it conflicts with their value driver to produce quality products/services (Interviewees D, E, L).
OSW future trends require a lot of capital investment	Keeping up-to-date with the changing OSW market requires high capital investment to update resources, which smaller companies find difficult (Interviewee N).
It becomes more difficult for smaller businesses to compete in the OSW industry	Smaller businesses do not have the resources to invest in order to compete with larger companies (Interviewee G, N).
The cost to change and constantly improve products & services is high, but returns are low	The cost of adapting to the changing OSW environment is high but returns on investment are relatively low in some areas. There are quite small incentives to constantly improve (Interviewee I).
There is constant pressure on the internal processes of individual suppliers to be adaptable	The unique nature of projects demands bespoke solutions. It requires suppliers to develop their RD&E capabilities in order to be adaptable in the OSW industry (Interviewees D, J, K).

Table 5.23: Identified diagnostics related to System Four

It has been mentioned before that there is an issue within the industry concerning the definition of quality and price. This issue emerged again in the context of S4. More specifically, there is some dissonance between the industry-wide value driver to reduce

LCOE and internal company value drivers; due to the overarching industry's drive to reduce LCOE, suppliers are being pushed to reduce their prices. However, many companies find it difficult to compete on price because it is more important for them to deliver high quality products and services, especially as this directly impacts upon their reputation.

Updated OSW technologies, such as larger sized wind turbines, means that some suppliers will be forced to update their capacities, which requires high capital investments. For example, vessel providers would need to update the capacity of their vessels, and must invest in doing so. However, smaller companies lack the resources to compete with larger companies. As it was explained by Interviewee N, the OSW industry has moved into an industrialisation phase. Now, projects are larger and the general strategy has changed to use larger vessels and helicopters, as opposed to smaller crew vessels for O&M tasks. This has forced some smaller suppliers of particular boats and crew vessels out of the market.

The changing OSW environment requires constant adaptation to these changes. Some participants noted that it is costly to keep up with OSW changes, and that the returns seem to be low, thus limiting the incentive to change (Interviewee I). Based on these changes and the uniqueness of OSW projects, it can be suggested that there is a constant pressure on the internal processes of individual suppliers to be adaptable. In other words, there is a constant pressure on every company's S4 function. This is evidenced in Interviewee D's quote:

"*Innovations are coming so fast that we never seem to build the same cable twice*".

Evaluation

Based on the availability of various industry related organisations offering information support and practical opportunities to contribute towards OSW knowledge building, it can be argued that S4 works well at an industry level; it offers enough information about future trends for companies to decide how to best respond to these trends.

The constantly changing nature of the OSW environment requires companies to have high internal capabilities to respond to change when necessary. Therefore, companies need to have a developed S4 function in order to be competitive. All of the participants in this study that are involved in the development and construction phases of OSW farms have largely succeeded in this industry by having well-functioning S4. In support of this, Interviewee J described their company as being "*very dynamic and adaptable*". These are perhaps the key words that all OSW suppliers need to take into consideration in order to stay afloat in the OSW industry. Nevertheless, the participants' responses have also shown that adaptability to the OSW environment depends on internal company decisions rather than on joint decisions of the supply chain. This suggests that there is a limited S4 connection among project supply chain members on the system level. In other words, suppliers compete in the OSW as individual entities rather than as supply chains, as there is lack of evidence of joint S4 function among supply chain members.

5.4.6 System Five description and evaluation

Description

System Five (S5) is described as the ultimate authority that brings organisational closure. S5 is responsible for an organisation's identity and ethos. The role of S5 may be fulfilled by senior management in a more autocratic organisation, whereas it may be fulfilled by many people in a more democratic organisation. For example, the heads of S3 and S1. S5's role is to oversee the interaction between S3 and S4 to ensure the viability of an organisation (Espinosa and Walker, 2017).

This research considers the roles of OSW developers with regards to fulfilling the S5 function, particularly as they are the ultimate decision-makers in OSW projects. Some companies may act as sole developers, but often OSW projects are developed and constructed by companies as part of a joint venture. As mentioned before, developers are usually either private or public utility companies. Interviewee O also explained how there is a growing interest from overseas investors to buy equity stakes in these projects. Hence, more joint ventures are likely to be formed in future OSW developments.

This growing interest in OSW projects is partly explained by the ongoing transition from the oil and gas industry to the renewables sector. OSW, alongside other renewable energy projects, provide an opportunity for large 'Oil Majors' to invest in green energy (Interviewee O). This also means that OSW provides an opportunity for companies to change their ethos from being 'black' to 'green'.

Overall, the OSW industry-wide ethos is associated with Northern Europe; it was Denmark that made the first move in the industry as well as the first advancements in wind turbine technology. Thus, the knowledge and expertise within the OSW industry is largely possessed by Northern European countries, which have the majority of OSW farms installed in their waters (EWEA, 2009).

The identities of individual projects are largely associated with the development company or the companies that build them and, as it has been mentioned before, developers take a variety of different approaches and advocate varying work cultures. Some focus more on cost, others on quality, and some on both. However, all are currently bound by the overall drive to reduce LCOE. Therefore, the companies that achieve a lower LCOE are considered high achievers, especially compared to those that decide to build OSW projects with zero subsidies.

Diagnostics

There has not been obvious diagnostics identified in relation to S5. Every developer applies slightly different strategies to build a project, and so further research is needed to explore the strengths and weaknesses of each approach. However, two issues can be mentioned that potentially impact the performance of project development and construction tasks.

The first is that there are many contracted staff acting on behalf of the companies that build OSW farms. Since project development and construction is a temporary task, it can be understood why this is the case. However, as mentioned above, it is difficult to build long-term relationships with contracted staff as they are only there for the duration of the project. Moreover, their approaches may be based on personal experience rather than being company specific, thus limiting the opportunities to establish greater collaborative relationships.

The second issue concerns working directly with developers versus working with EPCI contractors, who act as intermediaries between developers and suppliers. As it was noted by the participants, working directly with developers makes it possible to form a 'project team' type approach to tasks, which is difficult to achieve when working with EPCI contractors.

Evaluation

The evaluation of S5 was based on an exploration of the roles of developers in terms of creating a more integrated project supply chain. Considering that developers define the rules of a project's execution for all supply chain members, it is evident that they can directly influence levels of SCI in their projects. One of the earlier identified facilitators of SCI, as listed in Table 5.14, was organisational culture. It became evident that the developers and companies who work collaboratively achieve higher levels of integration. It can also be argued that collaborative organisational culture of project developers can help to develop collaborative ethos of OSW project's supply chain.

According to the study participants, some OSW developers are collaboratively oriented and succeed in making project partners or suppliers feel part of one team, but such collaborative approaches are unusual. It is instead more common to have relationships that can be characterised as 'arm's length' during the development and construction of OSW projects.

5.4.7 Summary viability evaluation of the system in focus

The aforementioned subsystems of the VSM, namely S1, S2, S3, S4, and S5, all form part of one unified system where every subsystem is dependent on the others (Beer, 1985). The interdependence of subsystems contributes towards making the whole system viable. However, the key to the viability of the system is to maintain an internal balance within the subsystems, including within their interactions with the constantly changing external environment. The biological term used to explain this balance is 'homeostasis' which, in VSM terms, is defined as the "*stability of a system's internal environment, despite the system's having to cope with an unpredictable external environment*" (Beer, 1985: 17). Examples of homeostatic functions in the human body include those that stabilise body temperature, regardless of weather conditions, blood sugar levels, and hormones (Beer, 1985). According to Espinosa and Walker (2017), the idea of homeostasis is the essence of the VSM diagnosis, which also gives it the potential to be applied to any system in focus, including in a business context.

Therefore, to complete the VSM analysis, this study examined how balanced the system in focus is, in terms of its homeostats, by looking at the internal interactions of the subsystems as well as their interactions with the environment. The VSM consists of three main elements: the environment, operations, and management. This balance is said to be achieved through the homeostatic balance of these elements (Espinosa and Walker, 2017). Figure 5.4 below represents some of these key balances, which are indicated using red arrows. The balance between operations and the environment, operations and management, and management and the environment are displayed in the figure.

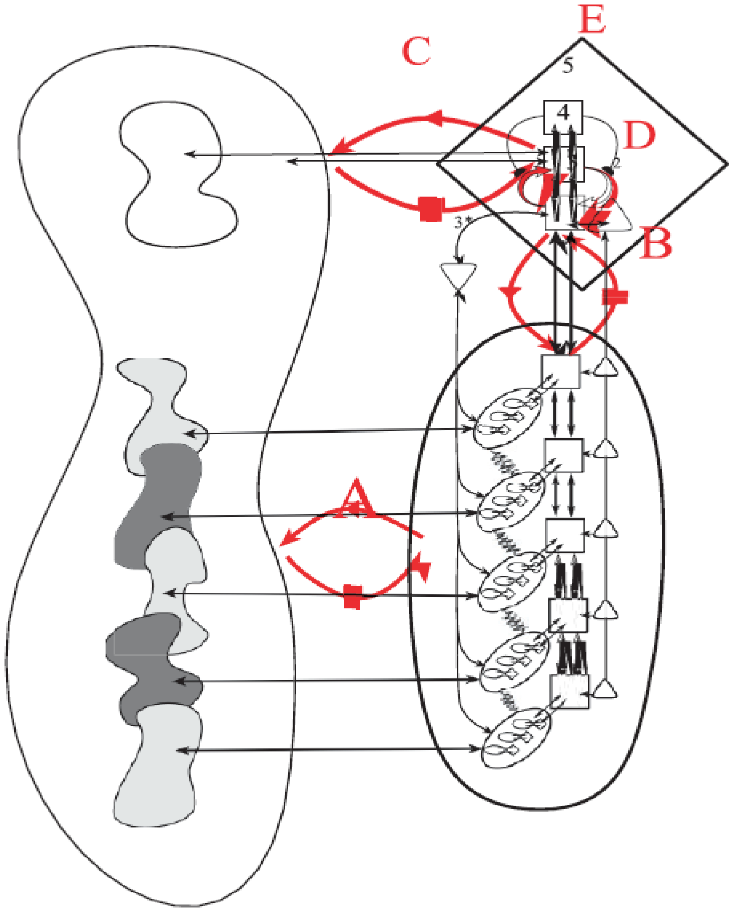

Figure 5.4: Main homeostats of the VSM (Morlidge (2010), cited in Espinosa and Walker (2017: 90))

Based on the descriptions and evaluations of the VSM subsystems of the system in focus, as well as a further evaluation of the entire system in terms of its main homeostats or balances, it can be said that there are some imbalances in the system that potentially affect the system's viability. One of the main issues affecting the whole system is the lack of visibility in terms of future project pipelines. Hence, there is a lack of visibility in terms of future demand within the OSW industry. From a developer's point of view, this makes it difficult to make any long-term commitments with regards to investing in the local economy (Interviewee B). From a supplier's point of view, who are considered as forming the operations in the VSM, it is also difficult to invest in their own capabilities to serve the OSW industry or to make any long-term plans. The irregular demand and the uncertainty of future pipeline of projects have also been identified as inhibiting factors for achieving SCI.

