

# Overcoming institutional barriers in socio-technical transitions: The case of ship electrification project

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## ABSTRACT

This study explores the transition to all-electric RoPax ferry transportation, focusing on the institutional structures within the current business ecosystem that hinder this shift. RoPax shipping, which combines wheeled cargo transport with passenger services, significantly contributes to greenhouse gas emissions due to its reliance on internal combustion engines. Although recent regulations from the International Maritime Organization and the European Union promote alternative fuels, the adoption of electric vessels remains limited. Drawing on empirical data from a two-year project developing an electric RoPax vessel for a Baltic Sea route, this research involves collaboration with a shipyard, a ship operator, and a local energy company. Utilizing a framework that integrates the Multi-Level Perspective on socio-technical transitions, institutional theory, and business ecosystem analysis, the study reveals that the stability of the socio-technical regime is maintained through entrenched business ecosystem structures. Findings indicate that existing value creation configurations obstruct the transition to electric vessels, emphasizing that business ecosystems reflect embedded institutional arrangements. The proposed framework illustrates how regime stability is shaped by interdependent actor roles and investment sequences, highlighting the need for structural reconfiguration to facilitate the integration of niche innovations into the dominant regime. The study concludes that successful transitions require not only technological advancements but also a comprehensive restructuring of ecosystem roles and responsibilities to overcome barriers and enable sustainable practices in the maritime industry.

## 1. INTRODUCTION

RoPax (Roll-on and Passenger) shipping combines the transport of wheeled cargo, such as trucks and trailers, with passenger services, often offering overnight accommodation and entertainment options. This mode is particularly prominent in Europe and is a relatively high source of emissions because of the relatively high speed of the ships. Today, these ships rely on internal combustion engines (ICE) powered by oil or in some cases LNG. Recent regulations introduced by the International Maritime Organization (IMO) and the European Union (EU) aim to push shipowners toward alternative fuels and propulsion technologies, though adoption of options like LNG remains limited. Considering these developments, all-electric battery-powered ships (further, ‘electric ships’) have the potential to bring GHG emissions to zero, depending on the grid mix where the ship is charged, while simultaneously reducing other environmental impacts, such as noise pollution, particle emissions and localised pollutant emissions.

All-electric battery-based powertrains have, however, long been held unfeasible for large vessels and long distances. The argument often cited is that batteries would need to be prohibitively large and expensive, making the concept impractical. While short-distance road ferries have demonstrated the viability of battery-electric propulsion (Rivero, 2025), larger RoPax vessels – capable of carrying hundreds of vehicles and more than 2000 passengers – have traditionally not been considered viable candidates for being equipped with battery powertrains. Recent discussions suggest that RoPax ferry routes could be suitable for electrification, too. Nevertheless, significant challenges remain, particularly regarding the operational, investment, and business model implications of transitioning to all-electric RoPax ferries. That is, a wider business ecosystem is affected (Adner, 2021), and a socio-technical transition needs to take place for the battery technology to compete with the dominant regime of ICE-powered RoPax ships (Geels, 2002).

This study examines how institutional structures within current business ecosystem constrain the transition to electric RoPax ferry transportation. It draws on empirical material from a two-year project developing the concept for an electric RoPax vessel operating between two countries in the Baltic Sea. The analysis is based on project communications and collaboration with a shipyard, a ship operator, and a local energy company, all working to create a feasible scenario for implementing the electric ferry on the focal route.

To analyse these dynamics, this study draws on a theoretical framework that integrates the Multi-Level Perspective (MLP) on socio-technical transitions,

institutional theory, and the concept of business ecosystems, which is described in the following section. By viewing regimes as institutionalised business ecosystems, we aim to achieve a more nuanced understanding of how industry structures resist or enable transition, particularly when technological change requires reconfiguring how value is created and distributed.

## 2. LITERATURE REVIEW

The transition to electrified shipping challenges not only technologies but also established industry structures, operational practices, and value creation logics. Analysing such transitions requires frameworks that capture both systemic stability and change. The MLP on socio-technical transitions and institutional theory have become central in this regard. In addition, the concept of business ecosystems highlights how value creation structures — the configuration of roles, activities, and interdependencies — form the basis for and stabilise socio-technical regimes. We integrate these perspectives to build a foundation for analysing the institutional and structural barriers to the electrification of shipping in the focal case.

The connection between the MLP and institutional theory has gained increasing attention in socio-technical transition studies. The MLP, developed by Geels (2002; 2011), conceptualizes transitions as interactions between three analytical levels: niche innovations, socio-technical regimes, and socio-technical landscape. It provides a structured way to understand how radical innovations emerge in protected niches, challenge dominant socio-technical regimes, and eventually reshape socio-technical systems under pressure from broader landscape developments. Institutional theory, in turn, focuses on how formal and informal rules, norms, and cognitive structures influence organizational behaviour and sectoral change (Scott, 2008). Institutional logics, legitimacy, and isomorphic pressures are key mechanisms through which institutional structures shape and stabilize socio-technical regimes (DiMaggio & Powell, 1983).

