**From Concept to Practice:**
**Designing Demand-Oriented Logistics Service Models for Emerging Offshore Wind Markets – A Readiness-Adaptive Modular Logistics Service Model:**
**The Case of Türkiye**

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**LIST OF ABBREVIATIONS**

| Abbreviation | Explanation |
|---|---|
| EU | European Union |
| EPCI | Engineering, Procurement, Construction, and Installation. |
| FEED | Front-end engineering design |
| GW | Gigawatt |
| HLV | Heavy-Lift Vessel |
| KPI | Key Performance Indicator |
| LCOE | Levelized Cost of Energy |
| LSP | Logistics Service Provider |
| LSLM | Logistics Service Provider Lifecycle Model |
| LSM | Logistics Service Model |
| MENR | Ministry of Energy and Natural Resources |
| NGO | Non-Governmental Organization |
| OEM | Original Equipment Manufacturer |
| OW | Offshore Wind |
| OWF | Offshore Wind Farm |
| OWP | Offshore Wind Project |
| OWTG | Offshore Wind Turbine Generator |
| PPP | Private Public Partnership |
| RE | Renewable Energy |
| SC | Supply Chain |
| SCM | Supply Chain Management |
| TR | Türkiye |
| WTG | Wind Tribune Generator |
| WTIV | Wind Turbine Installation Vessel |
| YEKA | Renewable Energy Resource Area (Turkish abbreviation) |

## EXECUTIVE SUMMARY

Offshore wind(OW) is increasingly recognised as a strategic pillar of global energy transition, with rapid capacity expansion placing increasing pressure on maritime, port, and logistics systems. While mature OW markets have developed highly integrated logistics ecosystems, emerging markets face structural gaps that can significantly constrain project feasibility, cost efficiency, and investor confidence. Türkiye represents such a case: despite strong industrial, shipbuilding, and onshore wind manufacturing capabilities, its OW industry remains at an early stage, with logistics readiness constituting a critical bottleneck.

This project examines how logistics service models can support the development of the country's industry by aligning domestic logistics capabilities with demand-side stakeholder expectations(hereafter referred to as ''stakeholders'' unless the full designation is required for analytical emphasis)namely utilities, developers, original equipment manufacturers (OEMs), and Engineering , Procurement , Construction and Installation (EPCI) contractors. Rather than treating logistics as a purely operational or asset-based function, the study reframes logistics as a strategic, service-oriented capability that directly influences installation lead time, schedule reliability, and levelized cost of energy (LCOE) in offshore wind projects(OWPs).

The study adopts a qualitative, desk-based single-case study design**,** grounded in a pragmatist research philosophy and an abductive approach. It synthesises international offshore wind logistics(hereafter referred to as ''logistics'' unless the full designation is required for analytical emphasis) literature with Türkiye-specific secondary data, including industry reports, policy documents, and institutional studies. The analytical focus is placed on the installation phase, identified in the literature as the most logistics-intensive and cost-sensitive stage of OWPs.

International analysis identifies six recurring logistics challenge themes:

(1) weather and environmental uncertainty,
(2) port infrastructure and capacity constraints,
(3) vessel availability and load optimisation,
(4) supply-chain coordination complexity,
(5) cost efficiency and installation time sensitivity, and

(6) data readiness and digital integration.

From these challenges, the study infers universal stakeholders' expectations for which the most critical include early logistics involvement at the Front-end engineering design (FEED) stage, access to heavy-lift ports and installation vessels, end-to-end coordination, digital decision-support systems, and demonstrable cost-reduction capability.

A comparative synthesis with the national context reveals a structural mismatch between these expectations and current domestic logistics readiness. While the country benefits from a strong manufacturing base, capable shipyards, and strategically located ports, gaps remain in offshore-ready port infrastructure, turbine-class installation vessels, integrated coordination mechanisms, and interoperable digital systems. Risk and key performance indicators (KPI) analysis classifies port readiness, coordination, cost efficiency, and digitalisation as high-risk dimensions, with weather and vessel availability posing moderate-to-high risks under current conditions.

To address this mismatch, the project develops a *Readiness-Adaptive Modular Logistics Service Model*, adapted from Tiwong et al.'s (2024) Logistics Service Provider Lifecycle Model. The proposed framework structures offshore wind logistics services across three lifecycle phases:

- Beginning of Life (BOL) – service creation, FEED-stage integration, strategic positioning, and relationship building.
- Middle of Life (MOL) – operational and financial performance management using KPI-based risk assessment.
- End of Life (EOL) – service lifecycle performance evaluation, learning, and service reconfiguration.

The model's modular and adaptive logic allows logistics service providers(LSPs) to operate effectively under uneven national readiness conditions while progressively building capabilities toward more integrated 4PL/5PL-type roles. It provides a practical pathway for aligning service design with stakeholder expectations, national constraints, and long-term competitiveness.

Academically, the study contributes by explicitly conceptualising offshore wind logistics as a service model, addressing the demand-side expectations gap in existing literature and demonstrating how frameworks derived from mature markets can be adapted to emerging contexts. Practically, it offers guidance for LSPs, stakeholders, ports and vessel suppliers, and policymakers on how logistics readiness can be strengthened through integrated service design rather than isolated infrastructure investments.

Overall, the study concludes that Türkiye's OW potential cannot be realised through physical assets alone. Strategic, demand-oriented logistics services, supported by phased capability development and digital integration, are essential to reduce risk, improve project bankability, and enable sustainable growth of the  industry.

## 1. INTRODUCTION

### 1.1 Background and Context

Offshore wind has emerged as one of the fastest-growing renewable-energy segments globally (IEA, 2024), combining large-scale power generation with strong synergies across the maritime, port, and logistics sectors. According to the Global Wind Energy Council, global OW capacity is expected to expand from 75 gigawatt (GW) in 2023 to more than 500 GW by 2050 (The GWEC Team, 2025). Moreover, amid growing geopolitical uncertainty, nations are turning to wind power as a secure, resilient source of clean domestic energy. This expansion creates substantial demand for highly specialised logistics systems in OWPs.

Türkiye (TR) has expressed ambitions to develop its OW potential as part of its national energy-transition strategy. The Ministry of Energy and Natural Resources has designated multiple Renewable Energy Resource Areas (YEKA) across the Aegean, Marmara, and Black Sea regions aiming to attract foreign investment and stimulate local industrial participation.

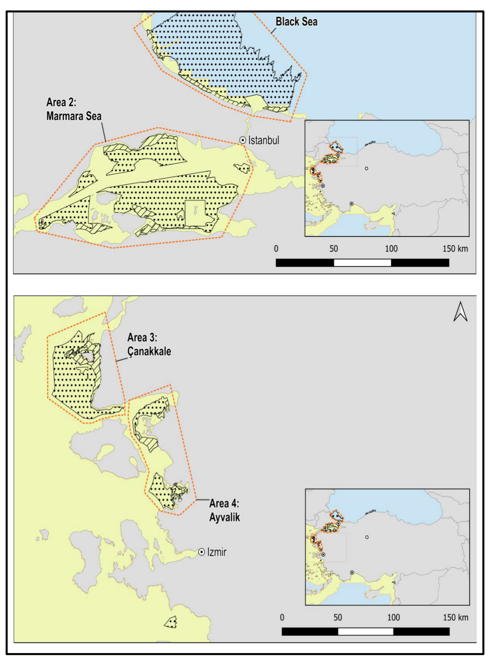


Figure 1: Areas designated by the government for offshore wind farms in Türkiye (World Bank, 2024)

In 2018, TR launched its first 1.2 GW OW tender, but no bids were received due to insufficient on-site measurement data and the important level of investor-perceived risk arising from the resulting uncertainty. To improve investor confidence, the Ministry of Energy and Natural Resources (MENR) shifted focus toward de-risking and greater transparency. This strategic shift is being operationalised through the European Commission's IPA II programme (implemented by the World Bank), which seeks to strengthen MENR's technical capacity for site assessment and tender design, establishing data-driven, investment-ready sites that meet international standards (European Commission, 2014).

Against the backdrop of this evolving policy environment, the principal body of literature in TR—most notably Durak (2025)—has focused on supply-side dimensions, with particular emphasis on logistics infrastructure and asset mapping. This focus reflects the recognition that a successful transition is unattainable without the requisite infrastructure and assets. International literature has noted that logistics contribute around 18% of the levelized cost of energy (LCOE) in OWPs (Poulsen and Hasager, 2016), underscoring their major cost impact. Complementing this, Zhang, and Nekstad (2023) report that inefficiencies during installation and commissioning may raise overall project costs by an additional 15–20%.

Collectively, these findings highlight logistics readiness as a decisive factor in determining the technical feasibility and economic competitiveness for the development of OW in the country.

## 1.2 Key objective, academic literature gaps, and main research questions

The motivation for selecting this topic derives from the author's company presence in the onshore logistics sector and its established long-term relationships with relevant industry stakeholders. This existing position provides a strategic foundation from which the company could contribute meaningfully as a LSP to the development of offshore wind logistics in TR, while simultaneously gaining a future competitive advantage as the market evolves.

In this regard, the project serves as an early-stage business initiation framework, informed by academic analysis, providing structured and evidence-based strategic guidance for LSPs, port authorities and operators, vessel operators, stakeholders (utilities,developers, OEMs, EPCI contractors) , and policymakers considering engagement in the industry. When market conditions mature, such LSPs could play a critical role in accelerating the logistics capability development required for OW expansion in the country, thereby contributing significantly to the broader development of the industry.

The international offshore wind farms (OWFs) literature consistently identifies insufficient or underdeveloped logistical infrastructure as a core constraint to project deployment and timely installation. The significant role of logistics strategy—particularly its influence on installation costs and overall project reliability—has been well established across multiple studies (Charton, 2019; Poulsen and Hasager, 2016; Poulsen, 2018; Vis and Ursavas, 2016). This body of research underscores that well-designed logistics systems are not merely supportive functions but are decisive factors in determining project feasibility, cost efficiency, and schedule performance. These insights will be examined in greater depth in the following sections.

Türkiye faces a series of structural and operational challenges in developing its industry. The experience of the 2018 YEKA bidding round underscored the critical importance of stakeholders whose requirements fundamentally shape project feasibility and market confidence.

This experience demonstrated that the country's logistics capacity must be reframed not only from a supply-side perspective but through a demand-driven understanding of what the market expects from a capable logistics ecosystem. This shift in perspective is consistent with Tiwong's (2024) Logistics Service Provider Lifecycle Model (LSLM), in which the identification of customer requirements forms the foundational link to designing service innovation.

Within this context, the thesis seeks to propose a demand-side-oriented Logistics Service Model (LSM) that explains how LSPs can actively contribute to the development of the country's industry .The model aims to show how LSPs can bridge the existing logistical and structural gaps that currently limit market readiness, particularly in areas such as port capacity, heavy-lift vessel and crane capability, digital integration, supply chain coordination efficiency, and installation-phase reliability.

Through this contribution, the study aims to advance the development of the country's emerging industry by aligning logistics capabilities with the expectations and operational realities of international stakeholders.

### 1.3 Aim and Objectives

To achieve this aim, the study pursues three objectives:

**a)** To identify and analyse existing literature on logistical challenges observed in international offshore wind farm case studies and to derive demand-side logistics requirements**.**

**b)** To consolidate and benchmark secondary data on Türkiye's port, vessel, and logistics infrastructure to assess alignment with inferred demand-side logistics requirements**.**

**c)** To develop an integrated conceptual framework that synthesises these insights into a logistics service model, with a specific focus on the role of logistics service providers, tailored to Türkiye's emerging offshore wind industry.

### 1.4 Research Questions

The investigation is guided by three research questions:

**a)** What logistics challenges associated with offshore wind are identified in the international literature, and how do these challenges inform demand-side logistics requirements?

**b)** What do secondary sources reveal about Türkiye's current port, vessel, and logistics infrastructure relevant to offshore wind development, and which demand-side logistics requirements can be inferred from this evidence?

**c)** How can insights from international and national analyses be synthesised into a logistics service model tailored to Türkiye's emerging offshore wind industry?

These research questions are addressed sequentially across the thesis. RQ1 is examined in Chapter 2 and early sections in Chapter 4 through a review of international offshore wind logistics literature, identifying recurring challenges and inferring demand-side requirements. RQ2 is addressed in Chapters 3 and 4 by analysing Türkiye's port, vessel, and logistics infrastructure in comparison with these requirements. RQ3 is addressed in Chapters 5 and 6, where insights from the international and national analyses are synthesised to develop a demand-side-oriented logistics service model tailored to the country's emerging industry.

## 1.5 Scope and Limitations

This study adopts a qualitative, exploratory, and descriptive desk-based, single-case study research design (Saunders, Lewis, and Thornhill, 2023). It relies entirely on published secondary sources, including academic literature, consultancy reports, government documents, and industry databases. The focus is on the Installation phase of the OWP lifecycle, the most logistics-intensive and cost-sensitive stage (Charton, 2019).

Türkiye serves as a single, context-specific case for comparative analysis with mature offshore wind markets. Insights are derived through thematic, comparative, and interpretive synthesis, allowing interpretation of patterns across international and national contexts. Policy and legal frameworks are referenced only when directly relevant to logistics operations but are not analysed in depth. Consequently, the study's conclusions centre on logistics coordination and service-model development rather than regulatory reform.

## 1.6 Rationale and Relevance

This project is both academically and practically relevant. Academically, it contributes to the OW literature by examining logistics service modelling in the context of the national setting, with a particular emphasis on demand-side stakeholder requirements and market conditions. Practically, it provides a structured, evidence-informed framework for domestic LSPs and investors seeking to prepare for future OW opportunities, demonstrating that logistics readiness gaps are more effectively addressed through integrated service design than through isolated infrastructure investments.

## 1.7 Structure of the Dissertation

The dissertation is organised into seven chapters:

- Chapter 1 introduces the research background, problem, aim, objectives, and questions.
- Chapter 2 starts by clarifying terminology and presents a literature-based analysis of international and Turkish offshore wind logistics contexts, identifying players, critical operational bottlenecks and deriving demand-side stakeholder requirements.
- Chapter 3 outlines the research methodology and data sources, explaining how data are collected, processed, and analysed within the overall analytical framework.
- Chapter 4 presents the findings and comparative synthesis between international benchmarks and Türkiye’s current capabilities.
- Chapter 5 develops and explains the conceptual framework From Concept to Practice, integrating theory with empirical synthesis.
- Chapter 6 discusses academic and practical implications; identifies remaining research gaps and opportunities.
- Chapter 7 concludes the study and provides strategic recommendations for industry stakeholders and policymakers.

## 2. ANALYSIS OF PROBLEMS

### 2.1 Conceptual Foundations and Scope

Logistics management constitutes a specialised function within supply chain management (SCM), focusing on the efficient movement and storage of goods, services, and information from their source to the point of final (CSCMP, 2024). While SCM integrates all business functions strategically, logistics ensures the operational flow and coordination required to deliver value. This value-creation role provides the conceptual bridge to this study, which follows Lambert's (1992) view of logistics as a customer-oriented discipline—an approach aligned with the thesis's demand-side orientation rather than a purely asset-based perspective.

In this context, a LSM represents a structured framework used by LSPs to design, plan, integrate, and deliver logistics activities. Recent studies highlight important dimensions of contemporary LSM development. Mutke et al. (2015) emphasise the role of digital tools in enhancing process integration and improving coordination within logistics services. Tiwong et al. (2024), in their review of logistics service provider lifecycle model (LSLM) in the context of Industry 4.0, underscore the importance of digitally enabled capabilities, stakeholder collaboration, and iterative feedback loops in service-model design. Together, these contributions illustrate how modern Logistics service models integrate digital transformation with stakeholder-oriented design principles to improve the structure and performance of logistics services. While both studies offer valuable insights into logistics service design, Tiwong et al.'s (2024) lifecycle-based perspective provides a more suitable foundation for this research, as it explicitly addresses service evolution, stakeholder interaction, and adaptive capability development—dimensions that are critical for modelling logistics services in an emerging offshore wind context.

Building on this perspective, the present study applies the logistics service provider lifecycle model proposed by Tiwong et al. (2024) to the context of Türkiye's emerging industry where logistics efficiency plays a critical role in shaping project feasibility and cost outcomes (Poulsen and Hasager, 2016; Charton, 2019).

To operationalise this model within OW context, it is necessary to situate logistics services within the broader Wind Farm Life Cycle (WFLC), to clarify the project phases to which the analysis applies and to justify the study's analytical focus. Consequently, the *WFLC* is summarised here both to contextualise OW development and to indicate which phases extend beyond the scope of this study. It consists of four stages:

**1.** Development & Consent,
**2.** Installation & Commissioning (I&C),
**3.** Operations & Maintenance (O&M),
**4.** Decommissioning (Mills, 2019).

This study focuses on the *Installation phase,* which is widely recognised as the most logistics-intensive and cost-sensitive stage (Charton, 2019; Poulsen, 2018). The analysis is limited to Wind Turbine Generators (WTGs) — nacelle, blades, hub, and tower — as identified by Poulsen and Lema (2017) as a distinct sub–supply chain. These components require specialised handling, pre-installation storage, and assembly—particularly for the nacelle—alongside heavy-lift infrastructure and weather-dependent coordination, offering high potential for logistics optimisation and service innovation. Within this phase, two distinct logistics flows can be identified. During the installation stage, two distinct logistics flows can be identified. Inbound logistics covers the movement of key WTG components—nacelles, blades, and towers—from manufacturing sites to pre-assembly and storage locations (Poulsen & Lema, 2017). Outbound logistics concerns the transport of pre-assembled turbine modules and installation equipment from ports or marshalling sites to the offshore location, typically relying on break-bulk and project-cargo shipping rather than standard container shipment. (Poulsen, Chen and Rytter,2013)

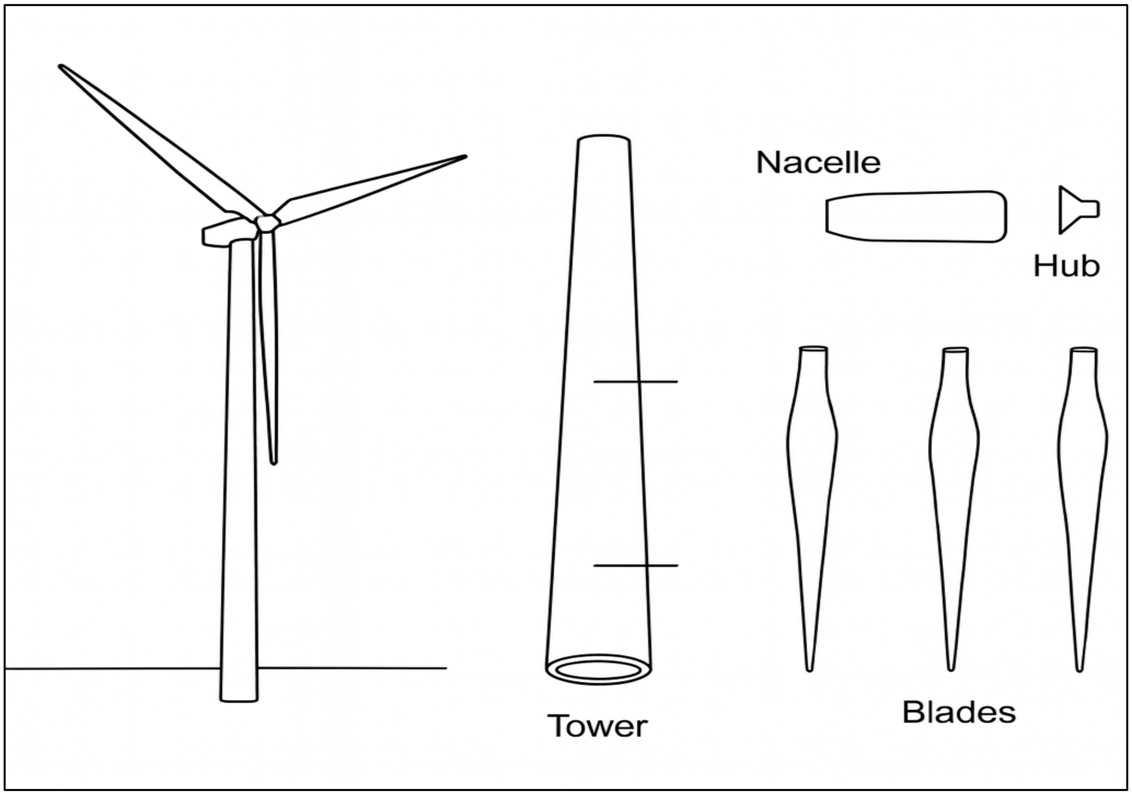


Figure 2: Wind Turbine Generator and its components

## 2.2 Demand-side Stakeholders and Procurement Models

Logistics in OW is shaped by procurement structures that determine how logistics services are contracted, governed, and coordinated. Accordingly, the stakeholder groups identified in this study are derived from a synthesis of existing literature on procurement models in OWPs. Within these models, the principal demand-side stakeholders— are developers (including utilities), original equipment manufacturers (OEMs), and EPCI contractors, each assuming different leadership and coordination responsibilities depending on the contracting framework (Poulsen, Chen & Rytter, 2013).

Procurement Models are (Mills, 2019, Poulsen 2018):

a) **Single Contracting Model** (EPCI contractor led) – A single EPCI contractor (e.g., DEME, Seaway 7) manages all project phases, including shipping and logistics. This centralises responsibility but limits developer control.
b) **Multi-Contracting** (Developer-Led) – The developer (e.g., Ørsted, Equinor) contracts multiple suppliers directly, achieving higher flexibility and control but facing coordination complexity.
c) **Turnkey (**OEM-led) – The OEM (e.g., Siemens Gamesa, Vestas) delivers fully installed turbines under long-term service agreements, controlling logistics.

These contracting structures determine how logistics roles are distributed and how integration can be achieved across the supply chain (SC). The degree of SC integration is a function of the procurement model, which defines leadership responsibilities, coordination mechanisms, and the allocation of information and risk. For emerging markets such as Türkiye, understanding these distinctions is critical for aligning domestic logistics capabilities with international procurement expectations and for designing service models that meet global performance standards.

As procurement models determine the leadership and coordination demands placed on logistics, it is essential to examine how LSPs respond to these requirements through various levels of service integration. The following section therefore analyses LSP roles and their functional development across procurement structures.

### 2.3 Role of Logistics Service Providers

Supply chain and logistics management are essential contributors to business operations and broader economic development. Enhancing logistics efficiency and performance directly strengthens a firm's competitive position and overall SC effectiveness. Within this system, LSPs play a vital role by facilitating the movement of goods and coordinating the critical activities that link suppliers, manufacturers, distributors, and end customers.

This section examines LSPs because in OWPs they form the operational core of logistics service design and function as the main link between stakeholders and project execution. Understanding their functional scope and integration potential is therefore essential for assessing how logistics coordination is structured in real-life projects.

