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Sailing through digital tides: assimilation of port community systems for just-in-time arrival

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Abstract

Purpose – The purpose of this study is to explore how the fit between port community systems (PCS) assimilation and just-in-time (JIT) implementation co-evolves over time.

Design/methodology/approach – A longitudinal and process-based multiple case-study design focusing on two Swedish ports was employed. Data were collected through 33 interviews, 17 observations and 12 archival documents during 2020–2025.

Findings – The realization of JIT's environmental and operational outcomes is contingent on the fit between PCS assimilation and JIT implementation. However, their fit was jointly constrained by the PCS governance structure, digital immaturity, regulatory frameworks, and commercial and operational dependencies, leading to inconsistent JIT implementation. These sources of misfit do not stem from port-level PCS decisions alone, but also from actions, constraints and incentives of other port call actors.

Research limitations/implications – This study is based on two Swedish ports that can be characterized as early adopters of PCS supporting JIT implementation. While context-specific, the findings offer insights for ports seeking to assimilate PCS.

Practical implications – The study provides managerial insights for ports and maritime actors adopting a PCS to support JIT port calls. It shows that realizing JIT's outcomes requires manager to treat the assimilation process as collaborative and iterative. To assimilate PCS and scale-up JIT's implementation, interoperability should be prioritized by addressing regulatory constraints and uneven digital maturity among actors to reduce reliance on parallel systems. Furthermore, effective JIT implementation requires governance designs that prioritize system-level coordination by configuring berth windows, commitment rules and clearly assigned responsibilities to dominant operational and commercial conditions in the port call system.

Originality/value – The study conceptualizes PCS assimilation and JIT implementation as two interrelated process streams and argues that fit/misfit can either originate from one process stream to influence the other or result from the interaction between the two processes.

Keywords Port community systems, Port call process, Just-in-time, Information systems assimilation, Process research, Maritime logistics

Paper type Research article

1. Introduction

Maritime transport actors are currently facing environmental and operational challenges. The environmental challenges stem from changes in European legislation about emissions, where shipping is now included in the European Emission Trading System, and the revised Energy Tax Directive removes long-standing tax exemptions. The implications of these changes

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include an estimated 11–40% increase in shipping costs (Vierth *et al.*, 2024). Simultaneously, port call delays are widespread, e.g. tankers and dry bulk carriers spend on average 9% of their annual operating time waiting at anchorage (IMO, 2020). These delays further increase shipping costs and contribute to commodity price inflation, raise emissions, accident risk and harm to marine ecosystems (Merkel *et al.*, 2022).

The implementation of just-in-time (JIT) arrival in the port call process can help address these challenges. JIT is an operational process in which the sailing speed of vessels is coordinated with the availability of resources and services at the port of destination. As such, it ensures effective voyage execution that decreases delays through slower sailing speeds, leading to lower fuel consumption and emissions by an estimated 5–20% (IMO, 2020; World Bank, 2025). Despite its potential, actual implementation remains limited, explained by two barriers (Mubder, 2024). Adjusting vessels' sailing speed is interdependent on agreement between charterers and shipping companies. However, due to the tradition of first-come-first-served (FCFS) and the contractual clauses between shipping companies and charterers, some shipping companies are incentivized to "rush-to-wait" as they will be compensated for their waiting through demurrage payments (Adland and Jia, 2018). Furthermore, the implementation of JIT involves several independent actors, e.g. shipping companies, charterers, terminals and service providers such as pilots. The interdependencies that exist in their planning and service provision processes require effective information sharing. Though the quality of information sharing remains insufficient to support JIT implementation (Veenstra and Harmelink, 2022).

Consequently, managing the interdependencies of JIT port calls requires effective coordination mechanisms (Mubder, 2024). Various studies have outlined the potential of information sharing as a mechanism to support JIT's implementation (Nikghadam *et al.*, 2023; Fuentes and Adland, 2023). However, these studies focus on modelling the potential of JIT enabled by information sharing, but assume the existence, adoption and use of the technology that facilitates information sharing. This assumption leaves the practical requirements of coordination and information sharing technology for JIT unexplored.

Maritime scholars and practitioners emphasize the importance of digital platforms such as port community systems (PCS) in supporting JIT (World Bank, 2025). However, empirical research on PCS is limited. PCS remains insufficiently defined in the literature, highlighting the need for further research that specifies its key characteristics. Without systematic characterization of PCS, they remain analytically vague, limiting the ability to explain variation in adoption and outcome across ports. Furthermore, the evidence suggests that PCS assimilation remains a challenge. For example, Maersk and IBM's TradeLens was discontinued, highlighting the risks of insufficient adoption and long-term viability of such platforms. In the context of PCS and JIT, a process and multi-actor perspective is necessary, but remains absent from the literature. The processes of JIT implementation and PCS assimilation are carried out in the port call context, which constitutes a loosely coupled system of multiple interdependent actors with distributed authority. In such contexts, JIT implementation and PCS assimilation cannot be understood from a single actor perspective, as it depends on the satisfaction, engagement and continued participation of the diverse actors within port calls. Existing research addresses certain barriers and enablers associated with PCS assimilation. However, they do not explicitly address how these barriers and enablers emerge, nor do they connect them to specific PCS outcomes such as JIT's environmental and operational benefits. This suggests that there is a need to better understand how the processes of JIT implementation and PCS assimilation evolve and fit together, and how the interactions among actors influence the fit between them. Addressing these limitations helps bridge the gap between theory and practice, leading towards sustainable maritime logistics.

The purpose of this study is to explore how the fit between PCS assimilation and JIT implementation co-evolves over time. We conceptualize PCS assimilation and JIT implementation as two parallel process streams and argue that a fit between them is necessary to realize the benefits of JIT in practice. Task-technology fit (TTF) is used as an analytical lens to study the fit between the processes. The study adopts a longitudinal and process-based multiple case-study design of two Swedish ports aiming to assimilate PCS to realize the benefits of JIT. To address the purpose, two research questions (RQs) have been formulated:

RQ1. Which characteristics can be used to describe and systematize PCS?

