



Rulebook

Deliverable D1.1

Project title	Physical Internet and the Key steps to Innovation-driven supply chain transformation towards Green, Affordable, scalable and collaborative Zero-Emissions Freight Transport solutions
Call	HORIZON-CL5-2024-D6-01
Type of action	HORIZON-IA
Project starting date	1 July 2025
Project duration	42 months
Project coordinator	FIT CONSULTING SRL



Document information

Deliverable title	D1.1 - Rulebook for Logistics Innovations
Related WP and title	WP1 - PI systemic scaling of logistics innovations
Related deliverable(s)	D1.1
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Version	1.0
Deliverable type	Report
Dissemination level	Public
Planned delivery date	30.04.2026
Actual delivery date	30.04.2026

QUALITY CONTROL (includes peer & quality control reviewing)

Reviewer(s)	Main changes
Name (Organisation)	
Amalia Ntemou (NCI)	Editing Suggestions
Paola Astegiano (FIT)	Editing suggestions and final quality check

DOCUMENT HISTORY			
Version	Date	Created/Amended by	Changes
0.1	20/08/2025	Harris Niavis	Initial skeleton version with basic structure, headings, and placeholders. Included empty tables, draft TOC, and minimal introductory text.
0.2	04/09/2025	Harris Niavis	Added official front matter (GA data, disclaimer, QA tables), full TOC and glossary, short intro and project context, partner roles for T1.1, purpose of the Rulebook, and structured sections with <i>partially filled</i> barrier/enabler tables and methodology placeholders.
0.3	19/11/2025	Alkis Pitelis	ToC Update
0.4	08/01/2026	Alkis Pitelis	T1.1 Input
0.5	20/04/2026	Ioanna Fergadiotou	Consolidation of the different input
0.6	22/04/2026	Paola Astegiano	Inclusion of FIT contribution
0.7	28/04/2026	Amalia Ntemou	Internal Review Completed
0.8	28/04/2026	Alkis Pitelis	Addressing reviewer's comments
Final	30/04/2026	Paola Astegiano	Final review and edits

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Funded by the European Union under Grant Agreement No 101202912.

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LIST OF ABBREVIATIONS AND DEFINITIONS

ABBREVIATION/TERM	DESCRIPTION
AFIR	Alternative Fuels Infrastructure Regulation
API	Application Programming Interface
CA	Consortium Agreement
CO ₂	Carbon Dioxide
CSV	Comma-Separated Values
D[x]	Deliverable [number]
DOA	Description of Action
EC	European Commission
eCMR	Electronic Consignment Note (digital form of CMR)
eFTI	Electronic Freight Transport Information
EU	European Union
GA	Grant Agreement
HHI	Herfindahl–Hirschman Index
ICT	Information and Communication Technology
IKIGAI	Project name (not expanded in text)
KPI	Key Performance Indicator
LIs	Logistics Innovations
LI1	Online and offline trustee matchmaking and volume pooling for electrification and increased intermodality
LI2	eFTI compliance Collaborative Service Platform for SMEs
LI3	Smart and synchromodal hubs for hyperconnected urban logistics
LI3A	Inland operational context of LI3
LI3B	Urban/orchestration operational context of LI3
LI4	Intelligent, standard end-to-end chain of custody for carbon emission calculation
LI5	Open volume pooled governance for reusable standard modular boxes
LI-Sx-Px	Logistics Innovation–Service–Process framework
LSP	Logistics Service Provider
M[x]	Month
MS	Milestone
PC	Project Coordinator
PI	Physical Internet
PO	Project Officer
PSC	Project Steering Committee
Px	Process
ROI	Return on Investment
SAB	Stakeholders Advisory Board
SRL	Scale Readiness Level

SULP	Sustainable Urban Logistics Plan
SUMP	Sustainable Urban Mobility Plan
Sx	Service
Task 1.1 (T1.1)	Mapping LIs scaling barriers and enablers
Task 1.2 (T1.2)	Innovation agenda and scaling factors
Task 1.3 (T1.3)	Impact assessment framework for scaling LIs
TEN-T	Trans-European Transport Network
TRL	Technology Readiness Level
WP[x]	Work Package
WPL	Work Package Leader
ZEL	Zero-Emission Logistics

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1. EXECUTIVE SUMMARY

This deliverable presents the IKIGAI Rulebook for Logistics Innovations (LIs), the primary analytical output of WP1 Task 1.1 and the backbone through which the project translates evidence on barriers and enablers into a structured basis for scaling LIs from isolated pilots to interoperable, Physical Internet (PI)–aligned solutions. As Component C1 of the IKIGAI architecture, it provides the analytical input to the PI Norm, Pilots Audit, PI Coalition, Twin Transition Genome and Impact Augmenter Kit, and introduces the Scale Readiness Level (SRL) concept, which extends Technology Readiness Level assessment to commercial, regulatory, societal and governance dimensions. The underlying analysis follows a four-phase methodology combining LI-level mapping, literature-based consolidation into 21 structural barrier families, procedure-level mapping across the five LI contexts, and comparative synthesis of literature- and pilot-derived evidence.

Both streams converge on four universal barriers: digital interoperability and data standards, data governance and trust, implementation complexity and digital capability gaps, and system integration and infrastructure gaps. Together, these account for roughly 86% of the pilot-level corpus and constitute the minimum viable intervention set for scaling.

2. INTRODUCTION

This deliverable presents the Rulebook for Logistics Innovations (LIs), developed within WP1. It consolidates the evidence, analyses, and insights identified regarding the barriers, enablers, processes, and strategic dependencies that influence the ability of the LIs to scale across diverse logistics environments. Its ambition is to define a coherent foundation for harmonised decision-making across technological, operational, market, societal, and regulatory domains, enabling the project to articulate a credible and practical pathway toward the wider adoption of zero-emission, collaborative, and digitally interconnected logistics operations across Europe.

The Rulebook sets the LIs within their broader innovation ecosystem and characterises the constraints and opportunities shaping their scale-up. In this way, the Rulebook contributes directly to IKIGAI's mission to facilitate the Twin Transition in logistics by ensuring that innovations are both operationally viable and institutionally supported.

2.1 PURPOSE OF THE RULEBOOK

The Rulebook provides the methodological backbone for how IKIGAI approaches the scaling of LIs. It consolidates the insights emerging from T1.1 into a coherent framework that not only summarises the barriers and enablers affecting each LI, but also establishes a shared agenda for innovation, standardisation, governance, and market adoption. It acts as an intermediary between the analytical work carried out in WP1 and the subsequent development of standards, procedures, and governance mechanisms across the later work packages.

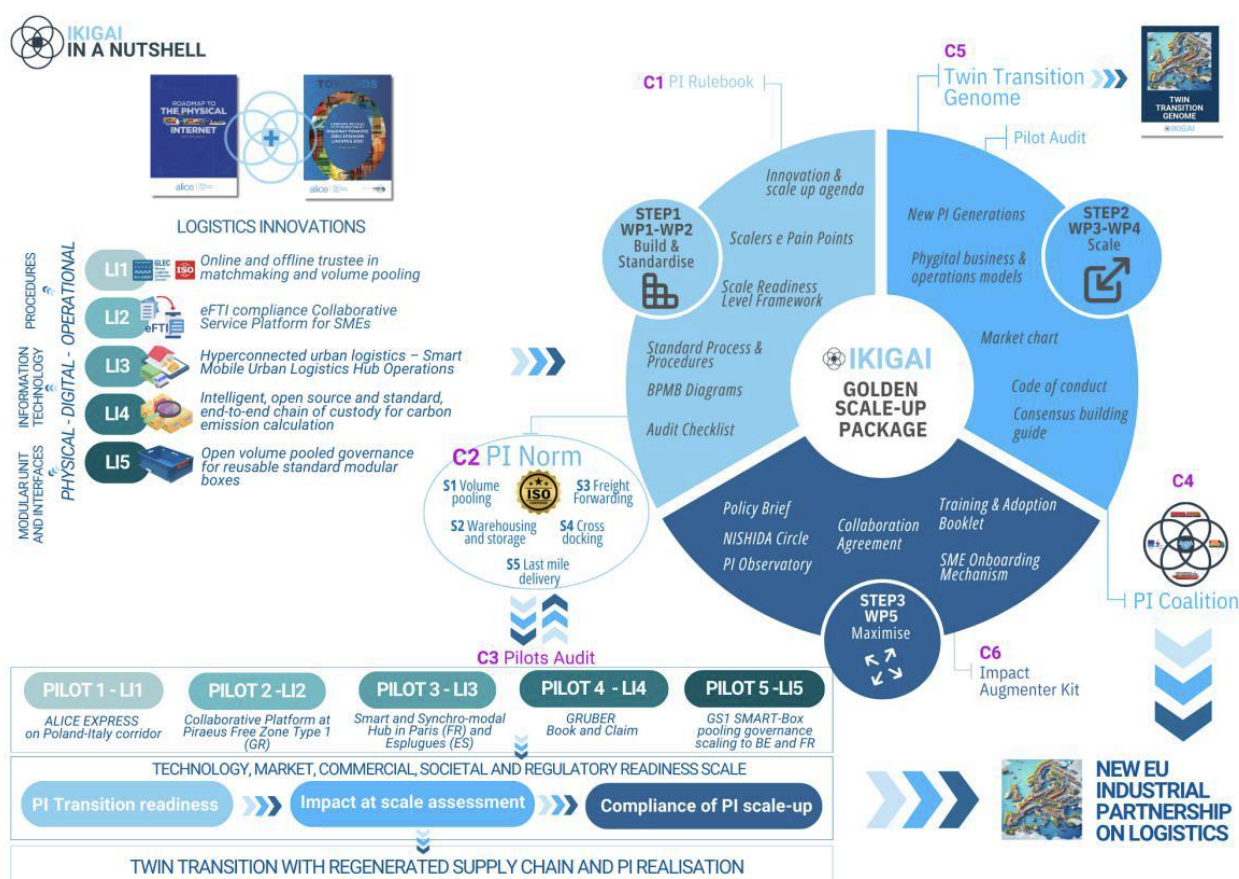


Figure 1. IKIGAI in a Nutshell

The Rulebook's purpose is aligned with the architecture illustrated in Figure 1 (*IKIGAI in a Nutshell*). In this architecture, the Rulebook corresponds to Component C1 and serves as the initial reference point for the PI Norm (C2), the Pilots Audit (C3), the PI Coalition (C4), the Twin Transition Genome (C5), and the Impact Augmenter Kit (C6). By clarifying scaling requirements and priorities, it enables subsequent components to build on a common basis. It also sets out guidelines and priorities for scaling up LIs by integrating market needs, policy requirements, societal, and operational conditions. It identifies mandatory rules that must be observed to ensure consistency and interoperability; "scalers," which are factors that actively facilitate the expansion of LIs; and "pain points," which represent barriers that must be addressed for successful adoption. It also establishes a realistic timeline for evolving LIs from their pilot phase into fully standardised, system-level solutions governed by new PI-compatible standards and procedures.

A defining feature of the Rulebook is the introduction of the Scale Readiness Level (SRL) concept. The SRL framework extends beyond the conventional Technology Readiness Level by incorporating commercial viability, market acceptance, regulatory alignment, societal uptake, and governance maturity. This multidimensional assessment enables a more accurate and holistic evaluation of each innovation's scale-up potential. The Rulebook also underpins supporting tools such as the PI Readiness Mapper and the CO₂ calculator, which will be used to validate LI effectiveness in real-life TEN-T demonstrations.

2.2 PROJECT AND WP1 CONTEXT

IKIGAI is designed to accelerate the transformation of European logistics by addressing fragmentation, inefficiencies, and the limited scalability of promising innovations. It does so through a combination of harmonised operational models, interoperable standards, data-sharing mechanisms, and governance approaches that collectively support the emergence of a PI-compatible logistics ecosystem. Within this broader ambition, WP1 provides the strategic and analytical framework for understanding how individual innovations can evolve into globally applicable solutions.

WP1 has three core objectives: the **first** is to *formulate a comprehensive innovation agenda that outlines how collaborative logistics processes can be standardised and integrated with zero-emission technologies and vehicles*. The **second** is to *identify the barriers and enablers that influence the scale-up of LIs, and to define strategies for systemic change that reflect commercial, operational, technological, societal, and regulatory realities*. The **third** is to *develop a holistic three-step impact assessment framework, together with dedicated tools, that enables the evaluation of each LI's maturity, efficiency, and adoption potential, moving beyond technological readiness to encompass broader market and governance dimensions*. The work undertaken in T1.1 plays a central role in fulfilling these objectives, as it provides the analytical foundation for T1.2 and for subsequent WP1 activities. T1.1 focuses on identifying and analysing the barriers and enablers that affect the scaling of LIs across the partner logistics networks. The collaborative work carried out by the consortium partners ensures that the analytical outputs reflect diverse operational, regulatory, and societal perspectives.

Analytical contribution of T1.1 to the objectives of WP1

T1.1 establishes, in a structured and evidence-based manner, what enables or constrains the scaling of the IKIGAI Logistics Innovations (LIs). Its role is not limited to documenting implementation obstacles observed in the pilots. Rather, it converts dispersed operational, organisational, technical, regulatory, and economic observations into a common analytical basis that can support replication, prioritisation, and later standardisation. In this respect, T1.1 is the point at which scaling becomes an explicit object of analysis rather than an assumed downstream consequence of pilot success.

IKIGAI does not only need to demonstrate that an innovation works under a given set of pilot conditions. It must also determine whether that innovation can travel beyond the original site, under which conditions, with which dependencies, and with what degree of adaptation. T1.1 therefore addresses the transition from

proof of operational relevance to evidence on scalability. This shift is critical because the ability of a LI to perform technically in a single setting does not in itself provide sufficient information about its replication potential across different corridors, actors, governance arrangements, and market environments. A pilot may function effectively while still depending on exceptional local conditions, informal coordination, temporary institutional support, or non-transferable infrastructure arrangements. T1.1 is designed precisely to surface these conditions and to make them analytically visible.

Within this framing, the task performs three closely connected functions: First, it identifies and structures the barriers that affect the scaling of the five LIs addressed by the project. Second, it identifies the enablers associated with these barriers and interprets them as scaling-enabling factors that can support broader deployment. Third, it transforms both types of findings into an analytical input for the PI Rulebook and for the readiness-oriented assessment logic developed later in WP1. Accordingly, the value of T1.1 lies not in generating a descriptive inventory alone, but in establishing a robust basis for subsequent prioritisation, standardisation, and assessment activities.

Before defining standardisation, scaling and readiness assessment can be formalised, the project must determine what blocks or enables scaling across contexts. Without this analytical step, later outputs would risk being either overly normative or insufficiently grounded in the realities of implementation. T1.1 therefore establishes the evidentiary and basis for the subsequent WP1 outputs.

The contribution of T1.1 is best understood in direct relation to the three objectives of WP1. The first objective concerns the shift from the statement that an innovation works to the more demanding proposition that it can be replicated at EU scale. This objective requires the project to identify not only whether a given solution performs under pilot conditions, but also which technological, operational, regulatory, market, and social conditions determine whether that solution can move beyond its initial implementation context. T1.1 directly supports this objective by identifying and structuring those conditions in a comparative way across the five LIs. In doing so, it makes scaling assumptions visible, testable, and comparable across pilots, thereby enabling a transition from anecdotal or site-specific understanding to analytically supported judgment.

The second objective of WP1 is to harmonise scaling criteria across Physical Internet (PI) development pathways and Zero-Emission Logistics (ZEL) solution areas. This objective addresses a major risk of fragmentation. If digital LIs are assessed independently of their environmental contribution, there is a risk that technically sophisticated solutions scale without generating meaningful decarbonisation benefits. Conversely, if green logistics solutions are promoted without sufficient attention to interoperability, governance, or data-sharing conditions, they may remain locally promising but systemically fragile. T1.1 contributes to this objective by creating a common analytical language through which these different dimensions can be examined together. It does so by applying a shared barrier and enabler framework across all LIs, while preserving traceability to the specific LI, process, and procedure in which each issue emerges. This makes it possible to assess PI and ZEL pathways jointly rather than as parallel and weakly connected agendas.

The third objective of WP1 is to support prioritisation. Not all innovations should scale at the same pace, through the same mechanisms, or under the same governance arrangements. Some innovations may be close to broader uptake but blocked by specific standards-related gaps. Others may offer strong long-term value but still require substantial institutional, operational, or market maturation. T1.1 supports this objective by identifying where the main pain points are concentrated, which enabling conditions appear recurrently across contexts, and which innovations are likely to require more staged or conditional pathways to scale. In that sense, the task contributes directly to the formulation of a priority-based agenda capable of answering four fundamental questions for WP1: what should scale first, where it should scale, under which conditions it should do so, and with which actors such scaling is most plausible and effective.

These three objectives are analytically interdependent and are jointly addressed through the structured understanding of scaling conditions developed in T1.1. The first establishes the need to move from pilot performance to scalability assessment. The second ensures that this assessment is conducted through a harmonised lens that integrates PI and ZEL requirements. The third translates that harmonised assessment into prioritised action. T1.1 contributes to all three by converting literature-derived and pilot-derived evidence into a structured understanding of scaling conditions. Its outputs should therefore be read as the first operational step in constructing the Rulebook and the broader WP1 logic.

Scope and internal logic of T1.1

T1.1 focuses on the five LIs of the IKIGAI project and analyses their barriers and enabling conditions at the level of LI, process, and procedure. This LI-Sx-Px anchoring is essential because the project does not seek a generic or abstract discussion of LI. It seeks to understand how specific innovations encounter scaling constraints within identifiable operational contexts, and how these constraints can be interpreted comparatively across the portfolio of innovations.

The task therefore operates through a combination of system-level framing and process-level traceability. At the system level, it seeks to identify recurring patterns of barriers and enablers that are relevant to collaborative logistics, PI alignment, and zero-emission transition. At the process level, it preserves the exact location where such patterns arise, namely within particular LI processes and procedures. This dual structure is necessary because neither level alone would be sufficient. A purely systemic account would lose the operational specificity needed for actionable conclusions. A purely process-specific account would remain fragmented and would not produce the common analytical basis required by WP1.

For this reason, the task is organised around five analytical domains: technological, operational, regulatory and policy, market and economic, and societal and organisational. These domains are used as a priori organising lens. They do not replace the barrier families developed from the underlying corpus but provide a higher-level structure through which these families can be interpreted consistently. This distinction is important. Barrier families capture recurring structural constraints, such as platform and system integration complexity, lack of trust among stakeholders, regulatory fragmentation across jurisdictions, or weak or uncertain business cases. The five domains provide the broader analytical categories within which these families can be discussed and compared. The domains thus serve interpretive clarity, while the families preserve semantic precision and traceability.

Within this structure, enablers are identified in relation to the barriers they address and are treated as scaling-enabling factors. This terminology is deliberate. The intention is not simply to list remedies or isolated good practices, but to identify those recurring conditions, mechanisms, and arrangements that can facilitate replication and broader uptake across contexts. These factors will later feed T1.2, where they will support the prioritisation and formalisation of the PI Rulebook. At the level of T1.1, however, they remain analytical findings rather than prescriptive rules.

T1.1 as input to the WP1 outputs

The linkage is substantive rather than formal. The barrier families identified in this task provide the structured representation of what hinders scaling across the LIs. The scaling-enabling factors provide the structured representation of what may facilitate such scaling. Together, they provide the analytical input for the PI Rulebook and for the readiness assessment logic developed later in the WP1.