Accordingly, the following conceptual classification establishes the foundation for analysing how LSP roles manifest in practice. LSPs are classified through hierarchical models based on service integration and outsourcing depth (Jenkins, 2023):

| Model | Name | Description |
|---|---|---|
| 1PL | First-Party Logistics | Self-managed logistics by asset-owning firms (e.g., developers operating internal fleets). |
| 2PL | Second-Party Logistics | Asset-based transport companies owning vessels or trucks but not offering coordination. |
| 3PL | Third-Party Logistics | Provide transport, warehousing, documentation, customs, and basic integration services. |
| 4PL | Fourth-Party Logistics | Manage multiple LSPs, offering strategic integration and control without owning assets. |
| 5PL | Fifth-Party Logistics | Digital network orchestrators coordinating entire supply chains via data platforms. |

This evolution reflects the growing importance of service integration, information sharing, and digitalisation in offshore wind logistics, where reliability and cost control depend on effective coordination across multiple actors. Accordingly, the following section presents international examples that demonstrate the 1PL–5PL spectrum in logistics.

## 2.4 International offshore wind LSP Model: Real-World Examples

Logistics involves a diverse range of LSPs operating at various levels of integration, and real project cases illustrate how these models function across the 1PL–5PL spectrum**.** These examples reveal a clear progression from asset-based execution (2PL–3PL) to data-driven orchestration (4PL–5PL). In mature markets, digital integrators increasingly play a significant role by synchronising port, vessel, and weather data—capabilities that remain underdeveloped in emerging contexts such as TR**.**

**1PL – Ørsted (Developer-Controlled Logistics)**

Ørsted exemplifies a 1PL model where the developer directly manages its logistics bases, vessels, and monitoring systems in Esbjerg, Barrow, and Borkum Riffgrund. Although heavy-lift tasks are subcontracted, Ørsted's long-term charters and control of fleet deployment ensure full operational oversight, maintaining data transparency and schedule reliability typical of an integrated 1PL model (Ørsted, 2024; Poulsen et al., 2013).

**2PL – Fred. Olsen Windcarrier (Asset-Based Operations)**

Fred. Olsen Windcarrier represents a 2PL provider focused on vessel ownership and execution. Operating jack-ups such as *Brave Tern* and *Bold Tern*, it performs turbine installation under direct contracts with developers and OEMs. The company delivers strong operational capability but limited supply-chain coordination**,** defining traits of a second-party logistics role (Fred. Olsen Windcarrier, 2025; offshoreWIND, 2013).

**3PL – Blue Water Shipping and Peterson Energy Logistics (Integrated Port Management)**

Blue Water Shipping, based in Esbjerg, manages port marshalling, stevedoring, customs, and documentation for projects such as Anholt and Hornsea. It coordinates multiple subcontractors without owning installation assets, aligning with a 3PL profile (offshoreWIND, 2012; Poulsen, Chen & Rytter, 2013; Skopljak, 2016).

Peterson Energy Logistics performs similar 3PL functions for the Sofia OWF (UK), combining onshore warehousing, offshore cargo runs, and helicopter logistics. Both firms function as intermediary integrators between asset owners and stakeholders, linking execution activities with scheduling and interface coordination. (Break Bulk News, 2024; Emanuel, 2024; Peterson Logistics, 2024).

**4PL – GEODIS (Control-Tower Coordination)**

GEODIS demonstrates 4PL orchestration at the Les Éoliennes Flottantes du Golfe du Lion (EFGL) project in France(GEODIS, 2025). It coordinated heavy-lift transport and float-off operations (submerging a transport vessel to allow floating structures to slide off the deck), while managing interfaces among shipowners and yards. This role provided strategic sequencing, risk control, and end-to-end supply-chain visibility—hallmarks of a fourth-party logistics ( Saratsopoulou, 2025).

**5PL – Wind Logistics Group and Port Community Systems (Digital Ecosystems)**

The Wind Logistics Group, formed in 2017 at Esbjerg, applies a 5PL model through shared vessel utilisation, cross-project scheduling, and standardised digital data exchange across the Esbjerg–Cuxhaven corridor (Wind Logistics Group, 2025).

Port Community Systems (PCS) in Esbjerg and Rotterdam extend this digital logic, linking port calls, customs, and cargo documentation in real time via platforms such as Customer Port and Portbase (González et al., 2024; Port of Esbjerg, 2020; Port Rotterdam, 2021; Portbase Rotterdam, 2025). These systems exemplify asset-light, information-driven coordination across multiple stakeholders.

Together, these examples illustrate a clear evolution from asset-centric logistics models (1PL–3PL) toward data-centric orchestration (4PL–5PL). Mature OW markets increasingly depend on integrators that deliver coordination, transparency, and digital interoperability—capabilities that the logistics sector in TR must further develop to meet international standards. This progression also provides important context for assessing where existing literature captures logistics integration effectively, and where conceptual and empirical gaps remain.

## 2.5 Literature Gaps and Conceptual Basis

While this study does not aim to provide a systematic review, the key sources examined through thematic analysis (Charton, 2019; Irawan et al., 2017 ; Díaz and Guedes Soares, 2023; González et al., 2024; Poulsen, 2018; Vis and Ursavas, 2016; Wüstemeyer, Madlener, and Bunn, 2015**)** consistently show that logistical inefficiencies—especially weather-related downtime, port-capacity constraints, vessel scheduling, and fragmented coordination—are major drivers of installation cost overruns and project delays.

**Logistics Service Model Conceptualisation:** The literature reviewed provides valuable insights into offshore wind logistics but does not focus explicitly on logistics service models (LSMs) or the strategic roles of logistics service providers (LSPs). *Poulsen, (2018)* remains the most comprehensive reference addressing logistics within OWPs; however, its focus lies primarily on cost reduction and process efficiency rather than on formalising on service-model structures. This study therefore addresses this *conceptual gap* by defining and applying an LSM framework tailored to the OW context, using established logistics-service typologies as its theoretical departure point.

**a) Demand-side perspective:** The analysed literature frequently models vessel use, port design, and weather exposure, but it does not explain how demand-side stakeholders formulate logistics service requirements or performance, reliability, and coordination expectations they hold—revealing a clear demand-side gap in offshore wind logistics research.

**b) Context-adapted frameworks:** Theoretical and empirical models analysed are derived from mature North Sea markets such as Denmark, Germany, and the United Kingdom. *Poulsen and Lema (2017)* extend this comparison to China, showing how differences in institutional capacity and supply-chain maturity affect logistics coordination and knowledge transfer.

However, no integrated logistics service framework currently addresses Türkiye's conditions, where port readiness, vessel availability, and institutional capacity differ significantly from those of mature markets. These differences limit the direct transferability of existing models (Saunders, Lewis, and Thornhill, 2023) and underscore the need for a context-adapted LSM.

**c) Digital integration as a strategic tool:** Díaz & Guedes Soares (2023) and Irawan et al. (2017) propose simulation-based logistics models and centralised digital platforms to improve scheduling, routing, and cost control in OW supply chains. Yet these digital tools are largely treated as operational supports rather than strategic enablers of service design and coordination. None of the reviewed studies link digitalisation to how LSPs —design, manage, or evolve services—for example, the transition from asset-based 3PL models to data-driven 4PL or 5PL coordination. González et al. (2024) similarly identify the interoperable data systems across design, logistics, and installation phases, which constrains predictive decision-making and real-time coordination.

Persistent data scarcity, limited model validation, and weak knowledge transfer further reduce the practical utility of digital tools for large-scale OWPs (Díaz & Guedes Soares, 2023; Poulsen et al. ,2013). Poulsen & Lema (2017) further note that limited transfer and training for knowledge transfer continue to hinder the development of digital capability.

Collectively, these findings show that although digitalisation is widely recognised in the international literature as vital for OW efficiency, no existing studies examine its use within offshore wind logistics in the national context.

# 3. METHODOLOGY (Saunders, Lewis, and Thornhill, 2023)

## 3.1 Methodology and Design

This section outlines the research methodology and qualitative research design adopted in the study, together with the multi-source secondary data underpinning the analysis. Positioned as applied research, the study focuses on addressing a real-world industry challenge through the development of a practical, evidence-based logistics service model. It explains how this evidence was identified, organised, and interpreted within the analytical framework that informs the development of the proposed LSM.

### 3.1.1 Research Philosophy: Pragmatism

The study adopts a pragmatist philosophical position, which prioritises practical problem-solving and the production of actionable insights. Pragmatism is well suited to studies situated in complex organisational and industrial settings and supports methodological flexibility when addressing real-world challenges such as the design of an LSM for an emerging OW market.

### 3.1.2 Research Approach: Abductive

An abductive research approach is followed, moving iteratively between theory and empirical observations rather than adhering strictly to deductive or inductive logic. The study does not begin with a fixed theory to test, nor does it attempt to generate theory solely from raw data. Instead, recurring patterns identified international offshore wind logistics literature and secondary evidence relating to Türkiye inform the development and refinement of a context-specific conceptual model. This iterative movement between data and theory enables the continuous adjustment of emerging propositions as new insights emerge.

### 3.1.3 Research Strategy: Single-Case Study (Moss, 2018)

A single-case study strategy is adopted, treating Türkiye as the case because the phenomenon under investigation—offshore wind logistics —is inseparable from its national context. OW is not yet operational but strategically significant, combining strong manufacturing capacity with nascent logistics capability. The objective is not cross-country comparison but the construction of a context-specific LSM aligned with national readiness conditions. This strategy allows diverse secondary data to be integrated into a coherent analytical narrative and supports context-dependent theory-building.

### 3.1.4 Research Design: Qualitative Interpretive Design

A qualitative interpretive research design is employed, enabling the study to identify meanings, structural patterns, and relationships embedded within the available evidence. This design is particularly appropriate where empirical datasets are limited or inaccessible and where understanding depends on contextual interpretation rather than numerical generalisation.

### 3.1.5 Research Method: Mono-Method Secondary Data Analysis

The study uses a mono-method qualitative approach based on multi-source secondary data, including academic literature, industry reports, technical documents, and institutional publications. This method is suitable for analysing emerging sectors where primary empirical data are unavailable and where conceptual insights can be generated from existing knowledge bases.

#### 3.1.6 Research Nature: Exploratory, Descriptive, and Interpretive

The research nature combines *exploratory, descriptive, and interpretive* components.

- Exploratory**:** clarifies the nature of offshore wind logistics challenges and demand-side expectations in an under-researched context.
- Descriptive**:** documents offshore wind logistics national characteristics such as port readiness, vessel availability, and coordination structures.
- Interpretive**:** explains underlying patterns and relationships, particularly how international insights translate into a new market context.

#### 3.1.7 Time Horizon: Cross-Sectional

The study employs a cross-sectional time horizon, analysing secondary data collected at a single point in time rather than tracking changes longitudinally. This is appropriate given the early-stage development of OW in Türkiye and the study's conceptual focus.

Together, these three elements provide a coherent foundation for developing a new, context-specific logistics service model tailored to the countries emerging industry.

### 3.2 Ethics of the Research Design

This study follows the ethical and methodological standards outlined by Middlesex University (MDX, accessed 13.12.2025). As the research uses only secondary documentary sources, there are no human participants, and ethical considerations focus on accurate representation**,** proper attribution, and responsible interpretation of all materials. All sources are cited transparently, and no selective reporting or manipulation of evidence is undertaken. The Research Ethics Screening Form signed by the author's advisor has been added to the Appendix H.

<u>Reliability</u> in qualitative documentary research relates to the consistency and transparency of the analytical process (Saunders, Lewis, and Thornhill, 2023). This study enhances reliability by clearly defining its source-selection criteria, applying systematic

thematic coding procedures, and using reputable academic, industry, and governmental documents that are themselves subject to established quality-control mechanisms**.**

Validity refers to the credibility of interpretations rather than statistical generalisability (Saunders, Lewis, and Thornhill, 2023). Internal validity is strengthened by systematically comparing multiple secondary sources and triangulating international OW evidence, which provides the analytical foundation for the thematic analysis used to assess Türkiye's readiness gaps. Conceptual validity is ensured by anchoring interpretations in established offshore wind logistics and supply-chain theory. Given that the aim is to develop a context-specific conceptual model, external validity is framed in terms of transferability to comparable emerging OW markets, rather than universal generalisation. Therefore, while the proposed model is tailored to Türkiye, the underlying analytical logic and risk-response patterns may be meaningfully transferred to similar emerging OW contexts facing comparable infrastructural and capability constraints. This aligns with qualitative research principles, where relevance to analogous or comparable settings, rather than universal applicability, constitutes the core basis of external validity.

## 3.3 Identification of Secondary Data and Analysis

Access to data was obtained through the Middlesex library, Google Scholar and through data bases including Emerald Insight**,** ProQuest, Science Direct (Elsevier), Springer Link**,** Taylor & Francis Online, as well as publicly available online sources**.**

Academic Literature: Peer-reviewed journal articles, conference papers, and doctoral theses addressing offshore wind installation logistics, optimisation models, supply-chain design, and cost-reduction strategies.

Industry and Corporate Sources: Web-based industry reports, case studies, and operational insights from offshore wind logistics providers, EPCI contractors, OEMs, and port community systems.

Governmental, Policy, and Institutional Sources: Strategic assessments, governmental frameworks, and Logistics and Supply-Chain Framework Sources: Documents defining logistics concepts, established logistic service providers' typologies, and general service-model frameworks.

Together, these sources constitute a comprehensive dataset that supports the comparative, conceptual, and model-building aims of the study.

Because the offshore wind logistics field is fragmented and multidisciplinary, the literature review and analysis were conducted using a multi-phase, structured process. This ensured that the review captured international best practices, Türkiye-specific insights, and LSM literature. The process of literature review and analysis consists of the following phases:

### 3.3.1 Phase 1 – Exploratory Scanning

An initial broad scan of academic and industry literature was conducted to map the general offshore wind environment, identifying dominant terminology and key areas of research.

The terms ‘offshore wind,’ ‘offshore wind logistics,’ ‘offshore wind supply chain,’ ‘offshore wind challenges,’ and ‘offshore wind stakeholders’ were searched. The installation phase was identified as the most extensively researched stage within the offshore wind literature.

### 3.3.2 Phase 2 – Source Screening and Selection Thematic Analysis

A relevance-based screening followed, focusing on sources that directly addressed offshore wind logistics, offshore wind supply chains, and installation logistics. Documents irrelevant to logistics, or focusing solely on energy economics or environmental impact, were excluded.

The review was deliberately limited to UK and EU geographies. These regions were selected not only for their geographic proximity to Türkiye, but also because they represent the longest-established offshore wind markets (Durak, 2025; Özdemir, 2025) and have demonstrated sustained interest in supporting the industry’s development in Türkiye (European Commission, 2014; Trade Council of Denmark, 2021). Selected sources focusing on the installation phase were organised into analytical themes through thematic mapping. The international literature yielded six dominant thematic clusters of logistics-related challenges, from which international demand-side logistics requirements were inferred.

### 3.3.3 Phase 3 – Türkiye-specific literature screening, selection, and interpretation

The literature search for Türkiye was conducted using the term ‘offshore wind Türkiye’ and was further structured around the six core challenge themes identified in phase two. The most comprehensive source addressing all relevant aspects for the country were Durak (2025) and World Bank (2024). In addition to the previously established themes, two context-specific themes—component manufacturing capacity and overall market preparedness—were incorporated, as these issues do not prominently feature in mature OW markets.

Four additional sources were identified to be relevant and included in the analysis. Literature focusing solely on wind resource assessment, site selection, regulatory procedures, or environmental impact analysis were excluded, as they fall outside the scope of logistics-centred inquiry.

### 3.3.4 Phase 4 – Comparative Synthesis

International thematic findings were systematically compared with Türkiye’s national readiness indicators to identify capability gaps and establish how global patterns translate into the national OW context. The inferred demand-side requirements for the country were therefore derived from the international analysis outlined in Phase 2 and subsequently adapted in the light of identified capability gaps.

### 3.3.5 Phase 5 – Integration with Strategic Frameworks

Insights from the literature were integrated with analytical tools and skills developed through the Middlesex MBA Business Strategy module including SWOT, TOWS, and Porter’s Five Forces to organise the evidence into strategic categories.

This integration enabled the study to situate empirical findings within broader strategic, competitive, and capability-based perspectives, providing a structured basis for determining priorities in the development of the LSM.

### 3.3.6 Phase 6 – Conceptual Model Construction

Finally, to identify a suitable *LSM* for adaptation to the OW context, a focused literature search was conducted using combinations of the terms 'logistics service model', 'logistics service design', 'customer-oriented services', 'client/customer–logistics interfaces', and 'digitalisation in service design'. The search omitted models that focus on manufacturing industries and prioritised research that: (i) emphasises customer-oriented service design, (ii) incorporates mechanisms for iterative improvement, and (iii) explicitly addresses digitalisation, factors interpreted by the author as essential.

Through this structured search, two published literatures have been referenced: Tiwong et al.'s *(2024) Logistics Service Provider Lifecycle Model (LSLM)* and *Mutke et al.'s (2015) Real-time information acquisition in a model-based integrated planning environment for logistics contracts.* As the analysis progressed, Tiwong et al.'s model was found to be more closely aligned with the objectives of this thesis. Its structured lifecycle logic, focus on customer-requirement translation, and emphasis on capability development provide a comprehensive foundation for constructing an adaptive LSM—particularly relevant in an emerging market such as Türkiye, where readiness gaps and evolving demand-side expectations shape logistics performance.

By contrast, Mutke et al. (2015), while valuable for understanding information acquisition and contractual information flows, places a narrower emphasis on simulation-based planning and therefore does not offer the broader service-oriented perspective required for the present study.

A KPI- and risk-based analysis was then conducted to operationalise and simulate the selected model for the national context, drawing on analytical tools and skills developed through the Middlesex MBA programme—specifically the Finance in Shipping and Digitalisation in Shipping modules. These competencies enabled a structured KPI based assessment of cost drivers, performance sensitivities, digital readiness, and risk–response priorities, ensuring that the adapted LSM reflects the country's infrastructural constraints, market readiness, and operational uncertainties.

# 4. LOGISTICAL CHALLENGES

A clear understanding of recurring logistical challenges is essential, as stakeholders expect LSPs to respond to these constraints effectively. Stakeholder expectations are therefore inferred from these recurring universal challenges, while the gap analysis for Türkiye assesses whether national infrastructure and operational capabilities can meet them. The LSM developed later in the study is designed to address these challenges and align stakeholder operational priorities with the country's context-specific conditions.

This chapter, insights from international thematic analysis and national secondary data, identifies core logistics challenges, derives the associated stakeholder expectations, and evaluates the country's readiness—thereby establishing the analytical foundation for the conceptual framework presented in Chapter 5.

## 4.1 International Offshore-Wind Logistics Challenges and Inferred Demand-Side Expectations

The international literature identifies six recurring themes influencing installation logistics performance: weather and environmental challenges, port infrastructure and capacity constraints, vessel availability and load optimisation, supply-chain coordination, cost efficiency, and digital readiness. Each theme corresponds to a set of operational requirements and qualitative key performance indicators (KPIs)**,** as presented in the thematic tables (Appendix A). The inferred stakeholder requirements are interpreted as largely universal, with necessary adaptations reflecting Türkiye's stage of readiness and local conditions. A consolidated summary is presented below, while the full analytical tables are provided in Appendix B**.**

### 4.1.1 Weather and Environmental Challenges

Weather remains the most critical source of risk in logistics. Studies emphasise that adverse weather—particularly wind speeds above 15 m/s and wave heights exceeding 3 m—restrict lifting, transporting equipment, and raising jack-up vessels, leading to idle vessel time and cost escalation (Vis & Ursavas, 2016; Díaz & Guedes Soares, 2023; Ekici, White and Drunsic, 2016) .Weather windows of safe operation significantly determine project scheduling efficiency, measured through weather-delay sensitivity indicators.

Stakeholders accordingly expect LSPs to provide simulation tools, forecast-integrated scheduling, and quantified weather-window assurance (Poulsen & Lema, 2017).

### 4.1.2 Port Infrastructure and Capacity Constraints

Port-related constraints remain among the most significant bottlenecks in logistics operations. Shallow quayside waters, insufficient load-bearing capacity, and limited lay-down areas restrict the extent of pre-assembly and lead to extended waiting times and operational delays (Díaz and Guedes Soares, 2023; Irawan et al., 2018). By contrast, ports such as Esbjerg illustrate the advantages of purpose-built offshore terminals, equipped with heavy-lift cranes exceeding 1,000 tonnes, deep-draft access, and round-the-clock operational capability.

Stakeholders therefore expect LSPs to secure access to heavy-lift, deep-draft ports and to apply standardised port-readiness metrics. In addition, the close spatial alignment of manufacturing sites and marshalling hubs is widely regarded as essential for achieving operational efficiency and minimising interface delays (González et al., 2024).

### 4.1.3 Vessel Availability and Load Optimisation

Shortages of jack-up and heavy-lift vessels remain a critical bottleneck, with high day rates and limited fleet size contributing to schedule delays and increasing the Levelized Cost of Energy (LCOE) (Díaz & Guedes Soares, 2023). Vis & Ursavas (2016) highlight the importance of deck-load optimisation (arranging the equipment on the vessel in an optimum way) and multi-vessel scheduling (coordinating the use of multiple vessels at the same time), supported by discrete-event simulation model of key processes.

Such simulation models enable planners to test alternative schedules, identify bottlenecks, estimate waiting times, analyse weather-related delays, and optimise the utilisation of vessels and critical equipment.

Stakeholders therefore expect LSPs to secure reliable access to suitable vessels and to maintain operational continuity through shared-fleet arrangements or long-term chartering strategies (Poulsen & Lema, 2017) and the use of data-driven voyage-planning systems that optimise fleet utilisation. Effective coordination of multi-vessel operations is essential (González et al., 2024), requiring LSPs to act as fleet orchestrators rather than simple vessel operators by integrating port, weather, and transit information within a unified scheduling platform.

### 4.1.4 Supply Chain and Logistics Coordination and Digitalisation

Studies highlight that multi-tier supplier networks often lack synchronisation, creating risks of component idleness, storage congestion, and delayed material flows, which in turn disrupt schedules and raise costs. Integrated digital platforms that connect production schedules, port operations, and vessel movements are therefore considered essential to maintaining operational continuity across the installation chain (Irawan et al., 2017; Díaz & Guedes Soares, 2023)

Fragmented contracting and procurement structures—typically divided among multiple transport, port, and installation contractors—further weaken accountability and dilute logistics leadership during critical phases. Mature-market evidence shows that stakeholders increasingly prefer a single, 4PL-level or EPCI logistics integrator to oversee end-to-end coordination from the front-end engineering design (FEED) stage onward (Poulsen & Lema, 2017) , at which point , core decisions on port selection, vessel strategy, pre-assembly layout, component flow, installation methodology, and weather-window assumptions are established.

Overall, stakeholders prioritise unified control, early logistics involvement, and digitally integrated planning to mitigate delays and strengthen project reliability.

#### 4.1.5 Cost Efficiency and Installation Time Optimisation

Installation and transport inefficiencies account for a substantial portion of total capital expenditure (Díaz & Guedes Soares, 2023; González et al., 2024). Studies indicate that increased pre-assembly and parallel operations can reduce project duration by 20–30 per cent (Vis & Ursavas, 2016).

Stakeholders therefore expect LSPs to view logistics as a strategic tool for cost control and to demonstrate clear, quantifiable impacts on lowering the LCOE (Poulsen & Hasager, 2016).