A number of attempts to integrate these perspectives to enhance the understanding of transition dynamics have been made. Geels and Schot (2007) highlighted the role of institutional logics in shaping regime stability and how institutional change interacts with technological and economic shifts in transition processes. Fuenfschilling and Truffer (2014) further developed this integration by examining how institutional structures define regime characteristics and influence transition pathways. Similarly, Raven (2004) investigated the role of institutional entrepreneurship in niche development, emphasizing

how actors navigate institutional constraints to promote innovative practices. Institutional structures define the stability of regimes and the opportunities for niches to scale.

In the MLP, the socio-technical regime refers to the dominant rule set or system of actors, institutions, technologies, and user practices that stabilizes existing sectors (Markard and Truffer, 2008; Sutherland et al., 2015). Regimes are characterised by self-reinforcing structures, incremental innovation, and resistance to radical change (Fuenfschilling & Truffer, 2014), exhibiting strong path dependencies and technological or institutional lock-ins (Klitkou et al., 2015). Regime actors are often oriented toward system optimization rather than transformation, and they tend to defend the status quo. While regimes represent the established way production systems are organised in industries, the MLP has been criticised for neglecting actors and their actions (Bünger & Schiller, 2022).

The concept of business ecosystems can address this shortcoming by explicating the configuration of roles, interdependencies, and value creation logics among firms within a regime. Business ecosystems are communities of various actors that are interacting to generate a solution for a specific need (Pidun et al., 2019). In other words, an ecosystem is typically defined by the value creation structure with the aid of which actors deliver a value proposition to the end customers (Adner, 2021). Business ecosystems can also be formed to enable and support the business activities of a keystone company that leads the activities in fulfilling the needs of the end customers (Iansiti & Levien, 2004). To make this happen, some level of orchestration is typically involved within ecosystems (Autio, 2022). However, individual actors are not controlled hierarchically in ecosystems, which makes ecosystems different from supply chains (Jacobides et al., 2018).

Similarly to acknowledging the institutional character of regimes within the MLP, scholars have applied institutional theory to business ecosystems, identifying institutional dynamics as a key layer that shapes how ecosystems emerge and evolve (Autio, 2022). Thomas and Ritala (2021) examine ecosystem legitimacy emergence through an institutional lens, conceptualizing legitimacy as a collective process where orchestrators, complementors, and external actors engage in discursive, performative, and identity-building activities. Tsvetkova et al. (2021) further embed institutional theory into the study of business ecosystems by exploring the regulative, normative, and cultural-cognitive institutional barriers affecting the transition to autonomous shipping ecosystems. They demonstrate that institutional lock-ins can prevent new business models from creating and capturing value, and that the structure of

incumbent business ecosystems, manifested in the value creation structure (who does what, who gets what) is in itself an institution.

Building on this understanding, we argue that the structure of business ecosystems, particularly the configuration of value creation activities, constitutes a crucial but under-theorised element of socio-technical regimes. These value creation structures shape roles, power relations, and coordination patterns, and because they are institutionalised, they help stabilise regimes and make change difficult. Incorporating the business ecosystem perspective into the MLP allows for a more granular analysis of regime dynamics, moving beyond the traditional focus on policy and technology. It can enhance our understanding of how ecosystems facilitate or resist transitions. In this study, we apply this integrated framework to an empirical case, exploring how institutional structures and business ecosystem configurations shape the feasibility of transitioning to electric RoPax ferry transport.

### 3. METHODOLOGY

This study investigates the institutional barriers to electrifying RoPax ferry transport through a case study situated in the Baltic Sea region. The case forms part of a two-year project assessing the feasibility of deploying an all-electric RoPax vessel operating between two countries. The project involved collaboration between a shipyard, a ship operator, and a local energy provider, all engaged in developing a viable concept for electric ferry operations on the focal route. A qualitative, exploratory case study approach was adopted, suitable for analysing complex socio-technical transitions in context-specific settings (Gustafsson and Tsvetkova, 2017).

Empirical material was gathered from a broad set of sources. Project communications provided the core of the material, including meeting notes, memos, and email correspondence, complemented by industry publications, brochures supplied by companies, policy papers, and data such as RoPax schedules, emissions, fuel consumption, route distances, vessel size, speed, and energy prices in different countries. Insights were collected through continuous discussions with stakeholders, which over the course of the project developed into more intensive exchanges once feasibility assessments began to produce concrete implications. These discussions were not structured as formal interviews but as consecutive exchanges that gradually deepened understanding of the stakeholders' interests and positions.