RQ2. How do barriers and enablers influence the assimilation of PCS to support JIT implementation?

This study makes two contributions. First, it advances research on JIT in maritime logistics by conceptualizing PCS assimilation and JIT implementation as two interrelated process streams, showing that the realization of JIT's environmental and operational benefits is contingent on the two processes fitting together. This conceptualization reveals two forms of fit/misfit. The first originates from one process stream influencing the other (e.g. PCS-side interoperability constraints driven by regulation and uneven digital maturity, and JIT-side commercial and operational dependencies that limit actors' ability or willingness to act on PCS-enabled information). The second form of fit/misfit originates when the two process streams must connect in practice (e.g. through governance arrangements that specify when JIT is initiated, who initiates it and how responsibilities and timing rules are defined). Second, the study contributes empirically by providing systematic characterization of PCS and by tracing how barriers and enablers influence the development of JIT-PCS fit over time. Understanding JIT-PCS fit is critical to achieve sustainable maritime logistics.

The remainder of this article is organized as follows. In Section 2, the frame of reference is provided, followed by the methodology in Section 3. Sections 4 and 5 present the case findings and the analysis, respectively. In Section 6, the findings are discussed and the conclusions are provided in Section 7.

2. Frame of reference

This section describes the process of digital platform assimilation and reviews relevant literature on JIT, PCS and broader digital platform assimilation in maritime logistics.

2.1 Digital platform assimilation

This study adopts the concept of digital platform assimilation due to its explicit and dual focus on both process and outcome (Hazen *et al.*, 2012). Assimilating digital platforms goes beyond the physical adoption of a platform to include outcomes of its use. Platform assimilation encompasses two outcomes: (1) Successful diffusion, i.e. the extent to which platform use has diffused across processes and actors. (2) Performance outcomes, i.e. realized cost savings and enhanced service quality (Mathauer and Hofmann, 2019).

The assimilation process of digital platforms encompasses three phases:

(1) Initiation: Identifying a performance gap and mobilizing resources to evaluate solutions and prepare for adoption (Selensky, 2023).

(2) Adoption: Selecting and installing the platform, including initial process integration (Mathauer and Hofmann, 2019).

(3) Use and diffusion: Embedding the platform in routines, supporting acceptance, adapting workflows and expanding use across processes and actors (Hazen *et al.*, 2012).

2.2 Just-in-time arrival and port community systems

The importance of coordination and information sharing to realize the benefits of JIT is emphasized in the literature (Nikghadam *et al.*, 2023; Fuentes and Adland, 2023). However, studies provide limited insights on what information must be shared and which systems should be integrated to support JIT. Moreover, information sharing quality among port call actors remains insufficient to support JIT port calls (Veenstra and Harmelink, 2022). This highlights the need to examine how digital platforms such as PCS can support port call information sharing for JIT. PCS connects maritime actors to streamline coordination through information sharing (Moros-Daza *et al.*, 2020). Its main outcomes are improved information quality, reduced paperwork and costs, regulatory compliance and supply chain flexibility (Di Vaio and Varriale, 2020; Jiang *et al.*, 2021). However, realizing these outcomes depends on effective use and assimilation (Mubder and Fredriksson, 2025).

Studies on PCS adoption emphasize both barriers and enablers. Brunila *et al.* (2021) examined the initiation phase of PCS adoption in European ports and found resistance to change, cybersecurity concerns and limited interoperability as primary barriers to PCS initiation. Vairetti *et al.* (2019) studied the enablers of PCS adoption in Latin American and Caribbean ports and found that interoperability, alignment with national logistics strategies, technical capabilities and regulatory ease are central for successful PCS adoption. Srour *et al.* (2008) examined the assimilation process of PCS and found that successful assimilation requires clearly defined goals, modular deployment of the platform, alignment with actor needs and sustained actor commitment. Simoni *et al.* (2022) found that the success of PCS depends on its ability to meet the needs of port actors' business processes.

Our review of the PCS literature reveals that existing studies mainly identify general adoption barriers and enablers, but do not explicitly link these factors to specific outcomes such as JIT's environmental and operational benefits. In the JIT context, limited attention has been given to the coordination capabilities PCS enable, the information that must be shared and the interoperability required to support coordinated port operations. Moreover, how PCS adoption and assimilation barriers affect the fit between PCS-enabled information sharing and JIT implementation remains underexplored. Addressing this gap requires a longitudinal, process-oriented and multi-actor perspective, because PCS assimilation and JIT implementation are interdependent processes that unfold over time and across multiple actors. Such perspective allows in tracing how actors align their operations and systems, information sharing practices and commitments within the port call process and how this alignment influence the realization of JIT outcomes.

2.3 Barriers and enablers of maritime digital platform assimilation

Various studies examine barriers and enablers associated with maritime digital platform adoption and assimilation. Focusing on initiation, Pinyanitikorn *et al.* (2024) emphasize performance expectancy, effort expectancy, social influence and facilitating conditions as key adoption enablers for online freight forwarding platforms. Moving to adoption, Zeng *et al.* (2021) show that container booking platform adoption among global shipping lines is shaped by intra-organizational factors (e.g. top management support, interoperability) together with inter-organizational factors (e.g. regulatory pressure, partner expectations and power relations). Zeng *et al.* (2020), focusing on container booking platforms in the Chinese context, found technological (e.g. information confidentiality, service quality), organizational (e.g. management support, firm size, ownership) and environmental (e.g. industry structure, institutional setting) factors as central for adoption. From a longitudinal perspective, Gekara and Nguyen (2020) illustrate how inadequate IT infrastructure, low digital skills, resistance to change and weak national broadband capacity can persist over time and ultimately trigger system overhaul in a container terminal system in Kenya. Finally, Wiafe *et al.* (2020) show that platform assimilation in Ghana's shipping sector depends on performance expectancy, facilitating conditions and user-related factors such as anxiety and attitudes towards use. Collectively, this literature indicates that platform outcomes in maritime logistics are shaped by multi-level technological, organizational and institutional conditions.