#### 4.1.6 Data, Model Validation and Market Readiness

González et al. (2024) observe that, although companies increasingly use advanced computational tools to plan lifting operations, assess weather windows, and schedule vessels, OWPs involve multiple actors—designers, logistics planners, and installation teams—whose data are not always shared effectively.
This lack of integration produces misunderstandings, delays, and inefficiencies across the design, logistics, and installation phases. In parallel, Díaz & Guedes Soares (2023) highlight a different limitation: many optimisation models remain insufficiently validated, as they have rarely been tested under real project conditions. Poulsen et al. (2013) and Poulsen & Lema (2017) add that even with strong digital tools, OWPs depend heavily on personnel with deep technical and process knowledge, yet cross-regional knowledge transfer remains limited. Recent offshore wind research shows that industrial and predictive digital twins play a critical role in improving model validation, uncertainty management, and real-time decision support by continuously integrating operational, environmental, and asset-level data (Haghshenas et al., 2023; Evi Elisa Ambarita et al., 2024)

Stakeholders therefore expect LSPs to implement validated digital-twin solutions and interoperable IT systems, supported by a skilled workforce capable of applying these tools effectively.

Across all six themes, the findings demonstrate that stakeholders expect LSPs to deliver specific, operationally measurable capabilities. First, LSPs must manage weather-related disruptions through forecast-linked scheduling, simulation-supported planning, and transparent evidence of achievable installation windows. Second, stakeholders require secure access to critical infrastructure and marine assets—deep-draft, heavy-lift ports with adequate lay-down areas, and guaranteed availability of WTIVs, heavy-lift vessels, and supporting craft through long-term charters or shared-fleet arrangements. Third, as projects mature in complexity, stakeholders prioritise end-to-end coordination, increasingly favouring a single 4PL/EPCI logistics integrator from the FEED stage onward to align suppliers, manufacturing hubs, ports, and vessels through interoperable digital systems and transparent data-sharing.

## 4.2 Türkiye's Port, Vessel, and Supply-Chain Readiness

The themes synthesised in section 4.1 provide a universal foundation for interpreting stakeholder expectations, which also apply to the national context (as described in Section 3.3.4). These expectations form the basis of the gap analysis, through which the study evaluates whether existing infrastructure and capabilities are sufficient to meet them.

The World Bank (2024) reports serve as the primary sources for assessing Türkiye's OW supply-chain readiness, providing the most comprehensive and structured evaluations available at the national level. Most of the peer-reviewed academic studies reviewed concerning national offshore wind industry, focus primarily on wind-resource assessment, site selection and design, techno-economic feasibility, and policy or governance aspects (Sogukpinar et al., 2025). Consequently, four other sources were identified as relevant to the present analysis and used as supporting evidence to complement the empirical synthesis.

*National Readiness* was assessed across port infrastructure, vessel availability, and component-manufacturing capacity, revealing several country-specific requirements. Unlike mature markets, component manufacturing emerged as a distinct challenge and was therefore explicitly integrated into the analysis. Digitalisation requirements, although not prominently addressed in the domestic OW literature due to the industry's early development and consent stage, are incorporated into the conceptual model developed in Chapter 5. This does not diminish their importance; rather, digitalisation is considered a challenge that can be addressed in the shorter term, unlike asset-related shortages, which require large-scale infrastructure investments, as it involves adopting technological integrations already established in mature markets.

This chapter establishes the gap analysis, readiness assessment that underpins the conceptual framework developed in Chapter 5.

### 4.2.1 Component Manufacturing Readiness (full table in APPENDIX C)

Blades: Companies such as LM Wind Power, TPI Composites, and Siemens Gamesa located in the İzmir–Aliağa corridor provide a robust base for large-component fabrication. These factories could be upgraded to accommodate larger blade sizes and transition to offshore production; however, transporting 80–107 m blades require specialised trailers and access to deep-draft ports (World Bank, 2024).

Nacelles / Hubs: Local casting capacity supplying the Siemens Gamesa blade factory in İzmir is available (Dirinler İğrek Makina, Alpar Metal), but full nacelle integration still depends on imported sub-assemblies. Coastal assembly sites are therefore essential for reducing transport risks and costs associated with moving large nacelle units (World Bank, 2024).

Generators: This component category represents the weakest link. Although domestic firms with potential exist (Gamak, Ateş Çelik), they currently lack offshore-grade certification and operational experience (World Bank, 2024).

The analysis shows a moderately developed but uneven supply-chain landscape across key turbine components, which must be strengthened to support a transition to offshore wind.

#### 4.2.2 Port Infrastructure

Ports such as İzmir, Bandırma, and Filyos meet partial readiness criteria (Figure 3), but few currently offer the >12 m draft, >20 t/m² bearing capacity, and >1,800 m² per-turbine lay-down area required for 8–15 MW turbines. The report recommends developing dedicated construction ports equipped with ≥1,000-t heavy-lift cranes and integrated marshalling zones, following models demonstrated by ports such as Esbjerg.

The country's inland infrastructure is assessed as largely sufficient: according to the World Economic Forum's Global Competitiveness Report 2019 (Globalen LLC, 2019), Türkiye's Road quality indicator scored approximately 5.0 out of 7, exceeding the global average and reflecting relatively robust road infrastructure, which supports freight and oversized transport. However, effective coordination between inland transport capability and port-upgrade planning is essential for the development of offshore wind (World Bank, 2024).

#### 4.2.3 Vessel Availability

The country currently lacks dedicated jack-up and heavy-lift installation vessels and therefore depends on foreign fleets. Shipyards, however, possess the capability to build smaller offshore vessels and already supply Western developers. With a sustained project pipeline, this capacity could scale to larger installation assets. Turkish firms would nonetheless face entry barriers without international partnerships, although the availability of surplus European vessel capacity may ease early-stage development (World Bank, 2024).

It can be synthesised that the existing manufacturing base and shipbuilding capacity provide a solid foundation for future localisation; however, logistics capabilities—particularly port infrastructure and installation vessel availability —remain below international benchmarks. The absence of local production for several key components further exacerbates these constraints.

While the country possesses parallel industrial strengths, targeted logistics upgrades—especially in port lay-down areas, heavy-haul transport routes, and lifting capacity—are required to achieve full OW readiness.

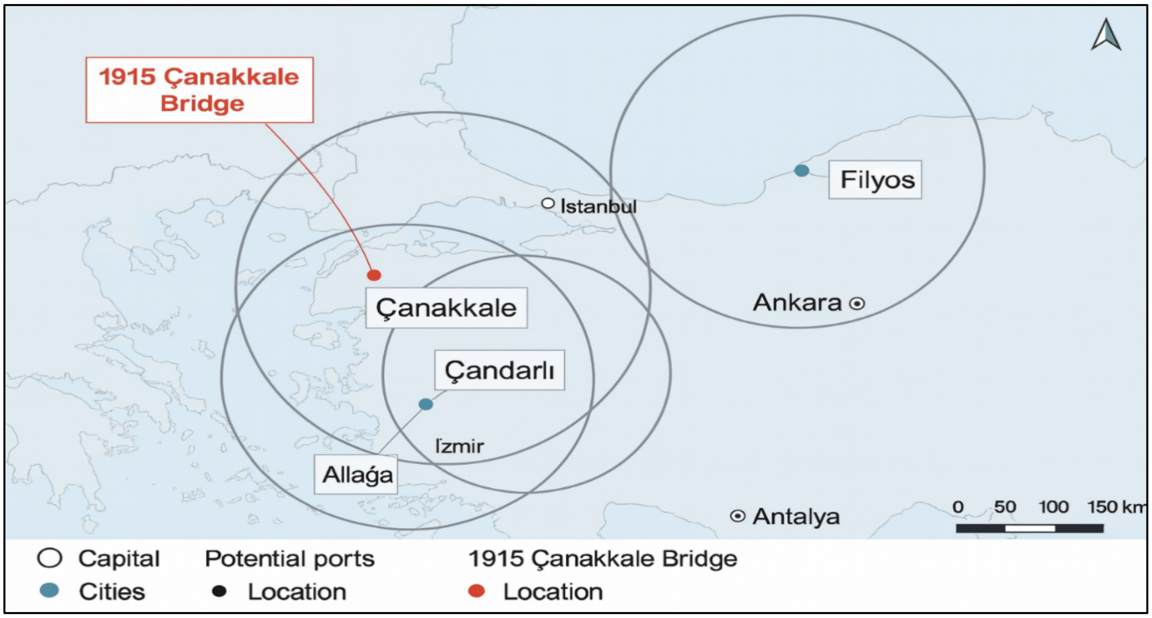


Figure 3: Location of potential ports in Aegean and Marmara seas (World Bank, 2024).

The next section presents a SWOT analysis to contextualise the findings, followed by a TOWS analysis that derives strategic options. While SWOT identifies existing internal and external conditions, TOWS translates these into actionable strategies by pairing strengths and weaknesses with opportunities and threats to inform the development of a national Logistics Service Model. In addition, a Five Forces assessment was applied to evaluate the competitive environment. Collectively, these analytical tools form the strategic foundation for the model proposed in Chapter 5. To contextualise these findings spatially, Figure 3 illustrates the geographical distribution of the potential ports and their 200 km service radii.

## 4.3 SWOT, TOWS and Porter’s Five Forces Synthesis

### 4.3.1 SWOT

| **Strengths** | **Weaknesses** |
|---|---|
| Established onshore wind supply base and OEM presence, fifth in Europe _Siemens Gamesa, LM Wind Power (World Bank,2024). | Lack of offshore experience and heavy-lift & jack-up vessel fleet (Yildirim et al., 2025) |
| Strong domestic demand of onshore wind equipment turbine equipment (Gönül et al., 2021) | Limited port capacity meeting offshore standards (World Bank,2024). |
| Strong steel fabrication and shipbuilding sectors (World Bank,2024). | Lack of inland location of manufacturing facilities. (World Bank,2024). |
| Well-connected road network in Aegean and Marmara regions (Soğukpınar et al., 2025) | Fragmented institutional coordination across ports shipyards and regulators (World Bank,2024). |
| **Opportunities** | **Threats** |
| Potential to develop regional logistics hub in Eastern Mediterranean Expansion of İzmir, Aliağa, Bandırma, and Filyos as offshore construction ports. (World Bank,2024). | Competition from established North Sea ports (Esbjerg, Rotterdam). (World Bank,2024). |
| Shipyard diversification into heavy-lift vessel construction. (World Bank,2024). | Limited domestic project pipeline may deter large-scale logistics investments. (World Bank,2024). |
| Public Private ownership (PPP) based port and vessel investments. (Gönül et al., 2021) | |
| Collaboration with European OEMs for technology transfer and localisation. (World Bank,2024). | Continued dependence on foreign installation vessels could increase costs and scheduling risks (World Bank,2024). |
| Three areas have been found economically feasible: Çanakkale area and North Aegean coastal corridor (Yildirim, 2022). | Uncertain project pipeline and regulatory delays. (Yildirim et al., 2025) |

Overall, the country combines strong industrial capabilities with a strategically located maritime corridor, offering a solid foundation for offshore wind logistics. However, the constraints identified— including limited port readiness, insufficient specialised vessels, and institutional fragmentation—underline the need for an integrated, demand-aligned logistics framework. These findings directly inform the rationale for the model developed in the following section.

### 4.3.2 TOWS Matrix interpretation (full analysis in Appendix D)

Using the SWOT matrix as input, the TOWS framework translates internal and external factors into actionable strategic options by pairing strengths and weaknesses with opportunities and threats:

**SO Strategies (leveraging strengths to capture opportunities):** Leverage the country's industrial base and OEM presence to position the İzmir–Aliağa corridor as a regional offshore wind logistics hub; integrate manufacturing clusters with upgraded ports through dedicated logistics corridors.

**WO Strategies (using opportunities to overcome weaknesses):** Apply public–private partnership (PPP) models for port upgrades (İzmir Aliağa, Bandırma, Çanakkale, Filyos); encourage shipyard–utility co-investment in heavy-lift vessels; introduce offshore wind logistics certification schemes to accelerate capability building.

**ST Strategies (using strengths to counter external threats):** Use existing marine-engineering expertise and public–private industrial clusters to compete with established North Sea hubs; develop joint R&D programmes with OEMs for next-generation 8–15 MW turbine components.

**WT Strategies (minimising weaknesses to defend against threats):** Implement phased capacity-building programmes, strengthen regulatory harmonisation and permitting processes, and reduce fragmentation in governance structures to mitigate exposure to external competitive pressures.

#### 4.3.3 Porter's Five Forces (full analysis in Appendix D)

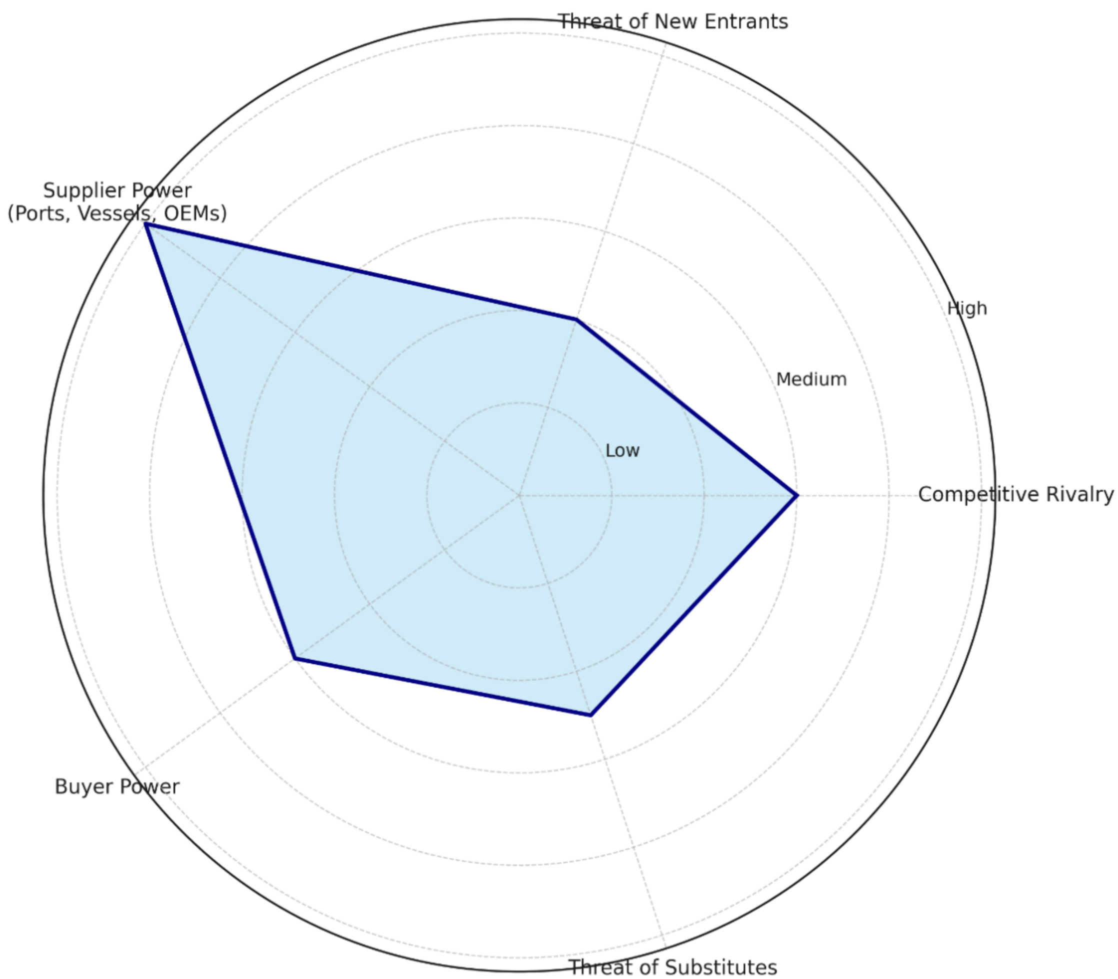


Figure 4: Offshore Wind Supply Chain and Logistics Radar Plot for Türkiye

The interpretation highlights a structurally constrained yet opportunity-rich competitive environment for the emerging industry. Supplier power remains high due to limited deep-draft port capacity and global shortages of specialised vessels. Buyer power is moderate, reflecting a small pool of developers with restricted contracting alternatives. *Entry barriers* are assessed as medium–low: although capital and certification requirements are substantial, the country's strong maritime and fabrication base creates a credible foundation for domestic entrants if supported by incentives.

Competitive rivalry is assessed as moderate, driven by the early-stage market structure and the expected participation of established European EPCI contractors.

Substitution risk is considered low to moderate; no direct substitutes exist for offshore wind logistics assets, although investment may shift toward solar, onshore wind, or hydrogen if  development stalls (Gönül et al., 2021).

Together, the TOWS and Porter analyses—particularly the elevated supplier power resulting from limited wind turbine installation vessels (WTIVs) and heavy-lift vessels (HLVs) capacity and port readiness—show that ’s logistics competitiveness will depend on early investment in port and vessel capability and on the development of integrative logistics-service models.

### 4.4 Comparative Synthesis and Transition to Framework Development

Synthesising insights from international literature and national data reveals a structural mismatch between inferred stakeholder expectations and local logistics capability. In mature markets, stakeholders operate within integrated, digitally coordinated logistics ecosystems typically coordinated by 4PL or 5PL providers. The domestic system, by contrast, remains supply-driven and asset-fragmented, relying on individual contractors and limited data integration. This fragmentation also characterises the offshore wind supply chain, where strong component-manufacturing capacity exists but is only partially aligned with logistics readiness (World Bank, 2024).

These findings indicate that the structural mismatch identified earlier extends beyond logistics operations and into the organisation of the wider supply chain, including component manufacturing and related upstream processes. This reinforces the need for a context-specific logistics-service framework that aligns decision-support requirements, industrial and infrastructure capacity, and logistics performance standards.

# 5. CONCEPTUAL FRAMEWORK FROM CONCEPT TO PRACTICE

## 5.1 Conceptual Foundations

The Readiness – Adaptive Model is designed as an offshore wind adaptation of the *Logistics Service Provider Lifecycle Model (LSLM)* developed by Tiwong et al. (2024). The LSLM provides a lifecycle -based framework for achieving stakeholder satisfaction by guiding the creation, design, delivery, and eventual decomposition of services. It structures logistics services across three sequential phases—the Beginning of Life (BOL), Middle of Life (MOL), and End of Life (EOL) and eight criteria ensuring that offerings are planned, executed, and continuously improved to meet customer requirements throughout the entire end-to-end lifecycle. The original Figure illustrating the structure of the Tiwong et al. (2024) model is provided in Appendix G.

## 5.2 Framework Development Logic

The framework is grounded in the strategic challenges and gaps highlighted in the preceding synthesis. Chapter 4 demonstrated that mature industries function through advanced coordination mechanisms supported by highly digitalised logistics-visibility systems. In contrast, Türkiye remains at an early development stage, characterised by fragmented assets, limited port readiness, the absence of WTIV/HLVs, and insufficient digital interoperability. These structural limitations, combined with the universal logistics challenges identified in the international thematic analysis, necessitate a model that is both ambitious and operationally realistic.

Accordingly, the model is built on three guiding principles:

- **Demand-driven design**: Logistics services must be aligned with the performance expectations of stakeholders rather than constrained by existing domestic capabilities.
- **Strategic realism**: Services must reflect the country's current readiness limitations and evolve through a phased capability-building pathway that addresses globally recurring offshore wind logistics challenges.
- **Competitive positioning**: Service architectures must anticipate the structural forces shaping market attractiveness—including port bottlenecks, vessel scarcity, and competition from established European hubs—while strengthening asset control, deepening collaboration models, and transitioning from a domestic-capability mindset to a regionally competitive offering.

Together, these principles shape the model across its three layers, ensuring that it is both internationally credible and firmly grounded in the operational realities of the country's emerging industry. At the same time, the constraints and opportunities identified earlier require the model to evolve through phased capability building, remain flexible and modular under varying levels of national readiness, and align with the stakeholder-defined performance standards. Accordingly, a dynamic and adaptive structure is required—one that can adjust as the national logistics ecosystem matures**.**

### 5.3 Readiness - Adaptive Modular Model

*The Readiness-Adaptive Modular Model* responds directly to this need. It integrates phased capability development with modular service components, enabling LSPs to operate effectively under various levels of port, vessel, and industry readiness. By allowing services to scale, reconfigure, or deepen as national capacity improves, the model ensures both strategic realism and competitive alignment with industry expectations.

The adapted Tiwong et al. (2024) framework is presented in Figure 4 to provide an overview of the model, followed by a detailed discussion of its phases and logic in the sections that follow.

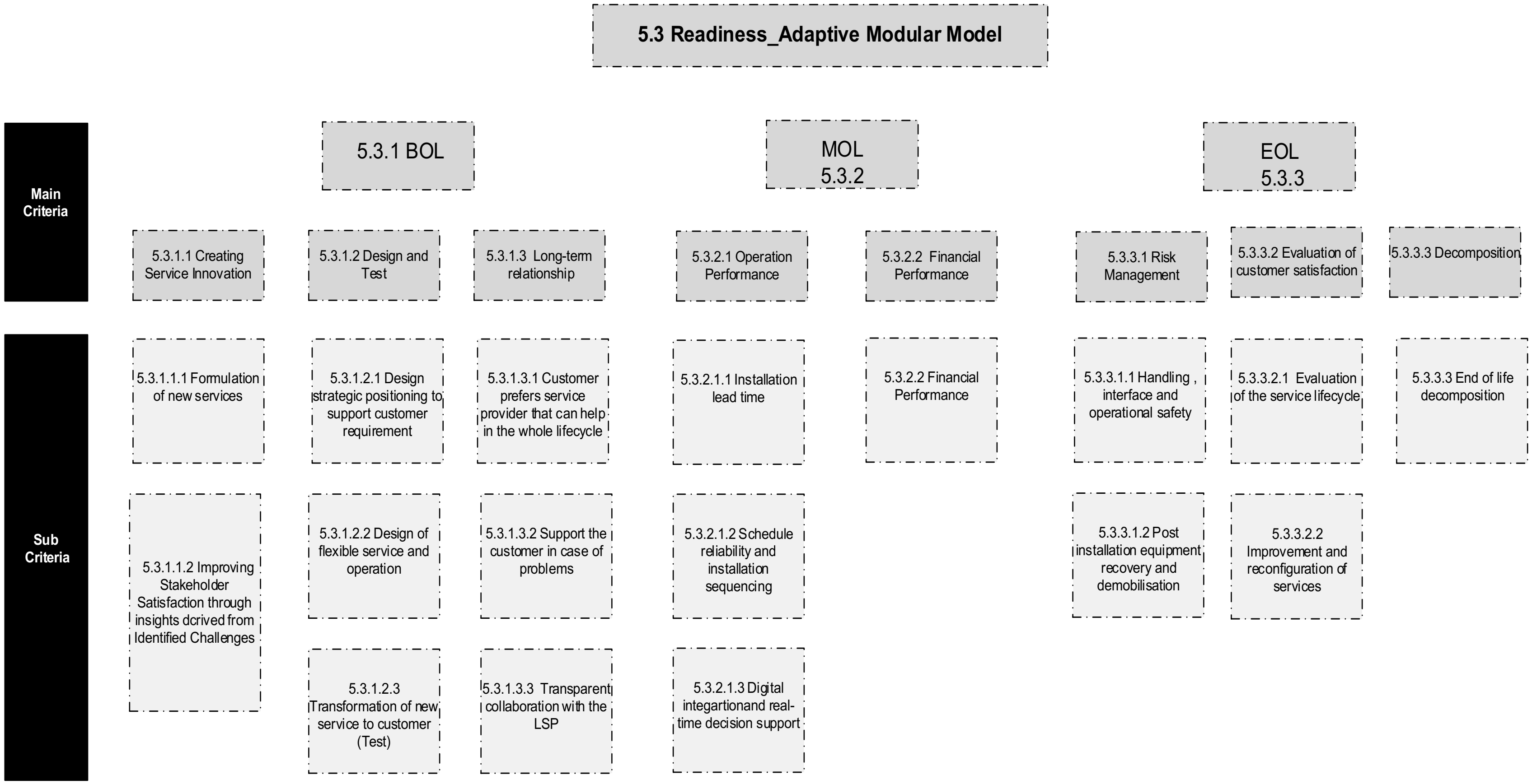


Figure 5: Readiness Adaptive Modular Model

### 5.3.1 BOL (Beginning of Life):

This phase focuses on service creation by identifying customer needs, designing, and testing new offerings, and establishing the strategic direction required to build long-term, value-based relationships. As an adapted offshore wind logistics service model, the BOL phase establishes the strategic foundations of service creation by aligning international stakeholder expectations with existing national capabilities and structural constraints.