In total, the study drew on discussions with experts from different organisational domains: shipyards (around 20 persons), shipowners (around 20

persons), ports (around 20 persons), energy companies (around 10 persons), policymakers at national and EU level (around 20 persons), academics (around 20 persons), and technology suppliers (around 30 persons). Stakeholders were located both in Europe and in China, which made it possible to capture international perspectives on the technological and institutional conditions for electric RoPax vessels. Discussions with each type of stakeholder centred on what electrification would imply from their specific standpoint, for example, shipyards focusing on design and construction challenges, ship-owners on operational and business model implications, and policymakers on regulatory and infrastructural considerations. This allowed the analysis to build towards an overall understanding of the interests, conflicts, and institutional barriers embedded in the wider business ecosystem.

The material was analysed using directed qualitative content analysis (Hsieh and Shannon, 2005). The approach was primarily abductive (Dubois and Gadde, 2002): institutional theory and the MLP served as guiding frameworks, but analysis was sensitive to additional themes emerging from the data. Initial coding was informed by concepts such as institutional barriers, niches, regimes, and ecosystem roles, while inductive categorisation was applied when recurring issues surfaced beyond the pre-defined categories, for instance related to energy pricing, cross-border electricity supply, and policy coordination. This iterative process enabled the combination of theoretical framing with empirical richness, producing a consolidated view of the institutional barriers shaping the feasibility of electric RoPax ferry deployment.

#### 4. ANALYSIS

Following the theoretical framework presented in section 2, Table 1 illustrates how the transition from conventional diesel-powered RoPax vessels to electric ships involves not only technological substitution, but also profound shifts in both socio-technical regimes and business ecosystem structure. This transformation unfolds across several key areas of industry logic: design, manufacturing, operations, and maintenance. We provide several individual examples of current institutional logics, and the shift required for the transition to all-electric battery-powered ships, which are not exhaustive.

In the current regime, the design logic is strongly rooted in an engineer-to-order tradition. Shipyards are positioned primarily as executors of unique customer specifications, with relatively little influence over vessel conceptualisation. This role allocation results in long construction times, high costs, and limited economies of scale. Value creation is tightly linked to customisation,

while value capture remains fragmented, depending on individual project contracts. By contrast, in case of electric ship construction, it is possible to shift to configure-to-order modular designs, albeit not necessary. It would re-organise roles within the ecosystem, positioning shipyards as solution configurators and enabling faster construction, lower costs, and improved standardisation. This transformation also restructures value creation around modular efficiency and increases the potential for learning effects across projects. In principle, this change in logic is technologically speaking independent of propulsion technology. Rather, the technological change enables opening a lock-in in the design process of the vessel.

Table 1: Analysis of institutional logics in the current and new business ecosystem structure.

Elements in the current regime	Existing business ecosystem		New business ecosystem	
	Regime characteristics	Business ecosystem structure	Regime characteristics	Business ecosystem structure
Design logic	Ships engineered-to-order; customised designs	Shipyards follow owner specifications; little design ownership; limited standardisation and learning.	Configure-to-order, modular designs	Shipyards act as solution configurators; modular production enables faster delivery and learning across projects
Manufacturing logic	Construction built around early diesel engine installation	Capital tied up early; fixed supplier relationships; limited flexibility in scheduling and procurement	Batteries installed late, flexible sequencing	Capital commitment deferred; more adaptable

				supply chains and project financing
Operational logic	Fossil fuel bunkering once or a few times a week; low infrastructure demands	Operators act independently; minimal coordination with ports	Charging at every port call; infrastructure dependency	Ports become service partners; tighter coordination and shared operational responsibility
Maintenance logic	Onboard engine maintenance requires crew	Crew needed for maintaining ship during operations	Minimal maintenance crew needed onboard	Smaller crews possible; potential to reduce speeds and costs; new land-based service roles emerge

Manufacturing logic in the conventional ecosystem is centred around the early installation of diesel engines (simply because it cannot be fitted into the vessel at a later stage due to its bulkiness), a practice that heavily influences the sequence of construction activities. The value chain is organised to accommodate this early capital commitment, embedding inflexible production routines and financial risk into the ecosystem. Capital is tied up early, shaping how actors coordinate investments and allocate responsibilities. In an electric ship, batteries can be installed at a late stage, allowing for greater flexibility in construction scheduling and financing. This alters the underlying value creation logic, enabling later capital commitment and reducing risk exposure during earlier phases of production.

Operational logic also reflects current institutional arrangements. Traditional ships require bunkering once or a few times a week, allowing port operations to remain flexible and relatively uncoordinated across infrastructure providers. Roles and responsibilities between ship operators and ports are loosely coupled, and value capture remains localised and opportunistic. Electrification disrupts this model: charging is required at every port call, which in turn requires standardised infrastructure and tighter operational coordination between ports and operators. The shift implies a redistribution of roles, with ports becoming enablers of daily operations, and alters value creation by embedding it within a more integrated, service-based ecosystem. New actors, such as local electricity grids, become important actors in the ecosystem, too.

