



Connecting the Inland Ports: A Framework for Multi-Municipality Data Sharing

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Abstract

Multi-municipality inland ports face a critical coordination gap. While organizationally autonomous, they must collaborate on shared operations. This collaboration currently relies on fragmented emails, spreadsheets, and disconnected local systems, leading to slow decisions, duplicated work, and blurred responsibility. This research addresses this socio-technical problem by designing a conceptual framework that prioritizes governance over technology. The BRIDGE (Business & Rules Integration for Data & Governance Exchange) Framework is a "capability-first" guide that provides a structured process for autonomous authorities to establish shared rules before building a shared platform. Using a design science strategy with the Port of Twente as the primary case, the framework was developed and validated. The resulting artifact is a layered, minimal, and technology-independent framework aligned with TOGAF's Business and Application perspectives. It introduces four explicit decision gates, Legal, Data-Quality, Cost, and Change, to ensure collaboration is sustainable, transparent, and auditable. Validation interviews with four inland ports in the Netherlands (Twente, Venlo, Brabant Ports, and Bergen op Zoom) confirmed the framework is highly relevant, understandable, and feasible when adopted incrementally. The primary barrier identified by stakeholders, cost sensitivity, is directly mitigated by the framework's emphasis on reusing existing tools and establishing a minimal, shared data core. The BRIDGE framework delivers a practical, repeatable process that enables multi-authority ports to build shared institutional capacity from the ground up.

Keywords: inland ports; multi-municipality; centralized communication; data sharing; conceptual framework; design science; governance; TOGAF.

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1. Introduction

1.1 Background and Motivation

Efficient communication and information sharing help ports run daily operations and plan ahead. In many inland ports with several municipalities, information exchange is still split across local administrations, terminal operators, and regional bodies. There is no shared digital platform between these authorities of municipalities. This often leads to duplicated work, inconsistent data, and slow decisions. A comparative study for the Research Topic (RT) Report found that the ports we examined, including Venlo, Zwolle, Kampen–Meppel, Brabant Ports, and Bergen op Zoom, mainly use email, meetings, and spreadsheets for coordination. The study showed that digital pilots exist, but no port in our sample reported an integrated or shared system for inter-municipal communication and data sharing at the time of study. This makes collaboration and strategic alignment difficult (RT Report, S. Suresh 2025).

A key reason is governance because no single authority is responsible for setting common standards or funding a shared approach. Port responsibilities are spread across several municipalities. There is no single digital or organizational framework to tie them together. Earlier research shows that such fragmentation can block effective operations and regional planning (Witte et al., 2014; Witte et al., 2016). The stakes are high. In 2024, inland vessels in the Netherlands carried over 332 million tonnes of cargo, which was an increase of about 1.5 percent compared with 2023. Better coordination helps at this scale (Centraal Bureau voor de Statistiek [CBS], 2025).

Digitalization efforts show what can work. Port community systems and smart-port projects link authorities, operators, and other parties in shared environments. They improve transparency, reduce manual work, and support data-driven planning (Notteboom et al., 2022; Yau et al., 2020). Their success depends on trust, standards, and clear rules for data ownership. Multi-municipality inland ports often do not yet have these conditions.

Although this research uses inland ports in the Netherlands as the context, the coordination problem is not unique to the Netherlands. Multi-authority port regions outside the Netherlands also face similar issues across municipalities and terminal operators (Ignaccolo et al., 2018; Ettore et al., 2023). The framework is designed to be portable: it avoids technology choices, defines a minimal shared metadata profile and

roles, and layers responsibilities that can be adapted to different legal and institutional settings.

The Port of Twente fits this picture. The Twentekanalen widening has been completed and handed over to the regional manager. This improves safe access for larger and more heavily loaded vessels and strengthens links to the ports of Almelo, Hengelo, and Enschede (Rijkswaterstaat, 2023). Day-to-day events still create pressure on coordination. For example, during planned maintenance on 8–9 June 2024, the locks at Delden and Hengelo were closed from 07:00 to 19:00, with extra night operations to limit disruption. Such cases require timely and consistent information across municipalities and operators, which is hard without a shared live view (Rijkswaterstaat, 2024). Findings from the RT Report indicate that current, mostly unstructured exchanges slow joint decisions, project delivery, and longer-term digital innovation (RT Report, S. Suresh 2025).

This research designs a conceptual framework, presented as an enterprise-architecture view for a centralized communication and data-sharing system tailored to ports in the Netherlands with multi-municipality governance. The framework is at the design level and not an IT system or a live platform. It defines organizational processes, enabling techniques, minimal data components, and four decision gates for onboarding and change. Given current capacity and funding constraints, the design assumes a centralized starting point for faster onboarding. The Requirements Analysis chapter explains this choice and its reasoning. The purpose of the conceptual framework is practical. It makes clear who shares what, who can access which data, and through which organizational and technical means. This clarity helps ports move from fragmented exchanges to more integrated, transparent, and data-informed governance (RT Report, S. Suresh 2025; Notteboom et al., 2022).

Considering the fact that the core problem isn't only specific to the inland ports in the Netherlands, the framework is therefore written to be portable: it avoids technology choices, specifies minimal shared metadata and roles, and uses layered responsibilities that can be adapted to different legal and institutional settings. In short, the work addresses a general design gap: how to start from a small, shared governance core and predictable routines, then scale deliberately across authorities.

1.2 Problem Definition

Multi-municipality inland ports in the Netherlands struggle to coordinate work and share data across municipal boundaries. There is no shared, governance-aligned system

for communication and data sharing. Each party maintains its own tools and datasets, and these are not connected. Day-to-day coordination then depends on emails, meetings, and spreadsheets. Information arrives late or in different formats, and decisions take longer. This pattern appears in ports such as Venlo, Zwolle, Kampen, and Meppel, Brabant Ports, and Bergen op Zoom, where collaboration relies on informal exchanges instead of a common digital environment (RT Report, S. Suresh 2025).

The underlying causes are known. First, responsibilities for port management are split across several municipalities and no single authority sets common standards or funds a shared approach. Second, there is no joint organizational or digital framework to coordinate work and data. Third, cross-municipal barriers such as trust, standards, security, and data ownership are hard to arrange. This combination weakens operational effectiveness and regional planning (Witte et al., 2014; Witte et al., 2016).

Work on Port Community Systems shows that shared environments can improve transparency, reduce manual work, and support data-driven planning. It also points to barriers that are hard to arrange across multiple municipalities, such as trust, standards, security, and data ownership rules (Notteboom et al., 2022; Yau et al., 2020). The literature describes the setting but does not provide a practical design that fits multi-municipality authorities.

This thesis addresses the following problem: multi-municipality inland ports lack a shared system that reflects governance and supports secure data sharing, which makes cross-municipal work inconsistent and slow. Typical joint tasks remain hard to manage together, including schedule alignment for vessels and works, status updates for incidents and maintenance, KPI monitoring and reporting, and role-based access to documents and permits. Local digital pilots can function within one organization but do not extend across municipalities. Without standard roles, data definitions, access rules, and decision paths, it is difficult to keep records consistent and auditable. It is also hard to give all parties timely, reliable views of the same information (RT Report, S. Suresh 2025).

To address this problem, the research designs a conceptual framework for a centralized communication and data-sharing system tailored to multi-municipality port authorities, using the Port of Twente as the application context (RT Report, S. Suresh 2025; Notteboom et al., 2022).

A centralized approach gives all parties one place to see the current status and upcoming actions. It reduces duplicate data entry and version conflicts. It applies one set of roles and access rules across municipalities. It speeds incident updates and maintenance planning. It also supports audit, compliance, and learning across projects. A central layer can still allow local systems to remain in use, while coordinating data exchange and decisions across them.

1.3 Research Objectives

The objective is to design a conceptual framework presented as a TOGAF-style enterprise-architecture view that guides a centralized communication and data-sharing system for multi-municipality inland ports in the Netherlands, using the Port of Twente as the context. To make the layering recognizable and comparable, the framework is aligned with The Open Group Architecture Framework (TOGAF).

TOGAF is a widely used enterprise-architecture framework used here only to organize the business and application views for clarity, and further details of the alignment are discussed in Chapter 5 (Hermawan & Sumitra, 2019). The framework specifies organizational processes, enabling techniques, minimal data components, and four decision gates for onboarding and change. It is design guidance for linking existing tools and manual work files. The technology layer and any software implementation or live deployment are out of scope.

To achieve this, the research is guided by the following specific objectives:

RO1: Describe current coordination and data-sharing practices and governance within multi-municipality inland ports in the Netherlands, using Port of Twente as the reference context.

RO2: Derive the functional and organizational or structural requirements for a centralized communication and data-sharing system between multi-municipality inland ports in the Netherlands.

RO3: Design the conceptual framework for multi-municipality inland ports in the Netherlands, defining its parts and the conditions for use in the Port of Twente context.

RO4: Map each requirement to the framework parts between multi-municipality inland ports in the Netherlands and present clear traceability from requirements to framework elements and decision gates.

Collectively, these objectives guide the research toward producing an applicable and theoretically grounded framework that strengthens coordination, enhances information transparency, and supports digital transformation in multi-municipality port authorities.

1.4 Conceptual framework: definition and role

A conceptual framework is a structured network of interlinked concepts that together provide an organized understanding of a phenomenon. It is not a set of disconnected ideas but a plane of related concepts linked by logical or theoretical relations. It offers an interpretive, not causal or predictive, view (Jabareen, 2009). It also functions as an organizing device and visual map of key concepts and their relationships that helps focus a study and guide design choices (Van der Waldt, 2020).

A concept is a mental construct with internal parts and relationships. Concepts get their meaning through links to other concepts and to their theoretical and practical contexts. Some authors broaden “conceptual framework” to cover the whole plan of a study, whereas a “theoretical framework” is a separate lens drawn from prior theory for analyzing data; to avoid confusion, this thesis uses “conceptual framework” in the narrower sense above and keeps it distinct from the theoretical lens (Kivunja, 2018). Taken together, the linked concepts form a framework that structures understanding and sets its limits (Jabareen, 2009).

In this thesis, the conceptual framework names three element types: organizational processes, enabling techniques, and minimal data components. It shows their relationships through four decision gates for onboarding and change. The framework is presented as a TOGAF-style enterprise architecture view that focuses on the business or governance and application perspectives. The technology layer is intentionally out of scope because no system build was done.

1.5 Main Research Question and Sub-Questions

Main Research Question:

How to design a conceptual framework to guide a centralized starting point for communication and data sharing between municipalities in multi-municipality inland ports in the Netherlands?

In this research context, a guide means to provide actionable design rules and procedures that teams can apply without building software: defined roles, minimal shared data items, information and decision flows, and four decision gates for onboarding and change.

To address this main question, the following sub-questions are created. Each sub-question aligns with a specific phase of the thesis and will be answered through literature analysis and framework design:

SQ1. What coordination and data-sharing needs do municipal and port stakeholders have today between multi-municipality inland ports in the Netherlands?

SQ2. What limitations exist in current frameworks for digital coordination, data-sharing, and organizational alignment in port and logistics settings?

SQ3. How do the framework's layers and mechanisms address the derived functional and organizational requirements, overcoming the limitations in current frameworks?

SQ4. What components and design principles should the conceptual design framework include?

1.6 Thesis Structure

This thesis is organized into seven chapters. Chapter 1 introduces the context and problem for multi-municipality inland ports in the Netherlands, states the research objectives, the main research question with sub-questions, and defines how the term conceptual framework is used. Chapter 2 explains the research design and methodology using Design Science Research and outlines the activities, data sources, and evaluation approach. Chapter 3 reviews prior work that informs the design and extracts insights that shape the framework's elements and gate logic. Chapter 4 analyzes the Port of Twente context and derives the functional and organizational requirements for a centralized start, recording centralization versus distribution trade-offs and mitigations. Chapter 5 presents the framework as a TOGAF-style enterprise architecture view, defines its parts and four decision gates, maps each requirement to the framework with a clear traceability

view, and states the design principles; the technology layer is out of scope. Chapter 6 reports stakeholder validation, the assessment criteria, and resulting refinements, and outlines a migration path toward more distributed setups. Chapter 7 provides conclusions and discussion by answering the research question, explaining implications for practice and research, separating limitations from sector-wide challenges, and outlining future work.

2. Research Design & Methodology

2.1 Research Strategy

This study uses Design Science Research (DSRM). DSRM is chosen because the aim is to produce a design framework rather than only describe coordination problems. A regular linear qualitative study would bring up themes and cases, but it would not result in a structured and evaluable design with named elements, decision rules, and clear traceability from problem and requirements to solution. DSRM provides a rigorous and iterative path from problem to artifact and evaluation, so each cycle can test clarity with stakeholders. It also refines the result while keeping academic rigor (Peffer et al., 2007). The output is a framework presented as an enterprise architecture view that follows TOGAF. It focuses on the business and application perspectives; the technology layer is out of scope.

The intended contribution is a Level-2 nascent design theory: named constructs and design principles that guide a class of problems, illustrated through a Level-1 conceptual application in the Port of Twente (Gregor & Hevner, 2013).

The specific DSRM structure followed in this research is based on the six-step process model proposed by Peffer et al. (2007):

1. **Problem Identification and Motivation:** Background research, stakeholder interviews, and the RT Report.
2. **Define Objectives of a Solution:** Derived from the empirical gap and stakeholder needs.
3. **Design and Development:** Define elements (organizational processes, enabling techniques, minimal data components) and the gate logic; present as an enterprise architecture view that follows TOGAF
4. **Demonstration:** A conceptual demonstration in the Port of Twente context to check fit.
5. **Evaluation:** a summative and formative assessment of clarity and relevance using a FEDS (Framework for Evaluation in Design Science Research) guided approach.

6. **Communication:** Results are reported in this thesis and presented to representatives from inland ports in the Netherlands.