The balance between the operations (S1) of different OSW suppliers and the environment is affected by the project-based nature of the OSW industry. This especially affects suppliers who predominantly operate in manufacturing environments. As mentioned by Interviewee G, there is little line production involved in OSW construction. This means that suppliers who predominantly operate in a manufacturing environment have to adapt their manufacturing to a project-based style, while maintaining both styles of manufacturing to serve different markets. In addition, the OSW industry provides a new context for suppliers who have never operated in offshore environments, which requires businesses to learn and adapt to this new context.

In terms of the system in focus, the internal balance between S1 and S3 is affected by the discontinuity of project supply chains comprised of different suppliers. In other words, every new project could require a new team of suppliers/contractors. This means that the balance between S1 and S3 needs to be established each time a new project begins. This is evident from the interviewees' responses about the lengthy contract negotiations involved in new projects and the lack of standardised contract terms. In addition, the S3* findings showed high levels of control. In a well-balanced system, it is assumed that there is less need for a high degree of auditing and control (Panagiotakopoulos et al., 2015), and that there is a greater balance between S1 and S3. However, in cases where framework or collaboration agreements are in place between parties, there are pre-agreed terms and prices, thus making the exchange between S1 and S3 more balanced.

A different internal imbalance within the system in focus can be observed between S1, S2, and S3. It was found that the biggest S2 issue affecting an overall project execution plan is delays. Delays may be caused by different internal and external factors, as shown in Table 5.21. Since there is a relationship between supply chain members, delays at one link may affect the timings of another. As it was mentioned by Interviewee M in section 5.3.9, tendering processes often feel rushed right the way through to completion, but the reasons for this are unknown. It could be due to delays in other parts of the supply chain, or due to certain decisions made at S3. However, Interviewee M was unable to give specific and definite reasons. Given the lack of visibility surrounding the issues that could potentially affect different parts of the supply chain, it is difficult to keep product and service delivery processes in balance.

The *ad hoc* nature of projects and the disjointedness of relationships between the suppliers and developers of projects suggests that there is an imbalance and disconnect between S1, S4, and S5. This means that there is no combined continuous development of products and services between suppliers and developers. This was made evident from Interviewee B's reply about their own preference to form further collaborations with different resources providers, as outlined in Table 5.5. The reasons for further collaboration predominantly include the opportunity for co-development in terms of technology or methodology. The disconnect between S1 and S4 may also suggest an imbalance in the development of the supply chain overall. Some areas will be more developed than others because certain suppliers have more dynamic capabilities in terms of their own self-development compared to others. However, it is important to note that this point does not apply to all developer and supplier relationships. Some developers, such as Interviewee A, have more collaborative relationships with certain strategic suppliers, thus exemplifying joint continuous development.

Furthermore, the imbalance between S1, S4, and S5 indicates that developers, who fulfil the role of S5, are more concerned with the external environment than the system's internal environment. This suggests that there is an imbalance between S5 and the environment. More specifically, there are environmental pressures coming from the UK government, which developers are required to address. One such pressure involves local content requirements. While the intention of these requirements is to help involve UK businesses with the OSW industry, which is viewed as being positive by both developers and suppliers, they also face criticism. For example, Interviewee A mentioned that the government has often overestimated their expectations in terms of the capabilities of UK companies to participate in the OSW industry. There is no doubt that many UK companies can provide products and services to the required standard, as well as being competitive in the UK and global markets. At the same time, there are many suppliers who cannot provide products and services to the required standard. In such instances developers are often required to support supplier development or engage in other areas of economic value creation to the area that they operate in. As mentioned by Interviewees C and N, this at best creates temporary gains because such contributions to the local economy may last for the duration of the project only. However, this issue could be improved if contributions are made more strategically by involving developers, the government, and suppliers to jointly contribute towards the areas of importance to all parties.

What is more, the imbalance between S1 and S5 makes it difficult to develop an overall system-wide collaborative environment and culture, thus making integration of the supply chain more complex. To achieve integration, there needs to be mechanisms in place to encourage collaboration and to make communication between relevant parties more open and effective. Based on the findings of this research, it is possible to say that the SCI of OSW projects could be achieved if it is guided by the developer in charge of the project, especially given that they are the ultimate decision-maker and creator of the project's identity. Interviewee A's approach to wind farm development and construction has shown that the balance between S1 and S5 already exists in some supply chain areas. However, this is an exception rather than the rule.

The imbalances between operations, management, and the environment show that the current state of the system in focus, or the current state of the development and construction phases of the OSW supply chain as a system, is unbalanced. Thus, it is not well integrated and cannot meet the criteria for being a viable system or, in this instance, a viable network. As mentioned previously, for the system to be viable all three elements of a viable system need to be in balance. As explained by Espinosa and Walker (2017), they require a state of 'homeostatic equilibrium'. Nevertheless, the participants gave examples of projects which supply chains or systems, function almost in a state of homeostatic equilibrium. This gives grounds to suggest that there are opportunities to build more viable, and therefore more integrated, supply chains within the OSW industry.

Chapter Six

Proposed Supply Chain Integration Strategies

6.1 Introduction

This chapter will propose SCI strategies based on the results and findings of the VSM analysis and the themes related to SCI. The proposed strategies are shown in Figures 6.1 and 6.2. Each strategy will be explained in turn and discussed in relation to the findings presented in Chapter Five.

6.2 Viable SCI Strategy

Figure 6.1 presents the first strategy proposed by this study, which is entitled the 'viable SCI strategy'. This strategy is based on the idea of SCI, where parties of an OSW project supply chain act as one team or one cohesive network. Table 5.5 of Chapter Five outlined the participants' preferences for forming greater collaborative relationships; where almost half of the participants expressed a preference to work directly with project developers. This is because it allows them to form more partnership-based relationships, as well as allowing suppliers/contractors to have greater insights of the projects planned for the future. This strategy assumes that developers will take responsibility for the interface management of different work packages within a project's supply chain, instead of delegating this responsibility to EPCI contractors. This suggests that the role of developers is as ultimate decision-makers to fulfil the role of S5.

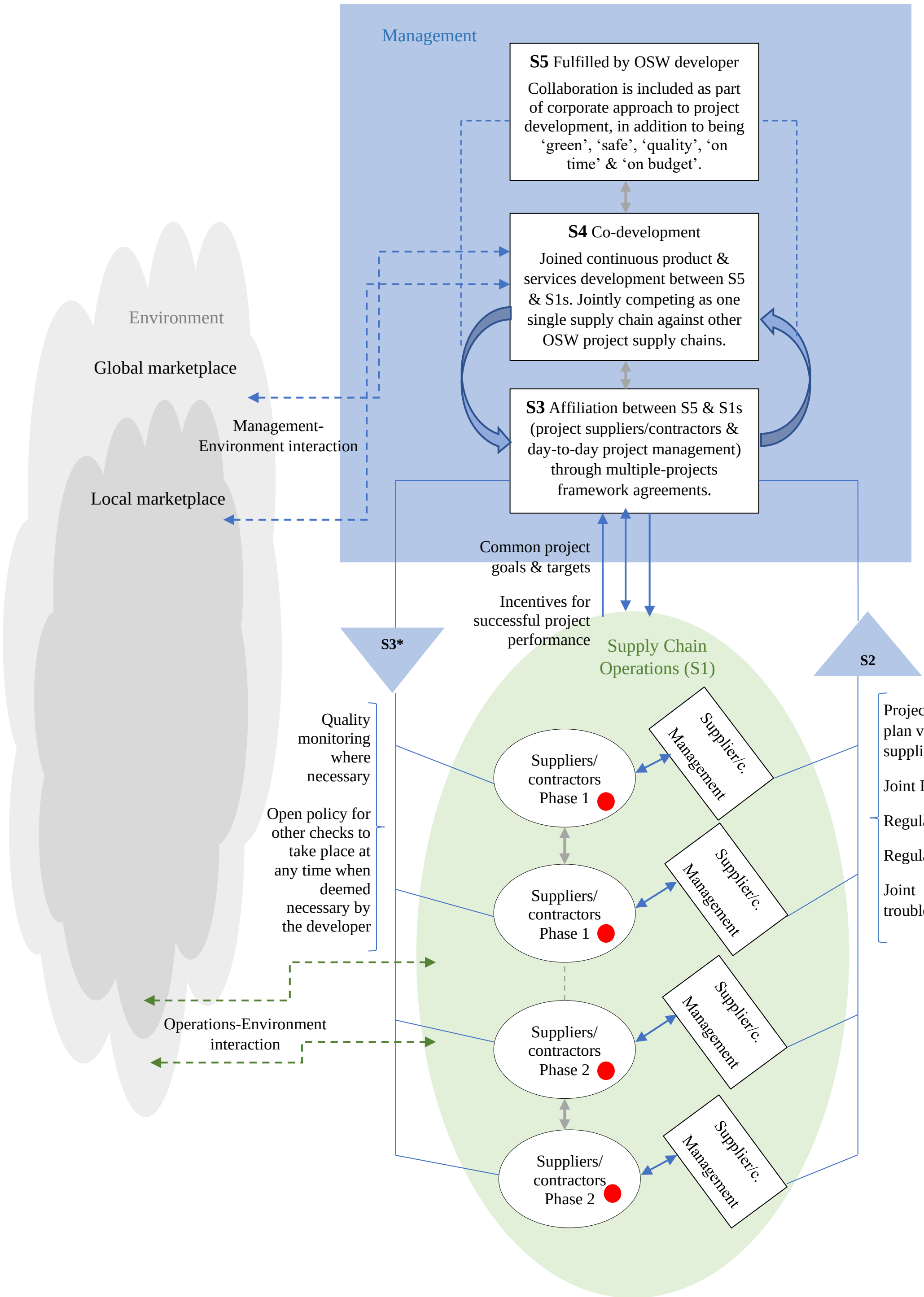

Figure 6.1: Viable Supply Chain Integration Strategy (Author)

Since this strategy assumes direct interaction between suppliers/contractors and developers, this model represents the interaction between first-tier suppliers/contractors, or direct suppliers and developers. However, it should be noted that similar principles can be extended to lower-tier suppliers also (Valenzuela Gonzalez, 2019). The suppliers/contractors that form part of the supply chain's operations, or S1, are marked in green in Figure 6.1. This study only examined the development and construction phases of OSW projects, and therefore suppliers/contractors are classified as phase 1 and phase 2 suppliers/contractors. Each supplier/contractor has their own management, which is represented by square boxes within the green area; linking individual suppliers/contractors using blue arrows. The grey arrows between suppliers/contractors indicate direct or indirect interactions between them. The red dots indicate a need for substitute suppliers in cases of emergency that may prevent the preferred suppliers/contractors from fulfilling their tasks.