Finally, maintenance logic can also change. Conventional vessels depend on onboard maintenance crews primarily tasked with managing ICE-based propulsion systems. This requirement sustains a business model where crew-related costs form a significant fixed expense, incentivising higher operational speeds and cost structures optimised for high-crew configurations. Battery systems, however, reduce the need for onboard maintenance, enabling a business model based on smaller crews and potentially lower operational speeds. This shift not only affects operational and maintenance logics but also redistributes roles across the ecosystem, creating opportunities for land-based service providers and altering how and where value is captured.

Altogether, these transformations reveal that the transition to electric RoPax ferry systems is not merely a technological substitution but involves a reconfiguration of institutionalised business ecosystem structures. Changes in roles, activities, value creation, and value capture must occur simultaneously to enable a successful transition, reinforcing the argument that business ecosystems form a critical, yet often overlooked, dimension of socio-technical regimes.

## 5. DISCUSSION AND CONCLUSIONS

This study demonstrates that socio-technical regime stability is maintained not only through technological systems and formal rules, but also through institutionalised business ecosystem structures. By analysing how design, manufacturing, operations, and maintenance logics are embedded in the incumbent maritime ecosystem, we show that value creation configurations constrain the transition to electric RoPax vessels. These findings support the view that business ecosystems are not neutral coordination mechanisms but reflect embedded institutional arrangements (Autio, 2022; Thomas and

Ritala, 2021). We also observed a reverse relationship, namely, how the technology shift enables a change in design logic, a part of the institutional arrangement. Hence, these changes are reciprocal in nature.

To conceptualise this, we propose a framework that integrates the Multi-Level Perspective with institutional theory and business ecosystem analysis. As illustrated in Figure 1, the regime can be understood as being structured by an institutionalised business ecosystem, where roles, routines, and value creation logics stabilise incumbent practices. Transition becomes possible when institutional work reconfigures this structure through changing roles and value creation logics so that niche innovations can align with viable ecosystem configurations and move from niche to regime level.

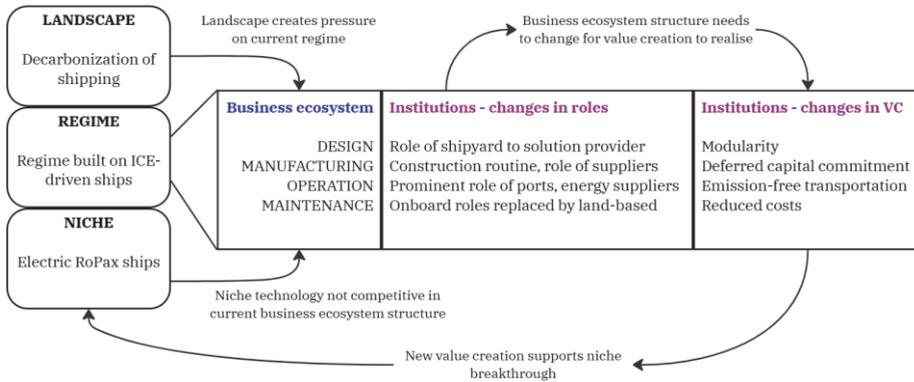


Figure 1: Regime reconfiguration through business ecosystem change.

Our analysis contributes to MLP transition studies by specifying how regime characteristics are operationalised through interdependent actor roles, investment sequences, and infrastructure dependencies (Geels, 2002; Markard & Truffer, 2008). In contrast to the common emphasis on public policy and technology as regime elements, we highlight how industrial practices, such as when capital is committed, how ships are designed, or which actors manage bunkering, serve to stabilise the dominant regime. This responds to critiques that regimes in MLP are often underspecified in terms of actor strategies and economic structures (Bünger & Schiller, 2022; Markard & Truffer, 2008).

From an institutional perspective, the case illustrates how ecosystem-level change requires more than legitimacy-building or normative alignment: it involves reconfiguring structural dependencies and redistributing responsibilities between firms (DiMaggio & Powell, 1983; Scott, 2008). For instance,

shifting battery installation to the end of the production process alters capital flows, and port charging requires new role definitions and infrastructure investment. These are both examples of ecosystem restructuring as institutional work (Fuenfschilling & Truffer, 2014; Raven, 2004).

Rather than assuming that technological change alone can drive transitions, our findings show how the absence of viable alternative business ecosystem structures can block progress, even when technical solutions and regulatory support are in place. This aligns with calls to pay more attention to “missing roles” or “ecosystem gaps” in transition pathways (Tsvetkova et al., 2021).

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