In relation to the Rulebook, T1.1 contributes by identifying the pain points that require prioritised attention and by clarifying the conditions under which those pain points can be addressed. This means that the Rulebook does not begin from abstract standardisation logic. It begins from a grounded understanding of where scaling breaks down, why it breaks down, and what kinds of enabling conditions recur across pilots

and literature. T1.1 therefore helps ensure that the Rulebook speaks to actual interdependencies in logistics systems rather than to idealised models of adoption.

In relation to the readiness-oriented outputs of WP1, T1.1 contributes by creating the conceptual bridge between observed barriers and the dimensions that will later be assessed through the Scale Readiness Level framework and the PI Readiness Mapper. This bridge is essential because readiness cannot be meaningfully assessed without a prior understanding of the types of constraints that shape adoption and replication. T1.1 thus provides the evidence base from which later assessment dimensions can derive their practical meaning.

Taken together, these contributions show that T1.1 is preliminary in sequence, but not in significance. . It is the step that turns heterogeneous evidence into a structured basis for action across the rest of WP1. This analytical output directly informs the identification of pain points and scaling-enabling factors, which are subsequently formalised as scalars and prioritisation elements within the PI Rulebook under T1.2.

T1.2 as input to the WP1 outputs

Building on T1.1's barrier and enabler evidence base, T1.2 formulates the IKIGAI Innovation Agenda by translating the identified enabling conditions into formal scalars, prioritised interventions and a sequenced timeline for evolving LIs from pilot implementation toward PI-compatible, system-level deployment. Its outputs feed directly into the Rulebook's scaling conditions and into the readiness-assessment logic operationalised through the Scale Readiness Level framework and the PI Readiness Mapper developed in subsequent WP1 activities.

2.3 RELATIONSHIP OF WP1 WITH THE OTHER WPs

The analytical value of T1.1 extends beyond WP1 because its findings are designed to inform several subsequent WPs. These interdependencies are not secondary. They are part of the reason why WP1 must begin with a structured analysis of barriers and enabling conditions rather than with isolated pilot descriptions or generic scaling recommendations.

The first and most direct linkage is with WP2, which addresses PI Norm and standardisation. The relationship between the two WPs is complementary and sequential. WP1 identifies where standardisation is needed and why. It determines where lack of standards, fragmented procedures, incompatible data structures, or unclear governance arrangements block scaling. WP2 responds by addressing how such standardisation can be specified, refined, or implemented through the PI Norm. In this respect, WP1 provides the problem diagnosis and prioritisation logic, while WP2 provides the normative and technical response. Without the analytical work of WP1, standardisation efforts would risk being detached from the actual constraints affecting the scaling of the LIs. Without WP2, the insights of WP1 would remain diagnostic and would lack an implementation pathway for formal standardisation.

A second key linkage is with WP3, which covers pilots and demonstrations. The relationship here is recursive. WP3 provides empirical evidence about how innovations behave in practice, including where frictions emerge in real operations, how actors coordinate, and which assumptions hold or fail under pilot conditions. WP1 interprets this evidence through a scaling lens, transforming site-specific observations into structured insights about replicability, interdependence, and readiness. Without WP3, WP1 would risk remaining overly theoretical or literature-driven. Without WP1, WP3 would remain largely site-specific, with limited capacity to generate transferable knowledge across pilots. The two WPs therefore form a feedback loop in which demonstrations provide operational evidence and WP1 translates that evidence into a broader scaling logic.

The third linkage is with WP4, which concerns the Twin Transition Genome and governance. Here the contribution of WP1 is to provide the prioritised scaling logic that WP4 can then express structurally in

governance models, roadmaps, and longer-term transition pathways. If WP1 answers which innovations should scale first, where, under what conditions, and with which actors, WP4 uses that analytical basis to articulate broader transition architectures. In that sense, WP1 functions as an analytical input to the Twin Transition Genome, while WP4 provides its structural and policy-oriented expression. The relationship is therefore one of translation from prioritised analytical insight to long-term governance and pathway design. A fourth linkage concerns WP5, which addresses impact, uptake, and dissemination. T1.1 contributes to WP5 by clarifying which innovations are most ready to be promoted, under which conditions, and to which audiences or territories such promotion is most relevant. This is an important distinction. Dissemination and uptake should not be generic or evenly distributed across all innovations regardless of maturity or systemic value. The analysis in WP1 supports a more selective and strategic approach by identifying which innovations show stronger readiness and scaling potential, and which ones still depend on substantial technical, organisational, or policy-related conditions before broader promotion is justified. In this way, WP1 helps ensure that dissemination and uptake efforts are evidence-based rather than uniform.

Finally, WP1 is linked to WP6, which addresses management, quality assurance, and risk. The findings of T1.1 contribute to this WP by identifying scaling-related risks, dependencies, and structural bottlenecks that need to be reflected in quality control and risk-management activities. In particular, WP1 feeds relevant information into the Expanded Failure Modes and Effect Analysis framework by clarifying where scaling may fail, under which conditions dependencies become critical, and which barriers are likely to have cross-cutting consequences across multiple innovations. WP6, in turn, ensures consistency, traceability, and quality control in how these issues are monitored and managed across the project.

These interdependencies show that T1.1 performs a bridging role across the project by connecting pilot evidence, standardisation needs, governance design, uptake strategy, and risk management.

2.4 IKIGAI OUTPUTS MAPPING TO GA COMMITMENTS

Table 1. Deliverable Adherence to GA Deliverables and Work Description

IKIGAI GA Item	IKIGAI GA Item Description	DR Chapter(s)	Justification
D1.1	Includes guidelines and priorities for scaling up LIs, addressing market, societal and policy barriers	All	
Task 1.1	Mapping LIs scaling barriers and enablers. T1.1 will identify and analyse the barriers and enablers for the Twin Transition and scaling of LIs within the partners logistics networks. It will identify trust-building measures and innovation catalysts. Technological and operational challenges, such as digital and physical interoperability, regulatory constraints, and social factors impacting collaboration, providing insights into enhancing logistics efficiency and advancing decarbonisation efforts. Data analysis and cutting-edge technologies will highlight strategies to address, with final validation through an online consultation with pilot stakeholders (M8).	3-7	T1.1 is operationalised through the four-phase methodology in Section 3 and its outputs (3.4–3.7): LI-partner mapping of 114 barrier–enabler entries, literature-based consolidation into 21 barrier families, procedure-level mapping across all LI contexts, and comparative synthesis validating the barrier families as the analytical unit for the Rulebook.
Task 1.2	Innovation agenda and scaling factors. T1.2 will deliver a strategic scaling mechanism for advancing the LIs across the ZEL/PI Roadmaps by eliciting processes that needs to be optimised and standardised. It will identify the factors that can accelerate the scale-up of impactful innovations. Due consideration will be given to incorporating best practices that have a great potential to be widely adopted as standards across supply chain networks and associated “scalable	8-10	T1.2 is reported in Sections 8-10, which translates the T1.1 evidence into the strategic scaling mechanism, identifies factors accelerating scale-up, and documents the online consultation and partner validation that underpin the PI Rulebook scalars.

	paths". ALICE will share knowledge from relevant projects and initiatives and FIT, will define the scaling mechanism to ensure the efficient implementation and expansion of these innovations. The result of this task will be the PI Rulebook (endorsed by all partners in T1.2), outlining the factors and steps for achieving significant advancement (from innovation to buyable solutions and replication). All target groups will be involved the definition of the agenda through surveys, in-depth interviews, workshops and 2 roundtables. Results will feed the impact assessment framework. All LIs partners and WP Leaders will validate the scaling-up mechanism.		
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3. Methodological Approach

The analytical approach of T1.1 follows a four-phase iterative process that combines practitioner evidence with systematic literature analysis. Each phase builds directly on the outputs of the previous one, ensuring that the empirical material from the IKIGAI Logistics Innovations (LIs) and the broader academic and grey literature are treated as complementary and mutually informing evidence streams rather than parallel and independent analyses. The figure below illustrates the overall process.

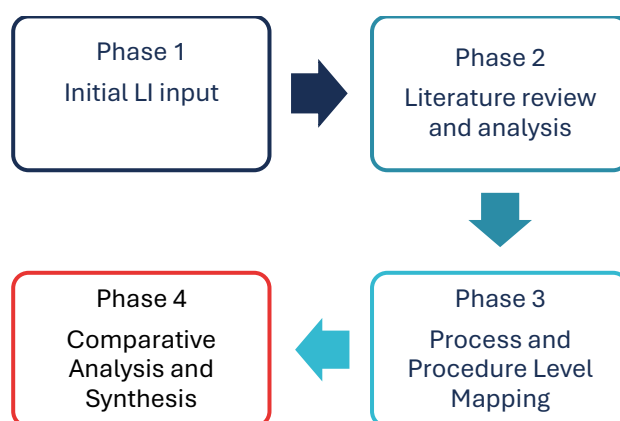


Figure 2. Four-phase analytical approach of T1.1

Phase 1: Initial Barrier and Enabler Mapping by LI Partners

In the first phase, structured inputs were collected directly from the five LI teams. Each team was asked to identify the barriers that constrain the implementation and scaling of their innovation, and the enabling conditions or mechanisms that could address those barriers. This input was collected through a standardised template that ensured comparability across LIs while preserving the operational specificity of each context. This first-phase dataset served two purposes: it provided a substantive empirical starting point grounded in real pilot contexts, and it generated the thematic vocabulary that would be used to structure the subsequent literature search.

Phase 2: Literature Review and Barrier Family Identification

The second phase used the outputs of Phase 1 as the analytical foundation for a systematic literature review. The barrier themes and categories identified by LI partners were translated into a set of neutral keyword clusters, which were then used to structure a desk research process across academic publications, conference proceedings, EU-funded project deliverables, and grey literature sources. A corpus of 273

unique documents was assembled through an iterative search and screening process informed by these clusters. Barrier extraction was conducted using a structured template applied uniformly across all documents. Following extraction, the dataset was cleaned, harmonised, and coded against the four analytical domains. Duplicate identification was performed in two stages, covering exact matching and cosine similarity-based approximate matching, before barriers were grouped into thematic clusters through unsupervised text vectorisation and clustering techniques implemented in R, with subsequent expert validation. This process resulted in the identification of 21 barrier families, each representing a recurring structural constraint type observed consistently across multiple documents and contexts. Concentration analysis including Herfindahl-Hirschman Index calculation, domain co-occurrence analysis, and Jaccard similarity measurement were applied to characterise the distribution, interdependencies, and multi-domain nature of the identified families. Each barrier family was also mapped to a set of scaling-enabling factors derived from the enabler fields recorded during extraction, establishing a direct analytical link between constraints and the conditions that can mitigate them.

Phase 3: Process and Procedure Level Barrier Mapping by LI Partners

In the third phase, LI partners were asked to provide a more granular layer of barrier analysis, moving beyond the LI-level overview collected in Phase 1, and building on the results of Phases 1 and 2. This followed an online workshop with all LI representatives (online consultation M8), where structured templates and results of Phases 1 and 2 were communicated. Each team mapped barriers and enablers at the level of individual services (Sx), processes (Px), and procedures, following the LI-Sx-Px anchoring framework used throughout WP1. This phase produced 21 procedure-level barrier entries across the five Lis' contexts, with each entry covering the five barrier categories. The finer granularity of this input served to anchor the abstract constraint patterns identified in the literature review to specific operational steps and governance moments within each pilot, making the analysis directly actionable for pilot design, process standardisation, and readiness assessment. It should be noted that at this phase LI3 comprised two distinct operational contexts (LI3A and LI3B) that are treated separately in the procedure-level analysis.

Phase 4: Comparative Analysis and Synthesis

The fourth phase brought together the findings from the three preceding phases into a structured comparative analysis. The barrier families identified through the literature review were mapped against the barrier profiles submitted by LI partners at both the LI level (Phase 1) and the procedure level (Phase 3), with the aim of identifying areas of convergence and divergence between the theoretical evidence base and the operational practitioner perspective. Areas of convergence, where LI partner inputs independently confirmed patterns identified in the literature, strengthen confidence in the identified barrier families as structurally robust constraint mechanisms applicable beyond specific pilot contexts. Areas of divergence, where LI input revealed constraint dynamics, sequencing dependencies, or contextual specificity not visible in the generic literature, highlight the analytical value added by grounding the analysis in actual pilot operations, and flag where the literature needs qualification or refinement. The synthesis of these four phases provides the empirical and analytical foundation for the barrier families, the scaling-enabling factors, and the readiness dimensions that flow into the subsequent components of WP1, including the Rulebook scaling conditions and the Scale Readiness Level framework.

The methodological focus has been on structured documentary inputs from partners via the LI barrier analyses and the Rulebook templates described above. These documents effectively capture expert judgement from LI leaders and technical partners in a written form, providing a rich qualitative evidence base without yet requiring dedicated synchronous engagement activities. This does not mean that **interactive stakeholder engagement** is absent from the overall WP1 methodology; a subsequent validation and

refinement stage is planned for M12, aiming to verify and enrich the Rulebook's findings with broader stakeholder perspectives.

Results are presented per phase in the following chapters and **the Annex**.

4. Phase 1 - Barriers and Enablers per Domain

4.1 BARRIERS

Across the five LIs, 114 barrier and enabler entries were recorded. The entries were organised along five analytical domains, namely technological, operational, regulatory and policy, market and economic, and social and organisational, providing an initial cross-domain picture of the constraint and enabling landscape as experienced by practitioners. Consolidated results are presented below.

Table 2. Barriers identified by LI teams

Technological	Operational	Regulatory & Policy	Market & Economic	Societal & Organisational
LI1 Online and offline trustee matchmaking and volume pooling for electrification and increased intermodality				
Lack of interoperability between systems and platforms; Lack of interoperable data standards; Poor data quality, timeliness and reliability; Security, privacy and confidentiality concerns; Scalability and performance issues; Limited digital infrastructure and connectivity	Complexity integrating new technologies with existing workflows; Fragmented and non-standardised operational workflows	Unclear liability and risk allocation; Regulatory uncertainty (competition/antitrust); Fragmented regulations across regions; Slow adaptation of regulatory frameworks; Misaligned incentives or subsidies	High initial investment costs; Uncertainty about ROI and scalability; Market fragmentation; Lack of critical mass/network effects; Unclear value proposition; Existing long-term contracts	Lack of trust and collaboration; Resistance to change and organisational inertia; Misaligned incentives and priorities; Limited digital skills and internal capacity; Fear of opportunism; Low awareness of pooling benefits; Change fatigue
LI2 eFTI compliance Collaborative Service Platform for SMEs				
Legacy systems and heterogeneous SME digital maturity; Limited digital readiness of SMEs; Fragmented data formats and IT systems; Incomplete or low-quality operational data; Difficulty synchronising multimodal schedules; Data sharing and confidentiality concerns	Fragmented operational workflows; High coordination complexity across actors; Inefficient loading and planning processes	Slow and uneven adoption of eFTI Regulation; Lack of harmonised national procedures for digital freight documents; Unclear responsibilities for data validation and liability; Complex port regulatory environments; Regulatory hesitancy towards real-time data exchange; Inconsistent acceptance of digital documentation	Fragmented SME-dominated markets; High coordination costs; Uncertain demand for collaborative services; Lack of incentives for greener or multimodal transport; Volatile fuel prices and inflation; Market distrust toward new digital platforms	Resistance to change among operators and staff; Limited awareness of collaborative logistics benefits; Fragmented communication between stakeholders; Lack of trust between competing actors; Workforce skill gaps; Organisational silos within companies
LI3 Smart and synchromodal hubs for hyperconnected urban logistics (INLAND)				
Different pallet/container standards; Limited availability of standardised micro-containers;	Difficulty synchronising multimodal operations; Restricted urban space for hubs	Urban logistics regulations and permitting constraints; Fragmentation across transport modes; Slow rollout of AFIR charging/refuelling	High upfront costs of zero-emission fleets; Limited financing options for small operators; Uncertain ROI for shared micro-	Cultural resistance to modal shift; Reluctance to share operational data; Fear of losing competitive advantage;

Technological	Operational	Regulatory & Policy	Market & Economic	Societal & Organisational
Compatibility issues between barge, bike and hub equipment; Fragmented IT systems across LSPs and municipalities; Limited real-time data exchange; Non-interoperable locker systems	and lockers; Network management complexity; Cold-chain operational rigidity	infrastructure; National labour law constraints	hubs and lockers; High operational and infrastructure costs	Fragmented priorities across municipalities; Acceptance challenges among citizens and operators
LI4 Intelligent, standard end-to-end chain of custody for carbon emission calculation				
Lack of trust in current emission reporting systems; Limited access to primary fuel data; Risk of fraud or data manipulation; Fragmentation of standards	High complexity of international custody chains; Continuous monitoring burden	Unclear regulatory acceptance of new accounting methods; Fragmented governance of carbon accounting frameworks	Unclear business incentives for adoption; Compliance and implementation costs	Resistance to moving away from default emission factors; Low data literacy across actors
LI5 Open volume pooled governance for reusable standard modular boxes				
Lack of interoperability between systems and warehouse setups across countries; High dependency on automation and digital tools; Integration challenges with legacy systems and scanners	Inconsistent palletising and packaging practices; Dual line-up complexity; Limited pilot infrastructure and equipment	Legal uncertainty around ownership, liability and data sharing; Existing contracts and national regulations hindering pooling; Lack of harmonised procedures across countries	Unproven business models for reusable packaging; Cost of automation and digital upgrades; Risk of market fragmentation if pilots are not harmonised	Lack of trust among stakeholders; Resistance to behavioural change; Limited stakeholder engagement in process redesign

4.2 ENABLERS

Technological and Operational Enablers

The technological and operational enablers identified across all five LIs converge on three interconnected mechanisms. First, the adoption of open, interoperable standards and APIs, including GS1 data models, eFTI-compliant data schemas, and federated data space architectures, is consistently cited as the foundational lever for resolving system fragmentation and enabling seamless data exchange across heterogeneous platforms. Second, modular and phased implementation strategies, including scalable architectures, digital label activation alternatives, and low-tech fallback options, are highlighted as essential for managing integration complexity and ensuring inclusivity for SMEs and actors with limited digital maturity. Third, real-time data infrastructure (encompassing IoT-enabled telematics, data streaming layers, advanced multimodal routing algorithms, and blockchain-based custody chains) is identified as enabling both operational coordination and the transparency required for emissions reporting and collaborative logistics. Across LIs, the recurring enabling theme is the shift from closed, proprietary systems toward shared, standards-based digital environments that lower the cost of participation without requiring all actors to reach the same level of technological readiness simultaneously.

Regulatory and Policy Enablers

The regulatory and policy enablers identified in the tables reflect a dual dynamic of clarification and harmonisation. At the EU level, the eFTI Regulation and its associated delegated and implementing acts are the most prominently cited lever, providing momentum for digital freight documentation, clearer role and

liability definitions, and a compliance framework that simultaneously creates obligations and removes ambiguity for early adopters. The EU Data Act, Data Governance Act, and Green Deal policy frameworks are identified as enabling structured and rights-based data sharing across supply chain actors, reducing the legal uncertainty that inhibits voluntary participation. At the cross-border and multimodal level, harmonised regulatory frameworks, including alignment with TEN-T corridor policies, AFIR charging infrastructure requirements, and national SUMP and Sulp integration, are cited as enabling conditions for deploying shared infrastructure such as charging points for barges and e-vans. At the governance level, safe-harbour guidelines, standardised legal templates for consortium agreements, and neutral trustee arrangements are identified as tools for managing competition law sensitivities and liability allocation without requiring comprehensive bilateral negotiation for each collaboration arrangement. The common thread across all LIs is that regulatory enabling is most effective when it reduces ambiguity rather than adding compliance requirements.