S3 shows an affiliation between suppliers/contractors and developers. This study identified framework agreements as a facilitating factor of SCI because they act as formal collaboration agreements that structure the ways people work together. Therefore, a viable SCI strategy assumes an affiliation between different suppliers/contractors and developers through multiple project partnerships using framework agreements. As explained by the study participants, framework agreements allow parties to pre-agree contract terms and prices. Using the language of the VSM, achieving such agreement between parties can be considered as the main resource bargain process, indicated by the up/down blue arrow between S1 and S3. Framework agreements could also relate to the legal and corporate requirements channel, indicated by the down arrow. The upwards arrow signifies the accountability channel. The proposed strategy ensures the accountability of parties by establishing common project goals and targets. In addition, incentives for successfully meeting those targets may further encourage accountability.

The results of the VSM analysis of S3* showed that there are some project areas which require close monitoring and control by developers. For example, certain manufacturing processes of the main components, as well as their installation offshore. Therefore, S3* is indicated using an inverse triangle, which includes quality monitoring where necessary and suggests an open policy for other checks to be performed by developers as required.

With regards to S2, the VSM analysis revealed that the biggest issue impacting all project parties is delays. In addition to external factors, such as difficult weather conditions, delays can be caused by the system's internal factors, like problems at individual supplier levels. These can create a knock-on effect upon other supply chain members also, which can create imbalances within the whole system, as discussed in Section 5.4.7. By making potential delays more visible to relevant parties, individual suppliers could adjust their plans to reduce the effect of the delays upon the execution of the overall project plan. Therefore, S2 in Figure 6.1 is indicated using an upwards facing triangle. S2 includes visibility of the project execution plan for all relevant suppliers/contractors, as well as joint ICT usage for the exchange of relevant information and regular feedback to suppliers about their products and services, including regular updates about project performance. Taking the effectiveness of the ROC room into consideration (as mentioned by Interviewee F in relation to the construction of onshore substations), S2 also includes joint troubleshooting methods. The ROC room allows all parties present on-site to discuss any issues and find solutions together. The ROC room concept can be incorporated into other parts of the supply chain.

A viable SCI strategy assumes that some of the same suppliers/contractors will be engaged in several projects, which provides an opportunity to achieve joint continuous development in terms of products and services between S1 and S5. This co-development is considered in S4. The co-development of products and services would also help to achieve greater standardisation across product designs, which is an area requiring improvement, as identified by the participants. Furthermore, co-development provides opportunities for competing supply chains, which are common in the automotive industry and occur when the whole supply chain competes against other supply chains (Dyer and Hatch, 2006). This would allow parties to continuously adapt to the changing OSW environment and is indicated using dashed arrows linking S4 to the environment. Management-environment interactions refer to the necessary monitoring of the OSW environment by management teams in order for the system to stay competitive.

Interactions between operations and the environment are also indicated using dashed right/left arrows; this refers to the interactions of each supplier with their own supply chains and marketplaces. However, as this study has found, in order to maintain continuous relationships with developers, suppliers must compete in both domestic and global marketplaces. This explains the presence of two marketplaces within the environment, as shown in Figure 6.1.

6.2.1 The benefits and limitations of a viable SCI strategy

There are broadly two strategies for developing OSW farms: multi-contracting and the use of EPCI or EPC contractors. Multi-contracting refers to the strategy where a developer creates and manages their own multiple work packages in order to execute an OSW farm project. In comparison, EPCI or EPC refers to the strategy where a developer chooses to delegate this responsibility to EPCI or EPC contractors, who act as an intermediary between the developer and the suppliers delivering the work packages (Thomsen, 2012). The proposed viable SCI strategy is based on the multi-contracting strategy. Although this strategy is considered to be extreme because it requires the management of a large number of individual contracts, it is possible (Interviewees A and B). Interviewee A provided an example of this type of approach.

This strategy requires developers to have large in-house capabilities in order to effectively manage all project tasks; from development and construction to the commissioning and operation of a wind farm. As it was explained by Interviewee B, it would be rare for a developer to have experience in all project areas. Nevertheless, organisations with increasing levels of competency do exist (Interviewee A). This high degree of ownership by different competencies could be suggestive of a high degree of vertical integration. Some argue that the task of SCM is to avoid vertical integration because vertical integration is associated with such limitations as diseconomies of scale and limiting competition (Wilding and Humphries, 2006). However, based on the results and findings of this research, the participants with experience of working directly with developers under a multi-contracting strategy viewed it as beneficial for both the developer and suppliers as it facilitates partnership-based relationships. This suggests that the correct balance of vertical integration may make project-based environments more efficient with clear start and end dates.

The viable SCI strategy includes the use of preferred suppliers/contractors over multiple projects in order to develop closer and longer-term relationships. However, this would limit the opportunities of other suppliers to be part of the same project supply chain. This type of SCI was viewed by some study participants as a drawback and limitation that obstructs competition within the overall supply chain (Interviewees E, I, and N). However, the literature review explained how the reduction in the number of suppliers is implied by SCI because it is impractical to maintain close relationships with all members of a supply chain. Instead, the focus should be on forming closer relationships with the suppliers that bring the most value to the overall supply chain (Sadler, 2007; Stevens and Johnson, 2016).

On a positive note, forming closer relationships between an OSW project developer and their preferred suppliers/contractors makes it possible to develop a more collaborative culture within the supply chain. Therefore, helping to achieve improvements to the homeostatic balance of the supply chain as a system. Achieving homeostatic balance within the supply chain would help to realise the identified advantages of SCI, as outlined in Table 5.4 of Chapter Five. Through the formation of continuous relationships, suppliers/contractors can align their processes to the requirements of a particular developer. According to the literature on project-based supply chains, supplier alignment to the dominant party's working strategy is one of the main drivers of SCI (Briscoe and Dainty, 2005). This also allows developers to familiarise themselves with their suppliers' outputs and would allow all parties to achieve some commonality in terms of their understanding of quality and price. Some dissonance was found between suppliers' internal value drivers, such as producing quality products and services, and the industry-wide value driver to reduce LCOE. Suppliers are often asked to reduce their price without compromising on quality. However, the study participants explained that it is more important for them to ensure the quality and longevity of their products, which comes at a price that some developers are reluctant to pay. This often creates conflicts of interest (Interviewees D, G, and K). In response, aligning developers' and suppliers' expectation about product quality and price would help to reduce the conflict resulting from the existing dissonance of quality and price definition.

Achieving an alignment between supply chain parties would also help to achieve greater standardisation and commonalities across different areas, such as information sharing and product design, which the majority of study participants would like to see improved. This could be achieved, in part, through developing a joint S4; where products and services are co-developed between suppliers and developers. This would help to develop the supply chain areas that require more attention, as well as allowing all parties within a system to work together in order to resolve particular issues, such as reducing LCOE.

Longer-term relationships between suppliers/contractors and developers could help to regulate demand. In turn, this could help suppliers/contractors to make longer-term investments in facilities and staff. Likewise, a larger number of permanent staff could work on a project as opposed to temporary contract staff, the latter of which was a problem identified by the participants as an inhibiting factor of integration.

Closer interactions between parties could also help to achieve the right balance between formal and informal relationships. Due to the high value of OSW projects and the high degree of risk, it was found that there are elevated levels of formal relationships and control. Some areas of the supply chain experience constant monitoring from developers. As argued by Espejo and Mendiwelso Bendek (2011), such a high degree of control and constant monitoring inhibits the development of trust and cohesion between parties. Based on the SCM literature, trust, alongside partnering, has been viewed as a critical success factor in construction projects, which can also safeguard against opportunistic behaviours (Khalfan, et al., 2007). Consequently, by developing continuous relationships it can be possible to establish the right incentives between parties to encourage the accountability of all parties and facilitate trust development, thereby encouraging greater performance of the whole system.

6.3. Strategic Cluster Integration Strategy

Figure 6.2 presents the second strategy, which is entitled the 'strategic cluster integration strategy'. The difference between this strategy and the first is that this strategy considers the integration of a specific part of the supply chain, rather than the supply chain as a whole. Furthermore, it is 'strategic' because it assumes the purposeful organisation of a cluster of business partners in order to collaboratively work towards a common goal. Interviews with various study participants revealed that some suppliers have already been self-organising into interest groups to consider different ways of working more collaboratively (Interviewees D, J, and K). Interviewee D described a consortium approach as a potential approach to working together, which may become more valued in the future. This is similar to the idea of Stevens and Johnson (2016), who argue that the future of SCI will be devolved, collaborative, supply chain clusters. By clusters, Stevens and Johnson (2016: 32) mean "*a network of suppliers and/or sub-contractors associated by type, product structure, or flow*".

Figure 6.2 represents a potential strategic cluster integration strategy based on an example of integration involving a cable manufacturer, cable protection manufacturer, and cable installation contractor. The primary aim of the strategic cluster integration strategy is the development of joint products and services that would benefit all of the parties involved, as shown in S4. The development of joint products and services would also allow parties to work collaboratively towards OSW developers as the main customers.