A detailed mapping to Tiwong et al. (2024) is provided below for the BOL phase as an illustrative example. Subsequent discussion of the BOL phase and later lifecycle phases therefore focuses on the adaptation of the model to the offshore wind context. Within the lifecycle logic adapted from Tiwong et al. (2024), the BOL phase encompasses the formulation of new service offerings (Tiwong's Stages 1.1–1.2), the strategic and operational architecture of these services (Tiwong's Stages 2.1–2.3), and the relationship-building mechanisms that shape long-term collaboration with stakeholders (Tiwong's Stages 3.1–3.3).

Consistent with this logic, the BOL phase integrates three analytical pillars developed earlier in the thesis—SWOT, Porter's Five Forces, and the TOWS matrix—to translate Türkiye's offshore wind logistics context into actionable service-design principles.

#### 5.3.1.1 Creating Service Innovation

##### 5.3.1.1.1 Formulation of new services

The creation of new service offerings and the development of service innovation are jointly shaped by TR's structural advantages and competitive constraints. The concentration of blade, tower, and steel-fabrication industries (manufacturing strength) in the İzmir–Aliağa corridor (geographical advantage) creates a natural foundation for factory-to-port coordination, component-flow optimisation, and integrated pre-assembly support. SO/TOWS strategies, including leveraging the İzmir–Aliağa industrial base to form a regional logistics hub, reinforce the importance of innovation-led service design. These industrial strengths reveal clear opportunities for designing logistics services that align closely with stakeholder requirements.

At the same time, critical weaknesses—particularly limited port readiness (e.g. insufficient quay strength), the absence of domestic turbine-class installation vessels—create identifiable service gaps that new offerings must directly address.

BOL aligns with the FEED stage, which occurs after concept development but before procurement and construction. FEED is the point at which critical logistics decisions are defined, including port selection, quay-strength and lay-down requirements, vessel strategy, weather-window assumptions, pre-assembly layout, and contracting models. If logistics input is not fully integrated at this stage, misjudgements in port suitability, vessel timing, or operational planning can lead to significant delays and cost overruns. In this stage the model also defines which performance dimensions matter (critical KPI families), are critical and which risk dimensions must be monitored (chapter 4.1.1 to 6). See also Appendix F for further detail.

##### 5.3.1.1.2 Improving stakeholder satisfaction through challenge-informed service innovation

As a result, activities such as port-readiness auditing, vessel-strategy advisory services, FEED (DNV, 2018; Poulsen, 2018) integrated logistics engineering, and early installation-planning support become high-value service differentiators.

The BOL phase shows that LSPs able to control, access, or invest in suitable ports—and capable of integrating FEED-stage engineering with vessel and port strategies—will hold a decisive competitive advantage. This is because stakeholders expect LSPs who can anticipate, design, and resolve infrastructural and organisational constraints before installation begins, positioning service innovation as a core driver of early market leadership.

#### 5.3.1.2 Designing and testing the service

##### 5.3.1.2.1 Designing for strategic positioning

Designing for strategic positioning requires transforming external pressures into a clear and compelling value proposition. Stakeholders increasingly demand logistics partners who can deliver continuity, visibility, and reliability across the entire installation chain. Although buyer power and competitive rivalry are moderate, LPs remain strategically influential because stakeholders prefer fewer logistics interfaces and favour LSPs capable of integrating multiple functions. At the same time, buyer power is constrained by the fact that only a small number of LSPs possess the necessary port access, heavy-lift capacity, and specialised installation expertise.

Given the excessive cost of delays, stakeholders increasingly prioritise reliability and risk reduction reinforcing their preference for logistics partners who can consolidate functions and minimise the number of interfaces they must manage. In this environment, national institutional fragmentation further strengthens the need for an LSP that can offer unified coordination, streamlined communication, and structured interaction across ports, shipyards, and suppliers. Together, these dynamics shape the service's competitive positioning and reinforce the rationale for integrated, digitally enabled logistics solutions.

#### 5.3.1.2.2 Design for flexible service

High supplier power—reflected in the scarcity of deep-draft, heavy-lift capable ports and limited access to WTIV/HLV fleets—elevates logistics services from routine operations to strategic enablers. This competitive reality requires service structures that offer flexibility and risk-resilience. Designing *adaptable* service and operational solutions becomes essential given uneven port readiness, varying heavy-lift capacity, and long transport distances between manufacturing sites and offshore deployment zones. TOWS/WO strategies therefore underscore the need for adaptable services that can function effectively across a wide range of port and vessel conditions, recognising that upgrades will progress at different speeds.

PPP-based port upgrades, hybrid vessel-access models (foreign charters combined with domestic yard cooperation), dual-port marshalling strategies, and modular service offerings form the basis of a readiness-adaptive modular model that allows LSPs to accommodate uncertainty while remaining aligned with stakeholder requirements. This modular logic follows from the need to address Türkiye's weaknesses and opportunities in phases rather than simultaneously, requiring service components that can be activated or combined as readiness improves. In practical terms, these modules may include port-readiness audits, FEED-stage logistics engineering, vessel-access strategy advisory, simulation-supported planning, and digital coordination support—each deployable individually or in combination depending on project conditions. Flexibility also supports compatibility with the diverse contracting structures used in the offshore wind industry.

#### 5.3.1.2.3 Transformation of to stakeholder and testing

The transformation and early testing of new services is supported *by* simulation-based planning tools (Mutke et al., 2015) port-layout mock-ups, FEED-stage scenario assessments, and preliminary schedule optimisation exercises. These tools enable LSPs to validate service concepts with stakeholders before formal contracting and reduce uncertainty related to weather windows, vessel sequencing, and port congestion. They also lay the groundwork for subsequent MOL performance monitoring.

#### 5.3.1.2.4 Long-term relationship – Life-cycle wide partnership, support, and trust

The long-term relationship requirements of the stakeholders are evident from the inherent difficulty of the projects, the collaboration required in all phases due to emerging industry dynamics and the lack of many eligible LSPs for the projects and the trust, transparency, and sustained support expectations value stable, lifecycle-wide partnerships that ensure continuity. SWOT-identified weaknesses—particularly fragmented coordination—underscore the importance of transparent communication channels, shared digital dashboards, and clear role definitions. Support during service design and in addressing prospective challenges (e.g. disruptions, weather conditions, vessel unavailability, or port bottlenecks) is critical for maintaining relationship durability. These elements position the LSPs not merely as a service provider but as a long-term strategic partner embedded within the stakeholder's installation architecture.

### 5.3.2 MOL (Middle of Life) Phase

#### 5.3.2.1 Operational and Financial Performance

The four MOL performance dimensions used in this model are derived directly from the six thematic challenges identified in Chapter 4. The MOL phase translates these thematic challenges into four performance dimensions—installation lead-time, schedule reliability, digital integration, and financial performance. Each dimension corresponds to specific risk scores allowing the model to convert earlier KPI analysis into installation-specific risk levels for the readiness adaptive modular service model. This provides a clear performance–risk profile for the emerging offshore wind logistics system and highlights where strengths exist under current readiness conditions and where vulnerabilities persist.

Installation lead-time performance operationalises chapter 4 – sections 4.1.1 to 4 (weather, port readiness, vessel availability, and supply-chain coordination), while schedule reliability and installation sequencing reflect the synchronisation and timing challenges highlighted in sections 4.1.1 ,4.1.3 and 4.1.4. Digital integration and real-time decision support correspond to section 4.1.6, which examines data readiness and system interoperability, and the financial performance dimension is informed primarily by section 4.1.5, supplemented by cost-related implications of sections 4.1.2 and 4.1.3.

In this way, each MOL heading translates the earlier thematic analysis into measurable KPI-based performance indicators and associates corresponding risk levels tailored to installation logistics. While summary findings are presented in the main text, detailed analysis of the performance themes, KPIs and associated risk scores provided in Appendix F**.** Each challenge described in chapter 4 is assessed using a 1–5 risk scale (Very Low to Very High). Scores reflect two weighted factors: (i) the importance of the challenge for OW development and (ii) the difficulty of mitigation within the Turkish context**.** These factors are combined through a weighted-average scoring approach, providing a clear measure of overall risk, and helping to identify priority areas for action.

The risk framework applied in this study draws on analytical methods developed through the Finance and Digitalisation modules of this MBA programme and has been adapted to the readiness-adaptive modular model . This enables the assessment of the relative importance and mitigation difficulty inherent in each of the four MOL performance dimensions in accordance with the country's current readiness stage, while also allowing the framework to be adapted to future readiness stages as conditions evolve**.**

#### 5.3.2.2 Operation Performance

**5.3.2.2.1 Installation lead time** refers to the overall responsiveness and speed of logistics processes, capturing how efficiently OW components move from manufacturing, through ports, onto vessels, and ultimately into installation sequences. It reflects the cumulative effect of weather conditions, port performance, vessel availability, and inland transport on system responsiveness and is monitored through KPIs that quantify the speed with which logistics processes convert inputs into offshore installation output.

Installation lead time is affected by four main categories of risk: First, weather and environmental uncertainty exerts a defining influence on installation dynamics. Weather-delay sensitivity and installation-efficiency indicators measure how wind speed, wave height, forecast reliability, and distance to site reduce workable days and increase vessel idle time (Vis & Ursavas, 2016; Díaz & Guedes Soares, 2023). These risks are intensified by dependence on foreign WTIV/HLV fleets and limited tow-out or floating-wind experience. Although technology importation can reduce exposure to some extent, weather-related uncertainty yields a Moderate–High risk score of 3.25 and remains a priority area for early capability development.

A second source of risk arises from port-infrastructure and capacity constraints. Port-efficiency, port-suitability, crane-utilisation, storage-efficiency, and infrastructure-readiness indicators capture how quay depth, lay-down space, crane capacity, and bearing strength limit pre-assembly throughput and generate congestion (Chandra Ade Irawan et al., 2017; World Bank, 2024). The long-term, large-scale industrial investments required to bring ports to OW-ready standards result in a High-Risk score of 4.0. Despite promising foundations at Aliağa, Bandırma, and Filyos, substantial reinforcement, dredging, corridor planning, and standardised OW port guidelines are still required to meet international installation requirements.

A third source of risk relates to vessel availability, scheduling, and load optimisation. Vessel-utilisation, load-optimisation, and operational-turnaround indicators show how long mobilisation distances, sub-optimal deck-space use, and fragmented multi-vessel coordination restrict installation sequencing and speed (González et al., 2024). These constraints produce a Moderate–High risk score of 3.43. However, mitigation is feasible in the mid-term through strengthened vessel-access strategies, international partnerships, enhanced digital load-planning capabilities, centralised scheduling, and the development of hybrid or auxiliary vessels in domestic shipyards.

Finally, inland supply-chain synchronisation and multi-tier logistics coordination significantly shape installation responsiveness. Route-optimisation, transit-cycle, and inland-transport indicators show how limited lay-down capacity, complex multi-node routing, dependence on inland factories, and inadequate heavy-haul corridors create systemic bottlenecks.

These constraints are reflected in a High-Risk score of 3.8. Addressing them requires coordinated improvements in multimodal transport capacity, digital planning, inventory and JIT management, and the establishment of a central 4PL/5PL coordination structure to ensure continuous component flow from factories to ports and vessels.

**5.3.2.2.2 Schedule Reliability and Installation Sequencing** reflect the ability of the logistics chain to maintain schedule reliability, ensuring that components arrive at the offshore site in the correct sequence, at the appropriate time, and within the constraints imposed by weather windows and installation milestones. This dimension captures how effectively different logistics tiers—manufacturing, ports, inland transport, and offshore vessels—are synchronised across the installation timeline.

Schedule reliability is assessed through KPIs that measure performance across the end-to-end chain. Scheduling-reliability indicators and coordination-efficiency metrics capture whether loading, jacking, transit, and installation sequences minimise vessel idle time (Vis & Ursavas, 2016; World Bank, 2024). Supply-synchronisation, network-integration, storage-adequacy, and cross-border-efficiency indicators assess the alignment between inland factory output, port staging activities, multimodal transport links, and international gateways (Chandra Ade Irawan et al., 22017; Díaz & Guedes Soares, 2023). Installation-performance indicators synthesise these patterns to show the extent to which turbines and components are delivered to site in accordance with planned weather windows and installation milestones.

Under TR’s current readiness conditions, weather-window loss, vessel-sequencing constraints, and supply-chain synchronisation gaps remain the primary determinants of schedule reliability

**5.3.2.2.3 Digital Integration and Real-Time Decision Support** refer to the capacity of the logistics system to exchange accurate, timely, and interoperable data across all actors—ports, vessels, manufacturers, weather services, and control centres—so that operational decisions can be continuously updated as conditions evolve. This performance dimension captures the effectiveness of digital systems in enabling coordination, forecasting, and dynamic replanning during installation.

It is assessed using KPIs that measure the quality, integration, and responsiveness of operational data. Forecast-reliability indicators show how well meteorological information supports daily planning and vessel dispatch (González et al., 2024; Díaz & Guedes Soares, 2023). Digital-readiness, model-validation capability, computational scalability, market-integration, knowledge-transfer processes, competence-readiness, and network-integration indicators collectively evaluate whether port, vessel, metocean, and supply-chain data operate within a digitally interoperable environment capable of supporting dynamic replanning and digital-twin deployment (Poulsen & Lema, 2017; World Bank, 2024). These KPIs reveal the maturity of the national digital backbone and the human-capital capacity required for cross-organisational coordination.

Digital-integration performance is constrained by four interrelated challenges: limited long-term metocean datasets, the absence of floating-wind operational data, restricted model-validation capability, and fragmented digital systems across ports, shipyards, and logistics providers. These limitations collectively place digital readiness in the High-Risk category score: 4.0**.** Addressing them requires national metocean measurement networks, high-performance computing capacity for optimisation models, digital-twin platforms, cross-border knowledge-transfer programmes, and specialised offshore-logistics training—measures that strengthen predictive, data-driven installation planning and enhance the system's ability to support real-time operational decision-making.

Moreover, it has been demonstrated by Haghshenas et al. (2023) and Ambarita et al. (2024) that, in mature applications, predictive and industrial digital twins enable continuous feedback between planning assumptions and operational realities, thereby enhancing schedule reliability, performance forecasting, and adaptive decision-making during installation phases.

#### 5.2.2.3 Financial performance

Financial performance reflects the extent to which the logistics system converts operational efficiency into cost-effective installation outcomes, capturing how scheduling, resource utilisation, and infrastructure constraints influence total project expenditure and LCOE. It therefore provides a quantitative link between day-to-day logistics decisions and their broader economic impact on OWP viability.

This dimension is assessed through KPIs such as cost efficiency, component-value sensitivity, installation performance, cost–time balance, port-cost efficiency, coordination effectiveness, and organisational maturity indicators. These indicators measure how operational choices—such as vessel idle time, deck-load planning, pre-assembly levels, routing, port selection, contracting structures, and governance arrangements—translate into installation CAPEX and LCOE outcomes (Díaz & Guedes Soares, 2023; González et al., 2024; Poulsen & Hasager, 2016; World Bank, 2024). They are particularly relevant for early-stage OWPs, which depend heavily on foreign WTIV/HLV capacity, exhibit variable port-cost structures, and operate within fragmented contracting frameworks.

Financial risk is shaped primarily by four interrelated cost drivers. The first concerns cost-efficiency and installation-time optimisation: installation expenditure is extremely sensitive to vessel idle time, long-distance mobilisation, port-stage inefficiencies, and the transport of high-value components, collectively producing a High-Risk score of 3.71. Additional exposure emerges from port-capacity gaps and vessel-charter constraints, which directly arises from cost trajectories and LCOE sensitivity. These risks are further amplified by gaps in organisational maturity across the logistics chain.

Mitigating these cost drivers requires early integration of logistics expertise into FEED stage, increased pre-assembly, optimised load planning, the use of centralised coordination structures (e.g.,4PL/EPCi), and progressive localisation of key components. Together, these measures strengthen the relationship between logistics performance and financial outcomes, supporting more predictable and financially resilient offshore wind installation projects.

### 5.3.3 EOL (End of Life) Phase

The EOL phase evaluates how effectively the logistics service performed during offshore wind installation by assessing whether the service delivered the operational, informational, and financial outcomes defined during the BOL phase and monitored through the MOL stage KPIs.

Each EOL subsection corresponds directly to the MOL performance dimensions and their associated KPIs. Risk management and handling, interface and operational safety extend Chapter 4, Sections 4.1.1–4.1.3, reflecting weather exposure, port-capacity constraints, and vessel-interface risks. Risk management related to post-installation demobilisation activities corresponds primarily to Sections 4.1.2 and 4.1.3, as these activities depend on port readiness and vessel coordination. Customer satisfaction and service-performance review incorporate Sections 4.1.4–4.1.6, including supply-chain synchronisation, cost efficiency, and digital integration.

The improvement and reconfiguration of services synthesise findings across all Sections 4.1.1-4.1.6 to inform the next BOL cycle. In addition, the EOL phase encompasses performance reviews, customer-satisfaction assessments, corrective actions, and service termination decisions. Within the OW context, these activities correspond to post-operation evaluation and capability development across ports, vessels, and supply-chain actors.

A natural limitation of this study, reflecting the pre-commercial status of the national industry, is the absence of empirical MOL KPI data, as Türkiye does not yet have an operational OW installation. Consequently, the EOL evaluation and subsequent BOL redesign operate on ex ante risk assessments rather than observed performance outcomes. However, this limitation does not affect the validity of the model, which is designed to function as a forward-looking framework for the emerging market.

#### 5.3.3.1 Risk Management

##### 5.3.3.1.1 Handling, Interface, and Operational Safety

In the EOL phase, handling, interface, and operational safety is evaluated by analysing how effectively offshore wind components were protected during transport, port handling, lifting, and installation. As shown by Mou et al. (2021), operational safety is shaped by environmental hazards such as high winds, poor visibility, and vessel-traffic complexity, all of which heighten the risk of unsafe lifting, misalignment, or accidental contact during handling operations.

Díaz & Guedes Soares (2023) similarly emphasise that heavy-lift operations, deck-load sensitivity, and weather-dependent lifting constraints create significant exposure to handling incidents, especially when components are moved under dynamic wind and wave conditions. Both studies highlight that cargo integrity depends on the correct execution of lifting protocols, stowage geometry, crane sequencing, and weather compliance, making these factors central to EOL evaluation.

Handling, interface performance, and safety are assessed by examining how vessel–port interfaces perform under operational stresses, including collision-avoidance failures, navigation-equipment issues, and mismanaged berthing or tow-out manoeuvres—risks documented extensively by Mou et al. (2021). Evaluating these aspects at EOL therefore reveals whether distribution processes were adversely affected by environmental conditions, port congestion, or coordination gaps, and identifies which procedures require reconfiguration in the next BOL cycle.

#### 5.3.3.2 Evaluation of customer satisfaction

##### 5.3.3.2.1 Evaluation of the service lifecycle

First, the evaluation of the service examines whether the LSP fulfilled its commitments in areas such as FEED-stage support, vessel and port strategy implementation, coordination quality, digital integration, and the robustness of day-to-day execution. This approach aligns with international findings indicating that installation logistics performance is highly dependent on the consistency of FEED-level decisions, port-readiness assessments, and vessel-interface planning (Díaz & Guedes Soares, 2023).

In practical terms, this involves reviewing how the service modules—port audits, vessel-access strategies, scheduling support, simulation tools, digital coordination, and supply-chain synchronisation— were delivered and whether they effectively mitigated handling and operational risks identified in OW operations research (Mou et al., 2021).

Second, the evaluation of outcomes measures actual performance against predefined MOL stage KPIs, including weather-related delays, port-handling efficiency, vessel utilisation, schedule adherence, information flow, and installation-cost outcomes.

These dimensions reflect the key operational determinants of offshore wind installation performance highlighted in the literature, such as weather-window sensitivity, port capacity constraints, and vessel-scheduling efficiency (Vis & Ursavas, 2016; Díaz & Guedes Soares, 2023). This assessment identifies where performance diverged from expectations (e.g., longer turnaround times, insufficient storage synchronisation, or forecast-related replanning delays) and where performance was met or exceeded expectations.

#### 5.3.3.2.2 Improvement and reconfiguration of services

Third the focus shifts to the improvement and reconfiguration of services, feeding lessons learned back into the BOL stage. Identified shortcomings—such as insufficient vessel redundancy, gaps in data interchange, misaligned sequencing, or underperforming port processes—are translated into revised service modules, enhanced digital workflows, updated coordination protocols, or refined FEED engineering inputs. Through this continuous improvement loop, the EOL phase strengthens the model’s adaptability, ensuring that future service cycles better align with stakeholder expectations, installation realities, and evolving offshore wind readiness conditions in Türkiye.

#### 5.3.3.3 End of life composition

In the composition stage of the EOL phase, the logistics service is reassembled into a refined configuration that integrates lessons learned from MOL performance and EOL evaluations. While decomposition separates the service into individual modules for diagnostic purposes, composition rebuilds the service by determining which modules should be retained, strengthened, redesigned, or removed entirely.

This process draws on evidence from installation KPIs—such as weather-delay sensitivity, port-handling efficiency, vessel utilisation, and coordination effectiveness—together with customer feedback, to identify which service elements contributed meaningfully to installation performance and which generated bottlenecks (Vis & Ursavas, 2016; Díaz & Guedes Soares, 2023).

Modules that underperformed during MOL, including those linked to weak forecasting integration, port-yard congestion, or insufficient vessel redundancy, are reconfigured and reintegrated in improved form, while high-performing modules—such as FEED-aligned port audits, digital coordination tools, and simulation-supported scheduling—are retained and codified as core components of the next service cycle.

In this way, the composition stage formulates a coherent and enhanced service architecture that prepares the BOL phase for the next project iteration, ensuring closer alignment with operational realities and industry-specific risks identified in offshore wind operations (Mou et al., 2021).

# 6. IMPLICATIONS

## 6.1 Academic Implications

This study contributes to the offshore wind and logistics literature in three main ways.