The broader maritime digital platform literature also makes limited use of process and longitudinal designs. Most studies focus on a single phase (e.g. intention, adoption or use), with fewer tracing dynamics across phases or examining how platform assimilation interacts with and reshapes operational processes over time.

3. Methodology

This section presents and motivates the methodological choices made in this study.

3.1 Research design and case selection

A longitudinal and process-oriented multiple case-study approach was used to examine how PCS assimilation and JIT implementation evolve over time. This approach is appropriate because empirical research on how these two processes unfold and intersect to realize JIT's benefits remains limited, indicating a nascent area where case-based research is suitable. It also allows capturing temporal dynamics by tracing how the processes develop across phases and how barriers and enablers influence progress within and between processes (Eisenhardt, 1989). Finally, PCS are implemented in loosely coupled port call settings involving multiple interdependent actors; a multiple case design enables incorporating diverse actor perspectives that influence PCS assimilation.

Swedish ports are relevant to study as cases, as the Swedish Maritime Authority (2026) has launched the Smart Port Call program in collaboration with industry associations to promote digitalization and JIT port calls. This initiative is motivated by the efficiency potential that JIT brings to shipping. Approximately 15% of tramp vessels calling at Swedish ports during 2019 experienced a median delay of 13 h (Merkel *et al.*, 2022). This context provided an opportunity to study empirically relevant cases of PCS assimilation supporting JIT implementation in Sweden. Sampling in case-based process research can aim to replicate patterns across comparable cases, to capture variation in how processes unfold, or to combine both (Grimm *et al.*, 2024). The cases were selected based on the third approach that combines the replication of patterns and variations. More specifically, the Ports of Gothenburg and Gävle were selected for two reasons. First, both ports adopted their PCS within a similar time period and targeted comparable outcomes from them, i.e. streamline information sharing and support JIT implementation to reduce fuel consumption and emissions. This reduces the risk that differences in the assimilation process are mainly driven by broader changes over time (e.g. shifts in digital maturity, regulatory pressure or industry-wide expectations) or by fundamentally different outcomes for the PCS initiative. This shared baseline supports a more credible comparison of process stages, turning points and outcomes relevant to the RQs. At the same time, the ports differ in their contextual conditions, which provides useful contrast for examining how assimilation unfolds under different operational conditions and actor settings. These differences help explore whether and how barriers and enablers play out differently across cases.

3.2 Data collection methods

Data were collected in real-time through interviews, observations and archival documents between 2020 and 2025. This longitudinal design made it possible to capture the unfolding PCS assimilation process at both ports across its key phases. Figure 1 outlines the timing of data collection and maps each period to the corresponding assimilation phase. Phase boundaries were defined using the month of actual PCS adoption in each port, which served as the temporal marker separating the pre-adoption and post-adoption phases. Appendix A provides more detailed information about the data collection timeline, including participant profiles, observed events and interview questions.

Thirty-three semi-structured interviews were conducted with actors involved in PCS assimilation and JIT implementation. These actors were managers from the port authorities, shipping companies and chartering companies. Furthermore, agents and service providers were also interviewed. This sampling of interviewees helped capture the managerial and operational perspectives associated with PCS assimilation and JIT implementation. The managerial

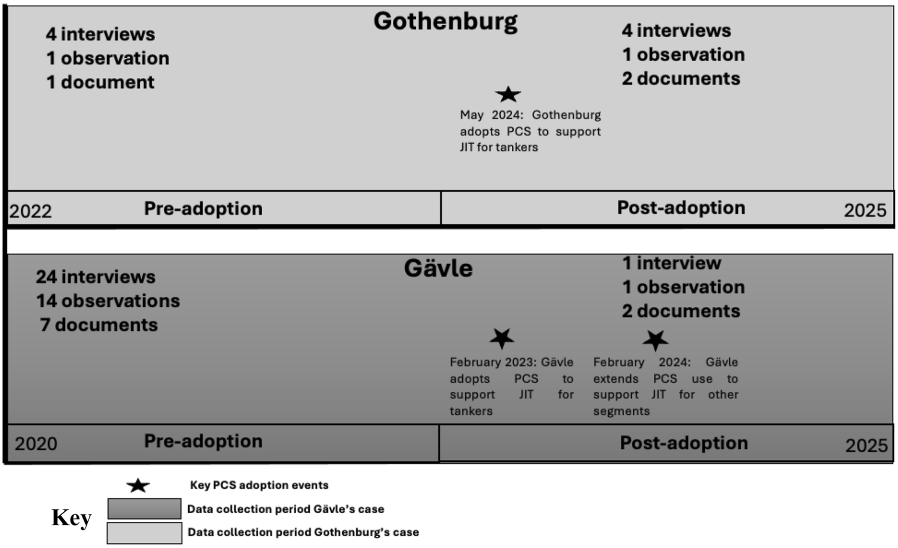

Figure 1. Data collection process. Source: Authors' own work

perspective includes the key motivations behind PCS adoption and its characteristics and configuration. The operational aspects focused on revealing the barriers and enablers that different actors perceive and experience in supporting tasks such as JIT implementation. All interviews were conducted online via Microsoft Teams, lasting between 30 and 70 min each.

Seventeen field observations were conducted at port activities and industry events to complement the interviews and gain contextual insights in real time into different assimilation phases. Furthermore, these observations provided insights about the interactions and dynamics among different actors during these observed events. At the Port of Gothenburg, pre-adoption activities were observed at the Donsö Shipping Meet, where goals and adoption timelines for the PCS and JIT were presented. Post-adoption experiences were captured during a seminar focused on ongoing PCS use challenges in the port.

At the Port of Gävle, extensive access was granted to three workshops – two addressing risk management and one showcasing a PCS sprint demonstration – as well as seven project meetings involving the port authority, a shipping company and an energy company. Additional observations were a seminar organized by the Swedish Maritime Authority on the Smart Port Call program and a FinTraffic seminar focused on PCS and JIT implementation.