Market and Economic Enablers

The market and economic enablers identified reflect the need to de-risk innovation participation for actors, particularly SMEs, who face high upfront costs and uncertain returns. The most frequently cited mechanisms are public-private co-investment schemes, green loans, leasing models, and EU and regional SME vouchers for digital adoption, all of which reduce the financial barrier to entry without requiring actors to commit to long-term obligations before value is demonstrated. Phased pilot deployment is consistently framed as an economic enabler in its own right: by generating evidence of measurable cost savings, load factor improvements, and reduced coordination overhead within bounded pilot contexts, it shifts the ROI calculation from speculative to evidence-based and attracts subsequent participants. Collaborative platforms that bundle matchmaking, routing optimisation, and eFTI compliance services reduce the per-unit coordination cost for individual SMEs and introduce new revenue streams through shared asset and warehouse arrangements. The involvement of credible consortium partners, including port authorities, GS1, and established logistics operators, is also cited as an economic enabler by reducing market uncertainty and increasing platform sustainability confidence. Across LIs, the pattern is one of staged economic de-risking: demonstrate value first at low cost, then scale participation.

Social and Organisational Enablers

The social and organisational enablers form the most heterogeneous category, reflecting the diversity of behavioural and relational barriers. Governance transparency (through neutral trustee roles, standardised KPI frameworks, benefit-sharing agreements, and role-based data access) is the most consistently cited mechanism, operating directly against the trust deficits and fear of opportunism that inhibit data sharing and horizontal collaboration. Co-design and stakeholder engagement processes are identified as enablers of organisational buy-in, particularly in contexts where operational staff and middle management bear the implementation burden of new digital workflows without necessarily perceiving the benefits. Training, simplified user interfaces, and phased onboarding programmes are cited across LIs as essential for addressing digital skill gaps and reducing resistance from logistics personnel accustomed to manual processes. Awareness campaigns, citizen engagement initiatives, and pilot demonstrations with visible operational benefits are identified as tools for shifting cultural attitudes toward modal shift, shared infrastructure, and collaborative logistics models. Reputation and performance monitoring systems are cited as mechanisms for sustaining collaboration over time by creating accountability without requiring centralised enforcement. The overarching enabling logic in this domain is one of gradual confidence-building: replacing perceived risk with demonstrated, visible, and fairly distributed benefit.

5. Phase 2 - Literature Review & Analytical Framing

5.1 METHODOLOGICAL APPROACH

This section details the literature-review component of the four-phase methodology introduced in Section 3, focusing on evidence-base construction, coding, consolidation and structural analysis..

The analysis is organised through a predefined analytical lens consisting of four domains: technological and operational, social and organisational, regulatory and policy, and market and economic. These domains are defined a priori and applied consistently across all stages of the methodology. They reflect the multidimensional nature of logistics transitions, capturing constraints related to infrastructure and systems, coordination and behaviour, institutional frameworks, and economic feasibility. Barriers are allowed to span multiple domains, reflecting the interdependent nature of transition processes. Rather than imposing an additional domain, cross-domain effects are identified empirically through interaction analysis.

The initial set of 114 barriers identified across LIs was not directly analysed in this task, but was used to inform the construction of keyword clusters for the literature search, ensuring alignment between project-specific observations and the broader evidence base. These barriers are not incorporated into the analytical dataset. Their role is to ensure that the documentary corpus reflects implementation-relevant challenges while maintaining analytical independence. Through a translation process, these barriers were converted into neutral keyword clusters aligned with academic and policy terminology, guiding the structured desk research process.

Table 3. Example of mapping of LI-derived barriers to keyword clusters used for literature search

Indicative barrier theme	Derived keyword cluster	Analytical purpose
Data sharing and trust limitations	data sharing, data governance, trust, logistics data ecosystems	Identification of governance and collaboration constraints
Interoperability and integration challenges	interoperability, system integration, APIs, digital logistics platforms	Coverage of technical and architectural barriers
Implementation complexity	implementation barriers, system complexity, digital transformation logistics	Identification of operational constraints
Regulatory uncertainty	regulation, compliance, policy frameworks, eFTI	Identification of institutional barriers
Weak economic incentives	business models, investment risk, cost-benefit LI	Coverage of market and financial constraints
Coordination challenges among actors	collaboration, stakeholder alignment, horizontal logistics	Identification of organisational barriers

5.1.1 EVIDENCE BASE CONSTRUCTION AND BARRIER DATASET DEVELOPMENT

The empirical foundation of the analysis is a documentary corpus comprising 273 sources identified through structured desk research. The corpus includes peer-reviewed articles, conference proceedings, books, policy reports, and Horizon project deliverables. The inclusion of implementation-oriented sources ensures that the analysis captures both conceptual and applied dimensions of logistics transitions.

Documents were identified iteratively using the keyword clusters derived from LI-informed themes. Throughout this process, document metadata were recorded and managed in Excel, enabling systematic tracking, filtering, and removal of duplicates. The resulting corpus provides a balanced and comprehensive evidence base. The full list of reviewed documents is provided in the Annex.

Barrier extraction was conducted manually using a structured template implemented in Excel. Each barrier was recorded as a distinct analytical unit, preserving the original formulation from the source alongside a

short interpretative description and associated metadata. This process resulted in an initial dataset of approximately 1,800 barrier observations. Treating barriers as the primary unit of analysis ensures that the methodology captures the full granularity of reported constraints and avoids distortions associated with document-level aggregation.

Following extraction, the dataset underwent a structured cleaning and harmonisation process. Barrier titles were standardised through lowercasing, trimming, and removal of formatting inconsistencies. Duplicate entries resulting from repeated extraction were identified and consolidated, while maintaining links to original sources. The dataset was then exported in CSV format and processed in R, enabling the application of analytical techniques that extend beyond spreadsheet-based capabilities. This combined use of Excel and R reflects a deliberate methodological choice, where Excel supports traceability and structured data management, and R supports computational analysis and text processing.

5.1.2 DOMAIN CODING, INTERACTION ANALYSIS, AND SIMILARITY-BASED CONSOLIDATION

Each barrier was manually coded according to the four analytical domains. Barriers were allowed to belong to multiple domains, and these assignments were recorded in a structured format enabling both descriptive and relational analysis. Initial descriptive analysis was conducted in Excel using pivot tables to examine the distribution of barriers across domains and the prevalence of multi-domain constraints. This step provides an initial indication of the structural complexity of the dataset.

For interaction analysis, the dataset was processed in R, where domain assignments were decomposed into binary indicators. To avoid bias from repeated observations within the same source, barriers were aggregated at the document level, ensuring that each document contributes at most one instance of each domain. Based on this representation, a domain co-occurrence matrix was constructed, capturing how frequently different domains appear together within the same documentary context.

To refine these relationships, the Jaccard similarity coefficient was computed, providing a normalised measure of domain interaction. This allows the analysis to move beyond frequency counts and identify structural interdependencies between technological, organisational, regulatory, and economic constraints. In parallel, barrier texts were processed using text vectorisation techniques (based on term frequency-inverse document frequency weighting), enabling similarity-based analysis. Cosine similarity was computed between barrier texts to identify semantically similar observations. A similarity threshold was applied to detect candidate duplicate barriers, which were then manually reviewed in Excel. This combined computational and manual procedure ensures that semantically equivalent barriers are consolidated while preserving conceptual distinctions.

Following duplicate consolidation, similarity relationships were used to identify clusters of semantically related barriers. Clustering was performed in R and subsequently validated through manual inspection to ensure semantic coherence and interpretability. Based on this process, representative labels were assigned to each cluster, forming barrier family seeds that capture the underlying constraint mechanisms. This process ensures that barrier families reflect empirically grounded and recurrent constraint mechanisms rather than arbitrary grouping, thereby preserving both semantic coherence and analytical validity.

5.1.3 CONSTRUCTION AND STRUCTURAL ANALYSIS OF BARRIER FAMILIES

Each barrier in the dataset was assigned to one of the identified families through a combination of similarity-based matching, keyword alignment, and manual validation. This resulted in a consolidated dataset structured around 21 barrier families, which constitute the primary analytical output of the methodology.

A barrier family dataset was constructed in Excel, aggregating information on barrier counts, associated documents, and domain coverage for each family. This aggregation enables the analysis to move from individual barrier observations to a system-level understanding of constraint structures.

Quantitative analysis was conducted to examine the distribution of barriers across families. This includes the calculation of the share of each family within the overall corpus, cumulative distribution measures, and the Herfindahl concentration index, which provides an indication of structural concentration. These indicators allow the identification of dominant constraint mechanisms and the extent to which barriers are concentrated within a limited number of families.

In parallel, category composition analysis was conducted to examine the internal structure of each family. This analysis calculates the distribution of domain assignments within each family, enabling the identification of families that are domain-specific and those that span multiple domains. This distinction is critical for understanding whether constraint mechanisms are isolated or systemic in nature.

5.1.4 METHODOLOGICAL ROBUSTNESS AND LIMITATIONS

The methodology combines manual evidence synthesis, structured data management in Excel, and advanced analytical techniques implemented in R, including similarity analysis, clustering, and co-occurrence modelling. This hybrid approach ensures robustness while maintaining transparency and traceability.

At the same time, limitations inherent to documentary analysis remain. Differences in reporting practices across sources affect the articulation of barriers. Clustering involves interpretative judgement despite computational support. Interaction analysis identifies structural relationships but does not establish causality.

These limitations define the scope of the results rather than undermining their validity. The methodology is designed to identify recurring structural constraint mechanisms and their interactions, providing a solid and empirically grounded foundation for the subsequent definition of scaling conditions and readiness dimensions within the PI Rulebook.

5.2 EMPIRICAL PATTERNS EMERGING FROM THE LITERATURE REVIEW

5.2.1 SCALE AND STRUCTURE OF THE EVIDENCE BASE

The literature review resulted in a structured barrier dataset extracted from peer-reviewed studies, EU project deliverables, and policy-oriented documents.. Each observation was classified according to the four analytical domains. At the level of base categories, the distribution of barriers is as follows:

Table 4. Distribution of barriers across analytical domains

Domain	Barrier count	Share (%)
Technological and Operational	798	34.0
Social and Organisational	799	34.1
Regulatory and Policy	404	17.2
Market and Economic	354	15.1

The near-equal distribution between Technological and Operational (34.0%) and Social and Organisational (34.1%) domains indicate that constraints are strongly concentrated in the Technological and Operational and Social and Organisational domains, which together account for more than two-thirds of all observations. In return, this shows that the primary challenges to implementation and scaling do not lie exclusively in infrastructure or exclusively in coordination, but in their combined presence. Secondly, Regulatory and Policy and Market and Economic barriers, while less dominant in absolute terms, remain systematically present across the corpus. Their relative weight suggests that they do not act as primary entry barriers but rather as conditioning factors that influence whether solutions can stabilise and expand beyond pilot

environments. This distribution already suggests that scaling constraints are not evenly distributed and that they are shaped by a combination of technical feasibility and organisational alignment.

5.2.2 RECURRING CONSTRAINT PATTERNS IN THE LITERATURE

A closer examination of the barrier observations reveals that the literature does not describe a wide diversity of unrelated problems. Instead, it repeatedly converges on a limited set of constraint patterns. A first pattern concerns the centrality of data-related constraints. A significant portion of the barriers relates to data availability, data quality, interoperability, and data sharing practices. These constraints appear across multiple domains. For instance, lack of real-time information flows is a technological issue, while reluctance to share data reflects organisational dynamics, and uncertainty around data ownership reflects regulatory conditions. The recurrence of these issues across sources indicates that data is not merely an operational input but a systemic dependency for coordination and optimisation.

A second pattern relates to interoperability and system integration. Many documents highlight the difficulty of connecting heterogeneous systems and aligning operational processes across actors. These challenges persist even in contexts where digital solutions are available, suggesting that the constraint lies not only in technology but in the absence of shared standards and integration frameworks. This pattern is particularly relevant for PI concepts, which rely on seamless interoperability across networks.

A third pattern concerns coordination complexity and trust. Logistics systems involve multiple actors with partially overlapping and sometimes conflicting objectives. The literature repeatedly points to coordination difficulties, lack of trust, and misaligned incentives as barriers to collaboration. These constraints are not episodic but structural, appearing across different logistics segments and geographical contexts.

A fourth pattern relates to regulatory and institutional uncertainty. Barriers associated with fragmented regulations, unclear policy direction, and legal ambiguity appear consistently. These constraints do not necessarily prevent initial experimentation, but they create uncertainty that limits long-term investment and scaling.

A fifth pattern concerns economic feasibility. High upfront costs, uncertain returns, and limited access to funding are frequently reported. However, these barriers rarely appear in isolation. They are often contingent on technological maturity, coordination mechanisms, and regulatory clarity. This suggests that economic barriers are not purely financial but are linked to broader system conditions.

Taken together, these patterns indicate that the literature converges on a relatively stable set of constraint types. These constraints are repeatedly observed across contexts, which supports their interpretation as structural features rather than context-specific issues.

5.2.3 DEGREE OF FRAGMENTATION AND OVERLAP IN BARRIER DESCRIPTIONS

While the literature converges on a limited set of constraint patterns, it does not describe them in a uniform way. Similar issues are often expressed using different terminology, levels of abstraction, and contextual framing. This is reflected in the structure of the dataset. Although the dataset is extensive, many observations refer to conceptually overlapping constraints. For example, issues related to interoperability may be described as “lack of standardisation”, “incompatible data formats”, or “integration complexity”. Similarly, coordination challenges may be framed as “lack of trust”, “misaligned incentives”, or “collaboration barriers”. This fragmentation is further illustrated by the distribution of barriers across domain combinations:

Table 5. Distribution of barriers by number of domains

Number of domains	Barrier count	Share (%)
One domain	1,251	69.5
Two domains	531	29.5
Three domains	10	0.6
Four domains	3	0.2

Not specified	5	0.3
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Approximately 70 percent of barriers are classified within a single domain, while around 30 percent span multiple domains, which indicates that, although many barriers are presented as domain-specific in the literature, a substantial share already reflects cross-domain interactions. The coexistence of single-domain and multi-domain barriers highlights two important aspects of the evidence; on the one hand, the literature tends to isolate specific aspects of problems for analytical clarity, and on the other hand, a significant portion of observations already recognises that constraints emerge from the interaction of multiple dimensions. This duality contributes to the fragmentation of the evidence. Similar underlying issues are sometimes split across domains, while in other cases they are presented as integrated challenges.

5.2.4 IMPLICATIONS OF THE EMPIRICAL EVIDENCE FOR SCALING ANALYSIS

The empirical patterns identified above have direct implications for how scaling challenges should be analysed. First, the concentration of barriers in specific domains indicates that certain types of constraints are more prevalent and therefore more likely to limit scaling. However, prevalence alone does not determine impact. The interaction between domains suggests that even less frequent barriers can play a critical role if they act as bottlenecks within a system. Second, the recurrence of similar constraint patterns across sources indicates that these barriers are not context-dependent anomalies. They represent structural features of logistics systems transitioning toward PI models.

Third, the fragmentation and overlap in barrier descriptions limit the usability of the evidence in its raw form. Without consolidation, it is difficult to compare findings across studies, identify priorities, or link constraints to actionable measures.

Finally, the presence of multi-domain barriers confirms that scaling depends on coordinated interventions across technological, organisational, regulatory, and economic dimensions.

5.2.5 ANALYTICAL NECESSITY OF BARRIER FAMILY CONSOLIDATION

The combination of recurrence, fragmentation, and interdependence observed in the literature creates a clear analytical requirement. The evidence base is sufficiently rich to identify consistent constraint patterns, but it remains too fragmented to support systematic comparison and prioritisation. Similar barriers appear under different labels, and related issues are dispersed across domains and sources. This consolidation step transforms fragmented observations into analytically comparable units, enabling prioritisation and direct linkage to scaling-enabling factors and Rulebook development. By grouping semantically and functionally similar barriers, it becomes possible to (i) identify recurring constraint mechanisms, (ii) compare their relative importance, (iii) examine their internal composition across domains, and (iv) establish links to enabling conditions. It transforms the literature into a structured representation of the constraint landscape..

The next section builds directly on this interpretation by presenting of the barrier dataset into 21 barrier families. These families represent recurring structural mechanisms that constrain the implementation and scaling of PI solutions. They provide the analytical foundation for subsequent prioritisation and for the identification of scaling-enabling factors within the PI Rulebook.

5.3 STRUCTURAL ANALYSIS OF BARRIER FAMILIES AND PRIORITISATION OF CONSTRAINT MECHANISMS

5.3.1 FROM INDIVIDUAL BARRIERS TO STRUCTURAL CONSTRAINT MECHANISMS

The application of the methodology described above in the grouping of the barrier dataset into 21 barrier families through similarity-based clustering and expert validation. This transformation constitutes a critical analytical step. It enables the transition from fragmented, source-specific observations to a structured representation of recurring constraint mechanisms affecting the implementation and scaling of PI solutions. Each barrier family captures a distinct pattern of constraints that appears consistently across multiple documents and contexts. The analytical value of this consolidation lies in its ability to reveal structural regularities that are not visible at the level of individual barriers. As a result, the analysis shifts from describing “what barriers exist” to understanding “how constraints are structurally organised”.

The purpose of this section is to examine the distribution, concentration, and internal composition of these barrier families, and provide the empirical basis for identifying dominant constraint mechanisms and a first level of prioritisation supporting the development of scaling conditions in the PI Rulebook. It should be noted that the barrier families identified above are interpreted in the context of the Rulebook as pain points, representing the most recurrent and structurally significant constraints to scaling.

5.3.2 DISTRIBUTION AND CONCENTRATION OF BARRIER FAMILIES

The distribution of barriers across the 21 identified families is presented below. The table reports the number of barriers associated with each family and their relative share within the total dataset.

Table 6. Barrier family distribution and share of the corpus

Barrier Family	Barrier Count	% of Corpus
Technical complexity and implementation burden	393	21.83
Data sharing reluctance	362	20.11
Data interoperability and semantic mismatch	271	15.06
Platform and system integration complexity	207	11.50
High upfront costs and investment risk	96	5.33
Coordination complexity across multiple actors	71	3.94
Insufficient digital infrastructure availability	59	3.28
Weak real-time information flows	41	2.28
Limited scalability and robustness of digital solutions	39	2.17
Data privacy and cybersecurity concerns	38	2.11
Lack of trust among stakeholders	37	2.06
Incomplete or low-quality logistics data	33	1.83
Unclear data ownership, access, and liability	31	1.72
Lack of interoperability standards and common protocols	30	1.67
Regulatory fragmentation across jurisdictions	24	1.33
Unclear or unstable policy signals	20	1.11
Legal uncertainty around data, contracts, and liability	18	1.00
Limited digital readiness of actors	11	0.61
Administrative burden and compliance complexity	10	0.56
Weak or uncertain business cases	5	0.28
Limited access to funding, incentives, or financial support	4	0.22

The distribution reveals a pronounced concentration of barriers within a limited number of families. The four largest families account for approximately 68.5 percent of the total barrier corpus, while the two largest alone account for approximately 41.9 percent. This indicates that implementation constraints are not widely dispersed across many independent issues but are instead clustered around a small number of recurring and structurally significant mechanisms.

This concentration is further confirmed through the calculation of the Herfindahl–Hirschman Index, which is approximately 0.14. The index, which measures the degree of concentration by aggregating the squared shares of each category, indicates a moderately concentrated distribution. This suggests that while no single

barrier family dominates the landscape entirely, a limited number of families exert a disproportionate influence on the overall structure of constraints.