First, it advances existing work on offshore wind logistics by explicitly conceptualising logistics services as the primary vehicle through which installation challenges are addressed. Existing studies tend to focus on discrete elements such as port capacity, port design, vessel scheduling, weather exposure and digital integration (e.g. Poulsen, 2018; Díaz & Guedes Soares, 2023; González et al., 2024) but do not frame these challenges within a coherent logistics service model tailored to offshore wind. By adapting Tiwong et al.'s (2024) LSLM to an offshore-wind context, the thesis shows how recurring challenges can be translated into a lifecycle-oriented, readiness-adaptive modular service architecture that links BOL, MOL and EOL activities to stakeholder expectations.

Second, the study addresses the demand-side gap in the offshore wind logistics literature. International research often analyses issues without systematically articulating how stakeholders formulate logistics requirements or evaluate logistics performance. By inferring stakeholder expectations from six universal challenge themes and then mapping these expectations onto Türkiye's readiness conditions, the thesis reframes logistics as a process of stakeholder requirement translation. This demand-side orientation extends the primarily supply-driven perspective found in much of the existing literature and aligns this logistics research with contemporary service- and customer-centric approaches.

Third, the research contributes to debates on context-specific framework transferability. Much of the evidence base originates from North Sea markets where port readiness, vessel availability, and digital maturity differ substantially from emerging contexts.

By treating Türkiye as a single case and explicitly showing where international patterns hold, where they diverge, and how they can be adapted through a readiness-adaptive modular model, the thesis demonstrates how a generic LSM framework can be operationalised in an emerging market with uneven infrastructure and institutional capacity. This helps clarify the conditions under which models derived from mature markets can be meaningfully transferred to new geographies.

## 6.2 Practical Implications for Logistics Service Providers and Industry

The findings have several practical implications for the country, LSPs, port operators, vessel operators, stakeholders, and other industry actors preparing for Türkiye's future OWPs.

First, Logistics must be positioned as a strategic, not purely operational, function. The high-risk scores for port readiness, vessel availability, coordination, cost efficiency, and digital integration show that logistics decisions materially shape installation lead time, schedule reliability, and LCOE. LSPs that can participate from the FEED stage, provide port-readiness audits, vessel-access strategies, and simulation-supported planning will have a significant competitive advantage over providers offering only transactional transport or stevedoring services.

Second, readiness-adaptive, modular services are essential under uneven national conditions**.** Given the variability between ports such as İzmir–Aliağa, Bandırma and Filyos, and continued dependence on foreign WTIV/HLV fleets, a single "ideal" logistics configuration is unrealistic in the short term. The Readiness-Adaptive Modular Model proposes service "modules" (e.g. FEED logistics engineering, port-readiness auditing, digital coordination platform, vessel-strategy advisory) that can be combined differently depending on the maturity of port and vessel capacity. This modular logic offers LSPs a practical blueprint to operate under today's constraints while building towards a more integrated, 4PL/5PL-type role over time.

Third, long-term, life-cycle partnerships will matter more than spot contracting**.** The case evidence shows that stakeholders value integrated, transparent, and digitally visible logistics support across the entire project lifecycle. Under conditions of scarce heavy-lift assets and relatively few qualified LSPs, stakeholders are likely to prefer a small number of strategic partners capable of offering life-cycle-wide support rather than fragmented, short-term contracts. LSPs that invest early in relationship-building, capability development and knowledge transfer are better positioned to secure multi-project, multi-year frameworks.

Fourth, digital integration and data capabilities are not optional add-ons but core capabilities. The high-risk classification for chapter 4, section 4.1.6 (data, validation, and market readiness) indicates that without interoperable digital systems—linking metocean data, port operations, vessel schedules, and inland flows—installation planning will remain reactive and vulnerable to weather and coordination shocks. LSPs, ports and shipyards therefore need to invest jointly in digital-twin concepts, port community systems, and decision-support platforms, potentially through national or regional digital integration initiatives.

### 6.3 Policy and Strategic Implications for Türkiye

For policymakers and public stakeholders, the study highlights four main implications: First, port policy must explicitly recognise offshore wind as a distinct logistics segment. Generic port development programmes are unlikely to deliver the >12 m draft, ≥20 t/m² bearing capacity, large lay-down areas and heavy-lift cranes required for 8–15 MW turbines. National port strategies should therefore define “offshore-wind-ready” standards and prioritise a limited number of construction ports for targeted PPP-based upgrades, particularly in the İzmir–Aliağa corridor, Bandırma and Filyos.

Second, YEKA and related tender frameworks can be used to accelerate logistics capability. Tender design can incorporate explicit criteria for logistics planning quality, FEED-stage logistics integration, digital interoperability, and knowledge-transfer obligations from international partners to domestic LSPs and ports. In this way, each new project functions as a lever for capacity building, not purely as a power-generation asset.

Third, a national offshore wind logistics competence centre is needed. The fragmented nature of port governance, shipbuilding, manufacturing, and regulatory bodies points to the need for a central coordination and knowledge hub. Such a body could develop guidelines for OW ports, support risk and KPI frameworks, facilitate training programmes, and act as an interface between government, demand-side stakeholders, and logistics actors.

Fourth, data infrastructure should be a public-good priority. Long-term metocean measurement, digital standards, and data-sharing frameworks are unlikely to be provided efficiently by individual firms. This need is reinforced by recent digital-twin studies in OW, which demonstrate that predictive modelling and operational optimisation are only feasible where reliable, standardised, and continuously updated data infrastructures exist (Haghshenas et al., 2023; Ambarita et al., 2024).

Public support for metocean networks, data hubs, and high-performance computing facilities therefore enables EOL learning outcomes to be systematically captured and fed back into the subsequent BOL phase, providing a collective foundation for improved logistics planning, model validation, and reduced risk premiums for early-stage projects.

## 6.4 Limitations

The study is subject to several limitations which should be acknowledged when interpreting its findings.

First, the study relies on secondary data. Due to the emerging nature of OW in Türkiye, stakeholders with substantial R&D investment in this area that could support the study were not identified at the time of writing. Even though the author had prepared a set of interview questions, the absence of suitable and available industry counterparts meant that primary data collection could not be undertaken. As a result, all analyses are based on published academic, industry, and institutional sources, and inferred stakeholder expectations remain interpretive rather than empirically validated.

Second, the pre-commercial status of Türkiye's offshore wind industry indicates that the country does not yet have an operational offshore wind installation at the time of writing, the MOL risk scores and KPI assessments remain ex ante simulations rather than ex post performance evaluations. The EOL phase is therefore conceptual, demonstrating how the model would function once empirical data become available, rather than reporting observed installation outcomes.

Third, the single-case study design emphasises contextual specificity by focusing on Türkiye as a single, context-specific environment. While the analytical logic and risk–response patterns may be transferable to other emerging markets, the specific readiness scores, port configurations, and industrial structures should not be generalised uncritically to different national contexts.

### 6.5 Recommendations for Future Research

First, comparative studies across emerging markets are recommended to extend the findings of this research beyond a single national context. Cross-case analyses of other emerging offshore wind countries (e.g. in the Eastern Mediterranean, the Black Sea region, or Asia) could further investigate how readiness-adaptive modular logistics service models perform under different institutional and infrastructural conditions, and whether similar modular service architectures emerge across varying national contexts.

Second, quantitative modelling of Readiness-Adaptive LSM impacts on LCOE should be pursued by integrating the conceptual framework with optimisation and simulation models, enabling estimation of how improvements in port readiness, vessel access, coordination efficiency, and digital integration translate into changes in installation duration, cost structures, and levelized cost of energy.

Third, further research on human capital and training requirements is needed to examine the skills, training programmes, and organisational arrangements required to deliver 4PL/5PL-level offshore wind logistics services, particularly in emerging market contexts where digital integration and lifecycle coordination capabilities remain underdeveloped.

Fourth, empirical validation of the proposed Readiness-Adaptive Modular LSM is recommended once projects commence, as primary data from Türkiye's first offshore wind installations would allow testing and refinement of the model, including the KPI structure and risk-weighting logic applied in the MOL phase.

# 7. CONCLUSION AND RECOMMENDATIONS

## 7.1 Summary of the Study

This thesis set out to explore how logistics service models can support the development of Türkiye's offshore-wind industry by aligning domestic logistics capabilities with demand-side expectations. To do so, it adopted a qualitative, desk-based, single-case study design, drawing on international offshore wind logistics literature, Türkiye-specific secondary data, and contemporary logistics-service modelling research. The analysis concentrated on the installation phase of the wind farm life cycle and on the WTG component sub-supply chain—nacelle, blades, hub, and tower—where logistics intensity and cost sensitivity are highest.

## 7.2 Answers to the Research Questions

**RQ1 – What logistics challenges for offshore wind exist in international literature and how do these challenges infer to demand-side requirements?**

The international literature reveals six recurring thematic clusters of challenges affecting OW installation performance:

1. weather and environmental conditions;
2. port infrastructure and capacity;
3. vessel availability, scheduling, and load optimisation;
4. supply-chain and logistics coordination;
5. cost efficiency and installation time;
6. data readiness, model validation, and market capability.

From these challenges, the study inferred a set of largely universal demand-side requirements. Stakeholders expect LSPs and ports to manage weather windows through simulation-supported planning; ensure access to heavy-lift, deep-draft marshalling ports; guarantee reliable WTIV/HLV access and efficient deck-load planning; provide end-to-end supply-chain visibility; demonstrate measurable LCOE contributions; and deploy validated, interoperable digital tools supported by skilled personnel.

**RQ2 – What do secondary sources reveal about Türkiye's current port, vessel, and logistics infrastructure related to OW, and what demand-side logistics requirements relevant to Türkiye's offshore wind development can be inferred from them?**

The synthesis of national sources, led by the World Bank (2024) and supported by additional academic and policy studies, shows that Türkiye combines strong industrial and maritime capabilities with significant OW readiness gaps. Component manufacturing is relatively advanced for blades, towers, and steel structures in the İzmir–Aliağa corridor but remains limited for generators and full nacelle integration. Several ports—İzmir, Aliağa, Bandırma, Filyos—meet part of the offshore-readiness criteria, yet few currently offer sufficient draft, bearing capacity and lay-down area for large turbines. The country lacks dedicated WTIV/HLV assets and depends on foreign fleets, although domestic shipyards can build smaller offshore support vessels and may upgrade to larger assets with a sufficient project pipeline.

Risk assessments across the six challenges classify port infrastructure, supply -chain synchronisation, digital readiness, and cost efficiency as high-risk areas, with weather & environmental uncertainty and vessel availability & scheduling in the moderate-to-high category. These patterns imply that demand-side requirements in Türkiye will prioritise secure access to upgraded ports, vessel availability, robust FEED-stage logistics input, integrated digital platforms, and LSPs capable of orchestrating complex multi-tier supply chains under capacity and data constraints.

**RQ3 – How can insights from these international and national analyses be synthesised into a logistics service model tailored to Türkiye's emerging offshore wind industry?**

To answer RQ3, the study developed a *Readiness-Adaptive Modular Logistics Service Model* by adapting the LSLM to the offshore wind context. The model structures services across:

The **Beginning of Life (BOL)** phase focuses on service creation, strategic positioning, and relationship building. In this phase, FEED-aligned logistics engineering, port-readiness audits, vessel-strategy advisory services, and modular service design translate thematic challenges, SWOT–TOWS strategies, and Five Forces insights into concrete logistics service offerings.

The **Middle of Life (MOL)** phase addresses operational and financial performance. Four performance dimensions—installation lead time, schedule reliability and sequencing, digital integration and real-time decision support, and financial performance—are monitored through KPI- and risk-based assessments derived from the six challenge themes, producing a structured performance–risk profile for Türkiye's offshore wind logistics system.

The **End of Life (EOL)** phase centres on service lifecycle evaluation, learning, and service reconfiguration. Handling and interface safety, demobilisation performance, stakeholder satisfaction are assessed and, with lessons learned systematically fed back into the subsequent BOL phase, thereby supporting continuous service improvement and reconfiguration of the overall service architecture.

The model's readiness-adaptive and modular logic enables LSPs and policymakers to operate effectively under current constraints while progressively building the capabilities required for internationally competitive, digitally integrated OW logistics.

## 7.3 Overall Conclusion

The central conclusion of the thesis is that also Türkiye has a potential for developing the industry, the potential cannot be realised through infrastructure investments alone. While upgrading ports, vessels and manufacturing capacity is essential, the ability to design and deliver integrated, demand-oriented logistics services will ultimately determine whether early projects are bankable, timely and competitive in terms of LCOE.

The evidence shows a structural mismatch between the service expectations of international stakeholders—who are accustomed to 4PL/5PL-led, digitally orchestrated logistics ecosystems—and Türkiye's current, largely supply-driven, asset-fragmented logistics landscape.

The Readiness-Adaptive Modular Model proposed in this study offers a practical pathway to bridge this gap by aligning service design with stakeholder requirements, readiness realities, and risk priorities across the BOL, MOL and EOL phases.

If implemented strategically, the model can support Türkiye in:

- positioning selected ports and corridors as regional offshore wind logistics hubs,
- investing in WTIV/HLV vessels,
- strengthening domestic logistics service providers as credible partners for global stakeholders,
- using digitalisation and data to transform logistics from a bottleneck into a source of competitive advantage, and
- ensuring that each new project contributes to durable capability building rather than isolated physical upgrades.

## 7.4 Strategic Recommendations

Based on the analysis and the proposed framework, the following high-level recommendations are suggested for key stakeholder groups.

### 7.4.1 For Policymakers and Public Authorities

- Designate and develop a limited number of offshore wind construction ports (e.g. İzmir–Aliağa, Bandırma, Filyos) with clear offshore-readiness standards (draft, bearing capacity, lay-down area, crane capacity) and coordinate upgrades through PPP structures.
- Create a national Offshore Wind Logistics Competence and Data Centre to coordinate guidelines, risk/KPI frameworks, training, digital standards and metocean data collection, and to serve as an interface between regulators, stakeholders, and logistics service providers.
- Embed logistics capability requirements into YEKA and related tender schemes, including criteria for FEED-stage logistics integration, digital interoperability, and binding knowledge-transfer and local-participation conditions.
- Support digital integration for offshore wind logistics through targeted R&D programmes, port community systems, and interoperability standards aligned with leading EU hubs.

### 7.4.2 For Logistics Service Providers, Ports and Shipyards

- Adopt the readiness-adaptive modular logic as a capability roadmap, prioritising early development of FEED-stage advisory services, port-readiness audits, simulation-supported scheduling, and digital coordination tools.
- Invest in strategic partnerships and long-term contracts with stakeholders to secure multi-project engagement and justify capability-building investments.
- Collaborate on digital platforms and data-sharing, integrating metocean data, port operations, vessel schedules, and inland transport into unified decision-support environments.
- Leverage shipbuilding and fabrication strengths to progressively participate in auxiliary offshore vessels, installation supports and specialised equipment, with a view to future participation in WTIV/HLV capacity.

### 7.4.3 For Stakeholders (Developers, OEMs, and EPC/EPCI Contractors)

- Engage qualified domestic LSPs and ports from the FEED phase onward, allowing logistics considerations to shape port choice, infrastructure specifications, installation strategy, and risk allocation.
- Use project and framework agreements to incentivise capability transfer, including requirements for joint planning, shared digital tools, and structured training programmes for Turkish partners.

## 7.5 Closing Reflection

Offshore wind represents both a technical and organisational challenge for Türkiye. The results of this study suggest that if logistics is treated as a strategic, demand-driven service domain and targeted infrastructure investments are made the country can leverage its manufacturing and maritime strengths to become a competitive actor in the Eastern Mediterranean market. The readiness-adaptive modular model developed here is intended as a starting point: a structured, but flexible, framework that can guide early decisions, be refined through experience, and ultimately support a more mature, resilient, and internationally integrated offshore wind logistics ecosystem.

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## APPENDICES

## APPENDIX A: Offshore Wind Installation Challenges

### Theme 1 – Weather and Environmental Challenges

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Weather Dependency** | Adverse wind speeds > 15 m/s and wave height > 3 m restrict lifting, towing, and jack-up operations. Severe weather leads to idle vessel time and increased installation cost. | Weather-delay sensitivity indicator (measures schedule robustness and resilience to metocean variability). | Apply forecast-based and statistical weather modelling to define safe installation windows; reschedule tasks dynamically through simulation tools. | Vis and Ursavas (2016, pp. 84–85); Díaz and Guedes Soares (2023, pp. 8–10). |
| **Weather and Downtime Risk** | Weather windows and met-ocean limits reduce workable offshore days; vessels remain idle, increasing cost and schedule pressure. | Weather-delay sensitivity indicator (assesses schedule resilience and vessel idle-time impact). | Use predictive met-ocean analytics, apply dynamic scheduling buffers, and increase onshore pre-assembly to shorten exposure. | Poulsen & Lema (2017). |
| **Weather and Downtime Risk** | Weather windows and met-ocean limits reduce workable offshore days; vessels remain idle, increasing cost and schedule pressure. | Weather-delay sensitivity indicator (assesses schedule resilience and vessel idle-time impact). | Use predictive met-ocean analytics, apply dynamic scheduling buffers, and increase onshore pre-assembly to shorten exposure. | Poulsen & Lema (2017). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Distance to Shore and Exposure Time** | Sites > 100 km offshore extend transit time and exposure to weather risk, raising vessel costs and LCoE. | Installation efficiency indicator (assesses time performance under distance-related constraints). | Increase vessel capacity and onshore pre-assembly to reduce trips; use seasonal installation planning based on historical weather patterns. | Vis and Ursavas (2016, p. 90); Díaz and Guedes Soares (2023, pp. 8–10). |
| **Wave and Sea-State Uncertainty** | Floating platform projects face major delay risk when wave height > 3 m and depth > 150 m; causes tow-out suspensions and anchor failure risk. | Risk-resilience indicator (qualitative metric of installation schedule adaptability to sea-state variability). | Integrate weather forecast modules into installation simulation models and design tow-routes that minimize wave exposure duration. | Díaz and Guedes Soares (2023, pp. 8–10, 16). |
| **Wave and Sea-State Uncertainty** | Floating platform projects face major delay risk when wave height > 3 m and depth > 150 m; causes tow-out suspensions and anchor failure risk. | Risk-resilience indicator (qualitative metric of installation schedule adaptability to sea-state variability). | Integrate weather forecast modules into installation simulation models and design tow-routes that minimize wave exposure duration. | Díaz and Guedes Soares (2023, pp. 8–10, 16). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Forecast Accuracy and Operational Planning** | Limited accuracy of forecast data reduces confidence in vessel and port scheduling, creating idle time and cost overruns. | Model validation and schedule-robustness indicator (evaluates forecast reliability in operational planning). | Employ integrated decision-support tools linking real-time weather feeds with logistics scheduling for adaptive re-planning | González et al. (2024, Sec. 2.3); Díaz and Guedes Soares (2023, pp. 16–18). |
| **Weather and Downtime Risk** | Weather windows and met-ocean limits reduce workable offshore days; vessels remain idle, increasing cost and schedule pressure. | Weather-delay sensitivity indicator (assesses schedule resilience and vessel idle-time impact). | Use predictive met-ocean analytics, apply dynamic scheduling buffers, and increase onshore pre-assembly to shorten exposure. | Poulsen & Lema (2017). |
| **Weather and Downtime Risk** | Weather windows and met-ocean limits reduce workable offshore days; vessels remain idle, increasing cost and schedule pressure. | Weather-delay sensitivity indicator (assesses schedule resilience and vessel idle-time impact). | Use predictive met-ocean analytics, apply dynamic scheduling buffers, and increase onshore pre-assembly to shorten exposure. | Poulsen & Lema (2017). |

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**Theme 2 – Port Infrastructure and Capacity Constraints**

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Port Capacity and Layout Limitations** | Limited quayside depth, quay length, and staging area (~1800 m²/turbine) restrict pre-assembly and cause queueing delays. | Port efficiency indicator (evaluates adequacy of staging and handling capacity). | Develop dedicated offshore wind marshalling ports; co-locate manufacturing and assembly to reduce double handling. | Díaz and Guedes Soares (2023, pp. 14, 16–18). |
| **Port Suitability and Accessibility** | Insufficient port draft and crane capacity lead to inefficient heavy-lift operations and vessel congestion. | Port suitability score (AHP-based index measuring logistical accessibility). | Select ports via AHP-based multi-criteria evaluation (depth, crane capacity, access); prioritize optimal connectivity. | Irawan et al. (2018, pp. 1193–1194). |
| **Crane Capacity and Heavy-Lift Constraints** | Most EU ports <1000 t crane capacity, limiting turbine size assembly and loading speed. | Port crane utilization (indicator of lifting adequacy and operational readiness). | Invest in 1000+ t cranes; enable parallel lifting operations to reduce idle time. | Díaz and Guedes Soares (2023, p. 14). |
| **Port Storage and Pre-Assembly Congestion** | Limited port space causes congestion during loading and staging, delaying pre-assembly activities. | Storage efficiency indicator (reflects space utilization and throughput effectiveness). | Use ports with 24/7 operational capacity; parallelize pre-assembly and installation; allocate buffer zones for heavy components. | Vis and Ursavas (2016, p. 83). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Regional Infrastructure Gaps** | Dependence on distant suppliers due to lack of local fabrication sites increases transport time and cost. | Infrastructure readiness indicator (qualitative assessment of port and regional supply-chain capacity). | Establish regional manufacturing hubs and integrated logistics corridors (e.g., Esbjerg–Cuxhaven model). | Díaz and Guedes Soares (2023, pp. 17–18); González et al. (2024, Sec. 3.1). |
| **Port and Marshalling Readiness** | Ports lack large laydown areas, heavy-lift quays, and sufficient bearing capacity; dual-port logistics used in Anholt case. | Port adequacy indicator (qualitative measure of infrastructure readiness for offshore logistics). | Designate dedicated marshalling hubs, expand bearing capacity (>20 t/m²), and develop Esbjerg-type shared-use models. | Poulsen & Lema (2017); Poulsen et al. (2013). |
| **Port Master Planning and Terminal Equipment (TEQ) Design** | Lack of heavy-lift design guidelines and inadequate master planning reduce operational efficiency. | Port readiness index (composite indicator combining depth, crane capacity, and laydown space). | Issue standardised port construction guidelines and expert plans for offshore wind logistics. | Poulsen et al. (2013, LogMS). |