Finally, twelve archival documents were reviewed. Gothenburg's materials comprised three documents describing the characteristics of the PCS, detailing the initiation and use of PCS for JIT voyage coordination, and the adjustment in the port's operating regulation post-PCS adoption. Gävle's documentation included a project plan, risk management reports and an emissions reduction report related to JIT. Additional materials comprised user instructions, feedback logs to customize PCS and a report describing the perspectives of actors regarding PCS and JIT. Combined, these methods enabled triangulation and provided a detailed understanding of the PCS assimilation process and JIT.

3.3 Data analysis

To analyse how the fit between PCS assimilation and JIT implementation co-evolves, the study followed an abductive approach combining inductive coding and theoretical interpretation. The analysis proceeded in three steps: (1) Developing first- and second-order concepts using the Gioia *et al.* (2013) method. (2) Applying TTF (Goodhue and Thompson, 1995) to structure aggregate dimensions. (3) Tracing process dynamics and conceptualizing PCS assimilation and JIT implementation as two interrelated process streams to explain how barriers and enablers influence fit over time (Cloutier and Langley, 2020).

Transcripts, field notes and archival documents were coded iteratively following the Gioia method. The first-order codes were respondent-centric and developed from interview transcripts and field notes. These were consolidated through comparison within and across cases. Then, first-order codes were interpreted into second-order themes representing barriers and enablers that influenced the fit between PCS assimilation and JIT implementation. During the coding process, one of the authors conducted the initial rounds of analysis, developing first-order codes and second-order themes through iterative coding cycles. The second author served as a second coder for reliability checks by challenging interpretations and highlighting inconsistencies in coding and theme development. TTF was then used as an analytical lens to connect the inductively derived themes to an established theoretical framework. TTF guided the aggregation of the second-order themes by distinguishing between barriers/enablers related to the task (JIT) and those related to the technology (PCS). This step provided the aggregate dimensions used to organize the data structure and ensured consistency in how barriers and enablers were interpreted across cases and phases.

Building on the TTF-structured and aggregated themes, the analysis then focused on explaining how PCS assimilation and JIT implementation unfolded as two interrelated process streams. To structure this process explanation, the analysis identified junctures at the intersection of the two process streams. In this study, a juncture refers to a recurring coordination situation in port calls in which PCS use is necessary to progress a JIT port call (e.g. initiating JIT through a berth-window request or coordinating interdependent services). Junctures are used analytically to capture where the PCS assimilation stream and the JIT implementation stream must connect in practice, making it possible to observe how barriers and enablers shape the development of fit or misfit over time. Junctures were derived analytically by tracing sequences of events and interactions in the empirical data and identifying recurring coordination situations – observed across multiple data sources and across cases – where multiple barriers and/or enablers intersected to influence the development of fit or misfit over time.

It is important to emphasize that in line with the process-oriented purpose of the study, the two ports were used to construct and refine a parallel process model rather than to conduct a balanced case-by-case comparison. The analytical unit was the development of JIT-PCS fit/misfit at coordination junctures, rather than each port as a standalone case. Gävle provided more extensive empirical data to trace the emergence of barriers and enablers during the early stages of PCS assimilation and JIT implementation. Gothenburg provided a more evenly distributed empirical basis across pre- and post-adoption phases, enabling comparison of how barriers and enablers developed as PCS assimilation progressed into use. The two cases were therefore used in complementary ways: Gävle strengthened the depth of process tracing, while Gothenburg strengthened the temporal and contextual comparison of the emerging parallel process model. This enabled the analysis to distinguish barriers and enablers that appeared across both ports from case-specific conditions that shaped how fit or misfit developed.

4. Case findings

This section outlines the outcomes that the ports targeted from adopting the PCS, their management of the pre-adoption phase and PCS characteristics, addressing RQ1.

4.1 The Port of Gothenburg

The Port of Gothenburg is Scandinavia's largest port, operating as a landlord authority on Sweden's west coast. It is the country's second-largest liquid bulk port, handling about 2,200 annual tanker calls and 40% of Sweden's imported energy products, including both finished fuels and semi-finished products for local refineries. The port's energy terminal hosts six terminals, three refineries and three storage companies. Both loading and discharging operations are handled in the port.

The port adopted its PCS in May 2024 to streamline information sharing and port call visibility. Tanker port calls accounted for approximately 85% of all delays, leading to increased emissions in the port area and motivating the port to encourage JIT. The port control manager emphasized the role of the PCS in enabling JIT: *"JIT came as an opportunity [through the PCS], effective information flow is the foundation for JIT and berth planning. If you do not have the right information, JIT will not work"*. The need for improved information sharing and coordination was further highlighted by an operations manager: *"Resources like pilots and tugboats are limited. If we have Very Large Crude Carriers arriving, we need five tugboats. We only have four here [In Gothenburg]. We have to borrow one from Denmark or Brofjorden. Some port calls require more resources and coordination, which complicates JIT"*.

4.2 The Port of Gävle

The Port of Gävle is a medium-sized landlord port on Sweden's east coast. It is the country's fourth-largest liquid bulk port, with significant jet fuel imports distributed to Stockholm Arlanda Airport. It has two berths for petroleum, heavy oil, chemicals and cement, and eight terminals operated by different companies. Discharging operations are mainly handled in the port.

The port adopted its PCS in 2020 to improve information sharing and port call visibility, and updated it in 2023 and 2024 to support JIT implementation at the energy and heavy oil/ chemical berths. Managers noted that port call information was often shared through manual modalities and lacked standardization. A traffic manager stated: *"I have 10 agents who work in 10 different ways"*. The port's sustainability manager described the PCS as: *"find a way to communicate and harmonize the process with other actors. A tool to streamline the information sharing process"*. The adoption was also motivated by the need to coordinate vessels' clashing arrivals. The sustainability manager added: *"We have two berths in the energy terminal, and within them we have eight energy terminals, where eight actors have to share the berth and coordinate. There we face challenges, and queues can occur, which is why vessels voyages carried out in rush sometimes"*.

Overall, both ports intended to achieve similar outcomes from adopting the PCS: streamline the information sharing process in port calls and reduce fuel consumption and emissions through JIT implementation.