Beyond these dominant families, the remaining barriers are distributed across a long tail of less frequent constraint mechanisms, each contributing marginally to the total distribution. This pattern reinforces the interpretation that the implementation landscape is shaped primarily by a limited set of recurring structural constraints rather than by a wide dispersion of isolated issues.

From a scaling perspective, this finding is particularly significant. The most concentrated barrier families can be interpreted as the primary pain points for scaling, as they represent the constraint mechanisms that most consistently hinder the transition from pilot implementation to broader deployment. Their identification provides a clear empirical basis for prioritisation, ensuring that subsequent scaling efforts focus on the most structurally impactful barriers rather than on less influential or context-specific constraints.

5.3.3 DOMAIN INTERACTION AND CO-OCCURRENCE STRUCTURE

While the distribution analysis identifies which barrier families dominate, it does not capture how different types of constraints interact. To address this, a domain interaction analysis was conducted based on document-level co-occurrence. The analysis examines how frequently barriers belonging to different domains appear together within the same document. To ensure that results reflect structural relationships rather than repeated observations, the dataset was aggregated at the document level, with each document contributing at most one instance of each domain.

A co-occurrence matrix was constructed to capture the frequency of domain pairings. However, raw co-occurrence counts are influenced by the overall frequency of each domain. For this reason, the analysis employs the Jaccard similarity coefficient as a normalised measure of association. The Jaccard similarity between two domains A and B produces values between 0 and 1, where higher values indicate stronger structural association.

Table 7. Jaccard similarity matrix of barrier domains

Domain	Tech & Operational	Social & Organisational	Regulatory & Policy	Market & Economic
Tech & Operational	1.00	0.849	0.708	0.650
Social & Organisational	0.849	1.00	0.704	0.703
Regulatory & Policy	0.708	0.704	1.00	0.596
Market & Economic	0.650	0.703	0.596	1.00

The results reveal consistently high similarity values across all domain pairs. The strongest relationship is observed between technological and operational barriers and social and organisational barriers, with a value of 0.849. This indicates that technological challenges are very frequently associated with coordination, behavioural, and trust-related issues. Similarly, social and organisational barriers show strong associations with regulatory and policy barriers, with a value of 0.704. This suggests that coordination challenges are often embedded within institutional and governance conditions. Technological and regulatory barriers also exhibit strong interaction, with a value of 0.708, indicating that technological deployment is closely linked to regulatory frameworks. Even the lowest observed similarity, between regulatory and market barriers at 0.596, remains relatively high.

These results demonstrate that barriers are systematically interdependent across domains. Scaling constraints do not arise from isolated deficiencies but from the interaction of multiple conditions. This has direct implications for the design of scaling strategies, which must address combinations of technological, organisational, regulatory, and economic factors.

5.3.4 DOMAIN COMPOSITION OF BARRIER FAMILIES

To complement the interaction analysis, the internal structure of barrier families was examined through category composition analysis. This analysis calculates the share of barriers within each family that are associated with each domain.

Table 8. Domain composition of barrier families

Barrier Family	Tech & Operational	Social & Organisational	Regulatory & Policy	Market & Economic
Technical complexity and implementation burden	0.35	0.55	0.17	0.19
Data sharing reluctance	0.34	0.69	0.24	0.15
Data interoperability and semantic mismatch	0.76	0.25	0.20	0.10
Platform and system integration complexity	0.57	0.36	0.18	0.19
High upfront costs and investment risk	0.07	0.09	0.06	0.93
Coordination complexity across multiple actors	0.11	0.76	0.13	0.27
Insufficient digital infrastructure availability	0.73	0.12	0.07	0.34
Weak real-time information flows	1.00	0.02	0.02	0.00
Limited scalability and robustness of digital solutions	0.54	0.38	0.10	0.23
Data privacy and cybersecurity concerns	0.50	0.39	0.63	0.03
Lack of trust among stakeholders	0.16	0.84	0.32	0.03
Incomplete or low-quality logistics data	0.85	0.39	0.15	0.06
Unclear data ownership, access, and liability	0.32	0.48	0.45	0.10
Lack of interoperability standards and common protocols	0.57	0.23	0.73	0.03
Regulatory fragmentation across jurisdictions	0.08	0.08	0.92	0.04
Unclear or unstable policy signals	0.05	0.10	1.00	0.05
Legal uncertainty around data, contracts, and liability	0.22	0.28	0.72	0.06
Limited digital readiness of actors	0.09	1.00	0.00	0.00
Administrative burden and compliance complexity	0.40	0.30	0.40	0.10
Weak or uncertain business cases	0.20	0.20	0.00	1.00
Limited access to funding, incentives, or financial support	0.00	0.00	0.00	1.00

The results show that many barrier families span multiple domains, which confirms that constraint mechanisms are inherently multi-dimensional. Even families with a principal domain often include significant contributions from other domains. For instance, data sharing reluctance combines strong social, technological, and regulatory components, indicating that it is not purely a behavioural issue but also a governance and infrastructure challenge. Similarly, data privacy and cybersecurity concerns combine regulatory, technological, and organisational dimensions. In contrast, some families are clearly domain-specific. Weak real-time information flows are almost entirely technological, while weak business cases and limited access to funding are entirely market-driven. This distinction is analytically important. Domain-specific barriers can often be addressed through targeted interventions, whereas multi-domain barriers require coordinated approaches across multiple dimensions.

5.3.5 STRUCTURAL IMPLICATIONS FOR SCALING AND PRIORITISATION

The combined analysis of distribution, concentration, interaction, and composition provides a coherent structural interpretation of the barrier landscape. The moderate concentration indicated by an HHI¹ of 0.14 demonstrates that scaling constraints are not evenly distributed but are dominated by a limited number of high-impact mechanisms. At the same time, the high Jaccard similarity values, ranging from 0.596 to 0.849,

¹ The Herfindahl–Hirschman Index (HHI) measures concentration by summing the squared shares of each category, with higher values indicating stronger concentration.

demonstrate that these mechanisms are strongly interconnected across domains. The domain composition analysis further confirms that most barrier families are multi-dimensional, spanning technological, organisational, regulatory, and economic conditions. Taken together, these findings indicate that scaling challenges are characterised by three structural properties: (i) concentration around a limited set of dominant constraint mechanisms. (ii) strong interdependencies across analytical domains, and (iii) multi-dimensional internal structure of barrier families

These results provide a clear empirical foundation for defining scaling conditions. Barrier families can be interpreted as structural constraints that must be mitigated for scaling to occur. Their distribution identifies where intervention is most impactful, while their composition and interaction patterns indicate which domains must be addressed jointly. These pain points provide the empirical basis for prioritisation within the PI Rulebook, ensuring that scaling efforts focus on the most structurally significant constraints rather than on isolated or context-specific issues.

5.4 SCALING-ENABLING FACTORS AND MAPPING TO BARRIER FAMILIES

5.4.1 FROM CONSTRAINT IDENTIFICATION TO SCALING-ENABLING LOGIC

Scaling conditions are understood as the combined set of constraints and enabling factors that determine whether an innovation can transition from pilot implementation to broader, replicable deployment. The structural analysis presented above establishes that barriers to the implementation and scaling of PI solutions are neither isolated nor evenly distributed. Instead, they are concentrated in a limited number of barrier families and exhibit strong interdependencies across technological, organisational, regulatory, and market dimensions. This configuration implies that scaling cannot be achieved through isolated interventions. It requires the identification of conditions under which these constraints can be mitigated in a coordinated manner.

Within the logic of WP1, this step corresponds to the transition from constraint identification to the articulation of scaling-enabling factors. These factors are not introduced as prescriptive solutions, but as empirically grounded conditions that facilitate the mitigation of barrier families. They are derived directly from the literature review through the extraction of “suggested enablers” associated with barrier observations and their subsequent consolidation.

This section identifies the scaling-enabling factors emerging from the evidence base and maps them to the barrier families, establishing the bridge to scaling conditions and readiness dimensions in T1.2..

5.4.2 DERIVATION AND STRUCTURING OF SCALING-ENABLING FACTORS

Scaling-enabling factors are derived from the “suggested enabler” field recorded during barrier extraction. These enablers are not treated individually. Instead, they are consolidated through a process analogous to barrier clustering, whereby semantically similar enablers are grouped into coherent categories representing recurring enabling mechanisms.

This consolidation results in a structured set of enabling factors that correspond to the dominant constraint mechanisms identified in the barrier families. The process ensures that enabling factors remain empirically grounded while achieving a level of abstraction suitable for analytical interpretation. The identified enabling factors can be interpreted as falling broadly within four interrelated areas, namely data governance and trust mechanisms, interoperability and standardisation frameworks, organisational coordination and collaboration models, and economic and policy support conditions. These categories are not mutually exclusive. As with barrier families, enabling factors frequently span multiple domains, reflecting the systemic nature of scaling processes.

5.4.3 MAPPING OF SCALING-ENABLING FACTORS TO BARRIER FAMILIES

To establish a direct analytical link between constraints and enabling conditions, scaling-enabling factors are mapped to barrier families through a one-to-many relationship. The mapping is derived through semantic

alignment between barrier descriptions and associated suggested enablers, validated through iterative review to ensure conceptual consistency. Each barrier family is associated with one or more enabling factors that address its underlying constraint mechanism. The table below presents this mapping.

Table 9. Mapping of barrier families to scaling-enabling factors

Barrier Family	Scaling-enabling factors
Technical complexity and implementation burden	modular system architectures; phased implementation strategies; technical integration frameworks
Data sharing reluctance	trusted data governance frameworks; data sharing agreements; incentive-aligned data ecosystems
Data interoperability and semantic mismatch	common data standards; semantic alignment frameworks; interoperable data models
Platform and system integration complexity	open APIs; middleware solutions; platform interoperability architectures
High upfront costs and investment risk	public-private co-investment schemes; risk-sharing mechanisms; staged financing models
Coordination complexity across multiple actors	collaborative governance structures; coordination platforms; stakeholder alignment mechanisms
Insufficient digital infrastructure availability	investment in digital infrastructure; shared digital platforms; connectivity enhancement
Weak real-time information flows	real-time data capture systems; IoT integration; data streaming infrastructures
Limited scalability and robustness of digital solutions	scalable system architectures; stress-testing frameworks; performance validation mechanisms
Data privacy and cybersecurity concerns	cybersecurity standards; data protection frameworks; secure data sharing protocols
Lack of trust among stakeholders	trust-building mechanisms; transparency frameworks; neutral data intermediaries
Incomplete or low-quality logistics data	data quality standards; data validation processes; data enrichment mechanisms
Unclear data ownership, access, and liability	clear data governance models; contractual frameworks; liability allocation mechanisms
Lack of interoperability standards and common protocols	standardisation initiatives; regulatory support for standards adoption; cross-platform compatibility frameworks
Regulatory fragmentation across jurisdictions	regulatory harmonisation; cross-border policy alignment; standardised compliance frameworks
Unclear or unstable policy signals	long-term policy roadmaps; regulatory clarity; stable policy incentives
Legal uncertainty around data, contracts, and liability	legal frameworks for data use; standard contractual models; liability clarification mechanisms
Limited digital readiness of actors	capacity building; training programmes; digital maturity frameworks
Administrative burden and compliance complexity	streamlined reporting systems; digital compliance tools; regulatory simplification
Weak or uncertain business cases	value quantification models; business model innovation; cost-benefit assessment tools
Limited access to funding, incentives, or financial support	targeted funding programmes; financial incentives; innovation support schemes

This mapping demonstrates that barrier families are not addressed by single interventions. Instead, each family requires a combination of enabling factors that collectively mitigate its underlying constraints. For example, data sharing reluctance is addressed not only through governance frameworks but also through incentive structures and trust-building mechanisms, reflecting its multi-dimensional nature. The mapping also reveals a strong structural alignment between barrier families and enabling factors. Dominant barrier families correspond to equally central enabling mechanisms. In particular, the four largest barrier families identified are associated with the following enabling configurations:

1. implementation complexity is addressed through modularisation, phased deployment, and integration frameworks

2. data sharing reluctance is addressed through governance, trust, and incentive alignment
3. interoperability constraints are addressed through standardisation and semantic alignment
4. system integration challenges are addressed through architectural solutions and platform interoperability

These correspondences shows that the enabling landscape mirrors the constraint landscape. This reinforces the interpretation of barrier families as structural representations of scaling constraints and enabling factors as structural conditions for overcoming them.

5.4.4 IMPLICATIONS FOR SCALING CONDITIONS AND READINESS DIMENSIONS

The explicit mapping between barrier families and scaling-enabling factors provides a direct bridge toward the formalisation of scaling conditions within the PI Rulebook. Barrier families can be interpreted as the conditions that must be mitigated for scaling to occur. Scaling-enabling factors represent the mechanisms through which this mitigation can be achieved. The combination of both defines the conditions under which an innovation can move from pilot implementation to broader adoption. Importantly, the analysis shows that these conditions are inherently multi-dimensional. Scaling is not determined by technological readiness alone, but by the alignment of technological, organisational, regulatory, and economic factors.

The analytical results presented in this section have direct implications for the subsequent structuring of scaling conditions within WP1. The identification of barrier families and their corresponding scaling-enabling factors provides a systematic basis for defining the conditions under which logistics innovations can transition from pilot implementation to broader deployment. Within the logic of WP1, this translation is operationalised in T1.2 through the formulation of scaling conditions and scalars within the PI Rulebook. In this context, the most concentrated barrier families represent the primary pain points that hinder adoption, while the associated scaling-enabling factors constitute the empirical basis for defining scalars, namely the mechanisms that facilitate scaling across contexts. This ensures that the Rulebook is not constructed on abstract assumptions, but is grounded in recurrent constraint–enabler relationships identified across the literature.

In parallel, the multi-dimensional structure of both barriers and enabling factors provides a coherent foundation for the definition of readiness dimensions. These dimensions reflect the different conditions that must be satisfied for scaling to occur, including technological readiness linked to system robustness and interoperability, organisational readiness linked to coordination and trust, regulatory readiness linked to policy alignment and legal clarity, and market readiness linked to economic viability and investment conditions. Importantly, these dimensions are not introduced normatively, but emerge directly from the empirical structure of the evidence. This analytical bridge extends further to T1.3, where these dimensions are operationalised through the Scale Readiness Level framework and the PI Readiness Mapper. In this context, barrier families and enabling factors are translated into measurable conditions, enabling the assessment of how close a given innovation is to scalable deployment and where critical gaps remain.

Taken together, this progression illustrates how T1.1 moves from descriptive evidence to structured analytical outputs that directly support both the Rulebook and the readiness assessment tools. It ensures that scaling is not treated as an implicit outcome of innovation performance, but as a condition that can be explicitly defined, assessed, and operationalised within the IKIGAI framework.

6. Phase 3 - Barrier Intensity by Logistics Innovation

In Phase 3, each LI team was provided with a structured mapping template that decomposed their innovation along three levels:

- Service (Sx): the Physical Internet service typology to which the LI contributes, drawn from the IKIGAI service classification (S1 Volume pooling and asset sharing, S2 Warehousing and storage, S3 Freight forwarding and intermodal transport, S4 Cross-docking, S5 Last-mile delivery).

- **Process (Px):** the main operational or governance process being piloted within the LI, aligned with the PI Norm procedural framework developed in WP2.
- **Procedure:** the discrete sub-steps within each process, reflecting the actual workflow sequence being designed, tested or operationalised in the pilot.

For each procedure, teams were asked to identify and articulate barriers under five standardised categories, consistent with the analytical framework applied across the project:

- **Technological barriers:** constraints related to system integration, data standards, interoperability, digital maturity and technical performance.
- **Operational barriers:** constraints arising from workflow complexity, coordination requirements, physical infrastructure, capacity and day-to-day execution.
- **Regulatory & Policy barriers:** constraints related to legal frameworks, compliance obligations, regulatory uncertainty, and governance gaps at European, national and local levels.
- **Market & Economic barriers:** constraints related to investment requirements, return on investment uncertainty, market structure, and business model viability.
- **Societal & Organisational barriers:** constraints arising from behavioural resistance to change, trust deficits, cultural norms, skills gaps and stakeholder acceptance challenges.

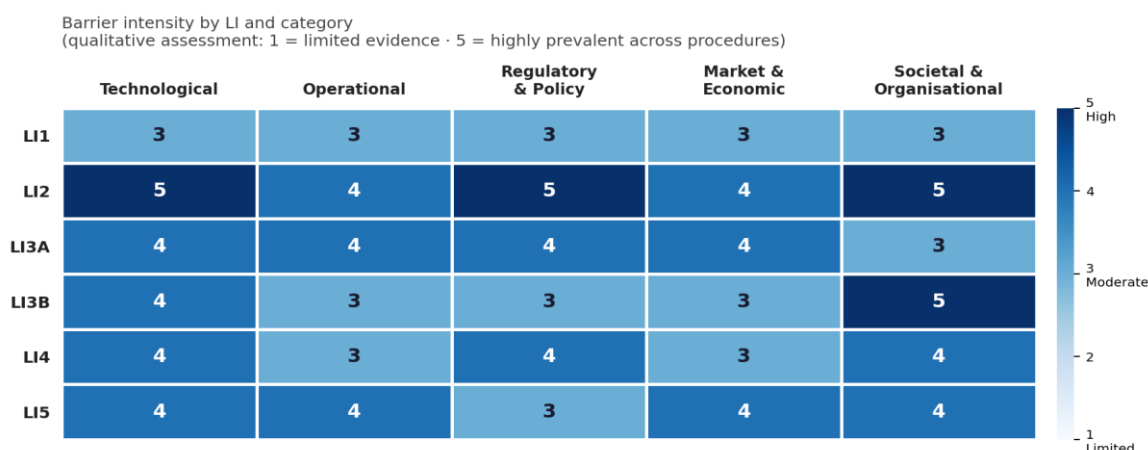


Figure 3. Barrier intensity by LI and category (qualitative assessment: 1 = limited evidence; 5 = highly prevalent across procedures)

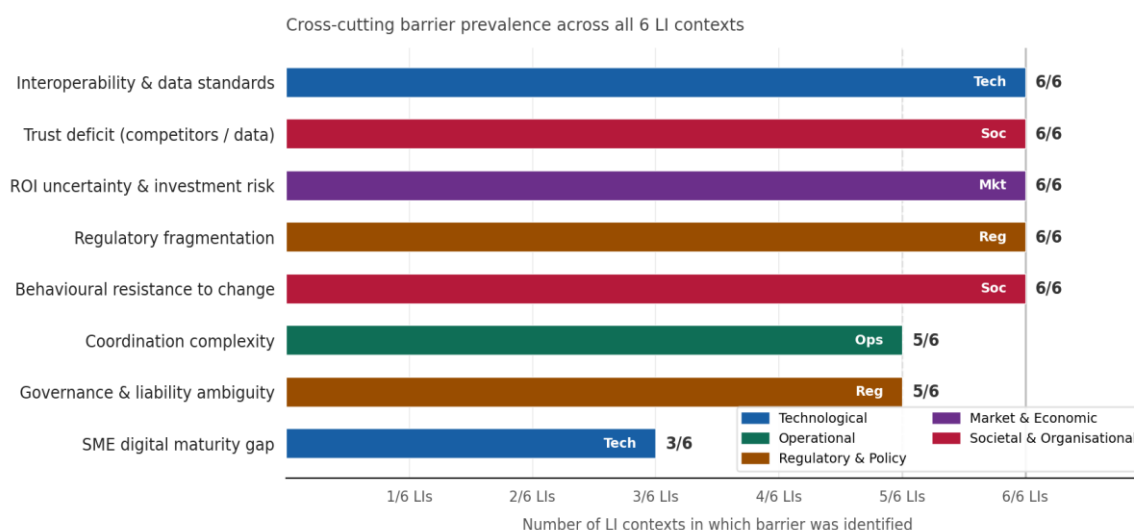


Figure 4. Cross-cutting barrier prevalence across all 6 LI contexts

Analysis of the barrier data submitted by the LI teams (**see Annex**) reveals a set of structural patterns that transcend individual LI contexts and reflect fundamental challenges for the Physical Internet paradigm. The following **eight conclusions** are drawn from a systematic comparison of barriers across all 21 mapped procedures. They are presented in order of analytical importance, beginning with the constraints that most directly condition the success of the overall project rationale.