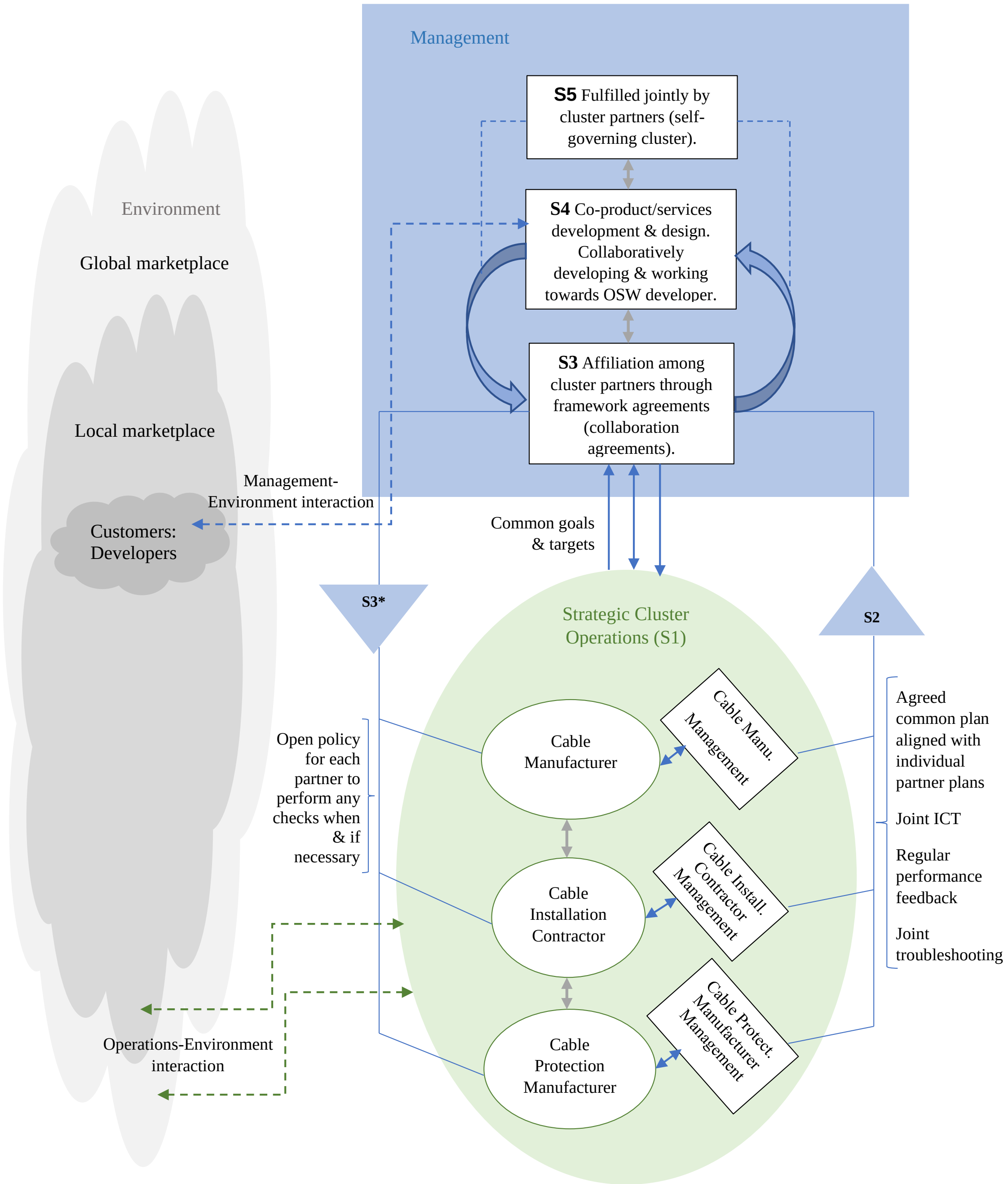

Figure 6.2: Strategic cluster integration strategy (Author)

A strategic cluster integration is based on the idea of self-governance (Espinosa and Duque, 2018). Therefore, S5 could be jointly fulfilled by cluster partners, either on an equal share basis or on the basis of one partner taking a leading role. Most likely, the partner taking the leading role would be the one who will benefit the most from the integration. Affiliation among cluster partners can occur through framework agreements or other forms of collaboration agreements, as outlined in S3. Legal, corporate norms, and resource bargains could be agreed upon as part of a collaboration agreement, which would need to be revised regularly to ensure that all cluster partners continue to benefit from the collaboration. Common cluster goals and targets will also help to ensure accountability of the partners.

Since it would be a voluntary collaboration, it is assumed that there would be no need for strict audits or checks of operational standards of one another. Nonetheless, maintaining an open policy for each partner to perform any checks if and when necessary could encourage the development of trusting relationships, as outlined in S3* (Espejo and Mendiwelso Bendek, 2011). To ensure the coordination of joint tasks (S2), common task plans need to be developed that align with each partner’s plans. S2 would also involve joint ICT usage to facilitate information sharing. Finally, regular performance feedback and joint troubleshooting could help to collaboratively resolve issues.

Operations-environment interaction refers to the interaction between each partner and their own supply chains and markets, which they individually operate within. To effectively cooperate as a strategic cluster, each partner has to maintain a relationship with their own supply chains. To ensure the effectiveness of the strategic cluster’s integration, each individual partner needs to be well-placed within their own market and all partners must contribute their knowledge and capabilities towards achieving the cluster’s shared common goal.

Management-environment interaction, in this case, refers to the interaction between cluster management with the OSW environment. In order to remain relevant within the OSW industry, cluster partners are required to maintain constant monitoring of the latest developments and future trends. By establishing a joint S4, it would be possible for cluster partners to develop their products and services together in order to better market themselves to OSW developers. This could not only improve individual partner competitiveness, but also the joint competitiveness of the cluster, especially due to its increased R&D capabilities, product design, and engineering.

Furthermore, strategic integration or collaboration between cluster partners would allow for further standardisation and improvements to individual product designs. Based on Interviewees D, E, J, and I's responses, there is currently no interaction between cable manufacturers, cable protection manufacturers, and cable installation contractors concerning the design and engineering of their products and services, although there is some interdependency amongst each other. For this reason, Interviewee J (a cable protection manufacturer) expressed an interest in working more closely with cable installation contractors to receive feedback about their product, which is a supplementary product that protects cables during installation. Cable protection manufacturers and cable installation contractors could also benefit from close collaboration with cable manufacturers because cable protection and installation procedures need to be developed to suit the specific design of a cable.

Similar interactions can be observed between primary and secondary steel fabrication, which can also be improved upon via strategic cluster integration. For example, the fabrication of wind turbine foundations as primary steel fabrications and the secondary steel fabrication of products used for the foundations. Therefore, by developing strategic clusters consisting of parties with a shared common interest, it may be possible to achieve more efficient product designs and engineering. In addition, similar to the proposed 'viable SCI strategy', strategic cluster integration strategy would also help cluster parties realise the identified benefits of SCI as outlined in Table 5.4, through improvements in homeostatic balance within the cluster.

6.4 Summary

The presented strategies identify potential ways of achieving SCI within OSW supply chains. They demonstrate the possible connections and interactions that could be established between supply chain parties based on the VSM and the findings discussed in Chapter Five. The main benefit of the proposed viable SCI strategy is that it would allow an entire supply chain to act as one team or one cohesive network, and to compete as a whole supply chain against other supply chains. In comparison, the main benefit of the second strategic cluster integration strategy is that it would allow for the integration of the parts of the supply chain where it would bring the most benefit. Both strategies demonstrate the potential for parties to form interconnected and balanced systems, thus leading to the identified benefits associated with SCI as outlined in Table 5.4 of Chapter Five.

Chapter Seven

Discussion of Results and Findings

7.1 Introduction

This chapter will discuss the key findings presented in Chapter Five and the resultant SCI strategies proposed in Chapter Six. Furthermore, it will clarify how the main findings relate to the existing body of knowledge as discussed in Chapter Two. The research findings will be discussed with specific reference to the four research questions provided in Section 2.11.

7.2 The Nature of SCI in the D&C and C&C phases of UK OSW Farms

Sections 5.3.1 to 5.3.6.6 served to respond to the first sub-question of this research: *What is the nature of SCI in the development and construction phases of UK OSW farms*? In order to develop a greater understanding of what SCI means in the context of the OSW industry, the study participants were first asked to explain their understanding of the term ‘SCI’. The results have shown that there was no unified understanding of SCI among the participants. This is expected given that limited descriptions of the OSW supply chain exist in the published literature, as discussed in Chapter Two. This also partly confirms the findings of Sweeney et al. (2015) who identified divergence between an understanding of logistics and SCM principles and their adoption in practice, which is largely due to a lack of consensus about what the terms ‘logistics’ and ‘SCM’ mean. Nevertheless, the participants’ answers referred to either internal SCI, external SCI, or both, which provide an established way examining SCI according to the SCI literature (Stevens and Johnson, 2016).

Another important aspect of SCI is integration among a project’s supply chain members. The majority of the literature discusses internal and external SCI from a focal firm perspective (Wong et al., 2011), whereas less is discussed about SCI among the members of a single supply chain. This could potentially be explained by the lack of systems thinking perspectives used in existing SCI studies.

This study found that the companies of some participants demonstrate high levels of internal SCI, referred by this study as integration of companies' own supply chains, especially manufacturing companies, which use practices such as CPFR. According to Harrison and van Hoek (2011), collaborative planning forms one of the highest levels of electronic integration among trading partners. This suggests that SCI is relatively established in manufacturing environments. This is a point that has also been made evident in the SCI literature, which predominantly discusses SCI in the context of manufacturing and retail industries (Cooper et al., 1997).

It has been found that the participants largely viewed SCI as a positive phenomenon; they recognised how increased collaborative relationships with relevant supply chain parties could lead to a number of benefits, including the collective management of challenges, continuous improvement and development, and efficiencies in product design and overall supply chain processes, as listed in Table 5.4. This suggests that there is value in having a more integrated supply chain; not only in process-based supply chains, but in project-based supply chains too. Moreover, SCI may lead to greater supply chain performance overall, which is an established perspective held in the SCI literature (Frohlich and Westbrook, 2001; Pagell, 2004; Flynn et al., 2010).

However, not all of the participants viewed integration as being necessary for several reasons. One reason was that the work scopes of some suppliers include specialist consultancy services, which are only required when and if necessary, without the need for coordination with other supply chain parties. Another reason was that some work scopes of suppliers are already well-organised. This resonates with Ireland's (2004) argument that SCI and collaborative business relationships may not be appropriate for all players of a project-based supply chain all of the time. In support of this argument, Caniels et al. (2012) added that it is important to maintain a balance between cost and benefits within integrative supply chain relationships to ensure the effectiveness of SCI.

Furthermore, given that the development and construction phases of OSW farms are relatively short in comparison to the O&M phase (which can last for up to 25 years), some participants expressed their opinion that integration is required more during the O&M phase than in the D&C and C&C phases. A similar argument is made by Cox (2009), who suggests that it makes little sense to have partnerships in construction due to the amount of one-off transactions. Instead, he argues that partnerships and long-term alliances should be formed during the O&M phase, where there are more repeat business transactions. However, the benefits of SCI, as identified by this study, oppose this view.

For example, an onshore substation contractor who formed partnership relationships with developers of OSW farms achieved efficiencies in product development and design, among other benefits. This highlights the advantage of forming more integrated relationships in the D&C and C&C phases. This example also shows that integrative relationships should be considered in supply chain areas where they could bring the greatest benefit.

The results from this study have demonstrated the extent of SCI in the development and construction phases of OSW farms, which vary between projects and largely depend on the developers' approaches to managing OSW farm supply chains. In turn, these approaches depend on the in-house capabilities of developers, which determine whether developers could manage the project supply chain themselves or whether they would need assistance from EPCI contractors. The participants' responses have shown that working directly with project developers leads to 'partnership type' project relationships. This suggests that OSW developers play a leading role in determining SCI. This finding corresponds with the project-based supply chain literature, which recognises project developers as dominant parties who are able to drive SCI by helping project suppliers align their working strategies to working strategy of the dominant party (Briscoe and Dainty, 2005). For this reason, developers of large projects are sometimes referred to as system integrators (Davies, 2017).