4.3 Pre-adoption phase of port community systems

The pre-adoption phase of PCS followed similar dynamics at both ports. Both ports initiated a range of inter-organizational activities such as risk management workshops and PCS sprint demonstrations. They further provided training programs and instruction documents for users describing how the PCS was intended to be used to implement JIT. These inter-organizational activities involved a wide range of port call actors, such as shipping companies, terminals, agents and service providers. This broad involvement made this phase complex. The port control manager, responsible for the PCS adoption process in Gothenburg stated: *"Involving many actors in the adoption process results in many requests about new features in the PCS. Many actors provide valuable feedback, and this has to be prioritized. This is a challenge. You cannot prioritize everything. It makes the project heavy"*.

While complex, these inter-organizational activities created two interaction spaces that proved beneficial to facilitate JIT-PCS fit. First, they created a *collaboration arena* for PCS development. By inviting port call actors to participate in various activities, the port authorities identified operational risks, obtained insights and feedback related to user requirements that were translated into configuration and customization decisions. For example, vessel names and IMO numbers were incorporated into the information sharing process to streamline PCS use for agents managing multiple port calls. Second, these activities created a forum for *top management influence* that strengthened motivation and commitment among actors to implement JIT. In one workshop, Gävle's chief executive officer framed PCS and JIT as aligned with national and international emissions-reduction goals, reinforced by empirical evidence on the potential of JIT provided by shipping companies. Thus, collaboration and top management influence improved user satisfaction through actionable feedback that informed PCS customization and strengthening motivation regarding the intended use of PCS to implement JIT.

4.4 Characterization of port community systems

The cases revealed six PCS characteristics: PCS services, actors involved, PCS ownership, governance structure, level of customization and digital interoperability.

PCS services refer to the core and value-added services of the PCS. Gothenburg's PCS includes three main service modules. The first enhances port call visibility by centralizing real-time operational information, such as the Estimated Time of Arrival and pilot boarding the vessel. The second supports JIT voyage planning and implementation, and the third provides predictive analytics such as weather-based risk alerts. Gävle's PCS offers similar services, but further enables some transactions, such as the booking of sludge services directly through the platform. The *actors involved* were similar in both ports, including port authorities, agents, shipping companies, terminal operators and service providers. In both ports, the *platform ownership* and operations belonged to the port authorities, i.e. each port maintains control over platform's development and governance.

The *PCS governance structure* determines the berth allocation policies through which the ports support JIT implementation. It specifies the operating rules (e.g. mandatory or voluntary JIT), defines who is expected to submit berth reservations and time windows, and what information should be provided. The governance structure also reflects whether the PCS operates as an open or closed system. Gothenburg governs its PCS-enabled JIT through a voluntary approach. This entails that it is optional for shipping companies to reserve berths and initiate JIT voyages, and the port continues to operate under a hybrid FCFS and berth reservation model. The system is closed, meaning only authorized actors have access, and information is not publicly visible. In contrast, Gävle governs its PCS use through a mandatory approach. All vessels are required to submit berth reservations through the PCS before arrival. Gävle's system is also open, with berth reservation and arrival information made visible to the public via the port's website and PCS application. However, full functionality still requires authorization, maintaining controlled use despite the transparency of the system.

The level of customization refers to whether the PCS is picked off-the-shelf or customized according to contextual needs. Both ports have customized their PCS based on specific requirements and contextual conditions. Finally, the *digital interoperability* refers to the PCS's capability to use the functions of the systems that it is interoperable with, share information with them and the level of automation of this exchange. Both Gothenburg and Gävle's PCS are interoperable with external systems, such as Maritime Single Window (MSW), FENIX (pilotage system), Automatic Identification System (AIS), Marine Traffic and weather systems. In both cases, the level of automation is hybrid – some information exchanges are automated, such as risk warnings based on weather data, while others require human input, such as manually entering the Estimated Time of Arrival into MSW, which is then automatically shared with the PCS. In Table 1, the characteristics of each PCS are summarized.

5. Analysis

This section outlines the identified barriers and enablers and explains how they influence the fit between PCS assimilation and JIT implementation over time, addressing RQ2.

Table 1. Summary of port community system characteristics

Characteristics	Ports	Description
PCS services	Port of Gothenburg	Real-time information sharing JIT implementation Predictive capabilities
	Port of Gävle	Real-time information sharing JIT implementation Predictive capabilities Transactions/ordering of services (waste services)
Actors	Port of Gothenburg	Port authority, agents, shipping companies, service providers and terminals
	Port of Gävle	Port authority, agents, shipping companies, service providers and terminals
Platform ownership	Port of Gothenburg	Owned by the port authority
	Port of Gävle	Owned by the port authority
Governance structure	Port of Gothenburg	Voluntary use with regards to berth requests and JIT initiation Operated as a closed system with restricted access
	Port of Gävle	Mandatory use with regards to berth requests and JIT initiation Operated as an open system with restricted access and use
Level of Customization	Port of Gothenburg	Customized based on specific requirements
	Port of Gävle	Customized based on specific requirements
Digital interoperability	Port of Gothenburg	Interoperable with MSW, FENIX, AIS, Marine Traffic, terminals system, weather system Information is shared manually and automatically
	Port of Gävle	Interoperable with MSW, FENIX, AIS, Marine Traffic, weather system Information is shared manually and automatically

Source(s): Authors' own work

5.1 Identified barriers and enablers of JIT-PCS fit

The barriers consisted of 25 first-order codes, which were conceptualized into eight second-order themes. The enablers consisted of 14 first-order codes, which were conceptualized into three second-order themes. These barriers and enablers (second-order themes), and their aggregated dimensions, are presented in Tables 2 and 3, respectively. The data structures of the coding process are presented in Appendices B and C, respectively.

5.2 Juncture 1: PCS governance structure, information deficiencies and the initiation of JIT

Managers from both Gothenburg and Gävle reported hesitation and inconsistency among port call actors in implementing JIT voyages. As one port control manager stated: *"We have addressed the actors who were involved in building the platform. There is a tendency to point fingers on one another. Agents and shipping lines say they do not have the mandate to implement JIT, the terminals say that no shipping lines and agents are initiating JIT"*. This indicates that uncertainty about JIT's initiation responsibilities existed in practice during the use phase. This hesitation is consequential because it occurs at the intersection of PCS use and JIT implementation. Initiating JIT is the point at which the PCS is intended to be used to activate the JIT process (request berth window), and when initiation does not occur, PCS use does not translate into JIT voyages in practice.