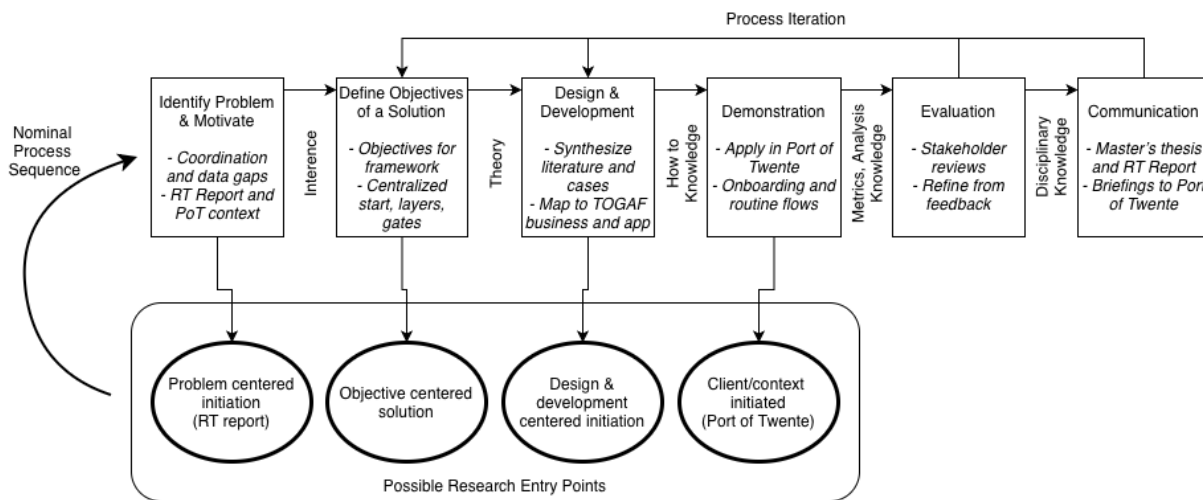


Figure 1: DSRM Process Model (Based on Peffers et al., 2007)

Figure 1 shows the Design Science Research steps used in this thesis. Each step is tailored to the Port of Twente by deriving the problem and objectives from the RT Report, designing a conceptual framework aligned to TOGAF business and application views, demonstrating it in context, and evaluating it with stakeholders.

This research includes four cycles. Cycle 1 combines the coordination problem using the RT Report and initial stakeholder interviews, and produces draft functional requirements and organizational or structural requirements (see Section 2.3 and Chapter 4). Cycle 2 uses those requirements and the literature to define the candidate element set (organizational processes, enabling techniques, and minimal data components) and a first version of the four decision gates, presented as an enterprise architecture view that follows TOGAF. Cycle 3 creates the requirement-to-element mapping, resolves overlaps, and refines the gate definitions, resulting in a clear traceability view. Cycle 4 runs structured walkthroughs with the Port of Twente and gathers feedback from peer inland ports to check clarity, usefulness, and feasibility; minor adjustments follow and are summarized in Chapter 6.

Following DSRM activities and the cycles, the research first defines the problem and the solution objectives, then designs the framework, demonstrates it conceptually in the Port of Twente context, and evaluates its fit with stakeholder needs. Evaluation follows the FEDS, a framework for evaluation in Design Science Research (Venable, Pries-Heje, &

Baskerville, 2016). It is used to check the framework with real stakeholders before any system is built, focusing on whether people can understand the elements and gates, find them useful, and apply them safely in their context.

2.2 Case Study Design

This study uses a single-case design to demonstrate and evaluate the framework in a real organizational setting. A case study is suitable when we need depth and context and when the topic is tied to its real-world conditions (Yin, 2014). The unit of analysis is how a multi-municipality port authority coordinates work and shares data, and the governance that shapes those activities (Yin, 2014).

The case is used to illustrate and assess the proposed design. Findings are generalized to the design and its principles rather than to a population of ports (Yin, 2014). The case is used to assess whether the framework's elements and four decision gates are clear, useful, and feasible in practice. Findings are interpreted for what they say about the design and its principles, not to estimate statistics for a population of ports (Yin, 2014). Evidence sources include the RT Report, semi-structured interviews, and public documents (RT Report, S. Suresh, 2025). Documentation links each claim back to its source, moving from transcripts and notes to coded themes and requirement statements, and then to the framework elements and gates (Yin, 2014).

2.2.1 Selection of the Netherlands as Context

The study is situated in the Netherlands' inland port system. This system includes regional and municipal port authorities that face shared logistical and governance challenges. As described in the RT Report, many ports in the Netherlands rely on fragmented practices such as emails, spreadsheets, and unconnected municipal databases. These practices create inefficiencies and limit coordination between municipalities and port operators. This context is relevant because it shows the organizational fragmentation and the lack of shared digital infrastructure that the framework is designed to address (RT Report, S. Suresh 2025).

Positioning the work in this setting also supports comparability with existing studies of port governance and digitalization. Prior research shows that inland ports play a growing role in regional logistics, yet often face governance complexity due to multiple actors and overlapping jurisdictions. Focusing on this environment aligns with DSRM's problem-centered entry, where real challenges motivate the artifact design (Witte et al., 2016; Witte

et al., 2014; Peffers et al., 2007). It also enabled feedback from peer inland ports during evaluation to check whether the design made sense beyond the focal case (Chapter 6).

2.2.2 Case Selection: The Port of Twente

The Port of Twente is the main case for theoretical demonstration and evaluation. It is a multi-municipality inland port authority that spans several local governments and industrial zones along the Twentekanalen corridor. The RT Report shows that each municipality maintains its own communication and data systems. This leads to duplicated effort, inconsistent data sharing, and limited visibility across operations. This setting provides an evaluation environment to examine whether the conceptual design framework can improve coordination, increase information transparency, and support more consistent communication processes at a design level (RT Report, S. Suresh 2025; Venable et al., 2016).

The Port of Twente is a regional collaboration of five municipalities: Almelo, Enschede, Hengelo, Hof van Twente, and Lochem, with support from the Province of Overijssel and Rijkswaterstaat along the Twentekanalen corridor. Governance is decentralized without a single joint organization; a board of deputy mayors sets direction, two working groups (Economics and Infrastructure) handle operations, and a port manager coordinates day to day as the central point of contact. Coordination relies on email, calls, and shared folders. The Infrastructure group uses a small SharePoint space, while the Economics group does not have a shared environment. Operational data remain in municipal systems, for example, ShipLogic for vessel movements and invoicing links, CODA for financial tracking, and GBI for asset management; a ProShipping dashboard exists but is rarely used. This profile is included here to justify case selection; Chapter 4 provides the detailed history, governance, and structure.

2.3 Data Collection

Data collection supports the first two activities of DSRM: identifying the problem and defining solution objectives (Peffers et al., 2007). The study uses semi-structured interviews with stakeholders from inland ports in the Netherlands. The interviews focus on governance, communication, and data-sharing practices that affect coordination between municipalities and port actors. This provides grounded input for the later design of the framework (Peffers et al., 2007).

2.3.1 Semi-Structured Interview Design

Semi-structured interviews were chosen to allow depth and consistency at the same time. The format lets participants explain their experience while the interviewer follows a clear guide (Myers & Newman, 2007; Rowley, 2012). The guide covered: governance responsibilities, current communication practices, use and limits of digital tools, barriers to coordination, and expectations for a future integrated system. Participants received a short briefing, gave consent, and were assured of anonymity if necessary (Myers & Newman, 2007; Rowley, 2012).

2.3.2 Interview Scope and Participants

Online oral interviews were held with stakeholders from four inland ports in the Netherlands. The set includes single-port authorities and regional clusters. Interviewees include municipal officials, logistics coordinators, digital strategy leads, and development-agency representatives. The interviews surfaced both organizational and technical issues. Recurring themes include fragmented responsibilities, informal communication, limited linkage between local IT tools, and the need for clearer coordination mechanisms (RT Report, S. Suresh 2025).

Across the four inland ports, the interview coverage was as follows:

(1) Port of Venlo, operating within the BluePorts Limburg network of eleven inland ports, has no single authority and no shared digital platform; a local berth-reservation pilot exists only in Venlo, and coordination relies on email, meetings, and Excel, with concerns about funding and fears of losing local control (INT-01). (2) The Port of Zwolle collaboration with Kampen and Meppel is not legally formalized and lacks joint systems. Zwolle informally coordinates, but communication is unstructured, budgets are tight, and there is no team or funding to start digitalization beyond intentions (INT-03). (3) Brabant Ports is a cooperative bringing municipal ports together. Early projects include a digital atlas, port-fee invoicing, and onshore-power integration, yet day-to-day work still depends on email and Teams without a shared CRM or dashboard. Digital maturity varies across municipalities, and change resistance and cost concerns are noted (INT-05). (4) The Port of Bergen op Zoom, a municipality-managed port within the Brabant Ports network, is introducing a digital port-fee system and a city-side digital twin. Capacity and funding constraints continue, coordination remains informal, and a shared platform is not yet in place (INT-06). Two seaports were also interviewed for contrast: Rotterdam operates with corporatized governance and uses centralized platforms such as Portbase

with system-based communication, highlighting the difference from inland multi-municipal contexts; Amsterdam shows similar corporatized features (INT-02, INT-04).

2.3.3 Use of the Research Topic Report as Secondary Data

The thesis also draws on the RT Report (S. Suresh, 2025) as secondary empirical material. The report documents the same inland ports in the Netherlands and provides their case summaries. The RT Report includes an interview register with IDs, interviewees, governance models, and dates, and it provides full case overviews for the six ports, including the four inland ports used here (Venlo, Zwolle, Brabant Ports, Bergen op Zoom) and two seaports for contrast (Rotterdam, Amsterdam). Key cross-port themes are analyzed in the RT Report's thematic analysis, for example, the section on stakeholder communication and coordination that notes all inland cases rely on email and meetings and lack shared inter-municipal platforms.

In this research, inland-port evidence is the primary input for deriving Functional Requirements and Organizational or Structural Requirements, while seaport material is used to contextualize differences in governance and digital capability.

These insights support DSRM Activities 1 and 2: they identify the core coordination problem and help define objectives for the proposed solution (Peffer et al., 2007). The combined results give a clear base for defining the functional and organizational or structural requirements in Chapter 4. This keeps the design relevant to issues observed across inland ports in the Netherlands, with the Port of Twente as the design context.

2.4 Framework Design and Validation Approach

This study follows Design Science Research Methodology (DSRM) for designing and assessing the conceptual design framework. It covers Activity 3 (Design and Development), Activity 4 (Demonstration), and Activity 5 (Evaluation) (Peffer et al., 2007). The work stays at a design level. It focuses on theoretical design and validation rather than technical build or deployment. This section reports four design cycles as outlined in Section 2.1.

Design logic (A3): The framework is designed by combining evidence from the RT Report and the interviews with insights from literature on port governance, digitalization, and data sharing (RT Report, S. Suresh 2025). The aim is to define the

functional and organizational or structural requirements for a centralized communication and data-sharing system in multi-municipality settings.

The requirements are turned into three element types: processes, techniques, and small data items. Four decision gates are then defined. The design is shown as an enterprise architecture view that follows TOGAF. It covers the business and application perspectives. The technology layer is out of scope. A traceability view links each requirement to the elements and gates it uses. This shows coverage and avoids overlap.

Demonstration (A4): No technical system is built. The demonstration is conceptual. The framework is presented to the Port of Twente manager and to three other inland port authorities. The goal is to check how well the design addresses the issues seen in the RT Report, such as fragmented communication, unclear responsibilities, and the lack of a shared structure. The discussion serves as a walkthrough.

Walkthroughs use a fixed set of materials: the framework figure, detailed notes for each layer and gate, and the mapping from requirements to elements. Each session lasts about one hour. Comments are recorded for each element. The peer ports are the same authorities from the RT Report interviews. This keeps a clear link between the evidence and the demonstration.

Evaluation (A5): Evaluation follows the FEDS framework (Venable, Pries-Heje, and Baskerville, 2016). It uses formative and summative theoretical assessment rather than quantitative tests. Formative evaluation verifies that each framework part aligns with the earlier requirements. Summative evaluations are done by presenting the completed design to representatives from other inland ports in the Netherlands with similar governance.

The feedback is used to judge whether the framework is understandable, relevant, and potentially usable in their context. This is a Human Risk and Effectiveness stance in FEDS, which focuses on understanding, acceptance, and perceived usefulness. Small changes from this feedback are summarized in Chapter 6. Peer-port walkthroughs form part of the evaluation.

3. Literature Review

This chapter reviews academic work that supports the design of a communication and data-sharing conceptual framework for multi-municipality inland ports. The RT Report (RT Report, S. Suresh 2025) provides interview evidence from inland ports in the Netherlands, and this review complements it. Together, they provide the empirical and theoretical base for practical steps toward digital transformation in multi-municipality inland ports.

Ports pursue digitalization to manage complex coordination across many public and private actors. Information is spread across organizations and changes quickly. Paper, email, and ad hoc files are hard to track and audit. Digitalization improves the timeliness and consistency of information, reduces manual effort, and lowers errors. It supports transparency and compliance with clear roles and records. It enables evidence-based planning and performance reporting. It also improves resilience during disruptions and supports safety. For small inland ports, a modest approach that standardizes data and routines can deliver benefits without large new systems.

The literature review has two goals. The first goal is to provide a clear theoretical basis for the problem of inter-municipal coordination and data sharing in ports: how multiple public and private actors work together, what information must move between them, and where typical breakdowns occur. The second goal is to extract ideas that can be used in design: frameworks, models, and simple design principles that help build a practical, design-level framework for communication and data sharing in inland ports with limited staff and budgets. The scope covers inter-organizational information systems, port community and smart-port work, multi-stakeholder governance, and public-sector information management. Architecture choices are not taken up here, and technology-layer details remain out of scope.

Since this is a design-oriented study, the review goes beyond a summary. It looks at which frameworks exist, the problems they address, where they fit in this context, and where they fall short on explanations. From this, the gaps are identified for practice. These findings are then used in Chapter 4 to derive requirements and in later chapters to shape the framework.

3.1 Literature Review Methodology

The literature review was conducted using a structured and systematic methodology based on the well-established guidelines provided by Kitchenham et al. (2007). This provides generic steps that are applied here to information systems and public-sector topics on governance, communication, and data sharing, ensuring transparency, reproducibility, and rigor across the search, screening, and extraction stages.

3.1.1 Search Strategy and Initial Data Collection

Firstly, three search strings were chosen to cover the key concepts of this research related to centralized communication, data sharing, and digital transformation in multi-municipality port authorities. The search strings were:

1. (“layered framework” OR “architectural model”) AND (“port governance” OR “multi-municipality” OR “digital transformation”)
2. “data sharing” AND “framework” AND “governance”
3. “process elements” AND “framework” AND (port OR logistics)

These search strings were put across five academic databases: Scopus, Web of Science, Google Scholar, SpringerLink, and the University of Twente Digital Library. The initial search gave the following results:

- Search String 1: 431 records
- Search String 2: 315 records
- Search String 3: 389 records
- **Total initial records: 1,135**

The next steps involved merging these results and removing duplicates and irrelevant papers using systematic filters.