This study found that the nature of SCI in OSW supply chains is formal because it is based on formal collaboration agreements; commonly referred to as framework agreements. Framework agreements can help parties to define the terms of a collaboration in order to develop a purposeful and structured approach to integrative relationships. In similarity to project-based supply chain descriptions in the literature, the nature of SCI in the OSW industry can be further described as being temporary (Tommelein et al., 2009; Davies et al., 2016). As a result, it was found that there is little continuity between project teams across different projects. Though, there is more continuity when framework agreements or strategic partnerships are in place. Although such a strategic approach to SCI in project-based supply chains is supported by some of the literature (Cox, 2009), this research has found that more incentives can be developed to improve SCI in the OSW industry.

7.3 Factors Constraining and Facilitating SCI in the UK OSW Industry

The project-based supply chain literature shows that SCI conditions vary depending on the context of the supply chain. Therefore, it was important to understand the constraining and facilitating factors of SCI pertaining specifically to the OSW industry. Sections 5.3.7 and 5.3.8 of Chapter Five outline the findings that contributed to the second research question of this thesis: *What are the current factors that facilitate or constrain integration in the development and construction phases of UK OSW farms*?

This study has identified the following inhibiting factors of SCI in the OSW industry: the unique nature of projects, irregular demand, the uncertainty of future pipelines of projects, temporary contract staff, the unreliability of individual supply chains, and the dishonesty of suppliers. It has been found that the unique nature of projects results in uncertainty regarding the number and type of required suppliers for a project, which means that every project could necessitate different suppliers. This makes it difficult to achieve greater SCI. The uniqueness of projects is recognised in the literature as one of the factors that make project-based supply chains more complex than process-based supply chains, thus helping to explain its impact upon SCI (Cox and Ireland, 2002).

In terms of irregular demand, it has been found that the nature of the OSW industry is highly cyclical, which makes demand for products and services volatile. This volatility in demand makes it difficult for OSW suppliers and contractors to make long-term plans or form long-term relationships. Therefore, irregular demand inhibits SCI. This finding is closely related to a study by Ireland (2004), who investigates the impact of lean and partnering approaches upon supply management in project-based supply chains. According to Ireland (2004), irregular demand is the main factor preventing lean and partnering approaches from being effective supply chain management methods within project-based environments.

Closely related to irregular demand is the uncertainty of future pipelines of work, which has been identified as another inhibiting factor of SCI. It has been found that irregular demand predominantly affects lower-tier suppliers, whereas the uncertainty of future work in the pipeline is an industry-wide problem affecting all players of the OSW industry. This includes developers, given that the visibility of the pipeline of projects largely depends upon the intentions of governments to invest in renewable energy. The uncertainty of future projects makes it more difficult for OSW players to build collaborative relationships and contribute towards SCI.

Another interesting inhibiting factor emerging from this study involves the use of temporary contract staff in OSW projects. It has been found that contracted staff constitute around 75% of project employees. This makes it difficult to form long-term collaborative relationships between supply chain parties. Additionally, some contracted staff may be most interested in personal gains, as opposed to forming lasting project relationships. Therefore, the use of temporary contract staff is an inhibiting factor of SCI in the OSW industry. This finding is similar to findings in the project-based supply chain literature, which argue that the temporariness and one-off nature of project-based SCM makes it problematic (Vrijhoef and Koskela, 2000).

This study also found that the unreliability of the supply chains of individual suppliers may affect a project's overall supply chain. This can strain existing relationships among OSW project partners. Therefore, the unreliability of individual supply chains is another inhibiting factor of SCI. This problem has been only partly discussed in the literature. For instance, the literature recognises that the involvement of multiple suppliers in a project makes it more challenging to coordinate different project activities, which often leads to delays and increased lead times (Mello et al., 2015). However, according to a review by Bygballe et al. (2010) on project-based supply chain articles, the scope of research on SCI predominantly concerns the dyadic relationships between a client and main contractor only. Hence, this gap in the literature may suggest an area for further research.

Another inhibiting factor of SCI found in this research involves the dishonesty of suppliers. It has been found that some suppliers may be dishonest during tendering processes by overstating their capabilities in order to win contracts. In such cases, suppliers often involve external subcontractors to help them meet demand. However, this practice is unacceptable within the OSW industry as it creates a range of quality risks in the supply chain, which results in expensive repairs during a project's lifecycle. Such dishonesty is closely related to trust issues, which in turn constrains the formation of long-term relationships and, consequently, SCI (Briscoe and Dainty, 2005; Forslund and Jonsson, 2009). Trust in project-based supply chains has therefore been reported as a major factor leading to the success or failure of construction projects (Latham, 1994; Egan 1998).

In terms of the facilitating factors of SCI in the OSW industry, this research has identified the following: framework agreements, strategic alliances and partnerships, European ISO standards and other guidelines, compliance with client requirements, joint project targets and goals, standardisation of communication, product design and other, formal and informal incentives, organisational culture, industry trade bodies, and personalities or human factor.

The study participants often mentioned the use of framework agreements as a formal way of managing collaborations between parties. The participants explained how framework agreements provide a structure for collaboration, which allows parties to pre-agree contract terms and prices that could last for the duration of several projects. Therefore, framework agreements have been viewed as a facilitating factor of SCI. Closely related to framework agreements, this study found that the existence of strategic alliances and strategic partnerships enable collaboration over several projects. Hence, they also facilitate SCI. However, given that strategic alliances and partnerships require parties to mutually share risks and rewards of an alliance (Olsen et al., 2005), the participants explained that strategic alliances are not used as a widespread approach to collaboration within the industry.

This finding regarding the use of formal collaboration agreements is consistent with findings in the project-based supply chain literature, which suggest that collaboration itself needs to be governed in time-limited projects (Lenfle and Loch, 2017; Chakkol et al., 2018). Nonetheless, it is held in the literature that, in order to achieve SCI in complex project environments, a combination of formal and informal arrangements is necessary (Briscoe and Dainty, 2005). This study provided less information about informal arrangements related to SCI within the OSW industry, but it did find support for the need to use formal and informal incentives to encourage collaboration between parties (Lavikka et al., 2015). The study participants noted that, even in instances of an indirect fault in their work, suppliers receive penalties from the client. These penalties strain buyer-supplier relationships. However, according to the study participants, there are no rewards given when suppliers perform well. Therefore, formal and informal incentives have been identified as an additional facilitating factor of SCI.

This study also identified the European ISO standards and other guidelines as facilitating factors of SCI because they help parties to share an understanding of the nature of certain procedures and processes, including work quality standards. Likewise, the project-based SCM literature argues that ISO standards are especially useful when supply chain parties are physically, socially, culturally, or institutionally distant (Chakkol et al., 2018). According to Chakkol et al. (2018), ISO standards help to reduce information asymmetry between buyers and suppliers. Chakkol et al. (2018) highlight the emerging role of the ISO 44001 collaboration standard as a useful tool that encourages collaborative performance in project environments. While this study has not aimed to explore the use of the ISO 44001 standard within the OSW industry, it has discussed whether it acts as a formal collaboration management tool. Even though some study participants were aware of this standard, it has not been applied within their companies. This finding therefore suggests that ISO 44001 is not commonly used in the OSW industry.

Another identified factor facilitating SCI includes compliance with client requirements. In the context of time-limited projects, it is important to ensure supplier commitment and compliance with the requirements specified in the contracts between parties. This is because supplier compliance helps to streamline supply chain processes. While this finding is less discussed in the literature, it relates to a more general understanding of the importance of collaborations and partnerships, including how collaborations and partnerships require commitment from all parties involved (Cox and Ireland, 2002; Olsen et al., 2005).

One way to ensure commitment from different parties is to establish joint project targets and goals at the beginning of a project, as discussed in proposed SCI strategies in Chapter Six. Joint project targets and goals therefore assist with the facilitation of SCI. Shared project goals are recognised in the literature as important for building trust between project parties (Khalfan et al., 2007). As mentioned previously, trust is an important success factor of project-based supply chains and is viewed as a prerequisite for performance improvement within project environments (Latham, 1994). Lehtinen and Ahola (2010) found that mutual trust and shared project goals are also prerequisites for the coordination of project-based supply chains.

The standardisation of communication, product design and engineering form another factor facilitating SCI. Based on the participants' experiences of working on different OSW projects, it has been found that there is a lack of standardisation within the industry in relation to information sharing, product design and engineering, including the approaches taken by engineers to different project tasks. The study participants noted that increased standardisation across different areas of the OSW supply chain would enable streamlined flows of information and products, as well as helping to achieve greater commonalities across supply chains. The problems caused by a lack of standardisation in project environments have also been recognised in the literature. For example, Ireland (2004) describes how the improved standardisation of product design and improved communication of work specifications for suppliers led one case company to achieve more collaborative SCM. This suggests that standardisation plays an important role in facilitating SCI.

Likewise, this study has found that organisational culture also facilitates SCI. More specifically, companies that are collaboratively-oriented tend to view partnership relationships as being beneficial for all parties, and they often have little objections to forming more collaborative relationships. The review of the literature found limited discussion about the role of organisational culture in forming more integrated supply chain. However, few articles mentioned organisational culture in relation to trust building and alliances formation (Dyer and Singh, 1998; Khalfan et al., 2007). Khalfan et al. (2007) mention that organisational culture can have an impact upon trust building in project teams while Dyer and Singh (1998) argue that organisational culture or rather incompatibility of organisational cultures is one of the factors of failed alliances. This finding of the importance of organisational culture in SCI development suggests anther potential area for future study.

Additional facilitating factors of SCI include industry trade bodies and personalities of people forming contractual relationships. It has been found that industry trade bodies often act as mediators between existing OSW industry players and those who are interested to become suppliers to the OSW. Industry trade bodies facilitate conversations between parties by organising various industry events. They can therefore be viewed as informal facilitators of SCI, who provide networking and meeting opportunities for OSW industry parties. Another interesting and important factor identified by this study involves the personalities of people forming contractual relationships. Human nature plays an important role in the building of more integrated supply chains. The study participants highlighted the importance of human relationships in the context of SCI, and whether different teams can collaborate effectively. Although this finding has not been directly discussed in the literature, one article mentions the importance of 'soft skills' for improving communication between project-based staff (Dainty et al., 2001). Dainty et al. (2001) find that soft skills can encourage inclusive attitudes among project staff, as well as helping to address the trust issues that commonly arise in project-based environments, particularly due to the adversarial and opportunistic behaviours of project parties. The importance of trade bodies and personalities could therefore provide opportunities for future research.