This hesitation is closely linked to the PCS governance structure, which defines when, how and by whom JIT is initiated through the platform. The governance structure was a frequently discussed topic during the pre-adoption phase, and both ports developed instruction documents describing how the PCS was intended to be used for JIT. The analysis reveals

Table 2. Barriers of JIT-PCS fit

Aggregated dimensions (based on TTF)	Barriers (second-order concepts) of JIT-PCS fit
PCS assimilation process characteristics	Ambiguous role allocation in PCS governance undermines JIT implementation
	Misalignment between PCS governance structure and JIT operational characteristics has negative effects on JIT's implementation
	Digital immaturity and insufficient digital infrastructure among port call actors affect the digital interoperability of PCS negatively, leading to difficulties in implementing JIT
	Existing regulation affects the digital interoperability of the PCS negatively, leading to difficulties in implementing JIT
	Institutional constraints hinder PCS customization to evaluate the outcome of JIT
JIT implementation process characteristics	Commercial dependencies, such as charterparty agreements, limit the ability to implement JIT
	Operational dependencies, such as vessel rescheduling, limit the ability to implement JIT
	Information deficiencies (and confidentiality) affect the digital interoperability and use of PCS to support and evaluate the outcome of JIT negatively

Source(s): Authors' own work

Table 3. Enablers of JIT-PCS fit

Aggregated dimensions (based on TTF)	Enablers (second-order concepts) of JIT-PCS fit
PCS assimilation process characteristics	Top management influence to justify and motivate the use of PCS and implementation of JIT to realize environmental benefits
	Inter-organizational collaboration among port call actors enhances customizations and thereby the ease of using the PCS
JIT implementation process characteristics	Trust among charterers, shipping companies and port authorities streamline the ability to implement JIT

Source(s): Authors' own work

that the workshops and instructions documents about the governance structure did not fully resolve initiation responsibility. In both ports, the instruction documents stated that JIT should be initiated by the agent and/or the shipping operator but did not specify which actor should initiate in practice. As a result, initiation remained a shared responsibility between agents and shipping operators. In the use phase, this ambiguity created a problem: *when responsibility is shared but not clearly assigned, neither agents nor ship operators necessarily take initiative, and the initiation process of JIT becomes inconsistent*.

In addition, *information-related constraints embedded in governance and port operating regulation* further limited the ability to implement JIT. In Gothenburg, safety regulations require agents to submit information about cargo from the three previous voyages before initiating a JIT voyage. Agents often lacked direct access to this information and had to request it from shipping companies, whose delayed responses hindered berth reservation and, thereof, timely adjustments to sailing speeds and thereby the implementation of JIT. Interviewees in both ports also emphasized that not all calling vessels were aware of the PCS and the JIT initiative. When shipping companies lack this awareness, they are less likely to initiate JIT through the PCS, regardless of PCS capabilities.

Furthermore, the pre-adoption efforts that focused on building acceptance and readiness also surfaced governance misalignment across shipping companies, which counterintuitively weakened willingness to initiate JIT through the PCS once it was in use. Observations in Gävle revealed divergent – and at times conflicting – preferences regarding how the PCS governance structure should dictate berth allocation and reservation. Shipping companies with long-distance voyages favoured a berth reservation window that enables booking 72 hours in advance, emphasizing longer planning horizons for JIT and greater potential for fuel and emissions savings. In contrast, companies with short-distance voyages favoured a 24-hour window, arguing that a longer window reduced berth availability and constrained operational flexibility. Similar disagreements were reported during the use phase, with managers representing different shipping companies expressing contrasting views on whether Gothenburg's or Gävle's governance structure better suited their operations. These findings point to a trade-off for JIT-PCS fit: *a standardized governance structure intended to support JIT may misalign with heterogeneous operating conditions across shipping companies, reducing willingness to initiate JIT through the PCS.*

From a JIT-PCS fit perspective, the intersection between PCS use and JIT implementation is negatively influenced by unclear initiation responsibility between agents and ship operators, conflicting governance preferences (e.g. 72 h vs 24 h) and information sharing constraints and limited awareness that limit timely JIT implementation.

5.3 Juncture 2: interoperability as a condition for JIT-PCS fit

Digital interoperability is critical to assimilate PCS because it determines whether the PCS can function as the main coordination platform through which JIT is implemented in practice. Effective interoperability allows actors to share real-time port call information and coordinate sequentially interdependent services, e.g. booking and confirming services alongside berth planning and JIT implementation.

In both ports, barriers constrained the digital interoperability of the PCS, decreasing its ability and effectiveness to coordinate and support JIT implementation. These barriers were *existing regulatory frameworks* and the *digital immaturity of port call actors*. As one port operations manager noted, "*Vessel reporting must go through the Maritime Single Window. It is a legal requirement*". Similar statements were provided by various actors with regards to FENIX. These constraints result in an "interoperability gap," where current regulations allow for unidirectional information sharing only: operational and transactional information can be transmitted from systems such as Maritime Single Window and FENIX to the PCS, but not the other way around. This asymmetry undermines the PCS's potential to operate as the main coordination platform and thereby the satisfaction of users. Agents are particularly affected by the interoperability gap because their tasks include government-related reporting and service coordination and transactions. Mandatory reporting to Swedish authorities must be carried out through MSW, and service transactions linked to the Swedish Maritime Administration (e.g. pilotage through FENIX) remain outside the PCS. As a result, agents must use multiple systems to complete these tasks, rather than handling them through the PCS. This limits the practical value of the PCS for agents and reduces its ability to function as the main coordination platform for JIT.