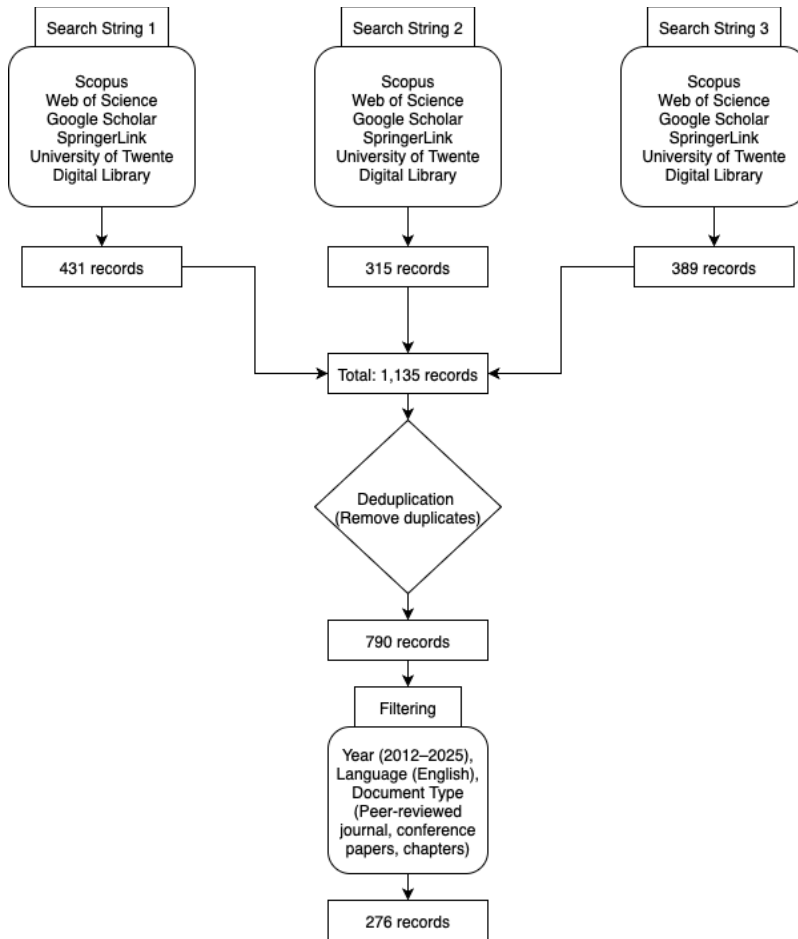


Figure 2: Initial Literature Search and Filtering Overview

This figure illustrates the initial search results per search string combining multiple databases, followed by deduplication and metadata filtering steps (year, language, document type). The figure shows how the total records were reduced from 1,135 to 276 for screening.

3.1.2 Deduplication and Filtering

The 1,135 initial records were merged and subjected to deduplication, removing redundant entries to yield 790 unique records. These were then filtered by publication year (2012–2025), language (English), and document type (peer-reviewed journal articles, conference papers, book chapters, and key reports). This wider filtering stage reduced it to 276 records eligible for screening.

3.1.3 Screening Process

The first screening phase evaluated the relevance of papers based on title and abstract. It focused on the occurrence of port governance, data sharing, and framework or model content relevant to the thesis context. This title and abstract screening excluded 215 papers, giving 61 for further refinement.

The screened 61 papers underwent subject/domain filtering focusing on port logistics, multi-municipality governance, and data sharing and communication systems. Papers lacking a clear framework or model focus were excluded. This reduced the set by a further 23, resulting in 38 records for full-text review.

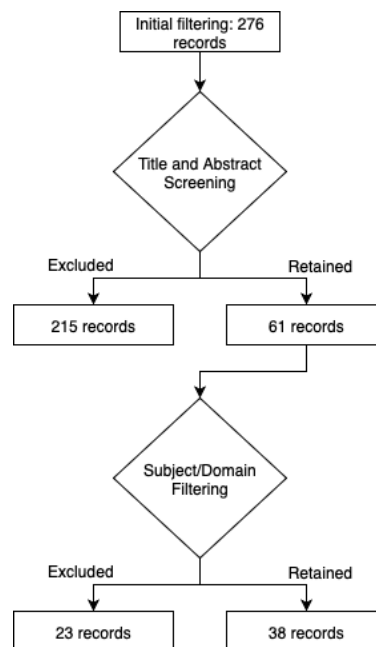


Figure 3: Screening Process Flow

This figure details the screening phases where 276 papers were filtered based on title and abstract relevance and subject/domain fit, resulting in 38 papers for full-text review.

3.1.4 Full-Text Review and Final Selection

The 38 full-text papers were fully assessed for clarity of conceptual framework and applicability to the thesis objectives. At this stage, 23 papers were excluded due to insufficient framework detail, lack of relevance, or methodological weakness.

Backward snowballing was performed on the 15 included papers' reference lists, applying Wohlin's snowballing approach for systematic additional retrieval. This review added 4 relevant papers after screening, resulting in a total of 19 final records selected for the literature review.

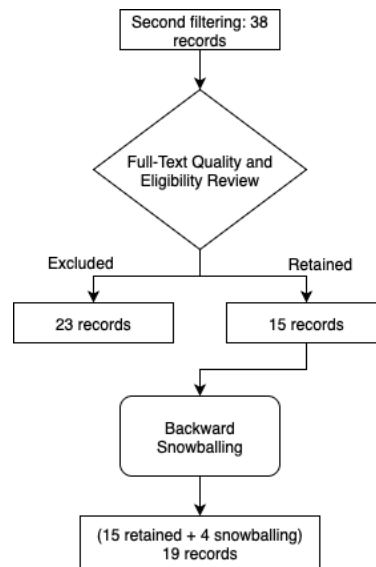


Figure 4: Full-Text Review and Final Selection

This diagram shows the full-text evaluation and backward snowballing process, increasing the final review set to 19 records.

3.2 Overview of Existing Frameworks & Models

Designing a centralized communication and data-sharing system for a multi-municipality port authority requires a clear view of proven approaches. This section reviews the main governance, data, and operational frameworks in the literature and explains how their principles can help in designing the conceptual design framework for the Port of Twente. For clarity, the review groups frameworks into four themes: governance and inter-municipal cooperation, data-sharing and security architectures, and operational and digital-transformation models for ports.

3.2.1 Governance and Inter-Municipal Cooperation Frameworks

Ports involve several municipalities and agencies that share tasks. This makes governance complex (RT Report, S. Suresh 2025, OECD, 2024). The Institutional

Collective Action (ICA) view helps explain choices in this setting. It shows how municipalities pick cooperation tools by weighing decision costs against loss of autonomy. Options include informal ties, contracts, delegated authorities, and mandated regional bodies (Tavares & Feiock, 2017). This is relevant for the Port of Twente because it highlights the trade-offs that shape how municipalities work together.

Municipalities can also take different roles in governing digital systems. Research identifies five mechanisms: regulating, providing, enabling, self-governing, and collaborating. These map to roles such as regulator, partner, and data provider (Voytenko Palgan et al., 2021). Power relations at the local level are not fixed. They can shift between command, concession, cooperation, and competition (Cristofaro et al., 2025). Therefore, a design needs flexibility so that data-sharing arrangements can adapt over time.

From a policy perspective, the OECD (2024) provides a concrete framework for inter-municipal cooperation calls for clear legal forms, cost-sharing rules, and monitoring structures to make collaboration durable (OECD, 2024). Taken together, these works provide the governance base for this research. The conceptual design framework for the Port of Twente should include a governance layer that turns these ideas into operational rules, decision procedures, and clear accountability.

3.2.2 Data-Sharing Architectures, Standards, and Security

Governance sets the rules for cooperation, but data-sharing architectures decide how information moves. In the port context, three coordination patterns are common: bilateral exchanges between parties, centralized platforms such as Port Community Systems, and federated models that keep data at the source but use shared standards for access (van der Keijl & Moonen, 2022). A recent study in RoPax ports identifies practical functions needed for a federated data space, including search and discovery, metadata availability, data exchange, archiving, data quality, data lineage, and security, and proposes a conceptual model aligned with the Gaia-X federated data infrastructure (Iancu et al., 2023). Gaia-X is a European initiative for a federated data infrastructure that enables interoperable and sovereign data sharing under common rules and building blocks. Together, these studies point to a growing hybrid approach that mixes central coordination with decentralized data ownership.

Comparative work across European data infrastructures supports this hybrid choice. Centralized Trusted Research Environments make transformation and quality checks easier. Federated networks scale well and help with GDPR compliance because data stays local. In practice, many initiatives combine the two: a central catalog and policy layer

with local nodes that store data and run analytics (Rujano et al., 2024). For a multi-municipality port, this balance suits better. It allows shared governance without forcing municipalities to hand over all datasets.

Centralized parts still need internal consistency. A Master Data Management (MDM) setup can help in this situation. It uses a master data system, a master database, and a warehouse layer with data-quality alarms, standard code mappings, and controlled exchange channels (Hong et al., 2017). Public-sector guidance adds a clear process for sharing: define the need and legal basis, draft a data-sharing agreement, transfer data securely, integrate it, analyze it, and adjust roles and processes (Taylor et al., 2014).

Security and privacy matter, regardless of the data-sharing model. The literature treats data as an asset that needs both governance and technical protection. Baseline controls include a clear legal basis and data-sharing agreements, role-based or attribute-based access control, logging and audit, and encryption in transit and at rest (Taylor et al., 2014). When data are sensitive or cannot be pooled, methods such as differential privacy, homomorphic encryption, federated learning, and secure multi-party computation allow analysis without wide disclosure (Wang et al., 2023). In multi-agency settings, multi-authority attribute-based encryption lets different bodies issue attributes that together grant fine-grained, revocable access with outsourced decryption (Chow, 2016). Together, the literature points to a layered security approach that can sit on top of centralized or federated sharing. The specific controls depend on data sensitivity, risk, capacity, and legal constraints, and they are turned into requirements in Chapter 4.

3.2.3 Operational and Digital-Transformation Frameworks for Ports

Operational problems in ports often come from planning that does not line up with information flows. A three-layer view makes this clear: contracting, planning, and physical operations. Weakness in one layer can cause delays in the others (Gumuskeya et al., 2020). A related model, Port 4.0, groups digital change into three areas: business-process automation, coordination and integration, and data-driven decisions. Enabling tools include IoT, analytics, and digital twins (Behdani, 2023).

Research evidence links these digital layers to performance. Connected-vehicle systems and digital infrastructure can improve truck turnaround and lower emissions by synchronizing gate operations and staging areas (Belcore et al., 2023). A simple five-layer data setup can also help: perception, transmission, database, application, and presentation. It has been validated in construction and can be applied to ports for real-time data capture and analysis (Xue et al., 2022).

Efficiency is not the only goal. Sustainability and long-term direction matter too. The Avoid–Shift–Improve (A-S-I) model links digital measures with environmental and social indicators and casts the port authority as a community manager (Ignaccolo et al., 2020). Analytic Hierarchy Process (AHP) helps rank actions in inland ports using people–planet–profit criteria (Lamsali et al., 2023). A foresight model separates very long trends from shorter innovation cycles so investments match durable policy paths (van Dorsser & Taneja, 2020). At the city level, four factors shape digital maturity: smart governance, smart environment, smart living, and smart technology (van der Hoogen et al., 2024). Together, these frameworks provide methods and metrics to design and assess a centralized communication and data-sharing system.

Table 1 provides a comprehensive overview, grouped summary of the frameworks reviewed in Section 3.2. It shows the broad area each framework informs and the underlying problem it addresses. Items are organized into five high-level categories: Strategy and transformation; Governance and institutional arrangements; Data architecture and management; Security, privacy, and access control; and Operations and service delivery. The ‘Underlying problem addressed’ column gives a one-line statement for each source.

Reference	Framework or model	High-level category	Addressed problem
Behdani (2023)	Port 4.0	Strategy and transformation	Setting direction for digital transformation
van der Hoogen et al. (2024)	Smart Municipality		Assessing and raising digital maturity
van Dorsser & Taneja (2020)	Foresight Model		Anticipating long-term trends for planning
Ignaccolo et al. (2020)	Avoid–Shift–Improve		Framing sustainability choices
Lamsali et al. (2023)	AHP Prioritisation		Prioritizing initiatives under constraints
Tavares & Feiock (2017)	Institutional Collective Action	Governance and institutional arrangements	Coordinating roles and incentives across municipalities

Voytenko Palgan et al. (2021)	Municipal Roles		Defining public-sector roles and capacities
OECD (2024)	Inter-municipal Cooperation		Structuring cooperative arrangements
Cristofaro et al. (2025)	Micro-Municipal Flows		Managing authority and decision pathways
Rujano et al. (2024)	Hybrid Architecture	Data architecture and management	Integrating central services with local data holders
van der Keijl & Moonen (2022)	Federated Port Patterns		Sharing data across organizations without centralizing datasets
Hong et al. (2017)	Master Data Management		Standardizing and reconciling shared data items
Xue et al. (2022)	Five-Layer Data Stack		Structuring data services and exchange layers
Iancu et al. (2023)	Federated Maritime Data Space		Establishing a shared data space concept
Taylor et al. (2014)	Data-Sharing Process		Governing the end-to-end sharing workflow
Wang et al. (2023)	Privacy and Rights	Security, privacy, and access control	Protecting data through governance and privacy methods
Chow (2016)	CP-ABE		Enforcing fine-grained, attribute-based access
Gumuskeya et al. (2020)	Operational Diagnosis Lens	Operations and service delivery	Identifying coordination gaps in day-to-day workflow
Belcore et al. (2023)	Connected Vehicles		Improving traffic and terminal flow coordination

Table 1: Framework Comparison

Port 4.0 sets direction for digital transformation in ports by treating the port as a network of organizations that must see the same picture and use shared meanings. It focuses on

governance of data, visibility of cross-organizational processes, and measurable outcomes. In this view, digital tools support agreements and routines rather than replace them. It prioritizes interoperability, traceability, and the ability to improve through feedback.

Across Port 4.0 studies, common building blocks appear. These include a shared vocabulary with minimal metadata for each dataset, clearly defined roles such as data owner and data steward, traceability of indicators from definition to report, and routines that control change through defined reviews and releases. Typical controls include role-based access, audit trails, and privacy stewardship, with collaboration across organizations and continuous improvement supported by transparent metrics.

A hybrid framework shows how authorities can coordinate with a central view while keeping data local. A central catalog and policy layer handles discovery, shared terms, quality checks, and access rules so parties can find, trust, and use information. Local systems keep their data and connect through lightweight links so existing tools can stay in place while authorities exchange only what is needed.

The hybrid model also gives a practical path for change in a multi-municipality setting. The design starts centralized to speed onboarding and create predictable routines. As standards and trust improve, selected data and processing can move closer to municipalities while the shared catalog, policies, and routines remain. This keeps local control, avoids unnecessary duplication, and still provides one coordinated view for regional decisions.