7.4 Reflection on the VSM Analysis

Section 5.4 presented the results and findings of the VSM analysis, which also provided the information required to answer the third research question: *How can VSM principles help to analyse and improve integration in the development and construction phases of UK OSW farms*? Based on the results and findings of the VSM analysis, this section reflects upon how the VSM can be used to help analyse SCI and find areas for improvement to achieve greater SCI.

A primary benefit of the VSM identified in this research is that it helps to understand a supply chain in terms of being a system. The term 'SCM' almost intuitively implies systems thinking, especially given that it was developed based on the idea of viewing the chain of supply as a single entity (Oliver and Webber, 1995). Therefore, this view has long been reflected in the logistics and SCM literature, which acknowledges the relevance of systems thinking as being valuable for holistically learning about SCM processes (Ellram and Cooper, 1990; Choi et al., 2001; Grant, 2012). The systems thinking perspective emphasises that the properties of parts can only be understood within the context of a larger whole (Capra, 1997). This is especially evident in the concept of SCI, which is characterised by "*joined up thinking, working, and decision making*" (Stevens and Johnson, 2016: 22).

Furthermore, despite the general acceptance of the value of systems thinking in logistics and SCM, this research has found that studies which employ systems theories often only use them as a background philosophy, as opposed to a guiding methodology (Fawcett et al., 2012). The review of the literature in this thesis found support for Lindskog's (2012a and 2012b) finding that systems thinking, as well as associated theories and approaches, remain underutilised within the logistics and SCM discipline. A further review of complex systems approaches, which form a branch of systems thinking, revealed several existing approaches that have relevance to logistics and SCM research. Examples include CAS, complexity sciences, and organisational cybernetics, of which the VSM is a part (Bohorquez Arevalo and Espinosa, 2015).

The VSM analysis provided a useful framework for analysing supply chain from a viable system perspective. It helped to view the interconnections between all parts of the system. In the context of SCM, these parts can be considered as businesses that form a specific supply chain. The interconnections between businesses were revealed and clarified through a process of mapping in accordance with the VSM diagram. The interconnections between businesses, which are viewed through the lens of VSM subsystems and their interconnection with the system's environment in which it operates, determine a system viability. This research considered viability of a supply chain as a system. The key to system's viability is maintaining an internal balance, which is ensured by subsystems in their interaction with a constantly changing external environment. By using the VSM to understand the interconnections between businesses, it is also possible to assess the levels of integration between them and, consequently, the levels of integration of the supply chains that they form.

Considering that the VSM analysis focuses on the structural coupling between the operations, management, and environment of a viable system, it has been helpful to distinguish these parts in relation to the OSW supply chain in order to assess the interactions among them. It has enabled a deeper understanding of the different suppliers and contractors that form the main operations of the OSW supply chain and reveal existing concerns related to the operations, outlined as diagnostic points in Table 5.19. Likewise, it has helped to form an understanding of the meta-systemic management of the OSW supply chain and the role of developers who are responsible for taking ultimate decisions. More importantly, it has provided an understanding of the interconnections between the meta-systemic management and the operations. The interconnections between the meta-systemic management of an OSW supply chain and a wind farm's operations or suppliers have been assessed through an analysis of each subsystem forming the VSM, namely S2, S3, S4, and S5. Any identified issues pertaining to these subsystems have been outlined as diagnostic points, shown in Tables 5.20, 5.22, and 5.23. Furthermore, it has assisted with an exploration of the OSW industry's environment based on a range of perspectives provided by the study participants, where any identified concerns were reported as diagnostic points in Table 5.18.

The VSM analysis assessed the balance of the system in focus by examining the interactions between S1, S2, S3, S4, and S5, and between these subsystems and the environment. A number of imbalances have been identified, which suggest that the current state of the OSW supply chain, as a system, lacks balance. By identifying the key imbalances, the VSM analysis revealed areas that could be improved upon in order to achieve a more integrated and robust supply chain. Moreover, based on the participants' examples of working within OSW supply chains, which can be described as more balanced systems, it could be seen that further steps can be taken to achieve greater viability and more integrated supply chains.

7.5 The Viable SCI strategy and the Strategic Cluster Integration Strategy

Based on the study's results and findings presented in Chapter Five, two SCI strategies based on VSM principles have been proposed. These strategies were detailed further in Chapter Six. To clarify, Chapter Six discussed two different SCI scenarios, as well as outlining the potential improvements that could be achieved in each scenario. This discussion thus contributed towards answering the fourth research question: *What potential improvements can be made to achieve a more integrated supply chain based on VSM principles*?

The first strategy was entitled the viable SCI strategy, as shown in Figure 6.1. It was based on the idea of SCI, where members of an OSW project supply chain act as one team or one cohesive network coordinated by the OSW project developer. This strategy reflects the study's finding that almost half of the participants expressed a preference to work directly with project developers rather than through EPCI contractors as intermediaries. The participants expressed this preference because it allows supply chain members to develop greater 'partnership type' relationships.

In order to develop closer long-term relationships, the viable SCI strategy included the use of preferred suppliers and contractors over multiple projects. This would allow supply chain parties to potentially achieve the advantages of SCI, as outlined in Table 5.4 of Chapter Five. One of the main advantages included continuous improvement and development, which allow supply chain members to align their processes to the requirements of a particular developer; the leading party determining the working strategy of a supply chain (Briscoe and Dainty, 2005; Davies, 2017). The formation of continuous relationships would also allow for the development of additional commonality and standardisation in supply chain processes, such as information sharing, as well as product design and engineering. The lack of standardisation was identified as an area that currently requires improvement. This was summarised in Table 5.15, along with other areas that the participants would like to see improved.

The multi-project continuous relationships implied by the viable SCI strategy allow supply chain members to co-develop products and services in supply chain areas that require greater attention. According to the study's findings, there are currently areas in the OSW supply chain that are more developed than others, thus creating a surplus in some areas and a shortage in others. The development of joint products and services would help to address this issue. Moreover, it would also allow supply chain members to address industry issues collaboratively, such as the reduction of LCOE.

Long-term relationships between project suppliers and contractors and developers could help to improve the aforementioned problem related to irregular demand, which was described by the participants as being a major challenge within the OSW industry. Closer relationships with project developers would help suppliers and contractors to make the plans of developers more visible for future projects, thereby allowing suppliers and contractors to make longer-term investments in facilities and staff. Moreover, a larger number of permanent staff could be employed on a project as opposed to using temporary contract staff, the latter of which was identified by the participants as being an inhibiting factor of integration.

The VSM analysis has shown that, at the present, there is a high degree of formal relationships and control exercised by developers within the development and construction phases of OSW farms, thus hindering trust and cohesion between supply chain parties (Espejo and Mendiwelso Bendek, 2011). As it was mentioned earlier, trust is critical for success in project-based environments (Latham, 1994; Egan 1998; Briscoe and Dainty, 2005; Caldwell et al., 2009; Forslund and Jonsson, 2009). Closer and longer-term relationships between developers and suppliers and contractors could help to improve trust between parties by establishing incentives that encourage the accountability of all parties involved, thereby promoting greater integration and performance of the whole supply chain.

The second strategy was entitled the strategic cluster integration strategy, as shown in Figure 6.2. This strategy was based on the idea of integrating a specific part of the supply chain, as opposed to integrating the whole supply chain as implied by the viable SCI strategy. This strategy was proposed following the study participants' desire for this type of purposeful cluster integration. Alternative phrases that have been used to describe this concept have included 'special partnerships', 'the consortium approach', and 'group integration'. This finding is closely related to the SCI literature, specifically an article by Stevens and Johnson (2016) which views the future integration of supply chains as taking the form of devolved and collaborative supply chain clusters.

The aim of this strategy included the purposeful organisation of a cluster of business partners to collaboratively work towards a common goal. This study viewed the development of joint products and services as the primary aim of strategic cluster integration. In similarity to the viable SCI strategy, the strategic cluster integration strategy can also help to achieve greater standardisation and improvements to individual product designs. This would help to achieve efficiencies in product design and engineering and, subsequently, efficiencies throughout the rest of the supply chain. In addition, cluster partners could potentially achieve the same SCI advantages, as outlined in Table 5.4.

Overall, the proposed strategies have importantly demonstrated how OSW supply chain members can achieve greater integration, which current literature provides little information about. Most SCI research focuses on ‘what’ can help integration rather than ‘how’ to integrate. For example, many authors highlight information sharing as a prerequisite for SCI, highlighting such information sharing tools as EDI and CPFR (Cooper, et al., 1997; Harrison and van Hoek, 2011; Wong et al., 2011). Others mention the importance of manual integration by working co-located (Voordijk et al., 2006; Harrison and van Hoek, 2011). In addition, a number of authors identify partnerships and trust as being critical factors of SCI in project-based environment (Dainty et al., 2001; Caldwell et al., 2009). However, literature on SCI in project-based environment also notes that even though integration is important, for efficient and effective outcome of projects, it is difficult to achieve in practice (Briscoe and Dainty, 2005).

The proposed SCI strategies respond to the criticism that SCI is difficult to achieve in practice by providing a holistic perspective on SCI, incorporating various factors that show how integration can be achieved. Both the viable SCI strategy and the strategic cluster integration strategy explain how supply chain members can be affiliated (relationship between S1 and S3). They show what governance structure and mechanisms, beyond traditional information sharing practices, can help to build trust and achieve cohesion among supply chain members (S5, S2 and S3*). In addition, the proposed strategies explain what common purpose and reason can drive SCI among supply chain members, enabling the whole supply chain to compete against other supply chains, as outlined in S4. While the idea of competing supply chains has long been discussed in the logistics and SCM, the SCI literature has provided little or no discussion about the reasons for individual business to engage in SCI of the supply chain they are operating in (Christopher, 2016). Therefore, the proposed strategies contribute to the understanding of SCI in project-based environment by not only outlining ‘how’ SCI can be achieved, but also ‘why’ it can be of benefit to individual supply chain members. Further contributions of this research and conclusion of the thesis will be provided in the next chapter.

Chapter Eight

Conclusion

8.1 Thesis Summary

This research has provided description of the OSW supply chain, whilst exploring the nature of SCI in the UK OSW industry. The thesis applied a systems thinking approach called the Viable System Model (VSM) to qualitatively explore the nature and potential of SCI in the development and construction phases of 'fixed bottom' rather than 'floating' OSW farms. The thesis proposed two SCI strategies based on the VSM that demonstrate the potential of SCI and the improvements that could facilitate the overall performance of OSW project supply chains. This research also identified several facilitating and constraining factors of SCI pertaining to the OSW industry, further contributing to an understanding of the nature of SCI and OSW supply chains.