Digital immaturity had a similarly limiting – and complementary – effect on PCS interoperability by constraining integration with private port call actors. As one port control manager explained: "*Our supplier [PCS supplier] is interested in developing a feature to share transactional information and to book towage services. However, we did not see maturity there [digital maturity of service providers], but if the platform will be used, we may develop it further. Sure, it makes things easier for shipping companies if the platform becomes the central system that they access everything through*". An operations manager also highlighted: "*Some terminals are quite digitalized, while others are behind, but have the willing*". In Gävle, limitations in the port's own digital infrastructure reinforced manual workarounds. As one project manager explained: *"We in Gävle do not know far in advance which agent represents the arriving vessel. Other ports have a separate agent platform. If we had a similar platform, we could send automatic emails to notify agents about booking berths, instead we rely on VTS manual interference to warn them"*. The consequence of constrained PCS interoperability among private actors and service providers leads to continued reliance on e-mails and manual modalities to conduct coordination and transactions of port call services. This in turn further limits the practical value of the PCS, again from the perspective of agents. A project manager recalled: "*One agent inserted the wrong vessel name and IMO-number. The system was able to detect this and warned the agent. However, this happened during the weekend, so the agent did not change the wrong information. This resulted in the vessel losing its berth window. The shipping agency had to compensate the shipping company with the demurrage costs*".

From a JIT-PCS fit perspective, misfit between JIT implementation and PCS assimilation emerged because regulation and digital immaturity jointly constrained the PCS from functioning as the main coordination platform for port calls. Regulation constrained Business-to-Government reporting and service transactions and digital immaturity constrained Business-to-Business coordination, reducing usefulness and satisfaction among actors who coordinate key JIT activities.

5.4 Juncture 3: commercial, operational and institutional dependencies in implementing and evaluating JIT outcomes

Both ports considered the adoption of PCS as a critical enabler of JIT. However, the implementation of JIT depended on broader commercial, operational and institutional arrangements beyond the PCS.

In both cases, *commercial dependencies* related to charterparty agreements limited the ability to execute JIT. PCS use and JIT implementation intersect through the Recommended Time of Arrival (RTA). However, the Recommended Time of Arrival communicated through PCS to adjust sailing speeds could conflict with charterparty terms, meaning JIT could only be implemented if charterparties allowed flexibility through clauses such as JIT or Virtual Arrival. This reveals the interdependency at the intersection of PCS use and JIT implementation: PCS can communicate RTA, but JIT implementation depends on aligned commercial agreements and actors' willingness to act on that information. Interviews revealed that incorporating JIT clauses is more feasible under relational conditions, where trust between charterers and vessel owners enables contractual flexibility. However, it is less so under transactional conditions, such as when cargo is resold during transit and each new charterer must approve speed adjustments, or shipping companies are incentivized by demurrage profits. As one project manager stated: "*Some shipping companies live on it [demurrage], their concept is based on arriving late"*. Another shipping operations manager underlined*: "JIT is not always the best way to generate profit if the market is good. If the market is bad, then maybe we slow steam"*.

Furthermore, *operational dependencies* limited the ability to implement JIT. A terminal operator noted: "*One reason we find it difficult to implement JIT is that we may need to reschedule our vessel order at short notice. If something happens at the refinery, say a production line is disrupted, we produce less of a certain component . . . we might prioritize a vessel carrying diesel ahead of the one scheduled to load gasoline*". These operational interdependencies emerged mainly in Gothenburg. Gothenburg is both a loading and discharging port, where refinery operations and short-notice production changes create a need to reschedule vessel order and maintain flexibility. This contrasts with Gävle, which is mainly a discharging port, where such production-driven rescheduling is less pronounced. This indicates that port context matters for JIT implementation, and that coordinating JIT can be more complex in loading ports like Gothenburg than in primarily discharging ports like Gävle. Overall, these findings show that JIT implementation depends not only on PCS capabilities and fit. It is also shaped by contextual conditions such as charterparty terms, commercial incentives and operational conditions that determine whether actors can act on PCS-enabled information.

Finally, the cases reveal difficulties for port authorities in measuring JIT outcomes. Assessing fuel and emission savings requires access to the JIT decision point (when a vessel reduces speed in response to an RTA), but this information is embedded in charterparty agreements and treated as *commercially confidential*. This limitation is compounded by *institutional constraints* under the landlord governance model, which restrict investments in PCS customization for measurement. As one project manager explained: *"I had a suggestion to add a new feature that would estimate the fuel and emission savings for JIT voyages. It was not prioritized because the municipality wanted to save money"*. From a JIT-PCS fit perspective, confidentiality and institutional constraints limit the ability to evaluate the savings in fuel and emissions savings obtained by JIT. Without evaluating current outcomes, it becomes difficult to identify what should be improved, such as adjustments to governance rules, role allocation or PCS customization to strengthen JIT implementation.

In Figure 2, a parallel process model that summarizes the analysis is provided.

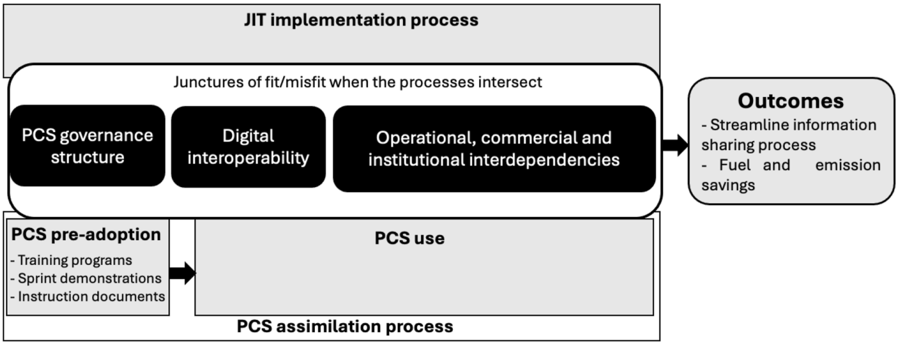

Figure 2. Parallel process model of the intersection between JIT implementation and PCS assimilation. Source: Authors' own work

6. Discussion

The adoption and assimilation of logistics digital platforms and other information systems has primarily been theorized through linear process models (Hazen *et al.*, 2012; Selensky, 2023). While valuable, an implicit assumption in this approach is that the platform is embedded and directly used in a process to achieve outcomes, e.g. a container booking platform intends to directly streamline the container booking process (Zeng *et al.*, 2020). However, other forms of platforms may not be embedded and directly used in an operational process. Instead, they support the emergence and/or improvement of an operational process that is carried out by multiple actors (e.g. the PCS is not directly used to decrease the sailing speed of vessels but helps do so through coordination). Therefore, this study distinguishes between execution-based platforms that are directly used to perform an operational process and generate outcomes, and coordination-based platforms that create value indirectly by enabling other actors to execute a related operational process outside the platform.