**Theme 3 – Vessel Availability, Scheduling, and Load Optimization**

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Vessel Availability and Charter Cost** | Heavy-lift vessels (HLVs) and tugs have high day rates; vessel shortages cause delays in critical lifting and towing phases. | Vessel utilization indicator (measures operational readiness and fleet sufficiency). | Use ordinary tugs for TLPs; optimize towing cycles; charter multiple vessels to increase operational overlap during weather windows. | Díaz and Guedes Soares (2023, pp. 14–16). |
| **Vessel Load and Capacity Optimization** | Limited deck space restricts number of turbines per trip; overcapacity vessels are costly and underutilized. | Load optimization indicator (evaluates vessel loading efficiency and scheduling balance). | Optimize deck load through discrete-event simulation; select vessel size based on turbine count and port–site distance. | Vis and Ursavas (2016, pp. 83–84, 90). |
| **Scheduling and Operation Sequencing** | Inefficient task sequencing prolongs vessel idle time and project duration | Scheduling reliability indicator (qualitative measure of operational sequencing efficiency). | Integrate vessel, port, and weather data for planning; allow parallel operations when feasible | Vis and Ursavas (2016, pp. 87–88). |
| **Vessel Transit and Turnaround Time** | Extended round-trip times for distant sites (>100 km) reduce available weather windows and extend project duration. | Operational turnaround indicator (reflects time efficiency per trip). | Use high-capacity vessels or semi-submersible barges; pre-assemble turbine modules to minimize offshore operations. | Vis and Ursavas (2016, pp. 89–90); Díaz and Guedes Soares (2023, pp. 8–10). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Multi-Vessel Coordination Complexity** | Coordination of multi-vessel logistics increases project complexity and raises risk of idle time. | Coordination efficiency indicator (assesses degree of synchronization among vessel operations). | Implement integrated scheduling systems and centralized logistics coordination; simulate alternative vessel routing scenarios. | Vis and Ursavas (2016, pp. 88–91); González et al. (2024, Sec. 4.1). |
| **Wind Turbine Installation Vessel (WTIV) and Heavy-Lift Vessel Capacity Limits** | Existing fleets undersized for 12–15 MW turbines; long build lead times create charter scarcity and cost inflation. | Vessel utilisation indicator (qualitative KPI tracking charter efficiency and scheduling adequacy). | Develop long-term policies (2030+), establish shared vessel pools, and explore hybrid jack-up/barge conversions. | Poulsen & Lema (2017). |
| **WTIV Availability and Fleet Mix** | Multiple WTIVs mobilised at Anholt due to weather and seabed disruptions, demonstrating need for redundancy. | Fleet adequacy indicator (assesses flexibility and availability of installation assets). | Maintain standby vessel contracts and diversify fleet portfolios across project phases. | Poulsen et al. (2013, Anholt Case). |

**Theme 4 – Supply Chain and Logistics Coordination**

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Supplier Coordination and Synchronization** | Lack of alignment between component manufacturing rate and installation schedule creates idle inventory or delays. | Supply synchronization indicator (evaluates alignment between manufacturing and installation rates). | Introduce supplier sub-models to balance production and outbound flow; coordinate port staging with production cycles. | Irawan et al. (2018, p. 1197); Díaz and Guedes Soares (2023, pp. 15–16). |
| **Complex Logistics Networks** | Multi-tiered supply chains (suppliers → ports → vessels → site) increase coordination difficulty and risk of bottlenecks. | Network integration indicator (assesses cohesion among logistics tiers and stakeholder communication). | Develop simulation-based logistics models integrating cost and time data; use centralized logistics platforms. | Díaz and Guedes Soares (2023, p. 5). |
| **Inventory Management and Port Storage** | Limited storage capacity at ports and plants leads to idle stock or shortages. | Storage adequacy indicator (reflects space utilization and just-in-time balance). | Optimize inventory via ILP and enforce holding-cost penalties to sustain JIT. | Irawan et al. (2018, p. 1198). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Transport Network Complexity** | Multi-node transport routes increase time and cost variability; inefficient routing raises LCoE. | Route optimization indicator (qualitative measure of transport network efficiency). | Apply Integer Linear Programming (ILP) to optimize routing, cost, and scheduling across multi-modal networks. | Irawan et al. (2018, p. 1195). |
| **Cross-Border Coordination** | Optimal port locations may fall outside national boundaries, complicating customs, and legal processes. | Cross-border efficiency indicator (reflects coordination of international logistics flows). | Adopt cross-border planning; prioritize total cost minimization over jurisdictional constraints. | Irawan et al. (2018, p. 1204). |

**Theme 5 – Cost Efficiency and Installation Time Optimization**

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **High Installation Cost and LCOE Sensitivity** | Installation costs represent 12–22% of total CAPEX; inefficiencies increase overall LCoE (50–125 €/MWh). | Cost efficiency indicator (qualitative measure of installation cost control and optimization). | Integrate logistics planning into early design; reduce vessel idle time and total installation days through pre-assembly. | Díaz and Guedes Soares (2023, pp. 1–2); González et al. (2024, Sec. 3.2). |
| **Component Cost Dominance** | Nacelle cost accounts for ~70% of total logistics expenditure, making nacelle transport efficiency critical. | Component value sensitivity indicator (assesses impact of high-cost components on logistics). | Prioritize nacelle transport optimization; explore shared transport and lightweight design. | Irawan et al. (2018, p. 1204). |
| **Installation Time Optimization** | Floating projects achieve up to 30%-time reduction compared to fixed foundations through pre-assembly and tug-tow methods. | Installation performance indicator (measures overall schedule efficiency and time savings). | Use integrated logistics models to identify time bottlenecks; optimize sequence and increase pre-assembly levels. | Díaz and Guedes Soares (2023, p. 16); González et al. (2024, Sec. 2.4). |
| **Transportation Cost vs. Time Trade-off** | Vessel underutilization and overland transport increase both time and cost. | Cost–time balance indicator (evaluates optimization between transport cost and efficiency). | Balance cost-time relationship with dynamic transport planning and vessel load optimization. | Irawan et al. (2018, pp. 1199–1200). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Port & Staging Cost Variation** | Port operations cost varies between 6–20 M EUR depending on site, affecting CAPEX. | Port cost efficiency indicator (qualitative measure of staging expenditure efficiency). | Evaluate port efficiency and centralize pre-assembly to cut delays. | Díaz and Guedes Soares (2023, p. 14). |
| **Project Coordination and Contracting Model** | Multi-contracting created fragmented responsibilities and weak logistics leadership. | Coordination effectiveness indicator (measures integration quality among contractors and logistics actors). | Adopt EPCi or appoint a dedicated 4PL logistics integrator to ensure early involvement in FEED stages. | Poulsen & Lema (2017). |
| **Lack of Logistics Strategy** | Case study (DONG Energy) revealed absence of formal logistics department or life-cycle integration. | Organizational maturity indicator (evaluates presence of structured logistics governance). | Create a centralized logistics competence centre; integrate horizontally across life-cycle phases. | Poulsen & Hasager (2016). |

**Theme 6 – Data, Model Validation, and Market Readiness**

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Data Scarcity and Model Validation** | Lack of real floating offshore wind data and confidentiality reduce benchmarking accuracy. | Model validation indicator (assesses robustness and reliability of simulation data). | Apply sensitivity analysis for parameter validation; integrate empirical data from pilot farms. | Díaz and Guedes Soares (2023, p. 17). |
| **Computational Complexity** | Large-scale optimization models (multi-product, multi-period) require extensive solver time. | Computational scalability indicator (evaluates model performance and efficiency). | Use decomposition or CPLEX solvers; modularize model stages for computational efficiency. | Irawan et al. (2018, p. 1203). |
| **EU Market Fragmentation** | Fragmented logistics networks and lack of skilled operators increase costs and reduce coordination efficiency. | Market integration indicator (reflects maturity of regional collaboration and operator training). | Standardize procedures, training, and digital coordination platforms to enhance cooperation. | Díaz and Guedes Soares (2023, pp. 17–18). |
| **Digitalisation and Data Integration Gaps** | Non-interoperable data systems across design, logistics, and installation hinder predictive decisions. | Digital readiness indicator (qualitative KPI of data interoperability and system integration). | Create digital twin and simulation tools to synchronize logistics and engineering workflows | González et al. (2024, Sec. 4.3). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | Proposed Mitigation Strategy | References (Harvard Style) |
|---|---|---|---|---|
| **Knowledge Transfer EU ↔ China** | Rapid Chinese offshore expansion faces capability gaps; limited transfer of EU logistics experience. | Knowledge transfer indicator (qualitative KPI assessing learning maturity across markets). | Facilitate joint ventures and standardized offshore training programs to accelerate skill transfer. | Poulsen & Lema (2017). |
| **Human Resources and Training Gaps** | Industry lacks sufficient logistics professionals and formal HRM frameworks. | Competence readiness indicator (evaluates workforce availability and skill preparedness). | Establish targeted logistics education and training programs under national wind strategies. | Poulsen et al. (2013, LogMS). |

## APPENDIX B: Inferred Demand-Side Stakeholder Requirements

### Theme 1 – Weather and Environmental Challenges

| Operational Requirement | Underlying Challenge | Implication | Stakeholder Expectation | References |
|---|---|---|---|---|
| **Weather-resilient and data-driven installation planning** | Unpredictable wind and wave conditions restrict lifting and towing operations | Downtime increases LCoE and erodes project reliability | LSPs must offer simulation-based planning, forecast-integrated scheduling, and quantified weather-window assurance.<br>(> 80 % operational weather efficiency) | Vis & Ursavas (2016); Díaz & Guedes Soares (2023); Poulsen & Lema (2017) |
| **Dynamic and adaptive scheduling** | Limited forecast accuracy causes idle vessels and poor resource use | Inaccurate weather data leads to costly delays | LSPst integrate real-time meteorological data and re-planning tools within installation control systems | González et al. (2024) §2.3; Díaz & Guedes Soares (2023) |

**Theme 2 – Port Infrastructure and Capacity Constraints**

| Operational Requirement | Underlying Challenge | Implication | Stakeholder Expectation | References |
|---|---|---|---|---|
| **Heavy-lift and deep-draft marshalling ports** | Limited quay length, depth, and bearing capacity (< 20 t/m²) restrict pre-assembly and loading | Port bottlenecks create schedule risk | Developers expect dedicated offshore-wind terminals with ≥ 1000 t cranes and 24/7 operations | Díaz & Guedes Soares (2023); Irawan et al. (2018); Poulsen et al. (2013) |
| **Integrated port–manufacturing clusters** | Lack of local fabrication and storage space | Long supply lines and congestion | Expect co-located fabrication–assembly zones enabling just-in-time component flow | González et al. (2024); Poulsen & Lema (2017) |
| **Standardised port readiness and planning** | Absence of design guidelines for TEQ and layout | Uneven infrastructure readiness | Require transparent port-readiness indices and compliance with offshore-logistics standards | Poulsen et al. (2013 LogMS) |

**Theme 3 – Vessel Availability, Scheduling and Load Optimization**

| Operational Requirement | Underlying Challenge | Implication | Stakeholder Expectation | References |
|---|---|---|---|---|
| **Guaranteed vessel availability** | Scarcity of WTIVs and HLVs inflates day rates | Charter scarcity increases LCoE | Developers expect long-term fleet pooling and redundancy plans. | Poulsen & Lema (2017); Díaz & Guedes Soares (2023) |
| **Optimized deck loading and turnaround** | Limited deck capacity and long transit routes | Under-utilized vessels raise costs | Expect data-driven load optimization and voyage simulation models. | Vis & Ursavas (2016) |
| **Coordinated multi-vessel operations** | Complex scheduling and weather disruption | Idle time from poor synchronization | Require digital fleet-orchestration platforms integrating weather, port, and routing data | González et al. (2024 §4.1); Vis & Ursavas (2016) |

**Theme 4 – Supply Chain and Logistics Coordination**

| Operational Requirement | Underlying Challenge | Implication | Stakeholder Expectation | References |
|---|---|---|---|---|
| **End-to-end supply-chain visibility** | Multi-tier supplier networks lack synchronization | Component idle time or shortage risk | Developers expect integrated digital platforms linking production, ports, and vessels. | Díaz & Guedes Soares (2023); Irawan et al. (2018) |
| **Centralized coordination and contracting** | Fragmented responsibilities across contractors | Weak logistics leadership and accountability | Demand a single 4PL/EPCi logistics integrator involved from FEED phase | Poulsen & Lema (2017) |

**Theme 5 – Cost Efficiency and Installation Time Optimization**

| Operational Requirement | Underlying Challenge | Implication | Stakeholder Expectation | References |
|---|---|---|---|---|
| **Logistics as a cost-optimization lever** | Installation inefficiencies raise LCoE by 12–22 % | Poor cost control undermines competitiveness | Developers require cost–time transparency and measurable LCoE contribution from LSPs. | Díaz & Guedes Soares (2023); González et al. (2024); Poulsen & Hasager (2016) |
| **Pre-assembly and modular operations** | Excessive offshore lifts increase exposure time | Reduced productivity | Expect ≥ 20–30 % time reduction through onshore pre-assembly and parallel operations | Vis & Ursavas (2016); Díaz & Guedes Soares (2023) |
| **Innovation implementation** | Fragmented R&D and low logistics innovation uptake | Limited process improvement | Require structured innovation funnels prioritizing cost, HSEQ, and reliability gains | Poulsen & Hasager (2016) |

**Theme 6 – Data, Model Validation and Market Readiness**

| Operational Requirement | Underlying Challenge | Implication | Stakeholder Expectation | References |
|---|---|---|---|---|
| **Empirical model validation** | Limited access to real-farm data | Weak confidence in digital planning outputs | Developers expect validated simulation models supported by pilot-farm evidence | Díaz & Guedes Soares (2023 p. 17) |
| **Digital interoperability** | Disconnected IT systems across design and logistics | Decision delays and data silos | Require digital-twin–based coordination and interoperable data platforms | González et al. (2024 §4.3) |
| **Skilled workforce and knowledge transfer** | Lack of trained logistics professionals and EU ↔ new-market knowledge flow | Capability gaps constrain scale-up | Expect certified training schemes and structured international learning programmes | Poulsen et al. (2013 LogMS); Poulsen & Lema (2017) |

## APPENDIX C: Türkiye Component Manufacturing Analysis

| Component / Category | Local Notable Companies | Track Record & Capacity in Offshore Wind | Capability in Parallel Sectors | Benefits of Türkiye Supply | Investment Risk in Türkiye | Size of Opportunity | Grade (Overall Maturity) | World Bank Finding (with page) | Interpretation / Logistics-Supply-Chain Implication |
|---|---|---|---|---|---|---|---|---|---|
| **Nacelle / Hub & Assembly** | Siemens Gamesa | 1 – No experience in offshore wind | 3 – Companies in parallel sectors can enter market with high barriers to investment | 2 – Some benefits in local supply but no significant impact on cost or risk | 1 – Investment needs market certainty ≥ 5 years | 4 – > 5 % of lifetime project expenditure | Medium | "Major WTG components such as the nacelle, hub, gearbox and bearing housing require large steel castings… However, several Turkish companies already present the potential to move into the sector. Siemens Gamesa has a nacelle factory in İzmir." (pp. 121–122) | Turkish firms can supply sub-assemblies, but full nacelle integration still imported. Heavy-haul logistics, large coastal lay-down yards, and coordination between foundries and ports are required for scaling. |

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| Component / Category | Local Notable Companies | Track Record & Capacity in Offshore Wind | Capability in Parallel Sectors | Benefits of Türkiye Supply | Investment Risk in Türkiye | Size of Opportunity | Grade (Overall Maturity) | World Bank Finding (with page) | Interpretation / Logistics-Supply-Chain Implication |
|---|---|---|---|---|---|---|---|---|---|
| **Generator** | Gamak, Ateşçelik, Aemot | 1 – No experience in offshore wind | 3 – Parallel sectors able to enter market with high barriers | 4 – Work for projects must be undertaken locally | 3 – Low investment (≤ US $ 50 M) serving small sectors | 2 – 2 % – 3.5 % of lifetime expenditure | Low | "Offshore WTGs have shifted to mid-speed and direct-drive options… Suppliers like Winergy, Bosch Rexroth and ZF Wind serve Europe; ABB and others in Türkiye could start serving the offshore market." (pp. 122–123) | High-value heavy modules likely imported initially; logistics must handle secure transport & storage near nacelle assembly areas; domestic generator firms can repurpose with targeted investment and certification. |

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| Component / Category | Local Notable Companies | Track Record & Capacity in Offshore Wind | Capability in Parallel Sectors | Benefits of Türkiye Supply | Investment Risk in Türkiye | Size of Opportunity | Grade (Overall Maturity) | World Bank Finding (with page) | Interpretation / Logistics-Supply-Chain Implication |
|---|---|---|---|---|---|---|---|---|---|
| **Blades** | LM Wind Power, TPI Composites, Siemens Gamesa | 1 – No offshore track record | 3 – Parallel sectors able to enter with high barriers | 2 – Some benefits in local supply but no major impact on cost / risk | 1 – Investment needs market certainty ≥ 5 years | 4 – > 5 % of lifetime expenditure | High | “The huge blade size requires advanced design and fabrication and imposes transport constraints. LM Wind Power operates in Bergama, Siemens Gamesa is building in Aliağa, and TPI Composites is active in İzmir.” (pp. 120–121) | Existing Aegean-region blade plants provide powerful base. Transport of 80–107 m blades demand reinforced roads, special trailers, and heavy-lift load-out cranes. Co-location near deep-draft ports minimises handling risk and delay. |

## APPENDIX D: TOWS Analysis Interpretation

| Internal / External Factors | | Opportunities (O) |
|---|---|---|
| **Strengths (S)** | **ST Strategies – Use Strengths to Mitigate Threats:**<br>• Simulate existing port and road connectivity to anchor pilot projects before foreign companies enter the market.<br>• Promote Türkiye's marine engineering expertise to secure regional contracts.<br>• Deploy public–private logistics clusters to compete with North Sea hubs.<br>• Digitalisation innovation, possibility of partnerships with mature market stakeholders.<br>• Leverage OEM partnerships for early participation in net - generation turbine. | **SO Strategies – Leverage Strengths to Exploit Opportunities:**<br>• Build on Türkiye's industrial base and OEM presence to position İzmir–Aliağa as a regional OW logistics hub.<br>• Use shipbuilding and heavy fabrication capabilities to diversify into offshore installation vessel construction.<br>• Develop joint R&D programmes with global OEMs for adaptation to 8–15 MW turbines and floating foundations.<br>• Integrate manufacturing clusters with port infrastructure via dedicated logistics corridors. |

| Internal / External Factors | | Opportunities (O) |
|---|---|---|
| **Weaknesses (W)** | **WT Strategies – Defensive Responses to Minimise** Threats and Weaknesses:<br>• Implement phased readiness programmes to build capability incrementally.<br>• Create a central Offshore Logistics Coordination Unit (OLCU) to harmonise regulation and permitting.<br>• Establish strategic alliances with European ports for interim heavy-lift capacity.<br>• Adopt modular, scalable port development plans to accommodate turbine size evolution. | **WO Strategies – Overcome Weaknesses by Using** Opportunities:<br>• Use PPP models to upgrade ports (İzmir, Bandırma, Filyos) to offshore-ready standards.<br>• Encourage co-investment between shipyards and utilities for jack-up or heavy-lift vessels.<br>• Introduce national offshore-logistics certification to formalise coordination.<br>• Incentivise relocation of inland manufacturers to coastal zones to reduce overland bottlenecks. |

## APPENDIX E: Full Porter's Five Forces Analytical Matrix

**Porter's Five Forces: Türkiye's Offshore Wind Supply Chain and Logistics Context**

*(Source: World Bank Offshore Wind Roadmap for Türkiye, 2024; author's synthesis)*

| Force | Key Factors | Intensity | Analytical Interpretation |
|---|---|---|---|
| **1. Competitive Rivalry (Industry Competition)** | Limited domestic competition; early-stage market with few active players. International competition from established North Sea logistics hubs (Esbjerg, Rotterdam, Cuxhaven). Entry of European EPCs (e.g., DEME, Van Oord) likely via joint ventures. | **Medium** | Rivalry remains moderate in Türkiye's nascent OW logistics market. As Türkiye launches its first YEKA offshore projects, competition will increase—especially among international players seeking early market positioning. |
| **2. Threat of New Entrants** | High capital intensity (vessels, cranes, port upgrades). Complex permitting and regulatory environment. However, Türkiye's strong shipbuilding base and geographic proximity to projects lower entry barriers for domestic firms. | Medium-Low | Entry barriers are substantial due to capital, safety, and certification requirements. Yet Türkiye's mature fabrication and maritime sectors can pivot into offshore logistics if supported by targeted incentives and partnerships. The first wave of YEKA projects will define whether new domestic entrants gain traction or remain peripheral. |

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| Force | Key Factors | Intensity | Analytical Interpretation |
|---|---|---|---|
| **3. Bargaining Power of Suppliers (Port Owners, Vessel Owners, OEMs, and Heavy-Lift Service Providers)** | Port operators control limited deep-water berths suitable for offshore staging. Vessel owners (jack-ups, heavy lifts) hold strong leverage due to global shortage. OEMs (Siemens Gamesa, GE, Vestas) and crane providers set technical standards. | **High** | Supplier power is currently high and constitutes a strategic vulnerability. Port owners control scarce physical infrastructure; vessel and crane owners dictate mobilisation costs; OEMs influence scheduling and integration standards. Unless Türkiye develops domestic vessel and port capacity, supplier dominance will continue to constrain project economics. |
| **4. Bargaining Power of Buyers (Developers, EPCs, and Utilities)** | Few buyers (e.g. Enerjisa, Borusan EnBW). Early-stage market limits their negotiation leverage with ports and vessel providers. Over time, as project pipeline expands, buyer concentration will strengthen their position. | Medium | Buyers currently face limited local alternatives for port and marine logistics, keeping their leverage moderate. However, in the medium term, as more projects enter the pipeline and multiple LSPs emerge, buyers will exert greater control over contracting terms, especially through multi-project procurement frameworks. |
| **5. Threat of Substitutes** | No direct substitutes for offshore-wind logistics assets. However, alternative renewable investments (solar, hydrogen, onshore wind %7.07-highest share ,7.07% | | 5. Threat of Substitutes |

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### APPENDIX F: KPI AND RISK ANALYSIS

Each challenge is assessed using a 1–5 risk scale (Very Low to Very High). Scores reflect two factors: **how important the challenge is for OW development and how difficult it is to mitigate within the Turkish context.** Both factors are combined through a **weighted-average score**, providing a clear measure of overall risk and helping identify priority areas for action.