i. Interoperability is the universal technological prerequisite

Across all LI contexts and all 21 mapped procedures, the inability of systems, platforms and data formats to communicate with each other is the single most consistently cited technological barrier. It manifests differently by context: fragmented ICT systems between shippers and LSPs in LI1, the digital maturity gap between SMEs and eFTI-compliant platforms in LI2, heterogeneous locker APIs and IoT connectivity in LI3A, tool incompatibility with the smart-contract orchestration layer in LI3B, TMS integration challenges in LI4, and RFID/barcode scanning inconsistency in LI5, but the common thread is structural. The IKIGAI innovations are, by design, network-effects solutions that only deliver value when multiple actors connect. The absence of common standards and interfaces directly prevents those connections from forming. Addressing interoperability is therefore not one barrier among many; it is a structural prerequisite for the entire project rationale to hold.

ii. Trust takes three distinct forms and each requires a tailored response

Every procedure row across all LIs surfaces trust as a constraint, but the nature of the trust deficit differs. In LI1 and LI2, it is horizontal trust between competitors, shippers and LSPs are asked to pool volumes and share lane data with actors they may otherwise compete against. In LI3B and LI4, it is data trust, actors fear that sharing operational or emissions data exposes strategic vulnerabilities. In LI5, it is institutional trust in a new neutral trustee model that departs from familiar pooling arrangements. In LI3A, a fourth dimension emerges: citizen and user trust in new delivery modalities. This multi-dimensionality means that trust-building interventions must be tailored per LI context. The neutral trustee architecture prominent in LI1 and LI5 represents a promising structural response, but its effectiveness depends on demonstrating governance integrity through the pilots before asking actors to commit fully.

iii. Governance design must precede, and is as important as, technical implementation

LI1 trustee model, LI4 Book & Claim rule design, and LI5 pool governance procedure all demonstrate that before any technical system can function, the rules governing ownership, liability, data access, gain-sharing and decision-making must be formally established. In LI5, the rule-based clearing mechanism remains in development, and this single gap blocks operational readiness regardless of the technology already in place. In LI4, the absence of established Book & Claim standards in freight logistics means that even technically sound verification systems lack a regulatory and commercial home. In LI3B, legal uncertainties around ownership and data sharing constrain what the smart-contract orchestration layer can actually verify and record. Governance therefore should be approached with the same rigour and urgency as technical ones; governance gaps cannot be resolved ex-post pilot implementation.

iv. ROI uncertainty creates a structural problem acute for SMEs

Across all LIs, operators and partners, especially smaller ones, are being asked to invest in onboarding, integration, training and infrastructure before the value proposition is proven at scale. Yet scale is precisely what is needed to generate the ROI that would justify the investment. This circularity is inherent to Physical Internet innovations, which are systemic and only deliver value through network effects. LI2 illustrates this most sharply: SME reluctance to invest without foreseeable ROI is a primary barrier to platform adoption,

yet without sufficient SME participation the platform cannot demonstrate the consolidated volumes that would prove its value. LI1 faces the same dynamic around corridor viability; LI4 faces it around first-mover risk for Book & Claim. Pilot design must therefore include de-risking mechanisms (subsidised onboarding, guaranteed minimum volume commitments, or risk-sharing arrangements) that protect the first-mover position.

v. Regulatory fragmentation operates at three levels simultaneously, creating a compounding burden

The regulatory barriers identified across the LIs do not all stem from the same governance level. At European level: eFTI Regulation uncertainty (LI2), absent Book & Claim standards (LI4), slow AFIR infrastructure rollout (LI3A) and competition law (LI1, LI2, LI4). At national level: uneven eFTI transposition (Belgium has not ratified eCMR, Greece has CMDS deviations) and country-specific labour, safety and retail regulations (LI5). At sub-national level: LI3A faces multi-municipality site approval processes and varying public space rules across 14 Barcelona municipalities. When these three levels interact, as in LI2 (port environment, national authority, EU regulation) and LI3A (municipal permits, national labour law, EU infrastructure directives), the compliance burden multiplies. Since harmonisation at European and national levels is largely outside the projects control, pilots must be designed to function within existing regulatory ambiguity while generating evidence that supports future policy alignment.

vi. Behavioural resistance is a systematic operational risk that is structurally underestimated

While interoperability attracts most of the technological attention, habit-based deviation from designed processes is a recurring practical risk with direct operational consequences. In LI3B, cargo-bike drivers adapting to streets and clients rather than confirming events in the orchestration system directly undermines the integrity of smart-contract verification; the technological solution fails because of a behavioural one. In LI5, staff reverting to established packing and loading routines rather than new scanning SOPs reduces EPCIS event log data quality and compromises the traceability value proposition. In LI2, the strong road-transport culture and resistance to shipment merging reflect deeply embedded operational norms that training alone cannot overcome. The implication is that change management must be integrated into pilot execution planning.

vii. Data is simultaneously the most critical enabler and the most contested resource

Every LI core value proposition depends on data being shared: pooled volume data (LI1), eFTI-compliant freight data (LI2), real-time hub and delivery status data (LI3), operational performance data for emission verification (LI4), and EPCIS track-and-trace events (LI5). Yet in every LI, data sharing is constrained by competitive sensitivity, cybersecurity concerns, unclear ownership and liability uncertainties. The tension between data as an input to collective efficiency and data as a private competitive asset is structurally unresolved in the sector. The project data space architecture and neutral trustee mechanisms are direct responses to this tension, but their success will depend on demonstrating, through the pilots, that aggregated and anonymised data sharing can deliver value without exposing commercially sensitive information at actor level.

viii. Barrier profiles differ meaningfully by LI, indicating the need for differentiated intervention strategies

While the above conclusions identify cross-cutting patterns, the relative severity of barrier categories varies significantly by LI. LI2 faces its heaviest burden on the regulatory side due to eFTI implementation complexity and the multi-authority Piraeus port environment. LI3B faces its most distinctive barrier in societal

readiness, specifically the low awareness of the Physical Internet concept among clients and public authorities, which is a communication and legitimacy challenge that technical solutions cannot address. LI4s most specific challenge is the absence of any institutional framework for Book & Claim in freight, making it simultaneously a regulatory and a market design problem. LI5s most operationally immediate barrier is the incomplete governance design for the open pool, which blocks readiness regardless of technical progress. These differences imply that a single cross-LI mitigation strategy will be insufficient; LI-specific workplans that prioritise the dominant barrier category in each context will be more effective.

Strategic implications

The eight conclusions above converge on a single systemic insight: the barriers are not independent, they form a reinforcing system. The trust deficit blocks data sharing; absent data sharing, interoperability investments cannot deliver value; without demonstrated value, ROI uncertainty persists; ROI uncertainty deters participation; and without critical mass, governance models cannot be validated. Breaking into this loop requires sequenced action. Governance frameworks and trust-building mechanisms need to come first, followed by technical integration, then scaled deployment. The cross-cutting analysis shows that **interoperability, trust, ROI uncertainty and regulatory fragmentation all appear across all LI contexts**. These four dimensions constitute the pillars of a horizontal IKIGAI mitigation strategy. The LI-specific barrier profiles then layer on top, informing LI-level work planning and ensuring that interventions are proportionate to the dominant constraint in each context.

7. Phase 4 - Literature Review vs LI Operational Input

T1.1 draws on two analytically complementary evidence streams. The literature review provides structural depth through the systematic analysis of 273 sources and 1,800 barrier observations, revealing recurring constraint patterns across heterogeneous contexts. The LI operational input provides pilot-grounded specificity through structured partner submissions mapping barriers at the level of service, process, and procedure across all LI contexts. Both streams draw on the same four-domain analytical framework, ensuring comparability while preserving methodological distinctiveness..

Four areas of convergence are identified where LI partner inputs independently confirm patterns established through the systematic literature review. These convergences strengthen the structural validity of the barrier families and support their use as the foundational architecture of the Rulebook and Scale Readiness Level framework.

Interoperability and data standards are the primary technological constraint

- Literature: Data interoperability and semantic mismatch is the third largest family at 15.1% of the corpus.
- LI Input: Interoperability is identified as the universal technological prerequisite, present in all 21 procedure rows.

Both analyses independently converge on the same root cause, and both identify open standards and interoperable APIs as the primary enabling response.

Data sharing reluctance is the dominant socio-organisational barrier

- Literature: Data sharing reluctance is the second largest family at 20.1%, strongly Social and Organisational at 69% of its internal composition.

- LI Input: Trust deficit is identified as the foundational societal barrier across all LIs, and ‘Data Governance, Trust and Collaborative Engagement’ is the largest consolidated family at 29.9% in the LI mapping.

Both converge on governance frameworks, neutral intermediaries, and incentive alignment as the principal countermeasures.

Economic barriers are secondary in volume but structurally enabling

- Literature: High upfront costs and investment risk is the fifth largest family at 5.33%, and the Market and Economic domain accounts for only 15.1% of the corpus.
- LI Input: ROI uncertainty creates a structural problem.

Both evidence streams consistently treat economic barriers as smaller in volume but disproportionately important as enabling conditions for attracting participation needed to prove value.

Constraints are inherently multi-domain and single-dimension responses are insufficient

- Literature: Jaccard similarity of 0.849 between Technological and Social domains; all pairs above 0.59; approximately 30% of barriers span multiple domains.
- LI Input: Seven of eight conclusions span two or more barrier categories.

Isolated interventions targeting a single domain are structurally insufficient regardless of their technical quality.

What the LI Input Adds Beyond the Literature

Four findings emerge from the LI partner submissions that are either absent from or underdeveloped in the general literature. These represent the analytical value added by grounding the analysis in actual pilot operations and constitute the most practically significant contributions of T1.1.

Governance must precede and is as important as technical implementation

Literature clusters governance barriers across multiple families but treats them as concurrent with technical ones. LI Input reveals that unresolved clearing rules, liability frameworks, and data governance arrangements block operational readiness regardless of technical completeness. In LI5, the incomplete rule-based clearing mechanism blocks all further progress. In LI4, the absence of an institutional framework for Book & Claim creates a gap that no technical solution can fill. This sequencing insight is not visible in the generic literature.

Regulatory fragmentation operates at three levels simultaneously

Literature captures regulatory fragmentation as a single family at 1.33% of the corpus. LI Input reveals that these operate at European level (eFTI implementation uncertainty), national level (eCMR ratification gaps), and local level (municipal permits across 14 Barcelona municipalities) concurrently. When all three levels interact, the compliance burden compounds in ways that generic literature cannot surface without the contextual granularity of pilot-level observation.

Behavioural resistance is a distinct operational risk, not a subset of implementation complexity

Literature clusters resistance to change within Technical complexity and implementation burden, the largest family at 21.8%. LI Input separates it as a distinct causal mechanism: in LI3B, drivers bypassing event confirmation steps directly undermine smart-contract integrity. In LI5, staff reverting to established routines reduce EPCIS data quality. This specific causal path from habitual behaviour to technical system failure is not visible in the literature.

Trust takes three analytically distinct forms requiring different responses

Literature treats Lack of trust among stakeholders as a single family at 2.1%. LI Input identifies three operationally distinct forms: horizontal trust between competitors required for volume pooling (LI1, LI2), data sensitivity trust around commercial information exposure (LI3B, LI4), and institutional trust in new governance models such as the neutral trustee arrangement (LI5). Each form demands a different intervention, and addressing one does not resolve the others. The cross-analysis of the two evidence streams produces four strategic implications for the design of IKIGAI scaling conditions, the Rulebook, and the Scale Readiness Level framework.

1. The evidence base is robust and internally consistent

Literature (structural, 273 sources) and LI Input (operational, all pilots) identify the same dominant constraint mechanisms through independent methods. This cross-validation strengthens confidence in the barrier families as the correct analytical unit for the Rulebook and Scale Readiness Level framework, and supports their use as the structuring logic for scaling conditions without requiring additional methodological justification.

2. The literature underestimates pilot-specific governance and sequencing needs

The most important analytical additions from LI Input, namely governance sequencing, three-level regulatory compounding, and three-form trust differentiation, all require operational pilot data to observe. Generic literature cannot surface them because they are context-embedded. This confirms that T1.1 methodology must combine both sources, and that the Rulebook must incorporate sequencing logic and contextual differentiation that a purely literature-based analysis would miss.

3. The four universal barriers form the core intervention set

Interoperability, Trust and governance, Implementation capability, and System integration appear across both analyses as the dominant structural constraints. Together they account for the large majority of the LI Input corpus. Any scaling condition framework that does not address all four will be structurally incomplete, and any intervention targeting only one of these families without considering the others is unlikely to generate sustained scaling effects.

4. Differentiated LI-level strategies are required alongside cross-cutting measures

The literature provides a common structural baseline applicable across all LIs. LI Input reveals that dominant barrier categories differ significantly by LI context: LI2 is regulation-heavy due to the eFTI environment; LI3B faces distinctive societal readiness constraints related to Physical Internet concept awareness; LI4 lacks an institutional framework for Book & Claim that technical solutions cannot substitute; and LI5 needs governance design resolved before any other enabling condition can take effect. Horizontal scaling strategies must therefore be supplemented by LI-specific sequenced intervention plans that prioritise the dominant constraint in each pilot context.

8. Innovation Agenda and Scaling Factors

8.1 FROM BARRIER ANALYSIS TO SCALING LOGIC

Task 1.2 builds directly on the results of Task 1.1 and translates the barrier analysis into a structured methodological logic for the scale-up of the Logistics Innovations (LIs) addressed in IKIGAI. While Task 1.1 was primarily concerned with identifying the main obstacles and enablers affecting LI deployment, Task 1.2 shifts the focus from diagnosis to progression. In other words, barriers are no longer treated only as constraints to be listed and discussed, but as signals of those conditions that still need to be strengthened, formalised, or aligned in order to support broader and more stable deployment pathways.

This change of perspective is important. Within the logic adopted in Task 1.2, scale-up is not understood simply as growth in volume or geographical extension. Rather, it is interpreted as a transition towards logistics solutions that become progressively more standardised, more interoperable, more replicable, and better aligned with the transformation pathways outlined by the Zero Emission Logistics (ZEL) and Physical Internet (PI) roadmaps. This means that the methodological focus moves from the question “which barriers are present?” to the question “what still needs to change for the LI to move towards a more scalable configuration?”.

The barrier analysis carried out in Task 1.1 showed that the most relevant constraints to LI scale-up do not appear as isolated and purely case-specific issues. On the contrary, they tend to recur across different innovation settings and to cluster around a limited number of structural domains. These domains concern technological readiness and interoperability, economic and market viability, regulatory and governance alignment, organisational and behavioural conditions, and operational arrangements. In practice, these barriers reinforce one another and often generate recurrent bottlenecks that slow down or prevent the transition from promising pilot solutions to wider deployment.

Task 1.2 addresses this challenge by introducing a common methodological framework that allows these recurrent barriers to be translated into a structured assessment of scale-up needs. The underlying purpose is twofold. First, the methodology provides a common logic to assess the current and target condition of each LI in a comparable way. Second, it creates the basis for identifying scaling mechanisms that can progressively evolve into a reusable mechanism library supporting future implementation and rulebook development.

8.2 DEFINITION OF THE SCALING DIMENSIONS

To support the application of Task 1.2 across the Logistics Innovations, a spreadsheet-based assessment tool was developed to guide the analysis in a structured and comparable way. This choice was made in order to move from a broad qualitative diagnosis to a more operational and measurable assessment framework. Within this tool, the first methodological step consisted in translating the barrier domains identified in Task 1.1 into a set of scaling dimensions. Five dimensions derive directly from the main barrier domains emerging from Task 1.1:

- technological conditions,
- economic and market viability,
- regulatory and governance alignment,
- societal and organisational conditions,
- operational conditions.

To this set, a sixth dimension related to **sustainability and circularity** was added. The inclusion of this additional dimension ensures consistency with the broader transition logic of IKIGAI, which does not treat scale-up as a purely technical or organisational issue, but as part of a wider transformation towards zero-emission, collaborative, and more resource-efficient logistics systems.

The resulting framework is therefore based on the following six dimensions:

- Operational
- Technological
- Regulatory, policy and governance
- Market and economic
- Societal and organisational
- Sustainability and circularity

Each dimension is expressed through four ordered **maturity levels**, ranging from an early-stage or fragmented condition to a more advanced and scalable configuration. In order to support later assessment steps, each maturity level is associated with a numerical score from **1 to 4**, where **1** indicates the lowest maturity level and **4** the highest. This scoring logic is necessary to make it possible to compare the current condition of each LI with its target condition and to calculate the corresponding gap in a structured and transparent way.

The maturity structure adopted for each dimension is summarised below.

Table 10. Scaling dimensions and relative maturity levels

Scaling dimension	Level 1	Level 2	Level 3	Level 4
Operational	Isolated	Local/Regional	Network-integrated	Scaled & optimised
Technological	Proprietary	Interoperable (basic)	Compliant & interoperable (advanced)	Intelligent & automated
Regulatory, policy and governance	Unclear / informal	Pilot-based	EU-aligned	Standardised & scalable
Market and economic	No / weak demand	Emerging	Stable growth	Mature / expansive
Societal and organisational	Siloed	Engaged	Coordinated	Institutionalised
Sustainability and circularity	Initial	Developing	Advanced	Systemic

8.3 DEFINITION OF THE TO-BE PROFILE AND TARGET SCENARIO

Once the scaling dimensions and their maturity levels had been defined, LIs has to identify a target scenario. For each dimension, the LI selects the maturity state it aims to reach. The selected levels should define a credible and achievable target condition, not an idealised or utopian end state. The resulting combination of selected maturity states identifies the TO-BE profile of the innovation. This TO-BE profile is interpreted through five target scenarios:

- **Baseline.** The innovation remains confined to pilots or to a limited corridor. Integration is partial. Adoption is slow and uneven. Sustainability actions exist, but they are not yet embedded end-to-end.
- **Collaborative.** Scale-up is driven mainly by coordination among shippers, logistics service providers, SMEs, and other partners. Shared workflows and trust mechanisms support broader participation and reduce fragmentation.
- **Accelerated.** Adoption increases because interoperability and compliance readiness reduce barriers to scale. Digital processes become repeatable across contexts. Sustainability moves closer to standard practice.
- **Disruptive.** Rapid change is driven by advanced digital capabilities and strong optimisation logic. The innovation can scale quickly, but uptake may remain uneven across actors or territories.
- **Transformative.** The innovation becomes part of a fully integrated ecosystem. Operations, governance, data sharing and sustainability work together end-to-end. Replication at scale becomes feasible.

A key point is that these scenarios are **not selected manually**. Instead, the excel spreadsheet derives the resulting target scenario through a set of **scenario rules**. This gives the target-setting process a higher degree of internal coherence, because the scenario is not chosen independently from the maturity profile but emerges from it. The rules interpret the TO-BE profile by combining three elements:

- the score reached in specific key dimensions;

- the average score across the six dimensions;
- the number of dimensions that reach at least maturity level 3.