This thesis began by summarising the following research problem:

How can a systems thinking approach; VSM help to understand the current state of SCI in the OSW industry and reveal potential areas for improvement in order to facilitate greater performance of the whole supply chain?

As explained in Chapters One and Two, emphasis has been placed on the supply chain and its integration in the OSW industry. This has especially been the case in the UK, which is the largest country in the world in terms of installed OSW capacity. To build on the success of OSW, the UK government has a vested interest in continuing to build domestic supply chains, which are able to support future OSW developments. However, despite the widespread use of the terms 'SCM' and 'SCI' in the OSW industry, there has been limited information about the meaning of these terms in the context of OSW. In terms of a discussion of logistics and SCM, this research has contributed to the literature on the OSW supply chain. It has described the OSW supply chain in Section 2.6 of Chapter Two. As clarified in this research, one of the main features of the OSW supply chain is that it belongs to a project-based environment rather than a process-based environment. Process-based environment is traditionally implied in continuous or line manufacturing supply chains, as well as retail supply chains.

To further contribute to the literature on the integration of OSW supply chains, a review of the relevant literature on SCI and SCM in project-based environments was conducted. The literature review showed that there is little consensus from scholars about what constitutes SCI and how best to achieve it. A common viewpoint held in the literature is that SCI is context-dependent and that it varies between companies and industries (Evans and Danks, 2002). As a result, there is no shared standpoint about how best to study SCI. However, there is general agreement among SCI scholars that there is a need to advocate systems perspective to explore SCI, but specific information about how this could be achieved is lacking (Sadler, 2007; Stevens and Johnson, 2016).

A further review of the literature revealed that, while the systems perspective is widely accepted in logistics and SCM as a background philosophy, it is not commonly applied as a methodological approach to logistics and SCM research. This study has used this limitation as an opportunity to contribute to the literature by taking the VSM as a systems thinking approach and applying it to a study of SCI in the OSW industry. At the time of writing this thesis, only two articles had been identified in the logistics and SCM field that use the VSM in their research, namely Puche et al. (2016) and Chan (2011). However, they provide limited information on details about the background methodology they used to apply the VSM. To avoid a similar criticism, this study has provided a detailed description of the steps taken to apply the VSM as part of case study research strategy, as described in Chapter Four.

The use of the VSM in this research has enabled the OSW supply chain to be viewed as a system. This has been achieved by revealing the different types and relevance of the patterns of interconnections among the businesses that make up the system in focus, shown in Figure 5.2. By further exploring these interconnections, areas for improvement to help facilitate SCI in the OSW industry have been identified. Furthermore, it helped to propose two strategies for SCI in the OSW industry, which explained the potential integration and improvements that could be achieved as the result of these types of SCI, thus helping to facilitate the overall performance of OSW supply chains.

8.2 Assessment of the Research Design

This study examined three underexplored research areas: the supply chain within the OSW industry, SCI within a project-based environment, and the application of the VSM in the context of SCM. The primary purpose of this research was to explore these areas further by taking a qualitative and exploratory research approach. Given its exploratory nature, the research design focused on subjective and intersubjective knowledge creation through adopting an interpretivist paradigm.

This thesis sought to gain context-dependent knowledge about the nature and potential of SCI within the OSW industry. Therefore, a case study research strategy was adopted as the most appropriate strategy for this research. The initial research design was based on a single holistic case study research strategy, with the aim to explore a single OSW project's supply chain (Yin, 2014). However, this was changed from a single holistic case study design to a single embedded case study design for confidentiality reasons (Yin, 2014). The potential problem of a single holistic case study design was that it could disclose information about the OSW project's supply chain processes, which was deemed confidential. Although a single holistic case study research strategy might have gained richer insights by applying the VSM to a specific supply chain, the revised research design helped to gain more detailed insights about different OSW project supply chain areas. This was achieved through a series of interviews with the study participants, who represented different work scopes of the OSW supply chain. As shown in Figure 5.2, the participants reflected upon their experiences in relation to working as part of different OSW projects.

As a result of the final research design, this study was able to contribute to an understanding of the four research questions initially outlined in Chapter Two. First, by obtaining richer findings about the nature of SCI in the OSW industry, with a specific focus on the development and construction phases of OSW farms. Second, by identifying several inhibiting and contributing factors of SCI in the OSW industry. Third, by exploring the feasibility of the VSM in the OSW supply chains. Finally, by proposing two SCI strategies based on the VSM that outlined the potential of SCI within the OSW industry. The proposed strategies also showed what improvements each strategy could bring to OSW supply chains. Further details about the research contribution will be provided in the following sections, along with details on the study's limitations and potential areas for future research.

8.3 Thesis Theoretical Contributions

The main theoretical and methodological contribution of this research is the application of the VSM as a systems thinking approach to SCM research. This research established usefulness and relevance of the VSM in gaining greater knowledge about SCI by applying it in the context of the UK OSW industry. VSM is primarily recognised as an intervention-based methodology among systems thinking practitioners and academics (Schwaninger, 2006b; Espejo and Reyes, 2011; Espinosa and Walker, 2017; Jackson, 2019). However, this research applied VSM in a case study research strategy, thereby showing VSM's applicability in non intervention-based research methodology.

This research followed Espinosa and Walker's (2017) first three steps of the 'methodology to support self-transformation' as a guidance for VSM application. The first two steps involving TASCOI analysis and recursion analysis helped to place boundaries around OSW supply chain for research purposes and helped to define and surface the system in focus, shown in Figure 4.4. The TASCOI analysis and recursion analysis helped to make the judgment about who needed to be included in the research explicit. The system in focus, as shown in Figure 4.4, served as a sample framework for selecting research participants. The final sample of the research participants formed the refined system in focus of the research as shown in Figure 5.2. VSM analysis followed as the third step of the methodology to support self-transformation and was employed at the data analysis stage.

The application of the TASCOI and recursion analyses also helped to widen the scope of SCI analysis in this research. The literature review revealed that existing studies on SCI in the context of project-based environments are predominantly concerned with dyadic relationships, usually between a client and the main contractor (Bygballe et al., 2010). This research considered relationships among different supply chain members forming the system in focus as shown in Figure 5.2. Full details of this study's methodological considerations and research design involving steps that were taken to apply VSM have been provided in Chapters Three and Four.

The VSM offered organisational cybernetics theory-based framework consisting of a set of conventions called systems (Beer, 1985). Together these systems form a viable system, where each system has its own function, similar to that of how human body organs each have their own functions within the human body. The primary focus of the VSM analysis is to assess how balanced the whole system is by assessing its systems' interdependencies and interconnectedness (Espinosa and Walker, 2017). This has made VSM useful and relevant approach to apply in the study of SCI, which helped to explore interconnectedness and current interactions among businesses forming OSW supply chain by conceptualising OSW supply chain as a system. In addition, VSM helped to reveal issues related to current interconnectedness among businesses, discussed as diagnostic points in Part Three of Chapter Five. Therefore, this research confirmed

VSM's usefulness in exploring complex SCM issues such as SCI. Theoretical description of the VSM has been provided in Section 2.9.2 and details on how each part of the VSM was described and assessed in this research has been provided in Part Three of Chapter Five.

Following VSM analysis and the study findings, this research proposed two SCI strategies based on the VSM principles, presented in Chapter Six. Both strategies explain how businesses forming part of operations of a single supply chain can achieve greater integration through a set of managerial functions and incentives, like for example joint product and services development. Proposed strategies also emphasise the importance for businesses to remain competitive in the environment they operate in. This study thus suggested that improved integration among supply chain members may improve competitiveness of the whole supply chain in the environment it operates in. By outlining how SCI can potentially be achieved in practice in the context of the OSW industry this study has contributed to the existing body of knowledge concerning SCI.

In addition to contributing to the question 'how' SCI can be achieved in practice, this research has also contributed to finding answers to the question 'why' businesses should engage in forming greater integration. This study identified several advantages associated with SCI presented in Table 5.4 based on existing experiences of study participants. In addition, this research found that joint products and services development in those areas where it can bring the most benefits can serve as a common purpose for driving SCI among OSW supply chain members.

This research has also contributed to the body of knowledge on SCI in project-based environments. Existing research on SCI has been based predominantly on process-based industry backgrounds such as continuous manufacturing and retail environments (Frohlich and Westbrook, 2001; Stevens and Johnson, 2016). This research explored the nature of SCI in the OSW industry which can be described as a project-based industry. This research has identified a range of advantages of SCI and facilitating factors impacting SCI supporting the view that integration can bring benefits to project-based industry environments in a similar way integration is valued in process-based industry environments (Briscoe and Dainty, 2005; Bresnen and Marshall, 2011).

8.4 Thesis Practical and Managerial Contributions

The results and findings of this thesis could also be useful for OSW industrial practice. It was established in Chapter One that the 'supply chain' is a term which is often mentioned in the OSW industry, yet there have been limited explanations of the OSW supply chain in the literature. By building upon the few existing academic and industry publications in this field, this thesis provided a more detailed description of the OSW supply chain in Section 2.6, which provided two key perspectives: a lifecycle perspective (Figure 2.7) and a network perspective (Figure 2.8) of the OSW supply chain.

This thesis has also provided useful information about SCI from theoretical standpoint, which can be used by companies operating in the OSW industry to evaluate their understanding of SCI and how it can be achieved in practice. The research findings have shown that OSW SCI largely depends on the OSW farm developers' approaches to manage their supply chains, which suggests that developers can be recognised as system integrators (Davies, 2017). This finding can be useful for OSW farm developers for them to consider their current practices in creating more integrative supply chains. Chapter Five outlined few disadvantages and considerably more advantages of SCI (Tables 5.3 and 5.4) that show what value integration has in the OSW industry. The identified facilitating and constraining factors impacting SCI in the OSW industry can inform interested parties about the opportunities and impediments to achieving a more integrated supply chain (Tables 5.13 and 5.14).

The diagnostic points identified using the VSM analysis, reported in Tables 5.18, 519, 5.20, 5.22, and 5.23, can further provide insights into the areas of the OSW supply chain that can be improved. Moreover, the proposed SCI strategies based on the VSM (Figures 6.1 and 6.2) explain and demonstrate 'how' and 'why' SCI can be achieved in practice and provide information on what benefits could be achieved as a result to strengthen OSW supply chain. However, as this is an exploratory research piece, further practical research would be desirable in order to explore the feasibility of the proposed strategies and to demonstrate their effectiveness in relation to SCI.