Governance work such as Institutional Collective Action and studies on municipal roles clarify why and how municipalities cooperate. They show that responsibilities, incentives, and autonomy help shaping coordination choices. This supports a governance-led design with named roles and simple agreements that protect local control while supporting collaboration work.

Data-architecture sources such as Master Data Management, five-layer stacks, and federated patterns add methods for common vocabulary, record control, and exchange layers. They support the need for a minimal shared metadata profile and a shared dictionary so terms do not drift. They also point to lightweight connectors that allow existing municipal tools to stay in place.

Process and security literature fills in the ways of sharing. Data-sharing process models describe the steps from request to publication and reuse, which informs the use of gates and defined approvals. Privacy and access-control work, including attribute-based methods, supports role-based access, audit, and change tracking so sharing remains accountable.

Operations and service-delivery models show day-to-day coordination needs. Examples include incident updates, maintenance windows, and traffic or terminal flow adjustments. These needs help in creating the Applications and Presentation layers so routine work is visible and consistent across municipalities.

Overall, these frameworks and models cover strategy, governance, data architecture, security, and operations. They do not yet provide a practical, governance-led and technology-light design that fits multi-municipality ports. The next section identifies the specific gaps that remain these literatures.

3.3 Identified Gaps in Literature

The literature presents many insightful ideas, yet it also leaves several gaps that are relevant to this study. The gaps are put into five areas: governance, architecture and interoperability, security and privacy, operations and process, and sustainability and foresight.

3.3.1 Governance and Institutional Gaps

Governance studies explain why and when to cooperate, but not how to encode those choices inside a digital system. The ICA typology helps pick components such as informal ties, contracts, delegation, or imposed bodies. It does not say how these choices translate into data-access rules, APIs, or audit trails (Tavares & Feiock, 2017). The municipal roles of regulate, provide, enable, self-govern, and collaborate are clear on paper, but not in machine-readable policies for a platform (Voytenko Palgan et al., 2021). Local authority flows such as command, concession, cooperation, and competition are described, but there is no implementation guidance for cross-jurisdiction data services (Cristofaro et al., 2025). The OECD sets out legal forms, cost sharing, and monitoring, yet it does not define the reference digital layer for identity, semantics, and interfaces to make these rules work in practice (OECD, 2024).

3.3.2 Architecture and Interoperability Gaps

Port data-sharing work lists three models: bilateral, centralized, and federated. It says little about standard vocabularies and federated identity and access management for day-to-day use (van der Keijl & Moonen, 2022). Maritime data-space proposals describe functions such as discovery, metadata, exchange, quality, lineage, and access. They give few details on APIs and ontologies (Iancu et al., 2023). European health-data work shows that hybrid setups scale and meet privacy law. Still, federated identity, policy alignment, and even data-quality enforcement remain hard problems (Rujano et al., 2024). On the centralized side, MDM gives standards, ETL, and quality checks, but not semantic models or cross-domain identity and access management (Hong et al., 2017). Five-layer operational stacks prove useful for pipelines from perception to presentation, but they leave inter-municipal semantics and governance to the reader (Xue et al., 2022). Port 4.0 states what to integrate, but not how to standardize API, identity, and semantics.

3.3.3 Security, Privacy, and Access Control Gaps

Data-governance literature lists tools such as differential privacy, federated learning, homomorphic encryption, and secure multi-party computation. It is sector-general and does not specify latency, reliability, or KPI trade-offs for real-time port coordination (Wang et al., 2023). Multi-authority CP-ABE supports cross-jurisdiction attribute issuance and attribute-level revocation. Known limits remain, such as small attribute universes, policy-visible ciphertexts with outsourced decryption, and a static corruption model. These need careful governance choices (Chow, 2016). Public-sector process models stress data-sharing agreements, secure transfer, and integration. They do not natively include modern privacy-preserving analytics or federated identity and access management (Taylor et al., 2014).

3.3.4 Operational and Process Gaps

Operational models show where coordination breaks down. For example, across contracting, planning, and physical layers. They do not define the data contracts and interfaces needed to fix the breakpoints (Gumuskaya et al., 2020). Simulation-backed studies show benefits from booking, priority, and buffers. They do not cover inter-municipal mandates, legal liability, or shareable KPIs (Belcore et al., 2023). Port 4.0 gives a strong capability map, but no set instructions for change management, workforce transition, or cyber risk control (Behdani, 2023). The five-layer construction stack is rigorous on layering but bound to projects. It does not address cross-jurisdiction rollout

or public-law constraints (Xue et al., 2022). Smart-municipality research sets targets for governance, environment, living, and technology. It does not explain how to arrange the data layer across municipalities (van der Hoogen et al., 2024).

3.3.5 Sustainability and Foresight Gaps

The A-S-I model links actions to outcomes and roles, but it does not specify the digital tools needed to measure these outcomes in a shared system. (Ignaccolo et al., 2020). AHP helps set priorities but does not provide a reference data architecture (Lamsali et al., 2023). Foresight models handle timing and inertia, not technical or governance standards (van Dorsser & Taneja, 2020). As a result, it is important to clearly define how sustainability goals and long-term trends link to the platform's KPIs, datasets, and access rules.

3.4 Design Implications for the Proposed Framework

As summarized in Table 1, the literature does not converge on a single solution and instead groups into five themes: strategy and transformation, governance and institutional arrangements, data architecture and management, security, privacy, and access control, and operations and service delivery. Taken together, these themes suggest a design that combines an operational digitalization lens with a data-sharing pattern and anchors both in governance, security controls, and routine processes. Within these themes, this research uses Port 4.0 as the digitalization lens and a hybrid centralized and federated architecture for data sharing.

Port 4.0 offers a strong operational base. The literature groups capabilities into three areas: business-process automation, coordination and integration across actors, and data-driven decision-making. It links port work with tools such as IoT, analytics, and digital twins. It aims for an interoperable, data-enabled ecosystem where routines and information move predictably between organizations (Behdani, 2023).

Port 4.0 also suits multi-municipality inland ports because it treats coordination among public and private actors as day-to-day operational work rather than a one-off software rollout. It focuses on transparency of key events like vessel arrivals, maintenance windows, and incident response, plus stewardship that ties data to KPIs with clear audit. This supports predictable routines, fair comparison across municipalities, and stepwise improvement under limited budgets while allowing local tools to remain in place with agreed review points and controls.

However, Port 4.0 has a scope gap for this research. Most work emphasizes technical capabilities and firm-level integration inside a port community, while this thesis must resolve cross-municipal governance and explicit data-sharing rules. Port 4.0 does not prescribe how municipalities share ownership of definitions, set common access rules, or run change control across authorities. A second framework is therefore required to cover those governance and data-exchange specifics.

The hybrid centralized and federated framework fills that gap. A central catalog or policy layer coordinates standards, access control, and quality assurance, in line with Master Data Management ideas (Hong et al., 2017). Local nodes run by municipalities or terminals keep their data and perform analytics under shared policies (Rujano et al., 2024; van der Keijl & Moonen, 2022; Iancu et al., 2023). Public-sector process guidance adds the steps for safe exchange, from defining the need and legal basis to secure transfer, integration, analysis, and organizational change (Taylor et al., 2014). The literature also provides ways to protect privacy and data rights. Cryptographic tools, such as multi-authority attribute-based encryption, support fine-grained access control and revocation when several municipalities are involved (Wang et al., 2023; Chow, 2016).

Bringing these strands together bridges operations and governance. Port 4.0 helps improve coordination and real-time decision-making inside the port ecosystem. The hybrid architecture ensures that governance, privacy, and cooperation are maintained across municipalities. Together, the two frameworks give a balanced and context-appropriate base for the Port of Twente. This provides the basis for the conceptual design framework as it helps to create a clear set of requirements in the next chapter.

4. Problem & Requirements Analysis

This chapter translates the empirical insights from the RT Report and the in-depth interview with the manager of the Port of Twente, conducted on 16 October 2025, into a clear set of requirements for the development of a centralized communication and data-sharing framework. The goal is to state what the system should support and which organizational or structural conditions are needed across the participating municipalities (RT Report, S. Suresh 2025).

The chapter first outlines the specific context of the Port of Twente, followed by the identification of recurring patterns seen across inland ports in the Netherlands. It also defines centralized and distributed approaches, compares their trade-offs, and explains the reason for a centralized starting point in this context. Based on these insights, the chapter formulates both the functional requirements that describe what the system should enable and the organizational or structural requirements that define how the system can be governed, maintained, and put into practice.

4.1 Port of Twente Context

This section describes what the current situation at the Port of Twente looks like and why its existing communication and data practices create the need for a centralized system based on the interview conducted with the manager of the Port of Twente.

4.1.1 Overview of the Port and Governance Structure

The Port of Twente is a regional collaboration between five municipalities, Hengelo, Almelo, Enschede, Lochem, and Hof van Twente, supported by the Province of Overijssel and Rijkswaterstaat. It includes several inland terminals along the Twentekanalen, forming a logistics corridor between the eastern Netherlands and the seaports of Rotterdam and Amsterdam. The collaboration operates through a decentralized governance model, where municipalities cooperate on shared port development without a formal joint organization.

A board of deputy mayors from each municipality makes strategic decisions on development priorities, funding, and regional positioning. Two working groups, Economics and Infrastructure, handle operational matters, while the port manager

coordinates daily activities and serves as the central point of contact among municipalities and external stakeholders.

Decision-making and coordination rely largely on informal communication and personal initiative. Meetings, direct calls, and document sharing are the current mode of collaboration. This light and trust-based model allows flexibility and local autonomy but also creates dependency on individuals and a lack of structured information flow.

External coordination involves Rijkswaterstaat, which manages the Twentekanalen, and the Province of Overijssel. This contributes to regional planning and funding. Broader discussions take place in forums such as Logistics Overijssel and Inland Shipping East, connecting public bodies and logistics companies. Despite these efforts, coordination remains loosely organized, highlighting the need for a more systematic framework for communication and data sharing across the network.

4.1.2 Existing Communication and Data Landscape

Communication within the Port of Twente partnership depends almost entirely on email, phone calls, and meetings (RT Report, S. Suresh 2025). The Infrastructure working group uses a limited SharePoint site, while the Economics group lacks any shared digital environment. The port manager manually collects and redistributes information, which keeps processes running but consumes time and risks inconsistency.

Operational data are stored across separate municipal systems. ShipLogic records vessel movements and links to the Twente Tax Authority for port-fee invoicing. CODA (Enschede) handles financial tracking, and GBI (Antea) supports asset management. A shared dashboard, ProShipping, provides freight-volume and CO₂ data but is rarely used due to limited awareness and access issues.

Each municipality maintains its own files and reporting routines, so there is no unified data environment. When an overview is needed, the manager collects data from each system by hand. This slows reporting and can lead to inconsistent conclusions.

External communication with the Province of Overijssel and Rijkswaterstaat follows the same pattern, mainly emails and periodic meetings, with occasional use of project-specific folders. The absence of a central digital workspace or dashboard means that collaboration remains fragmented and labor-intensive. This demands the need for a

shared platform that can streamline communication and data management across municipalities and partners.

4.1.3 Digitalization Objectives and System Expectations

The digitalization objective is to solve specific coordination problems in the Port of Twente partnership: late and inconsistent updates across municipalities, duplicated manual compilation of information, limited visibility of planned works and incidents, scattered documents, and weak traceability for decisions. These issues slow joint planning and create avoidable rework (RT Report, S. Suresh, 2025; Port of Twente manager, personal communication, October 16, 2025).

The goal is a centralized yet lightweight system that improves communication, transparency, and data-informed decisions. It should connect existing systems such as ShipLogic, GBI, CODA, and ProShipping into one accessible environment rather than introducing complex new software. Each municipality should be able to view and contribute shared information while keeping ownership of its own data. The system is expected to provide a shared live view of vessel movements, planned maintenance and works, incident status, and project updates. It should offer simple forms and file imports to reduce duplicate entry. It should enforce role-based access with clear permissions. It should keep an audit trail and version control for accountability. It should generate basic reports that support strategic oversight and day-to-day operations. These expectations reflect the needs expressed by local stakeholders and the common patterns seen across inland ports (RT Report, S. Suresh, 2025; Port of Twente manager, personal communication, October 16, 2025).

The expected system functionalities remain practical. The port manager emphasized that the platform should provide a consolidated dashboard with key indicators, ships per month, port revenues, expenditure against budget, and infrastructure forecast, updated weekly or monthly rather than in real time. Essential features include secure document exchange, meeting coordination, and reporting capabilities, supported by role-based access and mobile compatibility. The focus is on usability and continuity rather than technological aspects. By simplifying coordination, reducing manual data collection, and ensuring shared visibility, the system is expected to strengthen inter-municipal collaboration while maintaining the port's lean governance model.

Table 2 summarises the expected system functions and what each provides, based on the interview with the Port of Twente manager (personal communication, October 16, 2025).

Function	What it provides
Consolidated dashboard	KPIs such as ships per month, revenues, expenditure vs. budget, and an infrastructure forecast. Updated weekly or monthly from ShipLogic, CODA, GBI, and ProShipping.
Incident and works overview	Shared view of closures and planned maintenance with status and history for audit.
Secure document exchange	One place for agendas, minutes, permits, and contracts with version history.
Meeting coordination	Agendas, actions, and follow-ups with assigned owners.
Reporting templates	Standard monthly and quarterly reports that pull from the dashboard and finance exports.
Simple forms and file import	Short forms and CSV uploads to reduce duplicate entry with basic validation.
Role-based access	Standard roles across municipalities that control view, add, edit, and approve permissions, with least-privilege by default.
Audit trail	Logged changes and access records to support accountability.
Mobile access	Phone and tablet access to dashboards, incidents, and meeting items.

Table 2: Summary of expected system functions

4.1.4 Boundary Conditions and Constraints

The design of a centralized communication and data-sharing framework for the Port of Twente is expected to follow several practical and organizational boundaries. The collaboration operates with limited financial and technical capacity, relying on lower municipal budgets and existing IT infrastructures. Each municipality maintains its own internal systems and data policies, making large-scale replacement or full integration unrealistic. Political aspects also affect the boundary conditions. Municipalities value their autonomy and prefer a light governance approach, where shared tools support coordination without creating a new administrative layer.

Other constraints include uneven digital maturity among municipalities and varying familiarity with current systems. The port's operations rely heavily on a small team, particularly the manager, which limits the capacity for complex system rollouts. For this reason, digitalization must proceed incrementally, starting with a pilot involving one or two municipalities before scaling further. Security and privacy standards (GDPR compliance, access control, and data ownership agreements) are essential but should remain proportionate to the system's size and purpose. Within these boundaries, the framework is expected to deliver practical improvements. It needs to bring communication into one place, make information easy to access, and link existing data sources. It is also expected to support sustainability and be easy for all participating municipalities to adopt.