This rule-based logic allows the target scenario to act as a structured interpretation of the maturity profile rather than as an isolated qualitative declaration.

Table 11. Scenario rules

Scenario rules						
ScenarioID	Metric	Operator	Value1	Value2	Comment	Hint
TRANS	Sustainability and circularity	=	4		Transformative requires systemic sustainability (Systemic level)	Set Sustainability = 4
TRANS	Count(>=3)	>=	5		Transformative requires broad maturity: at least 5 dimensions scored ≥3	Reach COUNT(>=3) ≥ 5
TRANS	Average	>=	3,2		Transformative requires high overall maturity (average score threshold)	Raise Average ≥ 3.2
DISR	Technological	=	4		Disruptive requires cutting-edge technology (level 4)	Set Technological = 4
DISR	Regulatory, policy and governance	=	4		Disruptive requires standardised & scalable governance/compliance (level 4)	Set Regulatory, policy and governance = 4
DISR	Average	>=	3		Disruptive also requires overall maturity above a minimum threshold	Raise Average ≥ 3.0
ACC	Technological	>=	3		Accelerated requires advanced interoperability/compliance-ready tech (≥3)	Raise Technological ≥ 3
ACC	Sustainability and circularity	>=	3		Accelerated requires advanced sustainability readiness (≥3)	Raise Sustainability ≥ 3
ACC	Operational	>=	3		Accelerated implies network-level operations (not local pilots)	Raise Operational ≥ 3
ACC	Average	BETWEEN	2,7	3,4	Accelerated fits mid-high maturity (keeps it below fully transformative levels)	Adjust Average to 2.7-3.4
COLL	Societal and organisational	>=	3		Collaborative requires coordinated organisational adoption (≥3)	Raise Societal and organisational ≥ 3
COLL	Market and economic	>=	3		Collaborative assumes stable growth / repeatable demand (≥3)	Raise Market and economic ≥ 3
COLL	Average	BETWEEN	2,2	3	Collaborative fits low-mid maturity (above baseline, below accelerated)	Adjust Average to 2.2-3.0
BASE	Average	<=	2,2		Baseline corresponds to early-stage/limited maturity overall	Keep Average ≤ 2.2

In practical terms, each scenario is associated with explicit conditions.

The **Transformative** scenario requires the highest degree of systemic maturity. In the current logic, this means that:

- sustainability and circularity must reach level 4,
- at least five dimensions must score 3 or more
- the average score must be at least 3.2.

The **Disruptive** scenario is associated with strong technological and governance maturity and therefore requires:

- Technological = 4
- Regulatory, policy and governance = 4
- an average score of at least 3.0.

The **Accelerated** scenario reflects a more advanced but still intermediate transition profile and therefore requires:

- Technological ≥ 3
- Sustainability and circularity ≥ 3
- Operational ≥ 3
- and an average score between 2.7 and 3.4.

The **Collaborative** scenario is associated with stronger actor alignment and market stabilisation and therefore requires:

- Societal and organisational ≥ 3
- Market and economic ≥ 3
- an average score between 2.2 and 3.0.

The **Baseline** scenario corresponds to an overall early-stage condition and is associated with an average score of 2.2 or below.

In this way, the scenario rules combine dimension-specific requirements with an overall maturity interpretation.

Resulting Scenario:	Comment:
Accelerated	Adoption increases because interoperability and compliance readiness reduce barriers to scale. Digital processes become repeatable across contexts, and sustainability moves from “initiative” to standard practice. The innovation expands through structured rollout supported by a favourable regulatory environment.

Figure 5. Example of resulting scenario

The methodology also introduces an explicit **priority order** among scenarios. This is necessary because, in some cases, the selected maturity profile may satisfy the rule set of more than one scenario. In order to avoid ambiguity, each scenario is assigned a rank from **1 to 5**, where **1** is the highest priority and **5** the lowest. The order is: **Transformative (1)**, **Disruptive (2)**, **Accelerated (3)**, **Collaborative (4)**, and **Baseline (5)**. If more than one scenario satisfies all its rules, the tool assigns the one with the highest priority. This makes the resulting target scenario more robust and prevents the LI from being associated with multiple scenario labels at the same time.

In addition to this, the tool also includes a **near-match mechanism**. This is used when the TO-BE profile does not fully satisfy the complete rule set of any scenario. Rather than returning no result, the tool identifies the scenario with the **lowest number of unsatisfied rules** and treats it as the closest configuration. If more than one scenario has the same number of missing conditions, the same priority logic is applied and the higher-ranked scenario is retained. The tool then returns a **near-match output** together with a short hint indicating which condition is still missing. This is particularly useful because it helps refine the TO-BE profile and highlights where the selected target condition remains inconsistent or incomplete. In methodological terms, the near-match logic prevents the target-setting exercise from becoming rigid while still preserving analytical discipline.

Result	Resulting Scenario:
• If at least one scenario is fully satisfied, it returns the satisfied scenario with the highest priority (lowest Priority number) • If no scenario is fully satisfied, it returns: Near match (PreviousScenario -> BestScenario): plus the missing hints for the best scenario (the one with the lowest MissingCount)	Near match (Accelerated -> Disruptive): Set Regulatory, policy and governance = 4

Figure 6. Example of near-match result for scenario

Overall, the TO-BE scenario is therefore more than a descriptive category. It is the outcome of a structured interpretation of the target maturity profile and provides the methodological reference point for all subsequent stages of the assessment. By combining maturity levels, scenario rules, scenario priority, and near-match logic, this step ensures that the target condition of each LI is both analytically consistent and operationally meaningful.

8.4 ASSESSMENT OF THE CURRENT CONDITION

After defining the target condition, the methodology assesses the **current condition** of each LI. This step produces the **AS-IS profile** of the innovation and is based on two complementary elements: **relevance weighting** and **Current State scoring**.

First, each LI assigns a relevance level to each scaling dimension. The available levels are

- **Low (1)**
- **Medium (2)**
- **High (3)**

Relevance does not describe the maturity of the LI. Instead, it indicates how important each dimension is for the scale-up path of that specific innovation. This is a crucial aspect of the methodology, because the same gap may have a very different meaning depending on the LI. For instance, a technological weakness may be central in one case and secondary in another, while a governance issue may be decisive for a collaborative service but less critical in a more self-contained solution.

Second, each LI identifies its **Current State** through a **checklist-based assessment**. In order to support this step, a dedicated checklist of questions was prepared for each LI. These checklists represent the part of the methodology that allows the assessment to remain sensitive to the specific characteristics of each innovation. Rather than relying on a fully generic questionnaire, the method uses LI-specific questions that reflect the actual service logic, operational model, and implementation context of the case under analysis.

At the same time, these checklists are not independent from the common methodological structure. For each dimension, the questions are organised around the same maturity states used in the TO-BE analysis. This ensures internal consistency between target definition and current-state assessment. In practice, the LI uses the checklist to understand which maturity level best reflects its present condition and then selects the corresponding **Current State**. In this way, the assessment remains comparable across cases while still being tailored to the specific nature of each innovation.

This combination of a common maturity structure and LI-specific checklists is one of the main strengths of the tool. It allows the methodology to avoid a purely generic reading of scale-up conditions and introduces a degree of contextual adaptation that is necessary when dealing with heterogeneous innovations. The same logic can also be extended to future LIs beyond the current IKIGAI cases. If a new LI wishes to test the tool, an ad hoc checklist can be prepared following the same methodological structure, thereby preserving comparability while adapting the assessment to the characteristics of the new case.

At the end of this step, each LI has:

- one selected **Current State** for each scaling dimension;
- one **relevance level** for each dimension.

Table 12. Example of AS-IS methodology for LI1

Scaling Dimensions	STEP 2 - DEFINITION OF AS-IS				
	Relevance for LI	Relevance	Checklist	Current State	AS-IS
Operational	High	3	Isolated - Is the service currently limited to a single pilot flow or a single corridor setup with minimal replication? - Are onboarding and booking handled mainly case-by-case (e.g., via emails/calls) rather than through a standard process? - Is coordination between shippers, MTOs and LSPs mostly bilateral, without a shared operational cycle? Local/Regional - Are there repeatable procedures for onboarding and booking, but only with a small set of partners or within one corridor context? - Is the corridor service stable for a limited number of flows/volumes, but difficult to extend to additional terminals/legs? - Are exceptions (delays, capacity changes) managed with partial standardisation but still heavy manual effort? Network-integrated - Are LI1 processes (onboarding, booking, data sharing, procurement/tendering) standardised and used across multiple partners in the corridor? - Is volume pooling coordinated through a shared operating model (trustee roles + agreed interfaces between shippers, MTOs and LSPs)? - Can new shippers/LSPs be onboarded using a defined procedure with predictable steps and responsibilities?	Isolated	1

Together, these two outputs provide the baseline needed for the following step, namely the gap analysis.

8.5 GAP ANALYSIS AND PRIORITISATION

Once the **TO-BE** and **Current State** profiles have been defined, the methodology compares the two in order to identify the distance that still separates the LI from its target condition. For each scaling dimension, the gap is calculated as the difference between the target score and the current score. If the Current State is already equal to or higher than the TO-BE value, the gap is treated as zero. This means that only the maturity distance that still needs to be closed is carried forward into the analysis.

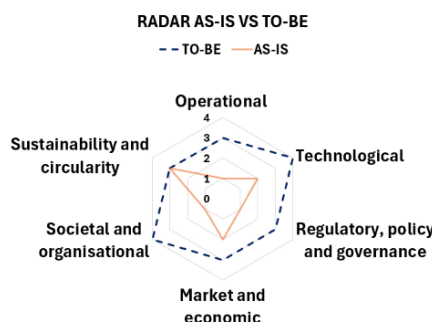


Figure 7. Radar representation of GAP Analysis

This first result is then combined with the **relevance level** assigned to the same dimension in the previous step. In practice, the raw gap is weighted according to the strategic importance of that dimension for the specific LI. The result is the **weighted gap**. This value is central to the methodology because it does not only show where a distance exists, but also how significant that distance is for the scale-up path of the innovation. A gap in a highly relevant dimension therefore has greater analytical importance than the same gap in a dimension considered less critical for that LI.

The weighted gap is then translated into a more readable diagnostic output through a prioritisation logic embedded in the tool. This logic associates each weighted gap with three elements: a **priority label**, a **rank position**, and a short **interpretative comment**. The priority label indicates whether the dimension is already aligned with the target or whether it requires attention at a low, medium, or high level of urgency. The

comment provides a short textual interpretation of this result. The rank introduces a further step by ordering the dimensions according to their relative priority.

Table 13. Example of ranked GAP Analysis

Dimension	Weight	TO BE	AS IS	WEIGHTED GAP	Priority label	RANK	Comment
Operational	3	3	1	6	High priority	2	Not aligned - Gap is 2 - High priority (2)
Technological	1	4	2	2	Low priority	4	Not aligned - Gap is 2 - Low priority (4)
Regulatory, policy and governance	3	3	1	6	High priority	2	Not aligned - Gap is 2 - High priority (2)
Market and economic	2	3	2	2	Low priority	4	Not aligned - Gap is 1 - Low priority (4)
Societal and organisational	3	4	1	9	High priority	1	Not aligned - Gap is 3 - High priority (1)
Sustainability and circularity	3	3	3	0	Aligned		Aligned

The **rank system** is particularly important because it turns the gap analysis into a decision-support structure. Rather than producing a flat list of values, the tool orders the dimensions from the most critical to the least critical on the basis of their weighted gap. In this ordered structure, **rank 1** corresponds to the dimension with the highest priority for intervention, while the following ranks indicate progressively lower levels of urgency. In other words, the rank does not simply describe whether a gap exists; it shows **where action should start first**. Dimensions that are already aligned with the target are not treated as priorities and therefore do not drive the ranking logic in the same way as non-aligned dimensions.

This ranking mechanism is useful because it helps distinguish between two different situations that would otherwise appear similar. A LI may have more than one open gap, but not all of them have the same strategic importance. By combining maturity distance and relevance, the methodology identifies which dimensions are most likely to constrain scale-up and which ones can be treated as secondary or already sufficiently mature. The outcome is therefore not just a gap profile, but a **prioritised view of intervention needs**.

	STEP 1 - DEFINITION OF TARGET SCENARIO (TO BE)	STEP 2 - DEFINITION OF AS-IS			STEP 3 - GAP ANALYSIS
Scaling Dimensions	Prospect State (To Be)	Relevance for LI	Checklist	Current State (AS-IS)	Ranked gap
Operational	Network-integrated	High	- Isolated - Is last-mile delivery still executed mainly as separate, mode-specific operations (road, river, bike), without synchronised handovers between modes? - Are cargo (un)loading, sorting, delivery and returns still managed with separate tools/systems, with no shared digital layer to coordinate operations end-to-end? - Are smart contracts not yet deployed to govern hub-network?	Local/Regional	Not aligned - Gap is 1 - Medium priority (2)
Technological	Compliant & interoperable (advanced)	High	- Proprietary - Are the different mode operators (road, river, cargo bikes) still using separate tools/systems, with no shared digital layer to coordinate operations end-to-end? - Are smart contracts not yet deployed to govern hub-network?	Interoperable (basic)	Not aligned - Gap is 1 - Medium priority (2)
Regulatory, policy and governance	EU-aligned	High	- Unclear / informal - Are collaboration rules between the involved operators (road, river, cargo bikes, hub actors) still informal, with responsibilities decided case-by-case? - Is there no agreed governance mechanism to manage handovers?	Unclear / informal	Not aligned - Gap is 2 - High priority (1)
Market and economic	Emerging	Medium	- No/weak demand - Is there currently no clear demand from shippers/receivers for synchronised zero-emission last-mile delivery via mobile hubs (river/road) compared to conventional van-based delivery? - Are there no committed commercial stakeholders providing regular service?	No/weak demand	Not aligned - Gap is 1 - Low priority (6)
Societal and organisational	Coordinated	High	- Siloed - Do stakeholders still operate mainly within their own organisational boundaries (road, river, bike), with limited cross-actor coordination for daily operations? - Are loading/unloading, sorting, delivery and returns handled separately?	Engaged	Not aligned - Gap is 1 - Medium priority (2)
Sustainability and circularity	Advanced	High	- Initial - Is the operation not yet delivering measurable reductions in travelled-km, energy demand, or CO₂ emissions compared to conventional delivery methods? - Are zero-emission modes (e-vans, cargo bikes, electric barges) not yet available?	Developing	Not aligned - Gap is 1 - Medium priority (2)

Figure 8. GAP Analysis for LI3

The gap analysis represents the point at which the methodology moves from descriptive assessment to structured diagnosis. Up to this stage, the tool defines the target condition and the current condition of the LI. With the weighted gap and ranking logic, it becomes possible to identify the most critical transition bottlenecks in a clear and ordered way. This prioritised output then provides the analytical basis for the following step, namely the translation of recurrent gap patterns into candidate scaling mechanisms.

8.6 FROM PRIORITISED GAPS TO SCALING MECHANISMS

The final step of the methodology consists in translating the prioritised gap profile into **candidate scaling mechanisms**. In this context, a scaling mechanism is not understood as a generic enabling factor, such as “more interoperability” or “better governance”, but as a **structured and replicable transition package** that can support one concrete step towards a more scalable and PI-aligned logistics configuration. In practical terms, a mechanism may combine process rules, coordination arrangements, governance provisions, digital supports, or standard operational artefacts, depending on the type of structural issue that emerges from the assessment.

A key point of the methodology is that it does **not** assign one mechanism to each individual gap. Such an approach would produce a fragmented output and would make cross-case interpretation difficult. Instead, the most relevant gaps are read together and interpreted as a **gap pattern**. When several dimensions point to the same underlying limitation, they are treated as part of a common transition problem. In this way, the mechanism does not emerge from a single score taken in isolation, but from the **combination, weighting and interpretation** of the most relevant gaps across dimensions.

This translation logic is also consistent with the broader conceptual approach developed in Task 1.2. The barriers identified in Task 1.1 are not treated as isolated obstacles to be solved one by one, but as interconnected signals of those organisational, operational, and technical conditions that still need to be strengthened, formalised, or standardised. The same logic applies here: the role of the mechanism is not to “fix” an isolated gap, but to respond to a recurring structural pattern that constrains progression from pilot application towards a more repeatable and transferable configuration.

The proposed mechanisms remain anchored to the **PI Norm core**. In particular, they are primarily associated with one of three main transition areas: **process standardisation, interoperable information and documentation flows and governance and compliance**. Other dimensions, such as market conditions, organisational readiness, or sustainability performance, remain highly relevant, but they are interpreted as factors that influence the urgency, feasibility, and applicability of a mechanism rather than as fully separate mechanism families.

At this stage of the work, the translation from prioritised gaps to scaling mechanisms has been structured through a **first draft mechanism table**. The purpose of this table is not to provide a final and closed taxonomy, but to establish an initial and consistent translation logic linking recurrent gap patterns to candidate mechanisms. It should therefore be understood as an evolving analytical component, which will need to be refined, adjusted, and expanded as the methodology is progressively applied to the different LIs and discussed with the pilot actors. In this sense, the current version of the table is intended to indicate the direction of the mechanism logic and to provide an initial basis for comparable interpretation across cases. Table 11 summarises this first draft translation logic.

Table 14. Example of Gap patterns and candidate scaling mechanisms

Prioritised gap pattern	Main issue identified	Candidate scaling mechanism	Primary PI Norm anchor
Operational + Regulatory, policy and governance	The service works in a pilot setting but is not yet formalised as a repeatable operating model	Standard operating model package	Process standardisation
Technological + Regulatory, policy and governance	Data exchange exists, but it is not yet robust enough for scalable and compliant deployment	Interoperable data-sharing and compliance package	Interoperable flows

Operational + Technological + Regulatory, policy and governance	The innovation lacks an integrated structure combining repeatable processes, interoperable flows and formal coordination	Integrated scaling package	Governance and compliance
Market and economic + Societal and organisational	The innovation is technically viable, but adoption remains weak and actor participation is not yet stabilised	Onboarding and adoption package	Governance and compliance
Sustainability and circularity + Operational	Sustainability goals are present, but they are not yet embedded in routine service execution	Sustainability integration package	Process standardisation

Taken together, this step allows the methodology to move from diagnosis to a first action-oriented interpretation. The weighted gap profile identifies where the most relevant scale-up constraints are located; the mechanism logic interprets those constraints as recurrent patterns and links them to a limited set of candidate transition packages. In this way, the assessment does not stop at the identification of what is missing, but begins to indicate which types of structured intervention may be needed to support the next stage of LI progression.

9. Cross-cutting insights

9.1 GUIDELINES FOR SCALING LIs

The analysis carried out in T1.1 and T1.2 indicates that the scaling of Logistics Innovations should be approached as a structured transition from pilot application to repeatable, interoperable and PI-aligned deployment, rather than as a simple expansion in size or geographical reach. In practical terms, this requires each LI to define a credible target condition, assess its current maturity in a structured way, and then prioritise the gaps that most constrain replication and broader uptake. Across the different LI contexts, the most robust scaling pathways are those that combine three mutually reinforcing elements: standardised operational processes, interoperable and compliance-ready information flows, and governance arrangements that clearly define roles, responsibilities and access conditions. This shows that isolated technical improvements are rarely sufficient on their own. Innovations scale more effectively when they are translated into integrated transition packages that reduce dependence on local exceptions, informal coordination and pilot-specific workarounds. On this basis, the Rulebook suggests a common direction of development for all LIs: from ad hoc implementation to repeatable service models, from fragmented data exchange to structured interoperability and from temporary pilot coordination to auditable and reusable governance mechanisms consistent with the PI Norm.