**Theme 1 – (4.1.1 in chapter 4 main text) Weather & Environmental Challenges**

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Weather Dependency & Downtime Risk** | High winds (>15 m/s) and waves (>3 m) restrict lifting/towing; reduce workable days; increase vessel idle time and cost overruns. | *Weather-delay sensitivity indicator* (measures how strongly installation performance is affected by wind speed, wave height, and weather-window loss). | **4** Weather delays are a major cost driver for foreign-chartered WTIV/HLV vessels, but improved forecasting and higher pre-assembly can partially mitigate exposure. | Forecast-based scheduling; predictive metocean analytics; dynamic rescheduling; higher pre-assembly. | Türkiye must charter foreign WTIV/HLVs at high day rates, making every weather delay financially severe; limited OW operational experience increases exposure. | Vis & Ursavas (2016); Poulsen & Lema (2017); Díaz & Guedes Soares (2023); World Bank (2024). |

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Distance to Shore & Exposure Time** | Greater distance increases transit time, fuel use, and exposure to metocean limits, lowering installation efficiency. | Installation efficiency indicator (assesses vessel productivity, transit-time ratio, and installation output per weather window). | 3 | Distance to Shore & Exposure Time | Greater distance increases transit time, fuel use, and exposure to metocean limits, lowering installation efficiency. | Installation efficiency indicator (assesses vessel productivity, transit-time ratio, and installation output per weather window). |

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Wave & Sea-State Uncertainty** | Variable sea states delay tow-out and mooring operations, especially for floating wind. | Risk-resilience indicator (evaluates how installation processes react to wave variability and sea-state disruptions). | 3 | Wave & Sea-State Uncertainty | Variable sea states delay tow-out and mooring operations, especially for floating wind. | Risk-resilience indicator (evaluates how installation processes react to wave variability and sea-state disruptions). |

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Forecast Accuracy & Planning Reliability** | Low forecast accuracy reduces scheduling confidence and causes idle vessels. | Forecast-reliability indicator (measures prediction accuracy and its effect on daily planning, vessel dispatch, and installation continuity). | 3 | Forecast Accuracy & Planning Reliability | Low forecast accuracy reduces scheduling confidence and causes idle vessels. | Forecast-reliability indicator (measures prediction accuracy and its effect on vessel dispatch, and installation continuity). |

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Theme 1 indicates that weather and environmental conditions play a defining role in shaping installation dynamics and highlight several key areas where operational readiness can be further strengthened in Türkiye. High wind speeds, distance variabilities, sea-state variability, and forecast limitations naturally influence the number of workable offshore days, yet these challenges also offer opportunities to enhance planning tools and improve the efficiency of vessel utilisation. Türkiye's reliance on foreign WTIV/HLVs and lack of knowledge with tow-out and floating-platform operations underscore the value of building domestic capabilities in these areas and offer opportunities for international partnerships. The MOL risk indicators consistently show that weather challenges are a priority dimension for improvement, particularly as Türkiye continues to expand metocean measurement systems and invest in OW-specific forecasting technologies. Overall, with targeted development in forecasting accuracy, operational training, and data infrastructure, Türkiye can significantly enhance its ability to manage weather-related installation variability and align more closely with international best practices.

The risk assessment for Theme 1 produces an overall score of 3.25**,** placing weather and environmental constraints in the Moderate–High risk category for Türkiye's offshore-wind development. While offshore distances and wave variability present manageable operational challenges, the combination of foreign WTIV/HLV reliance**,** limited metocean data**,** and immature forecasting capability heightens exposure to weather-related delays and cost overruns. However, the analysis also shows that these risks are partially mitigable through improved forecasting accuracy, expanded pre-assembly, dynamic scheduling tools, and investment in metocean measurement systems. Overall, the findings indicate that weather-related uncertainties remain a priority area for early strategic action, but targeted technical and operational enhancements can significantly reduce their impact over time.

**Theme 2 – (4.1.2 in chapter 4 main text) Port Infrastructure and Capacity Constraints**

| Challenge Area | Key Issue | KPI (MOL) | RISK(MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Port Capacity and Layout Limitations** | Limited quayside depth, quay length, and staging area (~1800 m²/turbine) restrict pre-assembly and cause queueing delays. | Port efficiency indicator (evaluates adequacy of staging and handling capacity). | 5<br>Significant quay and laydown upgrades are required, and these large-scale investments and civil works are difficult to accelerate in the short term. | Develop dedicated OW marshalling ports; co-locate manufacturing and assembly to reduce double handling. | İzmir–Aliağa, Bandırma and Filyos require expanded laydown zones and strengthened quay surfaces to meet >20 t/m² bearing needs; coordinated use of nearby industrial zones can enable integrated pre-assembly. | Díaz and Guedes Soares (2023).<br>World Bank (2024). |

| Challenge Area | Key Issue | KPI (MOL) | RISK(MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Port Suitability and Accessibility** | Insufficient port draft is needed for accommodating WTIVs. | Port suitability score (AHP-based index measuring logistical accessibility). | 5 | Port Suitability and Accessibility | Insufficient port draft is needed for accommodating WTIVs. | Port suitability score (AHP-based index measuring logistical accessibility). |
| **Crane Capacity and Heavy-Lift Constraints** | Most EU ports <1000 t crane capacity, limiting turbine size assembly and loading speed. | Port crane utilization (indicator of lifting adequacy and operational readiness). | 3 | Crane Capacity and Heavy-Lift Constraints | Most EU ports <1000 t crane capacity, limiting turbine size assembly and loading speed. | Port crane utilization (indicator of lifting adequacy and operational readiness). |

| Challenge Area | Key Issue | KPI (MOL) | RISK(MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Port Storage and Pre-Assembly Congestion** | Limited port space causes congestion during loading and staging, delaying pre-assembly activities. | Storage efficiency indicator (reflects space utilization and throughput effectiveness). | 3 | Port Storage and Pre-Assembly Congestion | Limited port space causes congestion during loading and staging, delaying pre-assembly activities. | Storage efficiency indicator (reflects space utilization and throughput effectiveness). |
| **Regional Infrastructure Gaps** | Dependence on distant suppliers due to lack of local fabrication sites increases transport time and cost. | Infrastructure readiness indicator (qualitative assessment of port and regional supply-chain capacity). | 4 | Regional Infrastructure Gaps | Dependence on distant suppliers due to lack of local fabrication sites increases transport time and cost. | Infrastructure readiness indicator (qualitative assessment of port and regional supply-chain capacity). |

| Challenge Area | Key Issue | KPI (MOL) | RISK(MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Port and Marshalling Readiness** | Ports lack large laydown areas, heavy-lift quays, and sufficient bearing capacity; dual-port logistics used in Anholt case. | Port adequacy indicator (qualitative measure of infrastructure readiness for offshore logistics). | 5 Lack of dedicated marshalling hubs directly affects installation sequencing and requires complex national-level planning to resolve. Difficult to accelerate in the short term. | Designate dedicated marshalling hubs, expand bearing capacity (>20 t/m²), and develop Esbjerg-type shared-use models. | Türkiye will likely adopt dual-port strategies (e.g., fabrication near İzmir + marshalling in Aliağa/Filyos); national guidelines are needed for bearing capacity upgrades and shared terminal use. | Poulsen & Lema (2017); Poulsen et al. (2013); World Bank (2024). |

| Challenge Area | Key Issue | KPI (MOL) | RISK(MOL) | Mitigation Strategy | Türkiye-Specific Implications | Ref |
|---|---|---|---|---|---|---|
| **Port Master Planning and Terminal Equipment (TEQ) Design** | Lack of heavy-lift design guidelines and inadequate master planning reduce operational efficiency. | Port readiness index (composite indicator combining depth, crane capacity, and laydown space). | 3<br>The absence of standardised OW port guidelines undermine efficiency yet can be addressed relatively quickly through coordinated planning. | Issue standardised port construction guidelines and expert plans for offshore wind logistics. | National OW port blueprint is required to harmonize TEQ standards, component flow layouts, heavy-haul access, and safety criteria; would accelerate readiness the Marmara Aegean corridor. | Poulsen et al. (2013, LogMS); World Bank (2024). |

Theme 2 highlights that port infrastructure is a central enabler of OW logistics, and while current capacity varies across Türkiye's ports, the overall landscape presents both clear challenges and strong development potential. International findings show that adequate quay depth, lifting capacity, and staging areas are essential for efficient pre-assembly and heavy-lift operations. Within this context, ports such as İzmir–Aliağa, Bandırma, and Filyos already provide a valuable foundation, and with targeted upgrades—particularly in heavy-lift reinforcement, lay-down space, corridor planning, and TEQ design—they can evolve into competitive OW hubs. The presence of nearby manufacturing clusters further strengthens this potential, as closer synchronisation between fabrication and port operations can significantly enhance logistics efficiency. While certain infrastructure gaps remain, the nation is well-positioned to build the port capabilities required for large-scale OW deployment through focused investment and integrated master planning.

Theme 2 yields an overall score of 4.00, placing port infrastructure and capacity constraints firmly in the High-Risk category for Türkiye's offshore-wind development. The most critical limitations—restricted quay depth and staging areas, inadequate draft for WTIV access, regional transport bottlenecks, and the absence of dedicated marshalling hubs—represent structural weaknesses that require major capital investment and coordinated long-term planning. While TEQ upgrades and master-planning improvements can offer partial relief, the scale and duration of required civil works mean that short-term mitigation will remain limited. Overall, the assessment underscores an urgent national priority for accelerated port development, integrated heavy-haul corridor planning, and clear offshore-wind port standards to ensure that installation operations can meet international performance and safety expectations.

**Theme 3 – (4.1.3 in chapter4 main text) Vessel Availability, Scheduling, and Load Optimization**

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | References |
|---|---|---|---|---|---|---|
| **Vessel Availability and Charter Cost** | Heavy-lift vessels (HLVs) and tugs have high day rates; vessel shortages cause delays in critical lifting and towing phases. | Vessel utilization indicator (measures operational readiness and fleet sufficiency). | 4<br>Reliance on foreign WTIV/HLV fleets makes availability a major bottleneck, however mitigation through domestic vessel development requires long investment lead times. | Use ordinary tugs for TLPs; optimize towing cycles; charter multiple vessels to increase operational overlap during weather windows. | Türkiye currently relies heavily on foreign HLV and WTIV fleets; early charter contracting, and domestic tug optimization will be essential to avoid cost escalation during YEKA projects. Development of a limited national heavy-lift pool would reduce exposure to global charter volatility. | Díaz and Guedes Soares (2023, pp. 14–16); World Bank (2024). |

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | References |
|---|---|---|---|---|---|---|
| **Vessel Load and Capacity Optimization** | Limited deck space restricts number of turbines per trip; overcapacity vessels are costly and underutilized. | Load optimization indicator (evaluates vessel loading efficiency and scheduling balance). | 3<br>Load planning inefficiencies increase trip numbers, but optimisation can be achieved relatively easily through digital modelling and vessel–port matching. | Optimize deck load through discrete-event simulation; select vessel size based on turbine count and port–site distance. | Long port–site distances in the Marmara and Black Sea make optimal load planning crucial; aligning vessel choice with Aliağa, Bandırma, or Filyos layouts will improve cost efficiency and reduce offshore idle time. | Vis and Ursavas (2016); World Bank (2024). |

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | References |
|---|---|---|---|---|---|---|
| **Scheduling and Operation Sequencing** | Inefficient sequence of loading, jacking, and installation increases idle vessel time and total project duration. | Scheduling reliability indicator (measure of operational sequencing efficiency). | 3<br>Sequencing problems create costly idle time, yet advanced scheduling tools and integrated planning can easily substantially reduce this risk. | Employ decision-support models integrating vessel, port, and weather data; plan simultaneous operations where feasible. | Türkiye's variable wind and wave patterns, especially in the Aegean and Western Black Sea, require advanced scheduling tools to prevent WTIV idle time; coordination with port masterplans will be critical for maintaining continuous operation flow. | Vis and Ursavas (2016); World Bank (2024). |

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| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | References |
|---|---|---|---|---|---|---|
| **Vessel Transit and Turnaround Time** | Extended round-trip times for distant sites (>100 km) reduce available weather windows and extend project duration. | Operational turnaround indicator (reflects time efficiency per trip). | 3<br><br>Longer distances to Black Sea and Marmara sites increase exposure, though higher pre-assembly and larger-capacity vessels offer effective mitigation. | Use high-capacity vessels or semi-submersible barges; pre-assemble turbine modules to minimize offshore operations. | Potential offshore sites such as Saros, Gelibolu in Marmara, and the Western Black Sea feature significant offshore distances; using larger-capacity vessels and high pre-assembly ratios at Aliağa/Filyos will be essential to maintain weather-window efficiency. | Vis and Ursavas (2016, pp. 89–90); Díaz and Guedes Soares (2023, pp. 8–10); World Bank (2024). |

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| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | References |
|---|---|---|---|---|---|---|
| **Multi-Vessel Coordination Complexity** | Coordination of multi-vessel logistics increases project complexity and raises risk of idle time. | Coordination efficiency indicator (assesses degree of synchronization among vessel operations). | 3 Fragmented port and contractor structures increase coordination difficulty, and establishing a central logistics control tower requires significant institutional alignment. | Implement integrated scheduling systems and centralized logistics coordination; simulate alternative vessel routing scenarios. | Türkiye's fragmented maritime operations (multiple regional ports, diverse contractors) create coordination risk; adopting a centralized logistics control tower—like Esbjerg's model—would significantly reduce idle vessel hours and interface delays | Vis and Ursavas (2016, pp. 88–91); González et al. (2024, Sec. 4.1); World Bank (2024). |

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | References |
|---|---|---|---|---|---|---|
| **Wind Turbine Installation Vessel (WTIV) and Heavy-Lift Vessel Capacity Limits** | Existing fleets undersized for 12–15 MW turbines; long build lead times create charter scarcity and cost inflation. | Vessel capability adequacy indicator" (Assesses whether the available WTIV/HLV fleet has the technical capability (lifting height, crane capacity, deck strength) to install the targeted turbine class (12–15 MW). | 4<br>Access to turbine-class WTIVs is limited and expensive, and developing or converting domestic vessels is a complex, long-term investment. | Establish long-term policy frameworks (2030+), create shared vessel pools, and consider hybrid jack-up/barge conversions. | Türkiye lacks turbine-class WTIV capability; coordinated investment incentives and joint ventures with international operators could ensure access to next-generation vessels without excessive charter premiums. Hybrid conversions in local shipyards may offer interim solutions. | Poulsen & Lema (2017); World Bank (2024). |

| Challenge Area | Key Issue | KPI (MOL) | Risk (MOL) | Mitigation Strategy | Türkiye-Specific Implications | References |
|---|---|---|---|---|---|---|
| **WTIV Availability and Fleet Mix** | Multiple WTIVs mobilised at Anholt due to weather and seabed disruptions, demonstrating need for redundancy. | Fleet adequacy indicator (assesses flexibility and availability of installation assets). | 3<br>Even when vessels exist, unpredictable weather and seabed conditions require redundancy, and this raises operational risk, though standby chartering and diversified fleet planning offer realistic mitigation. | Maintain standby vessel contracts and diversify fleet portfolios across project phases. | The nation’s exposure to unpredictable Aegean and Marmara weather regimes necessitates maintaining standby WTIV/HLV access during installation peaks; adopting Anholt-type redundancy will be vital to avoid cascading delays. | Poulsen et al. (2013, Anholt Case); World Bank (2024). |

Theme 3 highlights that vessel availability and multi-vessel coordination are central determinants of OW installation efficiency, particularly as turbine capacities reach 12–15 MW. International studies confirm that WTIV/HLV scarcity, high charter rates, and restricted deck space can constrain installation performance, yet these constraints also open avenues for optimisation through advanced load-planning, discrete-event simulation, and strategic charter management. Early-stage reliance on foreign installation vessels reinforces the importance of long-term charter agreements, structured regional partnerships, and data-driven fleet-utilisation models.

In addition, the country's strong shipbuilding base—in Tuzla, Yalova, and İzmir—creates a unique opportunity to develop auxiliary OW vessels and hybrid jack-up/barge conversions, reducing exposure to global charter volatility over time. As offshore sites vary in distance, from shorter Aegean routes to longer Black Sea transits, effective use of regional logistics hubs such as Aliağa, Tekirdağ, and Filyos will be essential for minimising mobilisation time and stabilising turnaround cycles. Weather-window sensitivity across these basins further underscores the need for integrated port-vessel-weather systems, centralised coordination mechanisms, and precise sequencing. With targeted investment in planning tools, vessel-access strategies, and regional hub development, the country can enhance installation performance and position itself competitively within the wider Eastern Mediterranean OW market.

The risk assessment for Theme 3 results in an overall score of 3.43, placing vessel availability, scheduling, and load optimisation closer to the High-Risk category for Türkiye's offshore-wind development. The most critical constraints—limited access to turbine-class WTIV/HLV vessels, dependence on foreign fleets, long mobilisation distances, and fragmented multi-vessel coordination—have significant implications for installation efficiency and project cost control. Although optimisation tools, pre-assembly strategies, and regional logistics hubs can partially mitigate these risks, long-term solutions require coordinated investment in vessel capability, shared fleet pools, and hybrid conversion programmes in domestic shipyards.

Effective risk reduction will also depend on structured international knowledge transfer, particularly in WTIV operations, floating-wind tow-out procedures, sequencing optimisation, and multi-vessel coordination—areas where Türkiye currently lacks operational experience. Overall, Theme 3 underscores the urgent need for vessel-focused capacity building, integrated scheduling systems, and formalised knowledge-transfer mechanisms to ensure reliable installation performance and competitive OW deployment in the Eastern Mediterranean.

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**Theme 4 – (4.1.4 in chapter4 main text) Supply Chain and Logistics Coordination**

| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye specific implications | References |
|---|---|---|---|---|---|---|
| **Supplier Coordination and Synchronization** | Lack of alignment between component manufacturing rate and installation schedule creates idle inventory or delays. | Supply synchronization indicator (evaluates alignment between manufacturing and installation rates). | 4<br><br>Tight synchronisation is difficult because inland factories and limited port laydown space make just-in-time flows extremely sensitive and challenging to stabilise. | Introduce supplier sub-models to balance production and outbound flow; coordinate port staging with production cycles. | Türkiye's strong manufacturing clusters (İzmir–Aliağa, Manisa) are located inland, increasing dependence on road transport and making tight synchronisation between factory output and port staging essential. Limited laydown capacity at ports makes just-in-time coordination more challenging in Türkiye than in mature European markets. | Irawan et al. (2018,). Díaz and Guedes Soares (2023); World Bank (2024) |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye specific implications | References |
|---|---|---|---|---|---|---|
| **Complex Logistics Networks** | Multi-tiered supply chains (suppliers → ports → vessels → site) increase coordination difficulty and risk of bottlenecks. | Network integration indicator (assesses cohesion among logistics tiers and stakeholder communication | 4<br>Fragmented multi-tier supply chains and weak digital integration significantly increase bottleneck risk, and establishing a unified coordination platform requires major institutional alignment. | Develop simulation-based logistics models integrating cost and time data; use centralized logistics platforms. | Türkiye's OW SC is still fragmented (factories → road → ports → offshore), increasing the likelihood of bottlenecks. notes that lack of integrated digital coordination-particularly in ports such as Aliağa and Bandırma—can affect operational continuity. | Díaz and Guedes Soares (2023). World Bank (2024) |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye specific implications | References |
|---|---|---|---|---|---|---|
| **Inventory Management and Port Storage** | Limited storage capacity at ports and plants leads to idle stock or shortages. | Storage adequacy indicator (reflects space utilization and just-in-time balance). | 4<br>Storage limitations pose a real constraint, but inventory optimisation and zoning solutions offer achievable mitigation if planned early. | Optimize inventory levels with ILP models; introduce holding-cost penalties to maintain just-in-time flow. | Ports in Türkiye have limited laydown capacity (<1800 m² per turbine) and restricted adjacent storage areas, making inventory build-up and JIT flows more sensitive. World Bank (2024) emphasises that “high pre-assembly + JIT” requires especially careful planning in Türkiye. | Irawan et al. (2018). World Bank (2024) |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye specific implications | References |
|---|---|---|---|---|---|---|
| **Transport Network Complexity** | Multi-node transport routes increase time and cost variability; inefficient routing raises LCoE. | Route optimization indicator (qualitative measure of transport network efficiency). | 4<br>Long inland transport routes, mountainous terrain, and insufficient heavy-haul corridors create high-risk variability that is difficult to reduce without major infrastructure upgrades. | Apply Integer Linear Programming (ILP) to optimize routing, cost, and scheduling across multi-modal networks. | Türkiye's major component manufacturing bases are in the Aegean, while deployment zones include the Black Sea and distant Aegean sites, making multi-modal heavy transport essential. Türkiye's heavy-transport corridors require upgrading to meet OW logistics standards. | Irawan et al. (2018). World Bank (2024). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye specific implications | References |
|---|---|---|---|---|---|---|
| **Cross-Border Coordination** | Optimal port locations may fall outside national boundaries, complicating customs, and legal processes. | Cross-border efficiency indicator (reflects coordination of international logistics flows). | 3<br><br>Cross-border routing offers flexibility but introduces customs and regulatory complexity, which can be mitigated with agreements and procedural harmonisation. | Adopt cross-border planning; prioritize total cost minimization over jurisdictional constraints. | Türkiye may use regional logistics hubs—such as ports in Greece, Bulgaria, or the Eastern Mediterranean—for certain turbine sizes and vessel draft requirements. This provides flexibility but requires streamlined customs processes and multi-country logistics protocols to support competitive OWoperations. | Irawan et al. (2018).<br>World Bank (2024) |

Theme 4 shows that the national OW SC has a strong industrial foundation but requires closer synchronisation and more integrated logistics planning to fully realise its potential. With major manufacturing clusters concentrated around İzmir–Aliağa and Manisa, the country already possesses a capable supplier ecosystem; however, the inland positioning of these facilities increases reliance on road transport and underscores the need to align factory output with port staging capacity. Limited laydown areas at candidate ports make just-in-time delivery and coordinated inventory management more critical than in mature European markets.

Another structural gap is the absence of a centralised 4PL/5PL integrator capable of orchestrating suppliers, ports, heavy transport, and vessel operations—something well established in hubs like Esbjerg and Rotterdam. The regulatory environment also requires further harmonisation, particularly regarding XXL-component transport corridors, port access standards and OW–specific procedures.

Geographically, the country benefits from access to multiple regional logistics corridors and retains the option of flexible cross-border routing through neighbouring ports when turbine size, draft constraints or vessel availability make this advantageous. Strengthening multimodal heavy-transport infrastructure, harmonising customs processes and adopting integrated digital planning platforms will significantly enhance competitiveness. With targeted coordination improvements, the existing industrial strengths can be transformed into a well-synchronised offshore-wind supply chain aligned with international best practice.

The risk assessment for Theme 4 yields an overall score of 3.8, placing supply-chain and logistics coordination firmly in the High-Risk category for Türkiye’s offshore-wind development. The most severe challenges relate to supplier synchronisation, fragmented multi-tier logistics networks, limited port storage capacity, and inadequate heavy-haul transport corridors—issues that together create systemic bottlenecks across inland manufacturing, port staging, and offshore installation interfaces.

Although inventory optimisation, ILP-based routing, and digital coordination platforms offer partial mitigation, meaningful improvement requires coordinated national action, cross-institutional alignment, and upgraded transport and port infrastructure. Overall, Theme 4 demonstrates that without strengthened synchronisation mechanisms, digital integration, and multimodal corridor development, Türkiye's OW SC will face persistent delays and cost escalation risks during early deployment phases.