4.1.5 Centralized vs. Distributed Approaches

A centralized approach refers to one core service that holds the shared workspace and runs the main coordination rules. A distributed or federated approach refers to data and control that stays with the source organizations, and coordination happens through shared rules and connectors. These two approaches are defined in various fields, for example, health information exchange in the cloud, multi-system energy coordination, large IoT networks, and edge security systems (Abughazalah et al., 2024; Li & Zhang, 2021; Park et al., 2021; Sharma et al., 2020).

Centralized designs tend to be easier to integrate and faster to start. They often reach better global performance because one place sees the full picture and can make consistent decisions. This effect is reported for overall efficiency in energy coordination, for fresher information in IoT scheduling, and for higher detection accuracy in edge security (Li & Zhang, 2021; Park et al., 2021; Sharma et al., 2020). At the same time, centralization brings clear risks. A single hub can fail, and it can attract attacks. More detailed information sits together, which raises privacy exposure and demands a trusted operator with strong controls (Abughazalah et al., 2024).

Distributed designs keep data closer to the source and spread the load. They can reduce network traffic to a hub and improve resilience. In edge security tests, a distributed scheme sent less data across the network than a centralized one (Sharma et al., 2020). They can also lower latency by placing services near users in some settings (Abughazalah et al., 2024). The trade-off is more coordination work and, in many cases, lower global performance. Devices or agencies act with partial information, so results may be less efficient or less accurate than with a central view (Li & Zhang, 2021; Park et al., 2021; Sharma et al., 2020). Distributed setups also need extra mechanisms to sense availability,

avoid conflicts, and preempt cleanly when local conditions change (Theimer & Lantz, 1988).

Given the varying levels of digitalization within municipalities in inland ports, their capacity, the resources and funding limits discussed via interviews conducted during the earlier phase (RT Report, S. Suresh 2025) and an in-depth interview with the manager of the Port of Twente, this research adopts a centralized starting point. A single shared workspace lowers the initial integration effort and applies one set of roles and access rules. This choice is made with a clear view of its risks. These include safeguards such as uptime and backup targets, checks to reconcile data when importing or connecting to municipal sources, role-based or attribute-based access, audit logging, and incident response procedures (Abughazalah et al., 2024; Sharma et al., 2020). As governance and capacity improve, parts of the design can move toward more distributed data holding and processing where that brings value (Li & Zhang, 2021; Park et al., 2021).

4.2 Functional Requirements

This section defines the functional requirements (FRs) of the centralized communication and data-sharing framework for the Port of Twente. These requirements describe the core capabilities the system needs to deliver. Each requirement is based on the RT Report and the port manager interview. It reflects both common patterns across ports and the specific context of the Port of Twente.

FR-01: Central Shared Workspace

The system must provide a single digital workspace where municipalities can access, exchange, and manage shared documents, meeting notes, and project updates. This addresses the current dependence on email and personal file storage, making sure that structured and traceable communication across working groups is set.

Derived from: Fragmented communication practices; manual document exchange by the port manager.

FR-02: Multi-Stakeholder Directory and Contact Management

A central directory should maintain contact information of internal (municipal) and external stakeholders, such as Rijkswaterstaat, the Province of Overijssel, and logistics partners. This feature supports transparency in communication and continuity during staff turnover.

Derived from: Lack of shared stakeholder overview; dependency on individual knowledge networks.

FR-03: Integrated KPI Dashboard

The framework must include key operational and financial indicators in a shared dashboard updated monthly. Core indicators include ship movements (ShipLogic), port revenues (ShipLogic -> Tax Authority), expenditures (CODA), and infrastructure condition (GBI). This ensures municipalities share the same overview for planning and reporting.

Derived from: Interview with port manager; cross-case need for transparency in port performance.

FR-04: System Connectivity and Data Import

The framework should integrate existing systems, ShipLogic, GBI, CODA, and ProShipping, through data connectors or imports rather than full replacement. This ensures continuity of existing operations while enabling shared access to relevant data.

Derived from: Existing systems operating in isolation; limited digital capacity and funding.

FR-05: Reporting and Export Tools

The system must allow automatic generation of standard reports (e.g., monthly overviews, financial summaries, infrastructure updates) and easy export to common formats. This reduces the manual workload currently carried out by the port manager.

Derived from: Manual data collection for board reports; lack of standardized templates.

FR-06: Shared Calendar and Task Coordination

A shared calendar should support scheduling of meetings, site visits, and project deadlines across municipalities and stakeholders. Combined with basic task-tracking features, it can replace fragmented email threads and improve visibility of ongoing activities.

Derived from: Decentralized meeting coordination and inconsistent follow-up between working groups.

FR-07: Role-Based User Views

The framework should provide each group with the access and views they need: municipal officers, harbor masters, finance teams, and external partners. Each user should only see relevant data, supporting clarity and compliance with privacy obligations.

Derived from: Need for transparency balanced with local data ownership and GDPR compliance.

FR-08: Mobile Accessibility

The system should be accessible through mobile or browser-based interfaces to support staff who work in the field or at different terminal locations.

Derived from: Port manager's emphasis on mobile usability; need for flexible, location-independent access.

FR-09: Information Traceability and Archive

All documents, reports, and meeting records must be stored with version control and traceable histories to ensure continuity during staff turnover.

Derived from: Risk of information loss and dependency on individuals for document retrieval.

These functional requirements specify what the shared workspace must deliver. For it to operate across several municipalities, clear rules are also needed for roles, ownership, access, security, availability, and change. Since the starting point is centralized, these rules must address single points of failure, data sovereignty, and synchronization. Section 4.3 sets these organizational and structural requirements.

4.3 Organizational or Structural Requirements

While the functional requirements describe what the framework should do, the organizational or structural requirements define how it should be governed, managed, and sustained within the Port of Twente's multi-municipality environment. These requirements ensure that the framework can operate effectively despite differences in local systems, capacities, and decision-making structures.

OR-01: Coordinated Governance Structure

A small, representative coordination group should oversee the framework's development and maintenance. This group should include the port manager and designated representatives from each municipality's working groups. It will set priorities, monitor progress, and handle decisions on data-sharing and feature updates.

Derived from: Decentralized decision-making and dependency on informal communication; need for continuity across municipalities.

OR-02: Data-Sharing Agreement (MoU)

A formal memorandum of understanding must define data ownership, access rights, and responsibilities of each municipality. This is intended to provide legal clarity under GDPR and builds trust by setting what information is shared, with whom, and for what purpose.

Derived from: Fragmented data ownership; varying privacy practices and local data policies.

OR-03: Defined Decision and Responsibility Matrix (RACI)

A clear distribution of roles and responsibilities should be established for managing and updating data across systems. For instance, harbor controllers maintain GBI data, finance teams manage CODA inputs, and the port manager oversees shared dashboards.

Derived from: Role ambiguity and dependency on a single manager; uneven engagement across municipalities.

OR-04: Security and Compliance Framework

The framework is expected to follow "middle-high" security standards as suggested by the port manager. This ensures access control, audit trails, and privacy-by-design principles. Compliance should be proportionate. It must protect sensitive data without creating excessive administrative work.

Derived from: Focus on data confidentiality; limited IT capacity among municipalities.

OR-05: Pilot-to-Scale Pathway

The rollout should begin with a pilot phase involving one or two municipalities to test functionality, usability, and coordination mechanisms. After evaluation, the framework can be gradually scaled to all participants.

Derived from: Limited resources, varying digital readiness, and preference for incremental adoption.

OR-06: Change Management and Training Support

A light but consistent change management approach should follow implementation. This includes introductory training sessions, recurring demonstrations, and short user guides to familiarise staff with the system.

Derived from: Uneven familiarity with digital tools; underuse of existing systems like ProShipping.

OR-07: Sustainable Funding Model

A transparent cost-sharing arrangement must be agreed upon. This is potentially based on traffic volume, budget capacity, or equal contributions from each municipality. External funding from the Province or EU programs may follow this.

Derived from: Financial constraints and differing municipal budgets; lack of a long-term funding structure.

OR-08: Continuity and Knowledge Retention

To reduce dependency on individuals, responsibilities and documentation should be distributed among multiple staff members. Assigning backups and doing regular handovers to keep the work going during staff turnover.

Derived from: Heavy reliance on the port manager; risk of knowledge loss and operational disruption.

Together, these eight organizational and structural requirements show how the framework will be governed, rolled out in steps, and kept running over time in the Port of Twente's multi-municipality setting. They provide the rules and roles that support the functional requirements described earlier and connect the problem analysis to the framework design in the next chapter.

5. Framework Design

This research designs a conceptual framework for coordination and data sharing in multi-municipality inland ports. It brings together five ideas: governance, coordination, data integration, applications, and performance monitoring. The framework is prescriptive. It proposes layers, decision gates, and traceable links from requirements to design parts. In design science terms, it contributes as a Level 2 nascent design theory, which provides prescriptive design knowledge rather than empirical prediction (Gregor and Hevner, 2013).

Conceptual frameworks can be represented using layered architectures because layers provide a clear and logical way to show how different conceptual elements connect and depend on one another. In such structures, each layer represents one level of abstraction, with higher layers relying on the foundations defined below them. This makes complex relationships easier to understand and prevents overlap between unrelated components. Parush (2015) demonstrated that layering helps clarify relationships between conceptual levels by separating them into ordered and interdependent parts. Each part explains a different aspect of the system but remains connected to the others. Grandjean (2020) also illustrated this idea through a multilayer conceptual framework that visualizes how interdependent systems interact within digital networks, showing that layered structures can effectively describe complexity without losing coherence.

The same logic is visible in widely used frameworks beyond academic theory. For example, the Open Systems Interconnection (OSI) model is described by Amazon Web Services as a conceptual framework that divides network communication into seven distinct layers, from physical transmission to user-facing applications. Although it originates from computer networking, its structure shows the benefit of layering as a way to organize conceptual logic rather than technical implementation. Each OSI layer has a defined role but depends on the correct function of the others, ensuring both separation and interconnection. Together, these examples confirm that representing a conceptual framework through layered architecture is both valid and effective. It allows abstract concepts to be organized logically, expressed visually, and understood systematically while maintaining clarity across different domains.

Following this, the requirements are translated from Chapter 4 into five layers that structure responsibilities and interfaces: Governance and Policy, Coordination and Standards, Integration and Connectors, Applications, and Presentation. Each requirement is mapped to one or more layers and is governed through four decision gates for onboarding and controlled change.

To make these layering recognizable and comparable, the framework is aligned with The Open Group Architecture Framework (TOGAF) (Hermawan & Sumitra, 2019). The business and application perspectives are used to organize the elements and gates. The technology layer is intentionally out of scope because no system build is included in this research. Section 5.2 introduces TOGAF and shows how the framework maps to it.

The framework also reflects the centralized starting point adopted in Chapter 4. This choice is made for faster onboarding under capacity and funding constraints, and it is balanced by safeguards for security, availability, and reconciliation that are embedded in the layers and gates. Stakeholder checks that assess clarity, usefulness, and feasibility are reported in Chapter 6.

5.1 Design Objectives

This section states the objectives that guide the conceptual design framework. The objectives reflect the requirements from earlier chapters. They define what the framework should enable for the Port of Twente and how it should operate in a multi-municipality setting.

Two foundations shape these objectives. Port 4.0 provides the capability context. It focuses on coordination and integration and on data-driven decisions, with automation as an optional enabler (Behdani, 2023). A hybrid centralized-federated architecture provides the governance logic. The starting point is centralized, with a single governance layer for policy, metadata, and data quality, while municipal systems remain in place and connect through lightweight imports and APIs. This can evolve toward more distributed exchange later if capacity and funding improve (Rujano et al., 2024).

Based on these points, this section defines specific design objectives that link each objective to its requirement base and to the supporting framework. This keeps the design transparent and makes later evaluation straightforward.

Objective	Linked FR/OR	Base framework
Shared KPI dashboard with monthly (default) and weekly (optional) cadence to enhance situational awareness	FR-03, FR-05	Port 4.0 - Data-driven decisions
Connect existing systems (ShipLogic, GBI, CODA, ProShipping) through lightweight connectors rather than replacements	FR-04	Port 4.0 - Coordination and integration

Provide shared workspace, role-based views, reporting, and a calendar for coordination	FR-01, FR-06, FR-07	Port 4.0 - Coordination and integration
Maintain central policy and metadata management while keeping data oversight local	OR-01 to OR-04	Hybrid architecture - Central hub with local nodes
Enable pilot-to-scale pathway with cost sharing and continuity measures	OR-05 to OR-08	Hybrid architecture - Governance and scalability

Table 3: Design objectives, requirement links, and base frameworks

5.2 TOGAF: Overview, Scope and Viewpoint

TOGAF (The Open Group Architecture Framework) is a reference for developing and governing enterprise architecture. Its core is the Architecture Development Method, which sets out a loop of phases that move from an architecture vision to the business view and then to the information systems and technology views. The method is iterative and keeps a constant focus on requirements and governance. The value of TOGAF is the shared structure and its common set of artifacts, such as principles, roles, and application services, which make designs easier to read and compare across contexts (Hermawan & Sumitra, 2019).

Practice shows that organizations rarely follow every step in TOGAF exactly. Teams keep the broad domains and the language, but tailor the steps and deliverables to fit their needs. Using TOGAF as a reference, rather than as a strict method, gives clarity without forcing work that is out of scope. This research follows that approach. TOGAF is used to frame the layers and the decision gates, so the framework has a clear place in the Business and Application perspectives, while the Technology layer remains outside the scope of this thesis (Kotusev, 2018; Hermawan & Sumitra, 2019).

The framework is organized with the Business and Application perspectives. The Business perspective covers principles, roles, decision rights, coordination routines, and data-sharing agreements. The Application perspective covers application services, shared data items, simple interfaces, and reports. The Technology perspective is not covered because this research does not design infrastructure or build software. This boundary keeps attention on governance and use, which is where the immediate value lies for a multi-municipality authority (Hermawan & Sumitra, 2019).

Only the parts of TOGAF that help at the design level are used. Material that aligns with the Vision, Business Architecture, and Information Systems Architecture phases briefs

the layout of layers and the content of the gates. Migration planning, detailed change management, and technology architecture are not developed here. The centralized starting point sits in the Business perspective as shared governance, with local systems linked through simple services in the Application perspective. This tailored use of TOGAF keeps the framework readable and traceable for stakeholders while staying within scope (Kotusev, 2018; Hermawan & Sumitra, 2019).