This work is conducted in combination with Tasks 1.3 and 3.1 where clear guidelines and priorities for scaling up LIs will be provided. The results will be included in D1.2 and D3.1.

9.2 INTERDEPENDENCIES BETWEEN BARRIERS AND ENABLERS

The barrier and enabler analysis undertaken in T1.1 demonstrates that constraints and enabling conditions in logistics scaling form a reinforcing system, where each dimension conditions the effectiveness of the others. Approximately 30% of the 1,800 literature-derived barrier observations span two or more analytical domains, and Jaccard similarity between the technological and social domains reaches 0.849, confirming that technological fragmentation, organisational misalignment, regulatory ambiguity and economic uncertainty rarely operate in isolation. The corresponding scaling-enabling factors exhibit the same multi-dimensional structure: interoperability standards deliver limited value without data governance frameworks that resolve ownership and liability; data governance frameworks in turn depend on trust-building mechanisms and neutral intermediaries to secure voluntary participation; trust mechanisms become credible only when supported by economic de-risking instruments that make first-mover participation viable; and economic incentives achieve scale only where regulatory clarity removes compliance ambiguity.

This chain logic is reinforced by the pilot-level evidence, which shows that the trust deficit blocks data sharing, absent data sharing prevents interoperability investments from delivering value, unrealised value sustains ROI uncertainty, ROI uncertainty deters participation, and insufficient participation prevents governance models from being validated at scale. The operational implication is sequencing: interventions targeting a single barrier family, however technically sound, are structurally insufficient, and effective scaling requires the simultaneous mobilisation of governance, technical, economic and regulatory levers in a coordinated configuration rather than through parallel but disconnected workstreams.

9.3 ALIGNMENT WITH ZEL/PI ROADMAPS

The scaling logic developed in this Rulebook can also be read against the two broader transition frameworks that shape the project context. The Physical Internet roadmap provides a structured view of how logistics systems are expected to evolve towards more open, standardised, interoperable and shared configurations across five areas of development.

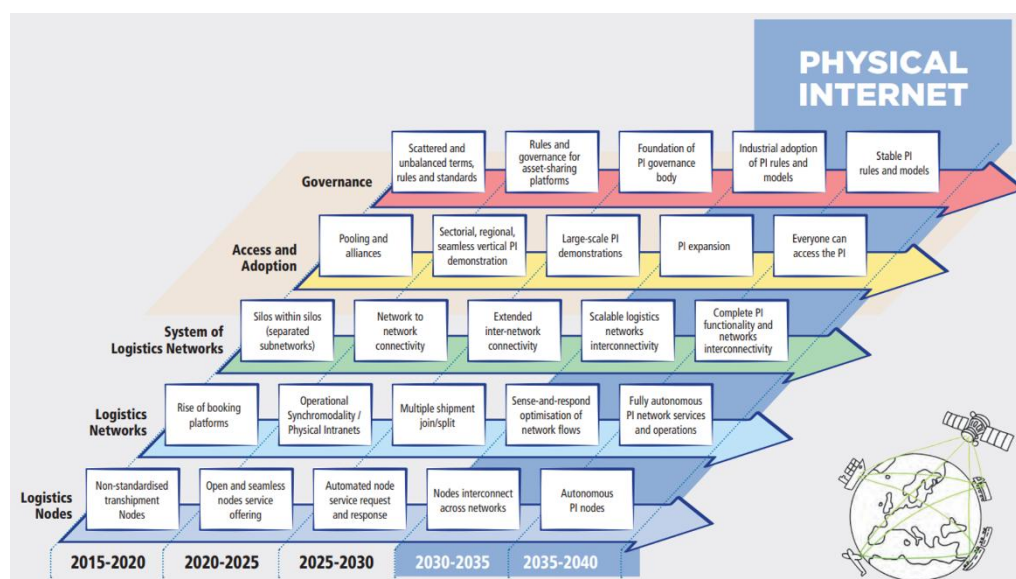


Figure 9. PI Roadmap

The Zero Emissions Logistics roadmap complements this perspective by identifying the main solution areas through which freight transport and logistics can reduce emissions over time. Read together, the two roadmaps provide the wider reference frame within which the five IKIGAI Logistics Innovations can be positioned: the PI roadmap clarifies the systemic direction of logistics transformation, while the ZEL roadmap clarifies the main decarbonisation levers that this transformation is expected to activate. In this sense, the roadmap alignment presented here is not an additional classification exercise, but a way to show how the scale-up pathways identified in T1.1 and T1.2 connect operational standardisation, interoperability and governance with the broader transition towards zero-emission and PI-compliant logistics.

The positioning exercise carried out through the dedicated PI and ZEL roadmap spreadsheets shows that the five IKIGAI Logistics Innovations should be read as complementary transition pathways rather than as isolated pilot solutions.

PI Mapping

In the PI mapping, the portfolio is concentrated mainly in Generation 2, which is consistent with the project ambition of moving the LIs from early demonstration towards more structured, interoperable and scalable configurations during the project lifetime. At the same time, the mapping highlights differentiated roles across the five PI areas of development. LI1 is positioned across all five areas, reflecting its cross-cutting relevance for nodes, networks, access and governance. LI2 is mainly located in Logistics Networks, System of Logistics Networks, Access and Adoption, and Governance. LI3 is centred on Logistics Nodes and Logistics Networks, with a strong urban and multimodal orientation. LI4 is positioned mainly in System of

Logistics Networks, Access and Adoption, and Governance, confirming its role as a traceability and trust-enabling layer rather than as a stand-alone operational network solution. LI5 spans all PI areas and is the one that already reaches Generation 3 in Logistics Networks, which makes it particularly relevant as an early case of more advanced operational standardisation and pooling logic. The overall picture confirms that the IKIGAI portfolio does not follow a single PI pathway, but combines several entry points across nodes, networks, adoption and governance in a coherent scale-up trajectory.

Table 15. Current Areas of Development for Lis

		Areas of development				
		Logistics Nodes	Logistics Networks	System of Logistics networks	Access & Adoption	Governance
Logistic Innovations	LI1 Trustee matchmaking and volume pooling	GEN 2	GEN 2	GEN 2	GEN 2	GEN 2
	LI2 efti collaborative service platform		GEN 2	GEN 2	GEN 2	GEN 2
	LI3 Smart Urban Logistics Hubs	GEN 2	GEN 2		GEN 2	
	LI4 Digital chain of custody & Book & Claim			GEN 2	GEN 2	GEN 2
	LI5 GS1 SMART-Box & open pooling governance	GEN 2	GEN 3	GEN 2	GEN 2	GEN 2

ZEL Mapping

The ZEL mapping confirms that this PI trajectory is coupled with a diversified decarbonisation logic. LI1, LI2 and LI5 are primarily associated with Solution Area 3, which focuses on improving the utilisation and sharing of fleets and assets through load optimisation, consolidation, pooling and more open transport and warehousing arrangements. LI3 is primarily positioned in Solution Area 2, highlighting its contribution to modal shift, multimodal optimisation and synchromodality in urban logistics. LI4 is primarily aligned with Solution Area 5, where its contribution is not direct emission reduction in itself but the creation of a credible information and accounting layer for allocating and reporting lower-emission energy choices across the chain. Secondary alignments show further links with Solution Areas 1 and 4, especially where the LIs support operational efficiency, the performance of logistics centres and fleets, and selected demand-management effects.

LI	Area role	Area name	Solutions	GHG positioning
LI1 Trustee matchmaking and volume pooling	Main	3. Fleets and assets are shared and used to the max	3.1 Load optimisation (E)	Medium-high impact on GHG in the medium-term
			3.2 Load consolidation and asset sharing (E)	
			3.4 Back-hauling (D)	
			3.5 Open warehouses and transport networks (B)	
	Secondary	2. Transport modes are smartly used and combined	2.1 Increased use of rail, waterborne and low-emission modes (D)	
			2.2 Multi-modal optimisation (E)	
			2.3 Synchromodality (B)	
LI2 eFTI collaborative service platform	Main	3. Fleets and assets are shared and used to the max	3.1 Load optimisation (E)	Medium-high impact on GHG in the medium-term
			3.2 Load consolidation and asset sharing (E)	
			3.4 Back-hauling (D)	
	Secondary	2. Transport modes are smartly used and combined	2.1 Increased use of rail, waterborne and low-emission modes (D)	
			2.2 Multi-modal optimisation (E)	
			2.3 Synchromodality (B)	
		4. Fleets and assets are energy efficient	4.1 Cleaner and efficient technologies (G)	
			4.4 Fleet operation (G, H)	
			4.5 Telematics / TMS (D)	
LI3 Smart Urban Logistics Hubs	Main	2. Transport modes are smartly used and combined	2.1 Increased use of rail, waterborne and low-emission modes (D)	Medium-high impact on GHG in a medium-term
			2.2 Multi-modal optimisation (E)	
			2.3 Synchromodality (B)	
	Secondary	3. Fleets and assets are shared and used to the max	3.1. Load optimisation (E)	
			3.2. Load consolidation and asset sharing (E)	
			3.4. Back-hauling (D)	
		4. Fleets and assets are energy efficient	3.5. Open warehouses and transport networks (B)	
			4.4. Fleet operation (G/H)	
			4.5. Telematics / Transport Management Systems (D)	
LI4 Digital chain of custody & Book & Claim	Main	5. Fleets and assets use the lowest energy source feasible	5.2. CNG/LNG (G)	LI 4 is an enabler, not particularly relevant
			5.3. Biofuels (H)	
			5.4. Hydrogen (C)	
			5.5. Electric / hybrids (A/E)	
			5.6. Logistics centres and warehouses (G)	
LI5 GS1 SMART-Box & open pooling governance	Main	3. Fleets and assets are shared and used to the max	3.1. Load optimisation (E)	Medium impact on GHG in a medium-term
			3.2. Load consolidation and asset sharing (E)	
			3.3. Modular packaging and boxes (E)	
			3.5. Open warehouses and transport networks (B)	
	Secondary	1. Freight transport demand growth is managed	1.5. Dematerialisation (F)	
		4. Fleets and assets are energy efficient	4.6. Logistics centres and warehouses (G)	

Figure 10. ZEL Analysis for LIs

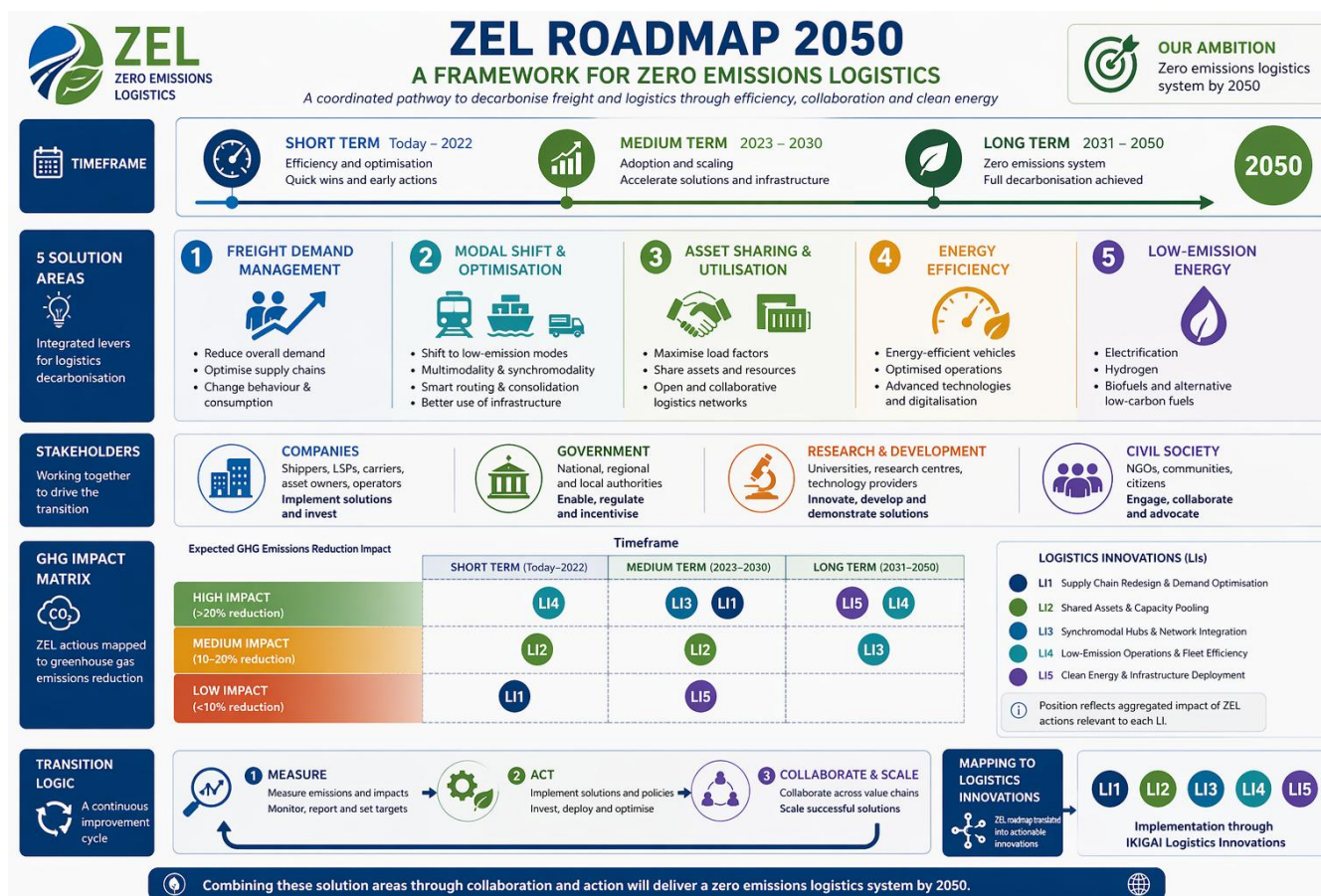


Figure 11. ZEL Roadmap 2050

Read together, the two mappings confirm the core logic of the Rulebook: the IKIGAI portfolio connects PI development steps with ZEL decarbonisation measures through three common levers, namely standardised processes, interoperable documentation flows and governance and compliance mechanisms.

10. Conclusions, recommendations, next steps

10.1 ROADMAP FOR IMPLEMENTATION (SHORT, MEDIUM, LONG-TERM)

The implementation roadmap emerging from T1.1 and T1.2 should be understood as a staged transition logic rather than as a closed action plan completed within WP1. In the short term, the priority is to consolidate the analytical outputs developed in this Rulebook, including the identification of scaling conditions, the structured assessment of current maturity, the prioritisation of gaps, and the initial definition of candidate scaling mechanisms, so that each Logistics Innovation can enter the next phase of the project with a clearer understanding of its main dependencies and transition needs. In the medium term, these outputs are expected to be operationalised through WP3, and in particular through Task 3.1, where they will support pilot planning, pre-audit activities, gap assessment and the first application of the PI-Norm-oriented readiness logic in the demonstration contexts. In the longer term, the objective is not simply to confirm the analytical findings produced in WP1, but to refine and update them through pilot evidence, audit results and impact-at-scale activities, so that gap profiles, implementation priorities and candidate scaling mechanisms can progressively evolve into a stronger basis for replication, standardisation and wider deployment. For this reason, the present deliverable should be read as the first structured layer of the implementation roadmap, while further developments related to scaling mechanisms, gap analysis, readiness and associated assessment elements will be discussed in the subsequent WP3 deliverables, especially those linked to Task 3.1.

IKIGAI ROADMAP FOR IMPLEMENTATION

From analytical foundation (WP1) to pilot execution, gap assessment and scale-up (WP3 – Task 3.1)

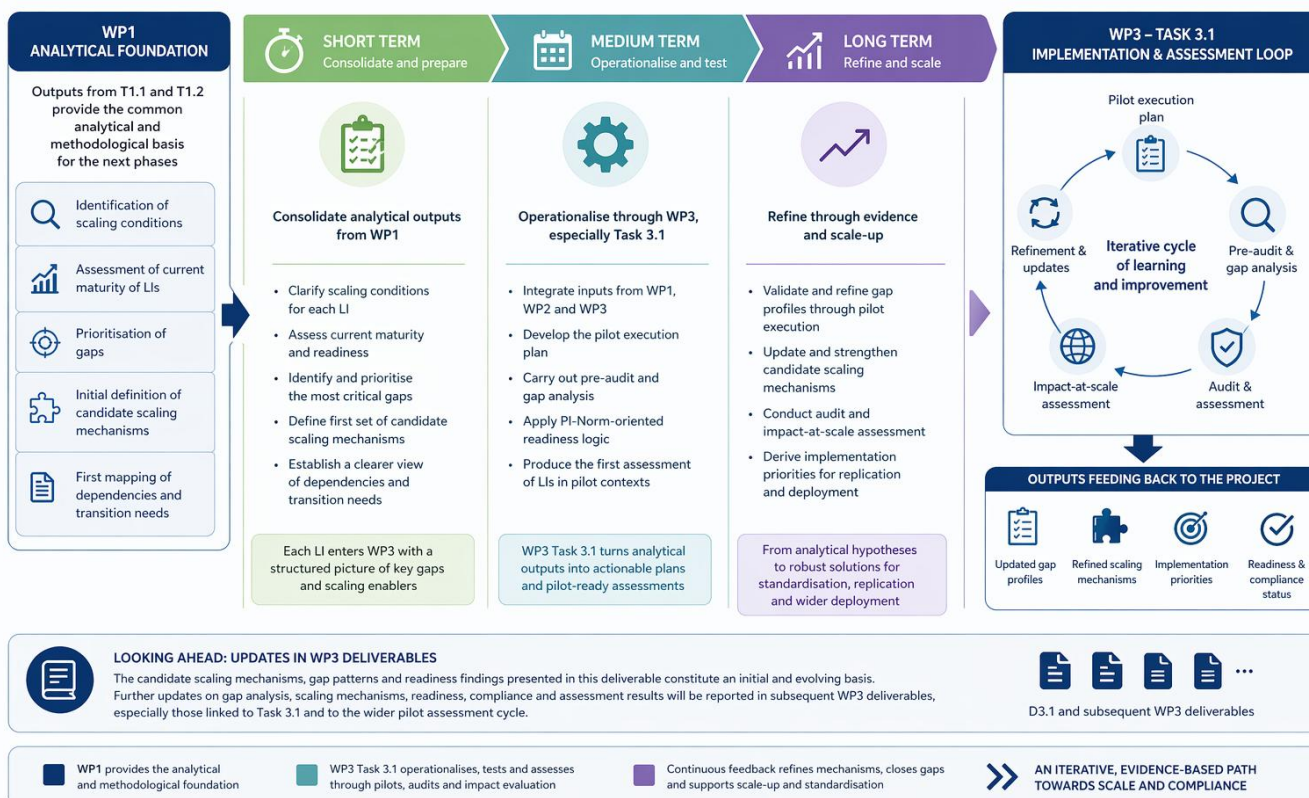


Figure 12. IKIGAI Roadmap Implementation

10.2 POLICY AND GOVERNANCE IMPLICATIONS

The evidence consolidated in this deliverable carries direct implications for policy and governance action at European, national and sub-national levels. At European level, the momentum created by the eFTI Regulation, the Data Act, the Data Governance Act and the Green Deal framework provides a supportive foundation, but the analysis shows that regulatory enabling is most effective when it reduces ambiguity rather than adding compliance requirements; accelerated adoption of delegated and implementing acts under eFTI, a clearer institutional home for Book & Claim in freight, and safe-harbour guidance for competition-sensitive horizontal collaboration would remove three of the most recurrent constraints surfaced in the pilot evidence. At national level, uneven transposition of EU instruments (including delayed eCMR ratification and country-specific deviations in digital freight documentation) compounds the coordination burden on cross-border LIs and should be addressed through targeted harmonisation support to Member States, backed by standardised legal templates for consortium agreements, liability allocation and data-sharing arrangements. At sub-national level, the multiplicity of municipal permitting, public-space and labour-regulation regimes encountered by urban LIs demonstrates the need for tighter integration between EU-level logistics policy and national SUMP/SULP frameworks, so that TEN-T corridor commitments and AFIR infrastructure obligations translate into coherent local deployment conditions rather than fragmented site-by-site negotiation. Beyond the regulatory dimension, the analysis points to governance design as a first-order policy concern in its own right: neutral trustee architectures, transparent benefit-sharing rules and standardised data-governance models are structural preconditions for scaling collaborative logistics, and public authorities have a legitimate role in endorsing, certifying or co-funding such arrangements to accelerate their adoption. These implications inform the scalers and sequenced interventions formalised in the Innovation Agenda (T1.2) and feed directly into IKIGAI's engagement with the PI Coalition (C4) and with EU, national and regional policymakers over the remainder of the project.