8.5 Research Limitations and Suggestions for Future Research

While every effort has been made to ensure the rigour and validity of this thesis through the chosen research design, there remains a few limitations to consider that provide opportunity for future research. First, this research was limited to the UK OSW industry, which meant that the focus of this research has solely been on the development of OSW farms around the UK coast. Therefore, the study sample was drawn from the companies that had previously taken part in these developments, which partly explains the limitations related to the sample size of this research. However, this limitation has been somewhat compensated for by the participants' expertise and experience of the OSW industry, which facilitated the collection of in-depth data that resulted in rich findings. To further advance this research and to address this limitation one suggestion for future research involves expanding the research context to include other OSW active geographical areas. In addition, this research can be advanced by trying to engage larger sample size.

Second, the focus of this research has been solely on the first two phases of the OSW farms lifecycle, namely the D&C phase and the C&C phase, as these phases have represented the project-based supply chain environment. The O&M phase which forms part of the third phase of the OSW farms lifecycle, has not been included in this research. However, the research findings have shown that the O&M phase naturally requires closer relationships among businesses because the O&M phase can last up to 25 years compared to three to five years of the development and construction phases. This finding therefore suggests the area for future research which can explore SCI specifically in the O&M phase of the OSW farms lifecycle. Third, this research involved the application of the VSM to a case study research design, as opposed to AR, which is a common research strategy for many systems approaches including the VSM (Espinosa et al., 2015). This means that this research applied only the first three steps of the methodology to support self-transformation (Espinosa and Walker, 2017). AR would have been more difficult to undertake given that the author of this thesis experienced challenges in terms of gaining detailed access to OSW farm projects to use as a single case study. The study found that the original research design involving a single case study strategy could have threatened to reveal the supply chain operations of a particular project, which would have consequently threatened the company's USP. This challenge was resolved by moving from a single case study research design to an embedded case study research design, which did not require the participants to refer directly to a particular OSW project.

Outlined limitation presents an opportunity to explore the practical feasibility of the proposed SCI strategies by following the subsequent three steps of the methodology to support self-transformation (Espinosa and Walker, 2017). To do that, it would be useful to test the proposed SCI strategies using an AR strategy that involves a more participatory approach. In addition to AR strategy, it would also be beneficial to explore the effectiveness of the proposed strategies in relation to particular OSW project case studies, which had not been possible in this research owing to the aforementioned limitations.

In addition to exploring feasibility of the proposed SCI in practice, future research could advance knowledge on SCI by further exploring SCI in different OSW projects. This study found that different OSW developers take different approaches to project management and, subsequently, to project supply chain management. Future research can investigate the different approaches taken by developers to facilitate SCI through a series of comparative case studies or AR using Espinosa and Walker's (2017) methodology. Moreover, it has been found that the inhibiting and facilitating factors affecting SCI, such as trade bodies, personalities of people forming contractual relationships, unreliable individual suppliers' supply chains, and organisational culture, have not been well documented in the literature. This provides an opportunity to explore the relationship between these factors and SCI using either qualitative or quantitative research.

Fourth, the challenge of this research concerned the application of the VSM to a supply chain context. In other words, it was applied to analyse the viability and hence integration of a network. This could potentially be viewed by proponents of the VSM as a limitation because the model is usually applied from the perspective of a focal organisation or a system. However, there have been examples of VSM applications to network contexts in previous studies (Schwaninger, 2006b; Espinosa and Walker, 2017: 249-312; Espinosa and Duque, 2018). In line with these studies who find value in applying VSM to a network context, the results of this study confirmed that the VSM provides a useful framework in the context of supply chains. However, more research is needed to further advance VSM applications in the network contexts by applying the VSM to different SCM backgrounds, including both project-based and process-based supply chain environments.

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Appendix A

Invitation Email Example

Good afternoon …,

I'm Julija Danilova a PhD researcher from the University of Hull, UK. We have not met directly but I tracked your name through different offshore wind sector news websites.

The reason I am contacting you is because I wanted to invite you to participate in my PhD research, where I believe your perspective related to … for offshore wind would be of great value.

In brief, I study supply chain integration in the UK offshore wind industry by taking systems perspective and applying one of the systems theories called Viable System Model to qualitatively analyse the industry's current supply chain integration levels and suggest any potential ways to improve integration, for the potential benefit of improved supply chain performance as a whole.

I have attached my project information sheet, which explains my research aims in more details and what participation would involve and for your convenience, I have also attached my interview guide, which shows the kind of questions I am interested to find the answers to.

I really hope that you can take part in my research, as I believe that your expertise will help me to build a more accurate picture of supply chain integration potential. In return, I will be very happy to share my study results with you upon completion of my research.

Thank you in advance for your consideration,

Kind regards,

Julija Danilova

PhD researcher in Logistics and Supply Chain Management

University of Hull

Appendix B

Project Information Sheet

Offshore wind industry supply chain integration analysis using Viable System Model

You are invited to participate in this research project exploring the extent and potential of the UK offshore wind farms development and construction supply chain integration, undertaken by Julija Danilova a PhD researcher in The University of Hull, Faculty of Business, Law and Politics. This invitation sheet provides more information on the aims of this research and your involvement in it.

The aim of the project:
This study explores the concept of integration or collaboration among businesses engaged in development and construction supply chains of the UK offshore wind farms. This study applies one of the systems theory and associated Viable System Model, in order to explore how systemic analysis of the UK offshore wind industry development and construction supply chains can help to understand current levels of supply chain integration and reveal potential areas for improvement, in order to facilitate performance of the whole supply chain. This research will be focusing on the factors that facilitate, as well as constrain integration.

Why have you been chosen?
By means of interviewing, this study aims to bring together perspectives of developers and major suppliers of products and services involved in the development and construction of the UK offshore wind farms, supply chains of which are perceived as temporary systems comprising businesses that are temporary interconnected in the process of building an offshore wind farm. Your views as a managing director for North & Midlands in one of the leading companies in the onshore substation market for offshore wind sector would help to build a picture about the current situation on supply chain integration and would help to articulate potential ways for any improvements.

Participation:
Participation in this study is voluntary. It will involve an interview that is expected to last approximately 30 to 45 min. You are free to decline to answer any of the interview questions if you so wish. Furthermore, you can withdraw from this study at any time without any negative consequences.

With your permission, the interview will be audio recorded to facilitate collection of information, and later transcribed for analysis. A copy of the transcript will be available to you should you wish to confirm the accuracy of our conversation.

All information you provide will be treated as confidential. Your name and the name of your organisation will not appear in thesis resulting from this study, however, with your permission anonymous quotations may be used.

Data collected during this study will be managed by me only and retained in a private computer for the duration of this research.

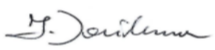
There are no known or anticipated risks to you as a participant in this study.

Should you have any concerns about the conduct of this research project, please contact the Secretary, Faculty of Business, Law and Politics Research Ethics Committee, University of Hull, Cottingham Road, Hull, HU6 7RX; Tel No (+44) (0)1482 463536.

I hope that the results of my research will be of benefit to all organisations directly involved in this study, as well as to the wider offshore wind industry and academic community by bringing greater understanding of supply chain integration potential.

I am very much look forward to speaking with you and thank you in advance for your assistance in this research.

Yours Sincerely,



Julija Danilova
J.Danilova-2008@hull.ac.uk
PhD researcher in Logistics & Supply Chain
Management, University of Hull
Project Supervisor:
Dr. Angela Espinosa

Appendix C

Semi-Structured Interview Guide

Interviewee: ________________________________

Date and time: ______________________________

Reminders to participant:

You are free to withdraw at any time

You are free to decline answers to any questions

All information shared will remain confidential and anonymous

Questions:

1. How do you understand the term ‘supply chain integration’?

2. Who are your main customers in the offshore wind industry?

3. What are the main activities or operations that (company) performs in order to provide its products/services to the offshore wind customers?

4. Do you work with the same set of suppliers to provide your products/services?

5. Could you describe the process of securing a contract or a purchase order and then the process of delivering that order?

6. How do you ensure that each of your main suppliers or businesses that you work with deliver on their tasks?

7. How often do your customers perform any inspections (formal or informal) during order processing time? [If at all]

7a. Do you ever perform any formal or informal checks on your suppliers/contractors?

8. How would you describe your relationships with different customers? [Probe: are they more transactional or partnership based, other?]

9. Could you describe your contractual arrangements with your offshore wind customers? [Probe: type of contract]

10. How easy or how difficult is it to form long-term partnerships with any of the key customers or suppliers?

11. Who are the most important customers or suppliers that you would benefit from having more collaborative relationships with?

12. How often do you experience any conflicts or issues between you and your customers and other supply chain participants? [Probe: source, conflict resolution mechanisms]

13. Do you use any standards for collaboration like for example BS11000/ISO44001? [Probe: effectiveness, importance of standards]

14. What do you consider as the most important value drivers in the offshore wind industry? [Probe: time, cost, quality, other]

15. Are there any shared information and communication technology (ICT) systems that you use to interact with your customers/suppliers on a day to day bases?

16. How easy or how difficult is it to incorporate any changes to the original order delivery schedules, if necessary?

17. How easy or how difficult is it for your business to adopt to any changes in the offshore wind industry environment? [For example: Technological, political, social, legal, environmental, other]

18. What improvements would you want to see in the current supply chain arrangements in the offshore wind industry?

19. Are there any best practice examples from other industry sectors that you think can benefit offshore wind industry?

20. Would increased supply chain integration improve current working practices in the offshore wind industry?

21. Overall, how would you evaluate current supply chain integration levels across the offshore wind industry?

Any last comments

Appendix D

Informed Consent Form

Informed Consent Form

I, Name of participant of Company

Hereby agree to participate in this study to be undertaken

By Julija Danilova

and I understand that the aims and purpose of the research is to explore how systemic analysis of the UK offshore wind industry development and construction supply chain can help to understand current levels of supply chain integration and reveal potential areas for improvement, in order to facilitate greater performance of the supply chain overall. The project focuses on the factors that facilitate, as well as constrain integration in the offshore wind industry.

By signing this consent form are agreeing to your participation in this research process and to the collation of the material. Participants have the right to withdraw from participation in the research process at any point and materials collated from them up to that point will be removed.

I understand that

1. The transcript of our conversation will be coded and my name and address kept separately from it.
2. Any information that I provide will not be made public in any form that could reveal my identity to an outside party i.e. that I will remain fully anonymous.
3. Aggregated results will be used for research purposes and may be reported in scientific and academic journals (including online publications).
4. Individual results **will not** be released to any person except at my request and on my authorisation.
5. That I am free to withdraw my consent at any time during the study in which event my participation in the research study will immediately cease and any information obtained from me will not be used.

Participant's Signature: Date:

The email contact details of the Researcher are:
Julija Danilova
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Faculty of Business, Law and Politics
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Appendix E

Data Analysis Process