5.3 BRIDGE: Framework Overview and TOGAF Alignment

This section gives overview of the conceptual design framework layers and sets a common reference. TOGAF’s Business and Application views are used to present the BRIDGE (Business & Rules Integration for Data & Governance Exchange) Framework clearly. They do not define or constrain the framework. The Technology layer is out of scope because no system build is included.

5.3.1 BRIDGE Framework

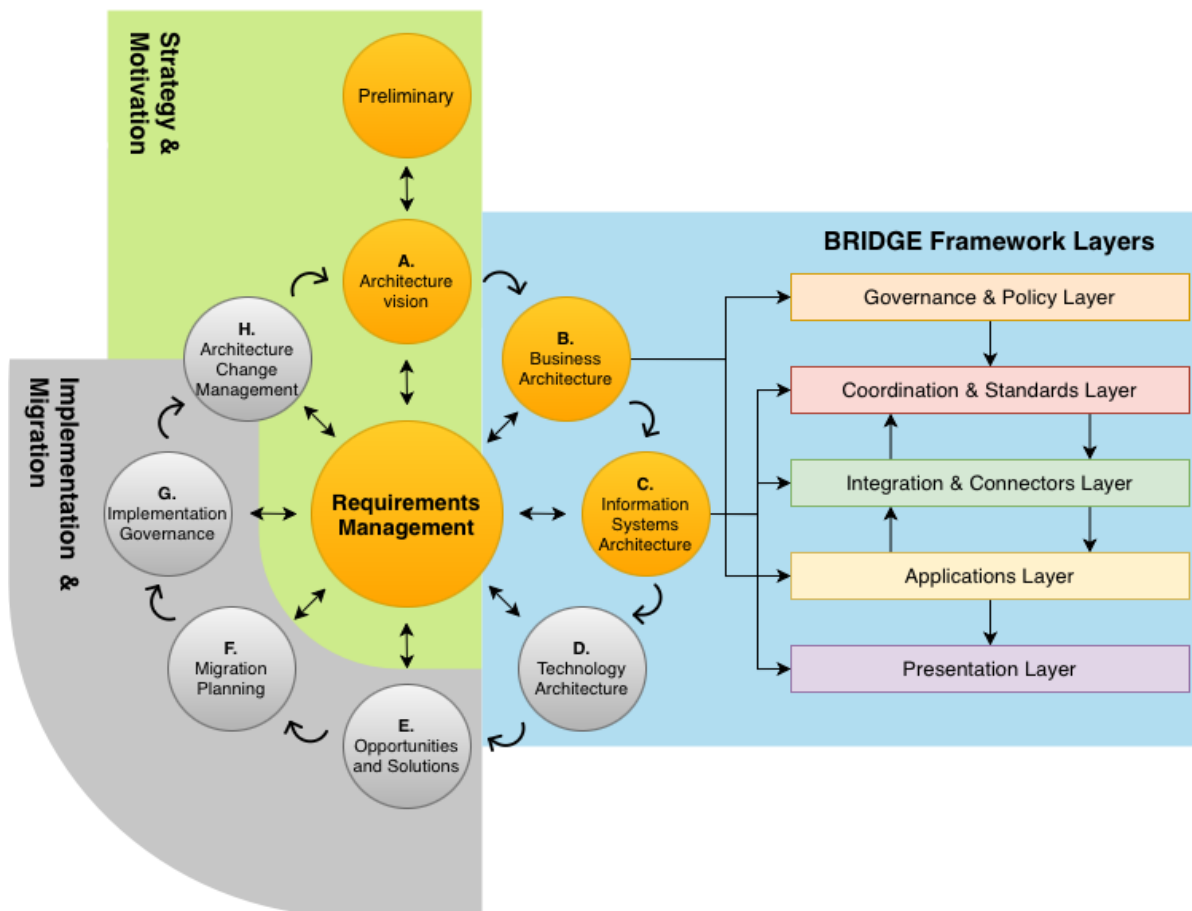


Figure 5: BRIDGE (Business & Rules Integration for Data & Governance Exchange) Framework with TOGAF alignment

For readability, the layers are presented using TOGAF business and application views only, without adding technology scope. The below table shows how the BRIDGE's layers and gates alignment with TOGAF elements. This keeps the design readable and comparable.

Framework elements	TOGAF alignment	Context
Governance & Policy Layer	Business Architecture (B)	Principles, roles, decision rights, MoUs, and data-sharing agreements, audit and accountability processes.
Coordination & Standards Layer	Information Systems Architecture (C) - Application & data objects	Shared data items and definitions, metadata/registers, code lists, and quality thresholds; policy register for data use.
Integration & Connectors Layer	Information Systems Architecture (C) - Application services & interfaces	File importers and simple APIs, with validation checks for incoming data.
Applications Layer	Business Architecture (B) with supporting Application services (C)	Routine processes, access rules, shared workspace services, action lists, meeting records, and simple workflows.
Presentation Layer	Information Systems Architecture (C) - User Services	Dashboards, reports, calendars, and views with agreed update frequency.
Legal Basis Gate	Business Architecture (B); Requirements Management	Confirm legal basis and purpose, roles and authority, and a signed data-sharing agreement.
Data-Quality Gate	Information Systems Architecture (C); Requirements Management	Verify shared items and definitions, mappings, and quality thresholds; confirm metadata and test a sample import.
Cost-Sharing and Sustainability Gate	Business Architecture (B); Requirements Management	Agree on funding split and support model; set backup and recovery targets; define exit and continuity terms.
Change-Impact Gate	Business Architecture (B) and Information Systems	Assess impact on roles, data, and services; approve or route for

	(C); Requirements Management	redesign; update registers and communicate changes.
Traceability and requirements	Requirements Management	Link each FR/OR to a layer and gate; keep a change log and decision rationale.

Table 4: Mapping of framework elements to the TOGAF view in Figure 5.

Figure 5 presents the BRIDGE (Business & Rules Integration for Data & Governance Exchange) Framework, visually mapping its five layers onto the standardized TOGAF Architecture Development Method (ADM). The name "BRIDGE" was chosen as a metaphor for the framework's core function: it is designed to connect autonomous municipalities over their operational gaps, just as a physical bridge connects separate landmasses. The acronym's letters represent the framework's core components and functions:

- **B for Business:** Anchors the framework in the Business Architecture (B), defining the organizational processes and policies.
- **R for Rules:** Emphasizes the Governance & Policy Layer, which establishes the formal MoUs, DSAs, and RACI matrix for collaboration.
- **I for Integration:** Represents the Integration & Connectors Layer, which links existing municipal systems without replacing them.
- **D for Data:** Relates to the Coordination & Standards Layer, which creates a shared "data dictionary" and quality checks.
- **G for Governance:** Highlights the governance-led approach and the four Decision Gates that control the process.
- **E for Exchange:** Represents the framework's primary goal: enabling secure and auditable data exchange between authorities.

Figure 5 and Table 4 work together to anchor the conceptual framework within a standardized, globally recognized methodology. The diagram provides the high-level visual map, while the table supplies the granular details and context for each component. Together, they demonstrate that the BRIDGE framework is not a replacement for TOGAF, but rather a specific, practical implementation of its core layers, tailored to the problem of multi-municipality port coordination.

This alignment also serves to support the Design Science Research Methodology (DSRM) approach, where the central "Requirements Management" hub of TOGAF is fulfilled by

the rigorous problem identification and requirements derivation conducted in Chapter 4 of this study.

BRIDGE framework introduces five layers that were selected to cover the full set of issues and requirements found in Chapter 4 while keeping the design simple enough to adopt. The selection and creation of these layers are supported by literature review, requirement analysis, interviews and the RT Report that showed problems in roles and agreements, inconsistent data definitions, weak links between local systems, unclear day-to-day routines, and the need for clear views and reports.

Strategy & Motivation (Preliminary & Phase A):

The "Strategy & Motivation" arc in the TOGAF diagram, which includes the Preliminary phase and Phase A, is conceptually fulfilled by the foundational work of this research. The Preliminary phase, which establishes the "why" and "how" of the architecture effort, is directly represented by Chapter 1 (Introduction) and Chapter 2 (Research Design & Methodology). These chapters define the core problem of fragmented communication, establish the DSRM strategy, and set the organizational context.

Phase A, "Architecture Vision," is where the scope, stakeholders, and vision for the solution are defined. This is accomplished in Chapter 4, "Problem & Requirements Analysis". The vision is the creation of a centralized communication and data-sharing system, and the scope is defined by the functional and organizational requirements derived from stakeholder interviews and the analysis of the Port of Twente.

Phase B: Business Architecture

The "B. Business Architecture" phase maps to the framework's Governance & Policy Layer, which defines the organizational principles, roles (RACI), and legal agreements. It also connects to the Applications Layer to the extent that it defines the business collaboration processes and routines. As shown in Table 4, this phase also governs the business-led decision elements, including the Legal Basis, Cost-Sharing, and Change-Impact gates.

Phase C: Information Systems Architecture

The "C. Information Systems Architecture" phase covers both data and application services, mapping to the remaining layers of the BRIDGE framework. It aligns with the Coordination & Standards Layer and the Integration & Connectors Layer by defining the shared data items and exchange mechanisms. It also aligns with the Applications Layer

and Presentation Layer by defining the specific user-facing services and dashboards. This phase technically governs the Data-Quality Gate, which ensures data integrity.

Out-of-Scope Phases (D, E, F, G, H)

The alignment diagram intentionally grays out "D. Technology Architecture" and leaves the implementation and migration phases (E, F, G, H) to visually represent the research's scope. This thesis delivers a conceptual design and does not specify the underlying physical infrastructure, servers, or network configurations required for a live system. Consequently, the next phases related to solution implementation, migration planning, and operational change management are also considered out of scope.

The Role and Granularity of the Alignment Table

While the diagram shows the high-level connections, Table 4 provides the detailed, component-level justification and functions as a comprehensive legend. Its most critical contribution is extending the mapping beyond just the five layers to include the framework's unique decision elements and gating checks. The table explicitly details how the governance-led gates (Legal Basis, Cost-Sharing, and Change-Impact) are functions of the Business Architecture (B), whereas the technical Data-Quality Gate is a function of the Information Systems Architecture (C). This provides a complete, traceable design linking all requirements from Chapter 4 to a logical, standards-based structure.

5.3.2 Centralized starting point in TOGAF view

The framework adopts a centralized starting point as discussed earlier. In the TOGAF view, this means shared governance in the Business perspective and shared application services in the Information Systems perspective. Local municipal systems remain in place and connect through simple services in the Integration layer. The aim is faster onboarding under current capacity and funding limits, with one place to apply roles, rules, and data standards. The definitions and trade-offs for this choice are set out in Section 4.1.5, and stakeholder validation is reported in Chapter 6.

Centralization creates specific risks. These include a single point of failure, concerns about data sovereignty, and the chance of stale or conflicting data during exchange. The framework addresses these through the requirements in Chapter 4 and through the gates defined in Section 5.5. The Legal Basis Gate confirms purpose, authority, and a signed data-sharing agreement. The Data-Quality Gate enforces shared items, definitions, mappings, and quality thresholds. The Cost-Sharing and Sustainability Gate sets funding, support, backup, and recovery targets. The Change-Impact Gate controls

updates to roles, data, and services. Together, these controls support a safe centralized start while leaving a path to add more distributed exchange later if capacity and trust improve.

5.4 Structured Outline of BRIDGE Layers

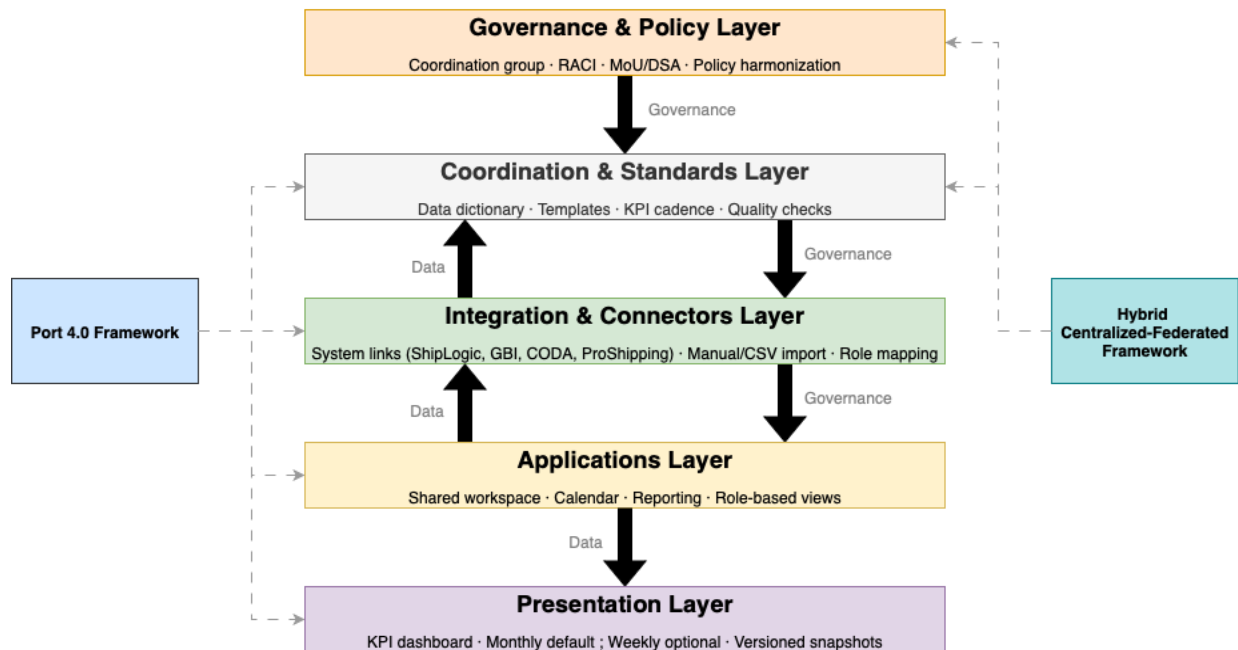


Figure 6: Layers of BRIDGE framework with origin frameworks; Port of Twente context

Figure 6 shows the five BRIDGE layers with Port of Twente as its context and how they interact. This means, elements inside each layer is structured based on the context of Port of Twente, the major contribution to the case study of this research. The side labels indicate the literature anchors (existing framework): Port 4.0 for operational coordination and a hybrid centralized and federated model for data sharing. Example items under each layer are illustrative (specific Port of Twente) and details follow in below sections I need your help with all this is it actually.