**Theme 5 – (4.1.5 in chapter 4 main text) Cost Efficiency and Installation Time Optimization**

How severely do these operational challenges translate into cost and time risks?

| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | Risk (MOL) | Proposed Mitigation Strategy | Implications for Türkiye | References (Harvard Style) |
|---|---|---|---|---|---|---|
| **High Installation Cost and LCOE Sensitivity** | Installation costs represent 12–22% of total CAPEX; inefficiencies increase overall LCoE (50–125 €/MWh). | Cost efficiency indicator (qualitative measure of installation cost control and optimization). | 4<br><br>Installation costs are extremely sensitive to vessel idle time and long-distance mobilisation, and mitigation depends on improving pre-assembly and scheduling capabilities that will take time to establish. | Integrate logistics planning into early design; reduce vessel idle time and total installation days through pre-assembly. | Türkiye's early OW projects will rely on foreign WTIV/HLVs, making installation time a major cost driver. Mobilisation from the North Sea or Asia significantly increases LCOE sensitivity. Increasing pre-assembly and reducing offshore exposure can yield substantial cost gains in Türkiye. | Díaz and Guedes Soares (2023); González et al. (2024); World bank (2024) |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | Risk (MOL) | Proposed Mitigation Strategy | Implications for Türkiye | References (Harvard Style) |
|---|---|---|---|---|---|---|
| **Component Cost Dominance** | Nacelle cost accounts for ~70% of total logistics expenditure, making nacelle transport efficiency critical. | Component value sensitivity indicator (assesses impact of high-cost components on logistics). | 3<br><br>Nacelle and heavy-component imports drive logistics cost, but localisation in Türkiye's Aegean region provides a feasible mid-term mitigation pathway. | Prioritize nacelle transport optimization; explore shared transport and lightweight design. | Türkiye imports high-value nacelles and heavy components from Europe, making transport efficiency and damage avoidance essential to control logistics cost. Localisation efforts (Aegean industrial base) could decrease long-distance transport costs over time. | Irawan et al. (2018). World bank (2024). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | Risk (MOL) | Proposed Mitigation Strategy | Implications for Türkiye | References (Harvard Style) |
|---|---|---|---|---|---|---|
| **Installation Time Optimization** | Floating projects achieve up to 30%-time reduction compared to fixed foundations through pre-assembly and tug-tow methods. | Installation performance indicator (measures overall schedule efficiency and time savings). | 3<br><br>Time-efficient installation is critical in windy basins, yet increased pre-assembly and sequence optimisation offer practical, achievable mitigation options. | Use integrated logistics models to identify time bottlenecks; optimize sequence and increase pre-assembly levels. | Türkiye's windy Aegean and Black Sea conditions make time-efficient installation especially valuable. Increasing pre-assembly in ports such as Aliağa can significantly reduce offshore installation exposure and enhance schedule reliability. | Díaz and Guedes Soares (2023; González et al. (2024). World Nank (2024). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | Risk (MOL) | Proposed Mitigation Strategy | Implications for Türkiye | References (Harvard Style) |
|---|---|---|---|---|---|---|
| **Transportation Cost vs. Time Trade-off** | Vessel underutilization and overland transport increase both time and cost. | Cost–time balance indicator (evaluates optimization between transport cost and efficiency). | 3<br><br>Long inland transport routes raise cost-time sensitivity, but digital load optimisation and dynamic planning provide workable mitigation. | Balance cost-time relationship with dynamic transport planning and vessel load optimization. | Inland manufacturing clusters (İzmir, Manisa) increase road-transport distances, making vessel load optimization and cost–time balancing more important for Türkiye compared to compact European OW regions. | Irawan et al. (2018). World Bank (2024) |

| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | Risk (MOL) | Proposed Mitigation Strategy | Implications for Türkiye | References (Harvard Style) |
|---|---|---|---|---|---|---|
| **Port & Staging Cost Variation** | Port operations cost varies between 6–20 M EUR depending on site, affecting CAPEX. | Port cost efficiency indicator (qualitative measure of staging expenditure efficiency). | 3<br><br>Significant differences in port cost structures affect CAPEX, although benchmarking and centralised pre-assembly can reduce variability effectively. | Evaluate ports by cost efficiency; centralize pre-assembly to minimize port queueing time. | Türkiye's ports differ significantly in cost structure; early OW development will benefit from cost benchmarking across Aliağa, Bandırma, Filyos and potential regional hubs. Centralized pre-assembly can reduce port time and cost variability. | Díaz and Guedes Soares 2023); World Bank (2024). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | Risk (MOL) | Proposed Mitigation Strategy | Implications for Türkiye | References (Harvard Style) |
|---|---|---|---|---|---|---|
| **Project Coordination and Contracting Model** | Multi-contracting created fragmented responsibilities and weak logistics leadership. | Coordination effectiveness indicator (measures integration quality among contractors and logistics actors). | 5 | Project Coordination and Contracting Model | Multi-contracting created fragmented responsibilities and weak logistics leadership. | Coordination effectiveness indicator (measures integration quality among contractors and logistics actors). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (MOL) | Risk | Challenge Area | What the Articles Report / Key Variables | KPI (MOL) |
|---|---|---|---|---|---|---|
| **Lack of Logistics Strategy** | Case study (DONG Energy) revealed absence of formal logistics department or life-cycle integration. | Organisational maturity indicator (evaluates presence of structured logistics governance). | 5<br><br>**Logistics strategy is a foundational enabler** for cost control and schedule optimisation. The absence of a structured logistics governance framework limits efficiency, though creating a national competence centre is a realistic and implementable solution. Developing this is a **long strategic process,** not a quick fix. . | Create a centralised logistics competence centre; integrate horizontally across life-cycle phases. | Türkiye is at the early stage of OW development and can benefit from establishing a national logistics competence framework to support planning, training, and coordination across stakeholders. | Poulsen & Hasager (2016). World Bank (2024). |

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Cost efficiency and installation time optimisation are central levers for OW competitiveness, and the emerging sector has considerable potential to improve both through targeted planning and integrated logistics design. International studies show that installation activities constitute a major share of project CAPEX, making vessel idle time, pre-assembly levels, and overall transport efficiency key determinants of LCOE. Early reliance on foreign WTIV/HLVs and long-distance mobilisation heighten the importance of precise scheduling and sequencing to minimise delays and control costs.

The predominance of high-value imported components—particularly nacelles—reinforces the need for careful handling, optimised routing, and gradual localisation to reduce long-distance transport expenditure over time. Inland manufacturing clusters around İzmir–Manisa further increase the importance of efficient road-to-port integration and vessel load optimisation to manage the cost–time balance. Port operational costs vary widely across Aliağa, Bandırma, and Filyos, suggesting that centralised pre-assembly and early logistics involvement can significantly reduce variability in staging expenditure and improve CAPEX efficiency.

At the governance level, fragmented contracting practices and limited logistics maturity underscore the value of appointing a dedicated 4PL integrator or adopting EPCi-style models to improve coordination among developers, OEMs, and suppliers. Establishing a structured logistics competence framework would also support long-term capability development and ensure life-cycle integration across stakeholder groups. With earlier logistics integration, enhanced pre-assembly capacity, and more coherent contracting structures, the national offshore-wind sector can strengthen its cost performance and align more closely with international best practice.

Theme 5 yields an overall score of 3.71**,** placing cost efficiency and installation time optimisation firmly within the High-Risk category for Türkiye's OW development. Installation-related costs are especially vulnerable to vessel idle time, long mobilisation distances, and port-stage inefficiencies, all of which significantly increase LCOE during the early deployment phase.

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High-value component imports and inland manufacturing clusters further heighten sensitivity to transport inefficiencies, while substantial variation in port operating costs reinforces the need for centralised pre-assembly and early-stage logistics integration. Governance-related challenges—including fragmented contracting structures and the lack of a national logistics strategy—represent some of the most difficult barriers to mitigate, requiring institutional reform and coordinated sectoral leadership. Overall, without strengthened governance, improved sequencing and pre-assembly, and long-term capability development, Türkiye’s OW projects will continue to face elevated cost risks and reduced competitiveness.

**Theme 6 – (4.1.6 in chapter 4 main text) Data, Model Validation, and Market Readiness**

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye Mitigation | References |
|---|---|---|---|---|---|---|
| **Data Scarcity and Model Validation** | Lack of real floating offshore wind data and confidentiality reduce benchmarking accuracy. | Model validation indicator (assesses robustness and reliability of simulation data). | 5<br>The absence of long-term metocean and floating-wind datasets critically limits model accuracy, and mitigation requires multi-year measurement campaigns and regulatory change. | Apply sensitivity analysis for parameter validation; integrate empirical data from pilot farms. | Establish long-term metocean measurement stations (LiDAR buoys, wave buoys) in Aegean & Black Sea; mandate open-data requirements for Türkiye’s first pilot OW projects; integrate national datasets into digital twin platforms. | Díaz and Guedes Soares (2023). World Bank (2024) |

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye Mitigation | References |
|---|---|---|---|---|---|---|
| **Computational Complexity** | Large-scale optimization models (multi-product, multi-period) require extensive solver time. | Computational scalability indicator (evaluates model performance and efficiency). | 3<br>Advanced optimisation models demand significant computation, but partnering with universities and establishing HPC infrastructure provides a realistic and achievable mitigation pathway. | Use decomposition or CPLEX solvers; modularize model stages for computational efficiency. | Develop national high-performance computing (HPC) support for OW modelling; collaborate with universities (İTÜ, ODTÜ) for offshore digital modelling labs; fund computation infrastructure under Türkiye's National Energy R&D Program. | Irawan et al. (2018).<br>World Bank (2024. |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye Mitigation | References |
|---|---|---|---|---|---|---|
| **EU Market Fragmentation** | Fragmented logistics networks and lack of skilled operators increase costs and reduce coordination efficiency. | Market integration indicator (reflects maturity of regional collaboration and operator training). | 4<br><br>Fragmented standards and limited regional coordination increase integration difficulty, and aligning national protocols with EU frameworks requires sustained institutional cooperation. | Standardize procedures, training, and digital coordination platforms to enhance cooperation. | Align Türkiye's OW logistics standards with EU protocols; join regional OW training alliances; create North Aegean cross-border corridor partnerships to reduce fragmentation. | Díaz and Guedes Soares (2023). World Bank (2024. |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye Mitigation | References |
|---|---|---|---|---|---|---|
| **Digitalisation and Data Integration Gaps** | Lack of interoperable data systems between design, logistics, and installation phases limits predictive decision-making. | Digital readiness indicator (qualitative KPI of data interoperability and system integration). | 4<br><br>The lack of interoperable digital systems across design, logistics, and installation phases restricts predictive decision-making, and building integrated digital-twin platforms is a complex, long-term undertaking. | Develop digital twin and simulation-based planning systems to align logistics and engineering workflows. | Create a national Offshore Wind Digital Integration Platform under EMRA; integrate port, vessel, metocean, and supply-chain data; adopt digital twin frameworks used in Esbjerg/Rotterdam. | González et al. (2024). World bank (2024. |

| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye Mitigation | References |
|---|---|---|---|---|---|---|
| **Knowledge Transfer EU** | Rapid Chinese offshore expansion faces capability gaps; limited transfer of EU logistics experience. | Knowledge transfer indicator (qualitative KPI assessing learning maturity across markets). | 4<br><br>Major capability gaps persist in advanced OW logistics, and mitigation depends on structured international partnerships and mandatory knowledge-transfer frameworks. | Facilitate joint ventures and standardised offshore training programmes to accelerate skill transfer. | Develop Türkiye–EU joint OW logistics training centres; formalise OEM-led knowledge-transfer programmes (e.g., Siemens Gamesa, Vestas) in İzmir region; require knowledge-transfer clauses in YEKA tenders. | Poulsen & Lema (2017). World bank (2024). |

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| Challenge Area | What the Articles Report / Key Variables | KPI (Qualitative) | RISK (MOL) | Proposed Mitigation Strategy | Türkiye Mitigation | References |
|---|---|---|---|---|---|---|
| **Human Resources and Training Gaps** | Industry lacks sufficient logistics professionals and formal HRM frameworks. | Competence readiness indicator (evaluates workforce availability and skill preparedness). | 4<br>The shortage of specialised offshore-wind logistics professionals poses a significant bottleneck, and developing a skilled workforce requires multi-year education, certification, and training programmes. | Establish targeted logistics education and training programmes under national wind strategies. | Create national OW Logistics Academy (İzmir-based) with maritime universities; integrate OW modules into maritime engineering curricula; launch technician-level training for offshore crane, HLV operations and digital planning systems. | Poulsen et al. (2013, LogMS). World bank (2024). |

Theme 6 illustrates that the primary obstacle to OW digitalisation and model readiness arises not from technological limits but from the absence of a coordinated national data ecosystem. The country currently lacks long-duration metocean measurement networks, floating-wind operational datasets, and integrated digital platforms—gaps that complicate model validation, reduce forecasting accuracy, and limit the effectiveness of predictive scheduling compared with mature markets.

At the same time, a rapidly expanding R&D base, strong engineering universities, and national digital transformation programmes offer a solid foundation for building high-resolution metocean networks, HPC-supported modelling environments, and digital-twin systems. Enhancing cross-border collaboration, aligning training structures with EU frameworks, and establishing logistics competence centres can also accelerate knowledge transfer and enhance market readiness.

The most effective pathway involves early expansion of data infrastructure, adoption of interoperable digital systems and the development of skilled human capital so that the first generation of OW projects is supported by robust analytics, validated models, and integrated decision-support platforms.

Theme 6 yields an overall score of 4.0, placing data readiness, digital integration, and market capability firmly in the High-Risk category for Türkiye’s OW development. Unlike physical infrastructure gaps, this theme concerns the entire digital backbone of the sector; without a coordinated national data ecosystem, essential functions such as weather modelling, route optimisation, pre-assembly planning, vessel scheduling, port sequencing, cost estimation, risk forecasting, installation simulation, and logistics synchronisation all remain constrained or fail to operate at the required level.

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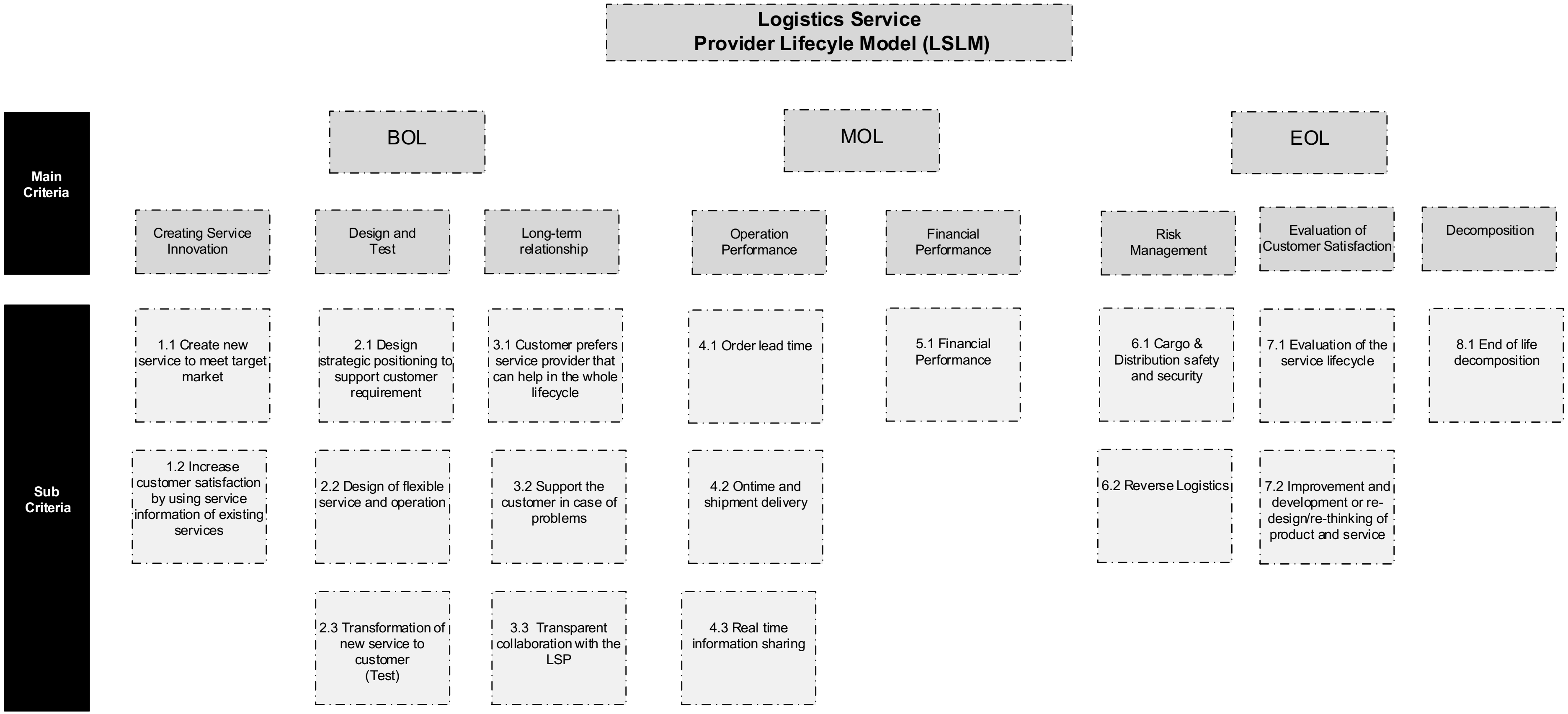
The lack of long-term metocean datasets, floating-wind operational data, interoperable digital systems, and a national data-governance model therefore represents a critical structural limitation that directly affects model validation, forecasting accuracy, and predictive installation planning. Although the country benefits from strong universities, a growing R&D base, and national digital-transformation programmes, substantial time and investment will be needed to develop HPC infrastructure, digital-twin platforms, cross-border training alliances, and specialised human capital. Overall, the assessment underscores that without early expansion of data systems, structured knowledge-transfer mechanisms, and comprehensive workforce development, Türkiye's first-generation OW projects will face significant uncertainty and limited analytical reliability.

## APPENDIX G: Tiwong's original Logistics Provider Lifecycle Model



## APPENDICES

## APPENDIX H: Signed Research Ethics Screening Form

*Do not amend before use*

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### Research Ethics Screening Form for Students

Middlesex University is concerned with protecting the rights, health, safety, dignity, and privacy of its research participants. It is also concerned with protecting the health, safety, rights, and academic freedom of its students and with safeguarding its own reputation for conducting high quality, ethical research.

*This Research Ethics Screening Form will enable students to self-assess and determine whether the research requires ethical review and approval via the Middlesex Online Research Ethics (MORE) form before commencing the study. Supervisors must approve this form after consultation with students.*

| | | |
|---|---|---|
| Student Name: | Diane Arcas Göçmez | Email: DA726@live.mdx.ac.uk |
| Research project title: | From Concept to Practice: Developing Demand-Side Oriented Logistics Service Models for Türkiye's Offshore Wind Sector | |
| Programme of study/module: | MBS 4856 Business transformation project | |
| Supervisor Name: | Ivelin Krastev | Email:surfbg@yahoo.com |

| *Please answer whether your research/study involves any of the following given below:* | | |
|---|---|---|
| 1. HANIMALS or animal parts. | ☐ Yes | ☒ No |
| 2. MCELL LINES (established and commercially available cells - biological research). | ☐ Yes | ☒ No |
| 3. HCELL CULTURE (Primary: from animal/human cells- biological research). | ☐ Yes | ☒ No |
| 4. HCLINICAL Audits or Assessments (e.g. in medical settings). | ☐ Yes | ☒ No |
| 5. XCONFLICT of INTEREST or lack of IMPARTIALITY. If unsure see "Code of Practice for Research" (Sec 3.5) at: https://unihub.mdx.ac.uk/study/spotlights/types/research-at-middlesex/research-ethics | ☐ Yes | ☒ No |
| 6. XDATA to be used that is not freely available (e.g. secondary data needing permission for access or use). | ☐ Yes | ☒ No |
| 7. XDAMAGE (e.g., to precious artefacts or to the environment) or present a significant risk to society). | ☐ Yes | ☒ No |
| 8. XEXTERNAL ORGANISATION – research carried out within an external organisation or your reseach is commissioned by a government (or government body). | ☐ Yes | ☒ No |
| 9. MFIELDWORK (e.g biological research, ethnography studies). | ☐ Yes | ☒ No |
| 10. HGENETICALLTY MODIFIED ORGANISMS (GMOs) (biological research). | ☐ Yes | ☒ No |
| 11. HGENE THERAPY including DNA sequenced data (biological research). | ☐ Yes | ☒ No |
| 12. MHUMAN PARTICIPANTS – ANONYMOUS Questionnaires (participants not identified or identifiable). | ☐ Yes | ☒ No |
| 13. XHUMAN PARTICIPANTS – IDENTIFIABLE (participants are identified or can be identified): survey questionnaire/ INTERVIEWS / focus groups / experiments / observation studies. | ☐ Yes | ☒ No |

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| | | |
|---|---|---|
| 14. [H]HUMAN TISSUE (e.g., human relevant material, e.g., blood, saliva, urine, breast milk, faecal material). | ☐ Yes | ☒ No |
| 15.[H]ILLEGAL/HARMFUL activities research (e.g., development of technology intended to be used in an illegal/harmful context or to breach security systems, searching the internet for information on highly sensitive topics such as child and extreme pornography, terrorism, use of the DARK WEB, research harmful to national security). | ☐ Yes | ☒ No |
| 16. [X]PERMISSION is required to access premises or research participants. | ☐ Yes | ☒ No |
| 17. [X]PERSONAL DATA PROCESSING (Any activity with data that can directly or indirectly identify a living person). For example data gathered from interviews, databases, digital devices such as mobile phones, social media or internet platforms or apps with or without individuals'/owners' knowledge or consent, and/or could lead to individuals/owners being IDENTIFIED or SPECIAL CATEGORY DATA (GDPR[1]) or CRIMINAL OFFENCE DATA.<br>[1]Special category data (GDPR- Art.9): "personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, and the processing of genetic data, biometric data for the purpose of uniquely identifying a natural person, data concerning health or data concerning a natural person's sex life or sexual orientation". | ☐ Yes | ☒ No |
| 18.[X]PUBLIC WORKS DOCTORATES: Evidence of permission is required for use of works/artifacts (that are protected by Intellectual Property (IP) Rights, e.g. copyright, design right) in a doctoral critical commentary when the IP in the work/artifactis jointly prepared/produced or is owned by another body | ☐ Yes | ☒ No |
| 19. [H]RISK OF PHYSICAL OR PSYCHOLOGICAL HARM (e.g., TRAVEL to dangerous places in your own country or in a foreign country (see https://www.gov.uk/foreign-travel-advice), research with NGOs/humanitarian groups in conflict/dangerous zones, development of technology/agent/chemical that may be harmful to others, any other foreseeable dangerous risks). | ☐ Yes | ☒ No |
| 20.[X]SECURITY CLEARANCE – required for research. | ☐ Yes | ☒ No |
| 21.[X]SENSITIVE TOPICS (e.g., anything deeply personal and distressing, taboo, intrusive, stigmatising, sexual in nature, potentially dangerous, etc). | ☐ Yes | ☒ No |

M – Minimal Risk; X – More than Minimal Risk. H – High Risk

If you have answered 'Yes' to ANY of the items in the table, your application REQUIRES ethical review and approval using the MOREform **BEFORE commencing your research**. Please apply for ethical approval using the MOREform (https://moreform.mdx.ac.uk/). Consult your supervisor for guidance. Also see *Middlesex Online Research Ethics* (MyLearning area) *and* *www.tiny.cc/mdx-ethics* (CS students).

If you have answered 'No' to ALL of the items in the table, your application is Low Risk and you may NOT require ethical review and approval using the MOREform before commencing your research. Your research supervisor will confirm this below.

Student Signature: [signature] Date: 15.10.2025

**To be completed by the supervisor:**

| *Based on the details provided in the self-assesment form, I confirm that:* | Insert Y or N |
|---|---|
| The study is Low Risk and *does not require* ethical review & approval using the MOREform | Y |
| The study *requires* ethical review and approval using the MOREform. | N |

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*Do not amend before use*

Middlesex University London

Superivsor Signature:............................... Date: 16/10/25........................

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