For the latter category, a parallel process approach is necessary, because outcomes depend on how platform assimilation and process implementation/coordination unfold and intersect in practice (Cloutier and Langley, 2020). This mode of theorizing is particularly relevant in logistics contexts characterized as loosely coupled systems. In this study, the adopted PCS supported the implementation of JIT. Hence, PCS assimilation and JIT implementation are conceptualized as two related process streams, and TTF is used as an analytical lens to explain how different barriers and enablers influence these processes and, consequently, the realization of fuel and emissions savings. This approach reveals two broader forms of fit/misfit. The first indicates that fit/misfits can originate primarily from one of the two process streams (PCS-side interoperability constraints or JIT-side commercial and operational dependencies) and then spill over to limit the other stream. The second indicates that fit/misfits arise because the two streams must intersect (e.g. governance, role allocation and timing rules for initiating JIT through the PCS), such that fit or misfit is produced in the interaction itself.

PCS digital interoperability emerged as a key PCS characteristic to support JIT implementation. However, it was constrained simultaneously by regulatory constraints and the digital immaturity of port call actors. While prior studies have acknowledged these barriers individually (e.g. Brunila *et al.*, 2021; Gekara and Nguyen, 2020), the findings show how they interact to limit interoperability. Regulatory constraints primarily affect the business-to-government side of interoperability, whereas digital immaturity constrains the business-to-business side. These constraints also originate from multiple sources, including port authorities that own PCS, actors that are using it and regulatory bodies, highlighting the complexity of assimilating platforms in loosely coupled systems such as port calls. These insights also provide further explain why the reliance on manual modalities remains the norm in maritime logistics.

The study shows that JIT implementation cannot be assumed even when technically advanced PCS are adopted, as commercial and operational dependencies may still constrain implementation. While the findings confirm the role of demurrage incentives identified in prior research, they also reveal short-notice vessel rescheduling as a salient and previously underemphasized barrier. This extends existing JIT literature by showing that incentive misalignment is not limited to the behaviour of shipping companies, but may also arise from charterers' scheduling practices.

The second form of misfit originates in the interaction between PCS assimilation and JIT implementation, rather than in either process alone. This interaction-related misfit is reflected in the governance structure that links PCS use to JIT by defining when JIT is initiated, who initiates it and what commitments are implied. In both ports, elements of this governance structure remained ambiguous. Some shipping companies viewed the timing of JIT initiation as misaligned with their operations. In addition, responsibility for initiating JIT (between agents, shipping operators or terminals) was not clearly assigned in practice, which contributed to hesitation and limited initiative to implement JIT. Together, these governance-related ambiguities help explain why PCS assimilation did not result in consistent JIT implementation.

7. Conclusion

The purpose of this study is to explore how the fit between PCS assimilation and JIT implementation co-evolves over time. The main conclusion is that JIT becomes viable once PCS is adopted and used, as it provides the information-sharing capabilities required to coordinate and implement JIT port calls. However, consistent and wider uptake of JIT are not determined by PCS capabilities alone, but depend on broader alignment of commercial, operational, regulatory and institutional conditions.

7.1 Managerial implications

The postponement of the Net-Zero Framework for shipping adds uncertainty that may delay investments in greener technologies, increasing the relevance of cost-effective measures such as JIT arrival. At the same time, the World Bank (2025) anticipates continued growth in PCS adoption. Together, these trends create a need for knowledge on how PCS should be assimilated to realize JIT's environmental and operational outcomes.

The managerial implications address both port and maritime by clarifying that PCS functions as a coordination platform that supports JIT by improving information sharing and port call visibility. Managers should treat the PCS assimilation process as collaborative and iterative. By involving and collaborating with actors, they can customize PCS iteratively and enhance satisfaction. A priority for port managers is interoperability that reduces reliance on parallel systems, particularly for agents. Parallel systems use is driven by regulatory requirements (e.g. mandatory reporting through MSW) combined with uneven digital maturity among port call actors. Interoperability should therefore be addressed on two fronts. First, ports should engage regulators and relevant authorities to adapt frameworks that constrain bidirectional interoperability and keep reporting and transactions outside the PCS. This limits the ability of PCS to operate as the main coordination platform and decreases satisfaction. Second, ports can use procurement and onboarding strategies to raise the digital maturity of private actors by setting minimum interoperability requirements and providing targeted support for integration and use.

Managers should design the PCS governance structure to address two challenges in JIT implementation: heterogeneous shipping operations and unclear initiation responsibility. Because shipping companies differ in voyage patterns and planning horizons, a single governance design is unlikely to satisfy all operational profiles. Governance should therefore prioritize system-level coordination and transparency, rather than optimizing for a specific segment. In practice, this requires managers to map the dominant operational profiles of calling shipping companies and design berth windows, commitment principles and responsibilities accordingly. The mapping should also account for commercial and operational conditions –such as charterparty flexibility, incentive structures and the likelihood of short-notice rescheduling in loading ports – to align PCS routines with when JIT is feasible. Clear role assignment is particularly important in the loosely coupled port call system, i.e. specifying who initiates JIT and who updates key information reduces ambiguity, clarifies accountability and supports more consistent implementation of JIT through the PCS.

7.2 Limitations

This study draws on a multiple case-study approach in the Nordic context. Future research could validate the findings through surveys or examine PCS assimilation in other contexts, as digital platform assimilation is shaped by different conditions. Long-term effects of PCS on competitiveness and power dynamics in maritime transport chains are another research direction.

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Supplementary material

The supplementary material for this article can be found online.

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