5.4.1 Governance and Policy Layer

This layer defines how municipalities and port stakeholders coordinate. It sets the legal and procedural conditions for data sharing. It establishes the coordination group and assigns roles and responsibilities using a RACI (Responsible, Accountable, Consulted, and Informed) structure. It creates the legal basis for exchange through a Memorandum of Understanding (MoU) or a Data Sharing Agreement (DSA). These agreements specify ownership, access rights, purpose of use, retention, and dispute resolution. The layer sets

security and privacy rules: audit logs, and GDPR-aligned controls for the Port of Twente. Together, these elements address organizational requirements OR-01 to OR-04 and support continuity and resource alignment in OR-07 and OR-08.

This layer governs the decision gates described in Section 5.5. It owns the Legal Basis Gate through approved MoUs or DSAs. It also owns the Cost-Sharing and Sustainability Gate through budget and resource agreements. It defines the Change-Impact Gate here and coordinates execution with lower layers via RACI updates and onboarding plans. It mandates the Data-Quality Gate, which is executed in the Coordination and Standards Layer.

The design follows the hybrid centralized-federated approach. A central coordination hub manages policy and metadata. Local management remains with municipalities for compliance and scalability. The layer also aligns with Port 4.0 principles that link effective digital coordination to clear governance and accountability structures (Rujano et al., 2024; Behdani, 2023). Hence, this layer sets the rules of engagement for all others. Policies flow downward for consistency. Accountability and autonomy remain distributed across municipalities.

5.4.2 Coordination and Standards Layer

This layer turns governance decisions into consistent practice across municipalities. It defines a light data dictionary with essential fields, formats, and units. It provides versioned templates for data reporting and sets a reporting cadence with monthly as the default and weekly as an option. It also sets minimum quality checks for completeness and internal consistency before shared use. These elements address FR-03, FR-05, OR-02, and OR-04. They also put the Data-Quality Gate from Section 5.4 into practice.

Functionally, this layer links governance and implementation. It converts rules into standard procedures so the layers work together. The standards package includes field lists and definitions, KPI formula sheets tied to the cadence, a short validation checklist, and change-log notes to inform the coordination group when definitions change. These tools keep information aligned and traceable across municipalities.

The design combines the hybrid centralized–federated perspective and Port 4.0. Shared definitions and quality rules support lawful exchange across autonomous nodes (Rujano et al., 2024). Comparable data enable coordination and integration and support data-driven decisions (Behdani, 2023). By standardizing structure and validation before integration, this layer supplies consistent inputs and keeps the framework testable for feasibility and fidelity in later stages (Moullin et al., 2020).

5.4.3 Integration and Connectors Layer

This layer provides the path for municipalities to exchange information without replacing their systems. It intakes data from ShipLogic, GBI, CODA, and ProShipping using the shared definitions and quality checks from the previous layer. The preferred method is a lightweight connector for each source. If this is not possible, a CSV import with the same validation checklist is used. Core functions include source configuration, mapping to the data dictionary, validation feedback, logging (timestamp, source, transformation), and role-based access that matches governance rules. This layer implements FR-04 and supports FR-05 and FR-09 by enabling reproducible exports and traceable snapshots.

Conceptually, this is the technical core of Port 4.0 coordination and integration. It enables interoperability without introducing a new platform (Behdani, 2023). In the hybrid centralized–federated view, it keeps local management while allowing central accommodation. Data stays on municipal infrastructure where possible. Transfers are limited to agreed fields and cadence. When central staging is needed, it follows the lawful basis and quality rules set by higher layers (Rujano et al., 2024). All mappings and validation routines are versioned for transparency (Ullah, 2021). This balance keeps integration feasible, secure, and aligned with governance and evaluation goals (Nilsen, 2015; Moullin et al., 2020).

5.4.4 Applications Layer

This layer provides the user-facing environment for daily coordination. It offers a shared workspace for notes and documents, reporting tools, a shared calendar for task management, and role-based views for managers, finance, infrastructure, and external stakeholders. Access is through web browsers and mobile devices to reduce operational overhead. This layer uses validated data from the Integration and Connectors Layer and creates reports and snapshots for the Presentation Layer. It implements FR-01, FR-05, FR-06, FR-07, and FR-08, and supports FR-09 through archived exports and versioned snapshots with clear sources.

Design choices follow Port 4.0 coordination and integration. The focus is on practical collaboration tools rather than complex automation (Behdani, 2023). Activity is logged and kept in audit trails. This aligns with the hybrid centralized and federated approach that uses proportional protection and shared accountability across municipalities (Rujano et al., 2024; Gale et al., 2013). To keep use consistent, this layer applies the Change-Impact Gate. It requires RACI updates, onboarding checklists, and short training before adding new users or datasets. Views and templates can be adapted to local needs while keeping

standard outputs, so adoption, feasibility, and fidelity can be assessed during evaluation (Moullin et al., 2020).

5.4.5 Presentation Layer

This layer provides decision support with a simple KPI dashboard. It uses validated outputs from the Applications Layer. Indicators update monthly by default, with a weekly option where data allow. Definitions and templates come from the Coordination and Standards Layer. The dashboard shows tiles and trends for operational, financial, and infrastructure KPIs. Each tile links to the underlying report. The layer also saves versioned snapshots for each reporting cycle so users can see what was shown at that time.

The dashboard supports oversight and coordination. It does not try to predict outcomes or prove causality (Behdani, 2023; Jabareen, 2009). Each visualization includes a short note on what it shows and why it matters in this context, without making claims beyond this setting (Kuechler & Vaishnavi, 2012). Access is set by role, so users only see what they need. This follows the hybrid centralized and federated approach with clear control and proportional protection (Rujano et al., 2024).

For later evaluation, each indicator displays its update schedule, data source, and validation status. Tiles show the template ID and last refresh time. Saved snapshots record what data were shown, when they were shown, and the validation state. This enables reproducible exports, an audit trail from data to visualization, and checks on adoption, feasibility, and fidelity (Gale et al., 2013; Moullin et al., 2020; Nilsen, 2015).

5.5 Decision Elements and Gating Checks

The conceptual design framework includes four decision gates that ensure all necessary conditions are satisfied before a new dataset or municipality is onboarded. These gates verify legal, data, cost, and organizational readiness in line with the governance structure and the requirements defined earlier. They keep the design process disciplined and transparent, finalizing Activity 3 of the Design Science Research Methodology (DSRM) before moving into demonstration and evaluation (Gregor & Hevner, 2013; McMeekin et al., 2020). Each gate is owned by a specific layer within the framework and ensures that adoption remains lawful, consistent, and feasible.

The Legal Basis Gate verifies that a valid Memorandum of Understanding (MoU) or Data Sharing Agreement (DSA) is in place before any data exchange occurs. It confirms data ownership, access rights, usage purpose, and retention period. Managed by the

Governance and Policy Layer, it ensures that all data sharing complies with the General Data Protection Regulation (GDPR) and that the roles of controllers and processors are clearly defined (Rujano et al., 2024).

The Data-Quality Gate ensures that datasets meet the minimum standards defined in the Coordination and Standards Layer. Each dataset is reviewed against the data dictionary and validation checklist before being accepted for shared use. Validation results are stored in the shared workspace to provide traceable proof of readiness. This gate prevents incomplete or inconsistent data from entering the shared environment and supports reliable downstream integration (Moullin et al., 2020).

The Cost-Sharing and Sustainability Gate checks that each municipality’s financial and operational responsibilities are agreed upon and recorded before participation. Managed within the Governance and Policy Layer, it ensures resources, budgets, and long-term support are in place for sustainable operation. This reflects Port 4.0’s focus on aligning resources and reducing implementation risks through incremental adoption (Behdani, 2023).

The Change-Impact Gate assesses whether each organization is ready to adopt and maintain the framework. The Applications Layer ensures that RACI updates, onboarding checklists, and short training sessions are completed before new datasets or users are added. This maintains consistency and accountability while enabling measurable evaluation of adoption and fidelity in later stages (Moullin et al., 2020; Gale et al., 2013).

5.6 Traceability Matrix

This section provides the formative validation of the conceptual design framework by showing how it satisfies the requirements defined in Chapter 4. The traceability matrix verifies internal completeness and alignment between requirements and framework components before the summative evaluation in Chapter 6. Each requirement is linked to the layer where it is implemented and to the specific mechanism that satisfies it.

FR	Requirement	Implemented layer(s)
FR-01	Shared workspace	Applications
FR-02	Central directory	Coordination & Standards
FR-03	KPI dashboard and cadence	Coordination & Standards; Presentation
FR-04	Connect existing systems	Integration & Connectors
FR-05	Reporting and export	Applications; Presentation
FR-06	Shared calendar	Applications
FR-07	Role-based views	Applications

FR-08	Mobile access	Applications
FR-09	Reproducible snapshots	Applications; Presentation

Table 5: Functional requirements traceability

OR	Requirement	Implemented layer(s)
OR-01	Coordination group	Governance & Policy
OR-02	Legal basis	Governance & Policy
OR-03	Roles and RACI	Governance & Policy; Applications
OR-04	Security and privacy	Governance & Policy; Applications
OR-05	Pilot to scale	Governance & Policy
OR-06	Change management	Governance & Policy; Applications
OR-07	Cost sharing	Governance & Policy
OR-08	Continuity	Governance & Policy; Applications

Table 6: Organizational requirements traceability

5.7 Design Principles

This section summarizes the core design principles that guide the framework and explains why its structure and mechanisms are expected to work in the context of multi-municipality inland ports. These principles show prescriptive design knowledge developed through the Design Science Research Methodology (DSRM) and represent the theoretical output of Activity 3 - Design and Development. Each principle is based on insights from Port 4.0 and the hybrid centralized-federated model and is supported by relevant literature.

Design Principle	Argument	Reference
DP1. Establish a coordination group before integration.	Clarifies authority and decision-making before system setup.	(Rujano et al., 2024; Behdani, 2023)
DP2. Use shared standards and templates.	Ensures consistent data across autonomous actors.	(Moullin et al., 2020; Rujano et al., 2024)
DP3. Apply lightweight connectors.	Reduces disruption and increases adoption feasibility.	(Behdani, 2023; Ullah, 2021)
DP4. Maintain proportional security and access.	Balances transparency with GDPR compliance.	(Rujano et al., 2024; Gale et al., 2013)

DP5. Introduce structured decision gates.	Keeps onboarding controlled and traceable.	(McMeekin et al., 2020; Moullin et al., 2020)
DP6. Separate coordination from operations.	Clarifies responsibilities across framework layers.	(Behdani, 2023; Rujano et al., 2024)
DP7. Provide transparent KPI dashboards.	Gives a clear, current view to all users without future predictions	(Kuechler & Vaishnavi, 2012; Jabareen, 2009)

Table 7: Design principles with Rationale

6. Framework Validation

This chapter validates the Port of Twente conceptual design framework developed in Chapter 5. The goal is to assess its practical relevance, feasibility, and clarity through expert feedback from inland-port authorities. Validation in this context is not technical but conceptual. It examines whether the framework is understandable, applicable, and contextually appropriate for multi-municipality port coordination.

6.1 Validation Approach

The validation followed a summative design consistent with Design Science Research Methodology (DSRM) Activities 4 and 5 (Peppers et al., 2007) and the FEDS framework for evaluation (Venable et al., 2016). It served as a stakeholder-based validation scenario that examined how well the conceptual design framework meets its purpose in real governance settings.

Discussions were held with representatives from four inland ports in the Netherlands: Port of Twente, Port of Venlo, Port of Bergen op Zoom, and Brabant Ports. Each session was semi-structured. Guided questions covered the framework's layers and decision gates. Open-ended prompts captured context-specific insights (Sale & Carlin, 2025). Table 8 lists the validation interviews. It shows the port authority, the interviewee, and the date for each session.

Port Authority	Interviewee	Date
Port of Venlo	Peter van Wijlick	14/10/2025
Brabant Ports	Hendrik-Jan van Engelen	15/10/2025
Port of Bergen op Zoom	Robert van Splunter	15/10/2025
Port of Twente	Frank van Zomeren	16/06/2025

Table 8: Validation interviews with inland port representatives

Feedback was analyzed against five qualitative dimensions drawn from implementation and design-science literature: adoption, feasibility, fidelity, cost, and sustainability (Moullin et al., 2020; Nilsen, 2015; Lewis et al., 2015). These dimensions focus on practical usability and stakeholder perspectives rather than quantitative measurement.

Expert feedback that led to clarifications or refinements is treated as constructive input. It strengthens the framework's design choices and justifications, in line with design-science guidance on prescriptive knowledge (Kuechler & Vaishnavi, 2012).

6.2 Evaluation Dimensions

The validation of the framework is carried out using five qualitative dimensions drawn from implementation and design-science literature: adoption, feasibility, fidelity, cost, and sustainability (Moullin et al., 2020; Nilsen, 2015; Lewis et al., 2015). These dimensions provided a structured yet flexible basis for interpreting expert feedback without the need for quantitative scoring metrics. Each dimension represents a practical aspect through which the usefulness and robustness of the conceptual design framework were examined.

1. Adoption refers to the extent to which stakeholders consider the framework relevant and usable within their organizational setting.
2. Feasibility assesses whether its proposed coordination and data-sharing mechanisms are realistic given current resources, technical capacity, and institutional arrangements.
3. Fidelity examines how clearly the intended logic of the framework, its layered structure, and decision gates, are understood and received when discussed with different port authorities.
4. Cost considers the proportionality between expected benefits and required resources, reflecting the principle of incremental and scalable implementation.
5. Sustainability evaluates whether the framework's governance logic, processes, and standards can be maintained and adapted over time.

6.3 Results of Validation

This section presents the findings from the summative validation of the conceptual design framework, based on expert feedback from four inland ports: Port of Twente, Port of Venlo, Brabant Ports, and Port of Bergen op Zoom.

6.3.1 Adoption

All four ports judged the framework relevant for coordination between municipalities. Port of Twente said, "For us, the flexibility across different municipalities is a major strength," and Port of Bergen op Zoom noted, "We are quite positive about this. Please share the material with colleagues at Brabant Ports and in local government," highlighting the interest in adoption. Both ports added, "We can try to use this directly for current coordination and communication issues."

Brabant Ports and Venlo said, “The framework is complete and logical, but we need concrete illustrations.” They also added, “Please include a few example KPIs and sample reports that show how data moves through the layers.” Brabant Ports also stated, “These examples can follow further study of implementation.” Port of Venlo added, “With clear examples, this could also apply to other inter-municipal collaborations outside the port domain.” Overall, adoption potential is high if the presentation includes simple, practical examples.

6.3.2 Feasibility

All four interviewees viewed the framework as feasible to implement, mainly because it is lightweight and incremental. Port of Bergen op Zoom proposed a gradual rollout, “start internally in one organization and then extend to other municipalities,” noting that “starting small will help build acceptance.” The same participant confirmed that a monthly default reporting cadence and the option for CSV or manual imports are practical with the systems they have currently in place.

The Venlo stakeholder also considered the framework realistic but cautioned, “We need to look into the cost and sustainability of building this for such a small market.” The recommendation was to use existing collaboration platforms, like Microsoft Teams, wherever possible to reduce overhead. This aligns with the framework’s platform intent, which defines governance, standards, and data-flow structures rather than prescribing a specific software product.

At Brabant Ports, questions focused on data storage and access: “Where will the data live, and which layer will end users actually see?” These queries indicate the need to clarify that the framework sets a governance and coordination structure, while technical implementation details, such as storage or hosting, are outside the current thesis scope. Finally, Port of Twente stressed mobile access, explaining that “operational staff will be fully mobile by 2026 and so mobile access is a great addition.” Together, these points confirm that feasibility is strong in principle, but depends on implementation quality, clear scope boundaries, and steady support for incremental, mobile-first adoption.

6.3.3 Fidelity

The validation interviews showed that participants understood the layered logic and the decision-gate structure after a short explanation. As one respondent put it, “after a quick walkthrough, I can see where our pieces fit.” Each interviewee was able to place their

elements in the right layers: governance rules and data-sharing agreements under Governance and Policy, shared definitions and KPIs under Coordination and Standards, operational systems such as ShipLogic or CODA under Integration and Connectors, collaborative tools under Applications, and dashboards and performance indicators under Presentation.

Several interviewees, especially from Bergen op Zoom and Venlo, said, “The diagram looked too dense at first glance, but once explained, it seems logical and well-structured.” This points to strong conceptual fidelity, but also to the need for a short legend or a reading order beside the figure to guide the first look.

Brabant Ports and Venlo stressed starting from the Presentation layer, “begin with what decision-makers need to see, so the lower layers can then be designed to support those views.” These comments indicate that the internal logic is clear and easy to follow; the presentation should add brief visual guidance and a few practical examples to help readers grasp it quickly.

6.3.4 Cost

Cost and ongoing maintenance risk emerged as the most critical practical barrier. Venlo stated this most directly, warning that “a build for a small user base would be really expensive and hard to keep updated,” and recommending to “reuse existing collaboration tools wherever possible.” Brabant Ports did not frame cost explicitly but asked, “Where will the data be stored?” and “What will end users actually see?” These questions show uncertainty about the scope and point toward resourcing concerns.

Bergen op Zoom did not mention cost barriers directly but noted that “it is not clear how municipalities would allocate funds for something like this.” Port of Twente pointed to recent budget cuts as a hurdle: “finding funds locally may be difficult, but provincial funding might provide additional support.”

Overall, cost acceptability depends on staying at an implementation level and using existing platforms where possible. A monthly default cadence rather than real-time updates, a CSV fallback, and role-based access keep costs and effort low. The framework should be positioned as governance and coordination logic that can run with minimal new tooling, not as a fully custom-built system.

6.3.5 Sustainability

The sustainability dimension received positive confirmation with practical cautions. Port of Twente said, “the framework can combine individuality in one general framework,” noting that “each municipality is a village on its own.” Port of Bergen op Zoom pointed shared calendars and role-based coordination as tools that build “ongoing planning discipline,” and the representative said, “I would promote the framework within Brabant Ports to see how other municipalities perceive this.”

Port of Venlo cautioned, “may be turning the framework into a specific digital system would create ongoing maintenance and update demands,” and stressed, “we need to limit administrative burden over time.” Brabant Ports did not comment directly on sustainability, focusing instead on completeness and fidelity. Taken together, interviewees viewed sustainability mainly as an organizational matter, governance, routines, and discipline rather than a purely technical one.

6.4 Refinement Insights

The validation led to a small set of focused refinements that improve clarity and practical fit without altering the structure of the conceptual design framework. First, the presentation of the layered architecture will be supported by a brief legend and reading order next to the figure so first-time readers can scan through the layers quickly. Second, one or two illustrative KPI or report walkthroughs will be added to show how definitions, mappings, permissions, and cadence move from Governance and Policy to Presentation. These examples will remain implementation-neutral and will use data items already discussed with the ports.

Third, the research will state the boundaries of the design clearly. The framework defines governance rules, shared standards, integration logic, and decision gates. It can be run with existing collaboration suites for workspaces and calendars, while connectors or CSV imports move data from operational systems. No specific platform is required. Fourth, a requirement for user-activity logging and an audit trail will be added in the Applications and Integration layers, with links to the Legal Basis and Change-Impact gates to support accountability.

Finally, the operational assumptions will be stated plainly: incremental onboarding; a monthly default cadence with a weekly option where feasible; CSV fallback alongside connectors; role-based access; and mobile access where needed. These refinements improve clarity, traceability, and feasibility while keeping the layered logic and governance principles intact.

7. Conclusion

7.1 Discussion

This research set out to design a conceptual framework for a centralized communication and data-sharing system for multi-municipality inland ports. The goal was to create an actionable, governance-led guide that could navigate the practical constraints of limited budgets, low digital maturity, and fragmented governance. This goal was met through the design of the BRIDGE (Business & Rules Integration for Data & Governance Exchange) Framework, a Level-2 nascent design theory that provides a practical solution to the coordination problems identified in the Port of Twente and validated by its peers.

The primary value of the BRIDGE framework is that it provides a controlled sequence for collaboration, answering the main research question: how to design such a guide. The answer is that the framework must be governance-led, minimal, layered, and gate-based. It is governance-led because it forces partners to first agree on roles (RACI) and legal agreements (MoUs) in the Governance & Policy Layer. It is minimal because it focuses on a small, essential common data set in the Coordination & Standards Layer. It is layered to separate concerns and map cleanly to enterprise standards like TOGAF. Finally, it is gate-based, using four decision gates to make the order of decisions, onboarding, operations, funding, and change, explicit and auditable.

This design directly addresses a core finding from the validation interviews: the shift from a "tools-first" to a "capability-first" mindset. The interviews confirmed that the primary barrier to collaboration is not a lack of technology, but a lack of shared rules. The deeper meaning of the BRIDGE framework, therefore, is that it fundamentally changes the conversation. Instead of asking "what software should we buy?", it forces municipalities to ask, "what rules must we agree on?" and "what information is essential to share?" This "capability-first" approach, guided by the framework's layers, is the framework's most significant practical effect. It reduces friction, clarifies responsibility, and prevents investment in technology before the organizational and legal prerequisites for sharing are met, directly reducing the "cost" barrier identified in the validation.

This leads to a clear assessment of the framework's strengths and weaknesses. The framework's logic is solid: the five layers, the four gates, the TOGAF alignment, and its validation as "relevant" and "feasible" by all four interviewed ports confirm its conceptual integrity. However, what is less solid is its implementation. As a conceptual design, its value is hypothesized, not yet quantitatively proven. Its success is entirely dependent on the boundary conditions identified in the research. The framework alone is not a blanket

solution; it is a structured guide that only delivers value if the "mandate to cooperate" and a "clear legal basis" exist. Its core risk is that it could be adopted superficially as a "paper-only" exercise, which is precisely what the four decision gates are designed to prevent by forcing tangible sign-offs on legal, data quality, and cost-sharing agreements.

This design also explains the deliberate compromises made, most notably the "centralized starting point". This was not chosen as the "best" technical architecture, but as the most feasible staging choice for the given context. It addresses the practical realities of mixed IT systems and limited budgets by lowering the entry cost and making responsibilities visible. The risks of this approach, a single point of failure or concerns over data sovereignty are explicitly managed because centralization is positioned as a temporary "staging choice," not a permanent end state. The framework's design allows for a clear evolution path where, as trust and standards mature, data can be federated while the central governance and policy layers remain, ensuring long-term institutional capacity.

Furthermore, the framework's potential value extends beyond the specific context of inland ports. This research addresses a general design gap: how to initiate coordination among autonomous organizations that lack a single, central authority. The core problems of fragmented governance, inconsistent data definitions, and a reliance on informal communication are common in many sectors. Validation feedback also suggested that with clear examples, the framework could apply to other inter-municipal collaborations. Any multi-agency environment, such as a regional public safety network, a smart-city initiative involving different utility providers, or a public-private partnership, faces similar issues.

The BRIDGE framework's strength is its portability as a process model. The framework's strength is that it is governance-led, meaning it puts rules and roles first. It is also technology-independent, so it avoids getting stuck on tool selection. Together, these principles provide a neutral, structured path for any group of autonomous stakeholders. The framework guides them as they negotiate and formally define the essential rules, roles, and data they need to collaborate. This process builds their fundamental institutional capacity to work together right from the ground up.

7.2 Contributions

The scientific contribution is a design-level account of how centralization can be made workable in a multi-municipality setting. It links a small shared data set, role-based routines, and a gate-based sequence of decisions into an organized decision architecture. This provides a Level-2 nascent design theory: named elements and simple rules that others can test and refine without a software build. It also reframes centralization as a

staged choice with explicit conditions, rather than a single option, and shows how to evaluate it using clarity, usefulness, and feasibility as practical criteria.

The practical contribution is a working guide that port authorities can use to organize coordination. It gives a shared set of terms and a clear order of steps, and turns these into simple checklists for scoping, comparing options, and planning. It offers wording that can be reused in funding notes, memoranda of understanding, and data-sharing agreements. It also provides a repeatable basis for onboarding new partners and assessing arrangements using the same criteria, so insights carry over across ports.

7.3 Limitations

This research has its limitations over various factors. This research remains at the design level, and there is no software build, pilot deployment, or quantitative impact study. If a prototype had been implemented and run in a live setting, the thesis could have reported concrete results on accuracy, timeliness, cost, and user uptake, rather than relying on perceived feasibility and usefulness.

Requirement analysis and validation are interview-based, where each port authority was represented by a single interviewee. This means views from other departments (for example, operations, IT, finance, and legal) may be missing. If multiple interviewees per port had been included, and if observation of meetings or routine work had been possible, the study could have resulted in more accurate findings and reduced the risk of blind spots or respondent bias.

The empirical scope is limited to inland ports in the Netherlands. No data were collected from ports outside the Netherlands. The Port of Twente serves as the main context. This narrows transferability to other governance models and legal settings. If comparative cases from other countries had been included, the study could have tested which elements of the framework fit well and which require adaptation.

The architectural alignment is adapted and selective. TOGAF is used only for the Business and Application perspectives, while the Technology perspective and migration phases are not developed. Cost, security, and legal aspects are assessed conceptually rather than tested in operation. If the technology view and a detailed roadmap had been produced, and if a structured security assessment (for example, threat modeling and a DPIA), a cost model (including TCO), and a legal review had been completed, the research could have given stronger guidance on operational risk and long-term affordability.

Time constraints also meant that alternative framework types were not designed and compared side by side. For example, the study does not present and test a fully distributed or data-space variant against the centralized start. If multiple designs had been built to equal depth and evaluated with the same criteria, the comparative conclusions would have been stronger and more generalizable.

Change management was also not examined in depth. The research does not develop a detailed plan for stakeholder engagement, training, communications, readiness assessment, or adoption-risk mitigation across municipalities. If a structured change-management approach had been designed and tested, the study could have offered stronger guidance on uptake, resistance, and sustained use.

Limitation was also encountered in the literature review, starting from the highly specific and niche context of this study. The body of academic research focusing directly on data-sharing frameworks for multi-municipality inland ports is limited, particularly within the Netherlands. While established literature exists for broader, related domains, few studies provided concrete design guidance for the specific socio-technical problem this research addresses. This scarcity, identified in the gap analysis in Section 3.3, meant that the BRIDGE framework could not be built as a direct extension of a single, proven model.

Together, these limits introduce threats to validity. Selection and response bias may have influenced the findings, and without pilots or international cases, the study cannot make strong claims about performance or resilience in practice. Future research should include several interviewees per port, follow use over time, run pilots with measurable outcomes, and add cross-country cases. This would reduce bias and provide a stronger empirical basis for the framework.

7.4 Future Work

This research provides the foundational design, the "v1.0" for the BRIDGE framework. As a Level-2 nascent design theory, its purpose is to be tested, extended, and refined through practice. The following directions are not just a list of tasks but an invitation to both practitioners and academics to collaborate on this work, moving it from conceptual design to validated artifact.

The most pressing next step is to run focused pilots in one or two ports to apply the framework and measure its outcomes. Researchers are invited to partner with practitioners to establish a short baseline period and conduct a before-and-after analysis. This will provide important quantitative data by tracking specific indicators, such as the time required to prepare updates, the number of duplicate entries removed, lead time for

joint decisions, and user uptake by role. These pilots should be followed for several months to observe which routines persist and which need adjustment.

Future research must also widen the empirical base beyond the single-interviewee-per-port limitation of this study. A more robust validation would involve multiple interviewees from each port, including representatives from operations, IT, finance, and legal departments. This should be supported with short observations of coordination meetings to capture practical challenges that interviews alone may miss.

To create a truly implementation-ready "BRIDGE v2.0," several core components must be developed and tested at scale. This includes developing a standard shared data set with common definitions, code lists, minimal metadata, and clear ownership. Furthermore, data synchronization must be tested at scale using frequent updates and realistic change patterns, alongside the implementation of a cross-municipal identity and access model with real users and regular role reviews. Finally, this work must be paired with the structured security, legal, and cost analyses that were out of scope for this design. This involves building a Total Cost of Ownership (TCO) view, completing a formal Data Protection Impact Assessment (DPIA), and structuring model clauses for data-sharing agreements to be tested with legal and audit teams.

Academics are invited to test the framework's theoretical boundaries. A key study would be to compare design variants, implementing a matched version of the framework in a more distributed or data-space arrangement and evaluating it against the centralized-start model using the same criteria. This would make the trade-offs explicit. Furthermore, a migration playbook should be written and tested. This playbook must set out the concrete steps and decision points for moving from the centralized start to a distributed model. This must cover adjustments to data ownership, synchronization, access control, and training.

This research provides a starting point grounded in the inland ports in the Netherlands context. The problem of multi-authority coordination, however, is global. Therefore, this research closes with a call for broader application. Port authorities, municipal leaders, and researchers beyond the Netherlands are welcome to apply, test, and adapt the BRIDGE framework to their own legal and institutional settings. This collaborative effort is essential for building a common language of digital coordination and transforming our inland ports from fragmented outposts into truly connected, resilient ecosystems.

AI Use Declaration

During the preparation of this thesis, I used Quillbot, ChatGPT and Google Gemini only for language editing, clarity improvements, and alternative phrasings of my own drafts. I also used Consensus and Perplexity for finding academic literatures. I did not use AI tools to generate data, conduct analysis, or write any findings or conclusions. All sources and claims were verified against the originals written by the author, and any AI suggested text was reviewed, edited, and integrated by the author, who takes full responsibility for the final content.

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