10.3 CONTRIBUTIONS TO PI NORM AND PILOTS

The outputs of T1.1 and T1.2 are designed to feed directly into the parallel workstreams developed in WP2 (PI Norm) and WP3 (Pilots), ensuring that standardisation and pilot implementation proceed from a shared evidence base rather than from independent starting points. For WP2, the 21 barrier families and their mapping to scaling-enabling factors identify where standardisation is most needed and why: lack of interoperability standards and common protocols, unclear data ownership and liability, platform and system integration complexity, and regulatory fragmentation across jurisdictions are the four areas where the Rulebook's pain-point analysis gives WP2 a prioritised agenda for specifying PI Norm procedures, data models and governance templates. The LI-Sx-Px anchoring preserved throughout §6 provides WP2 with procedure-level traceability, so that norm specifications can be tested against the actual operational contexts in which they must function. For WP3, the pilot-level findings deliver three operational inputs: a differentiated intervention logic reflecting that dominant barrier categories vary meaningfully by LI (regulatory in LI2, societal in LI3B, institutional in LI4, governance design in LI5); a sequencing principle establishing that governance rules, liability frameworks and trust-building arrangements must be resolved before or alongside technical deployment rather than afterwards; and a set of cross-cutting de-risking mechanisms, neutral trustee arrangements, phased onboarding, guaranteed minimum volume commitments and standardised benefit-sharing, that inform pilot design across all LIs. Together, these contributions ensure that WP2 develops standards addressing demonstrably binding constraints, and that WP3 pilots generate the evidence needed both to validate those standards and to populate the Scale Readiness Level framework and PI Readiness Mapper developed in subsequent WP1 activities.

11. References

11.1 LITERATURE

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11.2 RESEARCH PROJECTS

- [1] **ADMIRAL** (Horizon Europe, GA 101104163). Deliverable D3.2: *Drivers and barriers of collaboration in logistics networks.*
- [2] **AUTOSUP** (Horizon Europe, GA 101147468). Deliverable D1.1: *Classification of logistics automation technologies.*
- [3] **AUTOSUP** (Horizon Europe, GA 101147468). Deliverable D1.2: *Seamless multimodal automatic freight transport requirements.*
- [4] **BOOSTLOG** (Horizon 2020, GA 101006902). Deliverable D2.3: *Cloud Report on Logistics Services.*
- [5] **BOOSTLOG** (Horizon 2020, GA 101006902). Deliverable D2.5: *Cloud Report on Logistics Nodes.*
- [6] **BOOSTLOG** (Horizon 2020, GA 101006902). Deliverable D2.7: *Cloud Report on Logistics Networks.*
- [7] **BOOSTLOG** (Horizon 2020, GA 101006902). Deliverable D2.9: *Cloud Report on Innovation Initiatives.*
- [8] **DISCO** (Horizon Europe, GA 101103954). Deliverable D2.1: *Urban Logistics Transition Requirements.*
- [9] **DISCO** (Horizon Europe, GA 101103954). Deliverable D2.2: *Digital Transition Assessment Tool.*
- [10] **DISCO** (Horizon Europe, GA 101103954). Deliverable D3.1: *DISCO Data Space Open Software Repository, Version 1.*
- [11] **DISCO** (Horizon Europe, GA 101103954). Deliverable D4.1: *Agile Model Implementation Roadmap for Step 1 Demonstrations.*
- [12] **DISCO** (Horizon Europe, GA 101103954). Deliverable D7.2: *DISCO Knowledge Hub for Innovation, Upscaling and Capacity Building.*
- [13] **ePIcenter** (Horizon 2020, GA 861584). Deliverable D5.9: *Final TEN-T & Global Networks Recommendations.*
- [14] **ICONET** (Horizon 2020, GA 769119). Deliverable D1.1: *PI-aligned Digital and Physical Interconnectivity Models and Standards.*
- [15] **ICONET** (Horizon 2020, GA 769119). Deliverable D1.2: *PI Business and Governance Models.*
- [16] **ICONET** (Horizon 2020, GA 769119). Deliverable D1.6: *Requirements and High-Level Specifications for IoT-based Smart PI Containers.*
- [17] **ICONET** (Horizon 2020, GA 769119). Deliverable D1.7: *Generic PI Case Study and associated PI Hubs Plan, v1.*
- [18] **ICONET** (Horizon 2020, GA 769119). Deliverable D2.8: *Smart PI Containers – Tracking & Reporting as a Service (Final).*
- [19] **ICONET** (Horizon 2020, GA 769119). Deliverable D2.11: *Blockchain Transactional Ledgers and Smart Contracts as PI Enablers, v3 (Final).*
- [20] **ICONET** (Horizon 2020, GA 769119). Deliverable D4.1: *Roadmap as to how the PI will enhance the strategic evolution of the T&L sector for Europe.*
- [21] **LEAD** (Horizon 2020, GA 861598). Deliverable D1.3: *Knowledge for innovative actions, measures and business models in the LEAD Living Labs.*
- [22] **LEAD** (Horizon 2020, GA 861598). Deliverable D1.4: *Innovation Agenda.*
- [23] **LEAD** (Horizon 2020, GA 861598). Deliverable D1.5: *Reference LEAD Strategies.*
- [24] **LEAD** (Horizon 2020, GA 861598). Deliverable D2.2: *Digital Twin Models Library.*
- [25] **LEAD** (Horizon 2020, GA 861598). Deliverable D2.3: *Decision Support System & APIs, v1.*
- [26] **LEAD** (Horizon 2020, GA 861598). Deliverable D2.4: *Decision Support System & APIs (Final version).*
- [27] **LEAD** (Horizon 2020, GA 861598). Deliverable D2.4/D2.6: *Platform Validation & Data Pipeline.*
- [28] **LEAD** (Horizon 2020, GA 861598). Deliverable D2.6: *Final DDDAS System.*

- [29] **LEAD** (Horizon 2020, GA 861598). Deliverable D3.8: *Lyon Value Case*.
- [30] **LEAD** (Horizon 2020, GA 861598). Deliverable D3.10: *Budapest Value Case*.
- [31] **LEAD** (Horizon 2020, GA 861598). Deliverable D3.15: *Impact Assessment*.
- [32] **LEAD** (Horizon 2020, GA 861598). Deliverable D4.1: *Stakeholder Strategy*.
- [33] **LEAD** (Horizon 2020, GA 861598). Deliverable D4.5: *Transferability Platform*.
- [34] **LEAD** (Horizon 2020, GA 861598). Deliverable D4.6: *LEAD Roadmap and Policy Recommendations*.
- [35] **LEAD** (Horizon 2020, GA 861598). Deliverable D4.8: *Exploitation Plan*.
- [36] **LEAD** (Horizon 2020, GA 861598). Deliverable D4.9: *Open Source Packages and APIs*.
- [37] **SPROUT** (Horizon 2020, GA 814910). Deliverable D1.2: *Regulatory Assessment*.
- [38] **SPROUT** (Horizon 2020, GA 814910). Deliverable D1.3: *Innovative Business Models, Governance and PPPs*.
- [39] **SPROUT** (Horizon 2020, GA 814910). Deliverable D2.1: *Urban mobility transition inventory*.
- [40] **SPROUT** (Horizon 2020, GA 814910). Deliverable D2.2: *Current state of urban mobility*.
- [41] **SPROUT** (Horizon 2020, GA 814910). Deliverable D3.3: *Policy impacts of city-specific scenarios*.
- [42] **SPROUT** (Horizon 2020, GA 814910). Deliverable D4.3: *Impact assessment and city-specific policy response – Valencia pilot*.
- [43] **SPROUT** (Horizon 2020, GA 814910). Deliverable D4.4: *Impact assessment and city-specific policy response – Tel Aviv pilot*.
- [44] **SPROUT** (Horizon 2020, GA 814910). Deliverable D4.7: *Urban space management – Tel Aviv use case*.
- [45] **SPROUT** (Horizon 2020, GA 814910). Deliverable D4.11: *Impact assessment and city-specific policy response – Kalisz pilot*.
- [46] **SPROUT** (Horizon 2020, GA 814910). Deliverable D4.13: *Impact assessment and city-specific policy response – Ningbo pilot*.
- [47] **SPROUT** (Horizon 2020, GA 814910). Deliverable D4.14: *City-specific policy implementation plan – Kalisz*.
- [48] **SPROUT** (Horizon 2020, GA 814910). Deliverable D7.2: *Urban Agenda policy briefs*.
- [49] **SPROUT** (Horizon 2020, GA 814910). Deliverable D7.3: *A European Strategy to navigate urban mobility policy through transition*.
- [50] **SPROUT** (Horizon 2020, GA 814910). Deliverable D8.1: *Evaluation and results from city pilots – preliminary findings*.
- [51] **SPROUT** (Horizon 2020, GA 814910). Deliverable D8.2: *Multi-pilot lessons learned and city case clustering*.
- [52] **SPROUT** (Horizon 2020, GA 814910). Deliverable D9.6: *Final project report (including evaluation and exploitation summary)*.
- [53] **URBANE** (Horizon Europe, GA 101069782). Deliverable D2.1: *Validation report of Lighthouse LLs Implementation*.
- [54] **URBANE** (Horizon Europe, GA 101069782). Deliverable D2.2: *Demonstrator Setup*.
- [55] **URBANE** (Horizon Europe, GA 101069782). Deliverable D2.3: *Bologna Demonstrator*.
- [56] **URBANE** (Horizon Europe, GA 101069782). Deliverable D2.5: *Thessaloniki Demonstrator*.
- [57] **URBANE** (Horizon Europe, GA 101069782). Deliverable D3.1: *Collaboration Governance Ledger and Smart Contracts*.

12. Annex: Phase 3 Results: LI Barriers per Service, Process and Procedure

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
LI1 – Online and offline trustee matchmaking and volume pooling for electrification and increased intermodality	S1 – Volume pooling and asset sharing	P1 – Stakeholders onboarding (new procedures for onboarding and capacity sharing among shippers and LSPs/Intermodal operators)	Procedure 1: Stakeholder registration and volume submission	Fragmented ICT systems and lack of interoperability between shipper, LSP and intermodal platforms; limited system integration and heterogeneous digital maturity (especially among SMEs); complex data submission and harmonisation across participants	Complex coordination across multiple actors; legacy processes and workflows slow onboarding; integration of new pooling governance mechanisms into existing workflows disrupting established routines	Unclear liability allocation; data ownership and confidentiality concerns; competition-law sensitivities; compliance with data protection and contractual frameworks adds administrative burden	High onboarding and integration costs especially for SMEs; uncertain short-term ROI reducing incentives to join pooled ecosystems	Lack of trust and resistance to horizontal collaboration; organisational silos hindering transparent data sharing and governance alignment
LI1 – Online and offline trustee matchmaking and volume pooling for electrification and increased intermodality	S1 – Volume pooling and asset sharing	P1 – Stakeholders onboarding (new procedures for onboarding and capacity sharing among shippers and LSPs/Intermodal operators)	Procedure 2: Corridor analysis, definition and prioritisation	Limited real-time visibility and inconsistent data quality reducing reliability of volume aggregation and impact simulations; absence of common data standards complicating cross-company modelling	Difficulty aligning service requirements (lead times, frequency, equipment) across multiple shippers limiting viable corridor clustering; infrastructure constraints (terminal capacity, rail slots) restricting feasible options	Intermodal regulatory constraints and infrastructure access rules limiting modal shift potential; TEN-T alignment and cross-border coordination add complexity	Uncertainty about cost competitiveness versus road transport; unclear business case for electrification may hinder corridor prioritisation decisions	Misaligned incentives between shippers and LSPs; reluctance to reveal strategic lane information may weaken collaborative corridor definition
LI1 – Online and offline trustee matchmaking and volume pooling for electrification	S1 – Volume pooling and asset sharing	P1 – Stakeholders onboarding (new procedures for onboarding and capacity sharing)	Procedure 3: Capacity pre-commitment and corridor activation	Limited automation and system heterogeneity preventing seamless transition from governance approval to operational booking	Securing firm volume commitments aligned with available intermodal capacity in volatile	Unclear liability frameworks and risk-sharing mechanisms may delay formal commitments;	High upfront investments (e.g. electric trucks or rail slot guarantees) and unclear gain-sharing mechanisms may	Resistance to long-term collaborative commitments; fear of dependency; lack of trust in fair benefit

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
and increased intermodality		among shippers and LSPs/Intermodal operators)			demand conditions; complexity of cross-actor coordination for corridor activation	public procurement rules (where applicable) restricting flexibility	discourage early commitment	redistribution can delay corridor activation
LI2 – eFTI compliance Collaborative Service Platform for SMEs	S1 – Volume pooling and asset sharing	P1 – SME onboarding and platform access	Procedure 1: User registration and enablement	Heterogeneous SME digital maturity (many still operating on Excel without trained digital personnel); data transformation complexity mapping legacy formats to eFTI-compliant schema; cybersecurity risks when handling regulatory transport data; secure integration with Collaborative Logistics Platform and tributary systems (Port Community System, Customs Brokerage, eServices)	Limited digital capacity of SMEs requiring manual data entry; training needs for regulatory-compliant workflows; integration delays between onboarding and operational readiness	Ongoing uncertainty in national implementation of the eFTI Regulation and authority applications; deviation between Greek Digital Transport Order dataset and eFTI CMDS; misalignment between EU and national Competent Authorities	SMEs' reluctance to invest time and resources without immediate or foreseeable ROI; platform maintenance cost vs subscription model sustainability; data sharing viewed as risk (cybersecurity and commercially valuable datasets)	Strong road-transport culture in Europe; resistance to change from paper-based workflows; low trust in digital data sharing; reluctance to expose operational data to a shared platform datasets)
LI2 – eFTI compliance Collaborative Service Platform for SMEs	S1 – Volume pooling and asset sharing	P1 – SME onboarding and platform access	Procedure 2: Operations initialisation	Algorithm performance under variable demand; performance validation of insulated containers vs reefers not yet completed; data format mismatches between SME systems and platform	Handling non-modular load units (NMLUs); physical constraints at CDC (space, labour peaks); time window misalignment between incoming flows; niche underperforming markets served by local operators refusing services without sufficient	Legal clarity for digital document acceptance beyond eFTI CMDS by local authorities; cross-border documentation alignment challenges (e.g. Belgium has not ratified eCMR)	Uncertainty of volume stability for sustained bundling efficiency; investment cost for insulated container adoption; unresolved profit sharing models for collaborative transport agreements	Scepticism toward new insulated container technology; perceived loss of control over individual cargo; reluctance of SMEs to allow shipment merging

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
					volumes on other routes			
LI2 – eFTI compliance Collaborative Service Platform for SMEs	S1 – Volume pooling and asset sharing	P2 – Cargo consolidation	Procedure 1: Transport network setup	Limited real-time visibility tools for cargo clustering; integration challenges between platform and operator systems; data quality issues affecting shipment bundling algorithms	Coordination complexity across multiple SMEs with differing schedules; cargo type segregation and time window challenges	Cross-border regulatory fragmentation; eFTI documentation requirements for consolidated shipments; national eFTI implementation uncertainty	Unclear business case for SME participation; subscription model sustainability uncertain; uncertain demand for collaborative services	Lack of collaboration culture among competing SMEs; low trust in platform operator neutrality
LI2 – eFTI compliance Collaborative Service Platform for SMEs	S1 – Volume pooling and asset sharing	P2 – Cargo consolidation	Procedure 2: Shipment bundling and modular unit formation	Algorithm performance challenges for dynamic bundling under variable demand; limited interoperability between SME order management and the Collaborative Logistics Platform	Reluctance of local operators to provide services without sufficient volumes on other markets; handling mixed and non-modular cargo units; coordination of transport procurement offline	EU anti-trust legislation concerns around collaborative bundling; national variations in acceptance of consolidated digital freight documentation	Uncertain ROI for SMEs on collaborative bundling; unresolved profit sharing models for consolidated shipments; risk of volume instability undermining bundle efficiency	Fear of increased transparency exposing business-sensitive information; perceived loss of control over individual cargo during bundling
LI2 – eFTI compliance Collaborative Service Platform for SMEs	S2 – Warehousing and storage	P3 – Truck load optimisation and modal shift	Procedure 1: Load planning and synchromodal routing	Insufficient load optimisation tools; algorithm performance under variable demand; performance validation of insulated containers vs reefers pending; cybersecurity risks in operational data handling	Inefficient loading processes; handling non-modular and mixed-cargo load units; labour peaks at CDC; physical space constraints	Food transport safety certification requirements for insulated solutions; safety and compliance rules for mixed-cargo loading; eFTI load documentation requirements	Investment cost for insulated container adoption; uncertain cost-benefit for modal shift recommendations; high capex for SME infrastructure upgrades	Scepticism toward insulated container technology as alternative to reefers; workforce skill gaps for optimised loading; resistance to changing established loading routines
LI2 – eFTI compliance Collaborative	S3 – Freight forwarding and	P4 – Customer relationship and reporting	Procedure 1: Customer reporting and	Data quality and integration issues for cross-actor reporting; cybersecurity concerns with shared	Inconsistent reporting processes across actors; manual effort for	Reporting and compliance burdens under eFTI and national	Cost of reporting solutions vs SME willingness to pay; unclear ROI for	Trust and transparency concerns; fear of exposing

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
Service Platform for SMEs	intermodal transport		relationship management	performance data; lack of standardised reporting interfaces	regulatory compliance reporting; multi-stakeholder KPI coordination overhead	authority requirements; regulatory heterogeneity across member states	compliance investment; subscription model sustainability	operational inefficiencies to clients and authorities; low digital literacy for automated reporting tools
LI3A – Smart and synchromodal hubs for hyperconnected urban logistics (ESPLUGUES / Barcelona Metropolitan Area)	S5 – Last-mile delivery	P1 – Sorting and loading to Smart Urban Logistics Hub	Procedure 1: Hub sorting and multimodal loading	Different pallet/container standards; limited availability of standardised micro-containers; compatibility issues between barge, bike and hub equipment; fragmented IT systems across LSPs and municipalities; limited real-time data exchange; non-interoperable locker systems; automation limitations in sorting processes	Difficulty synchronising multimodal operations; restricted urban space for hubs and lockers; network management complexity across actors; cold-chain operational rigidity	Urban logistics regulations and permitting constraints; fragmentation across transport modes; slow rollout of AFIR charging/refuelling infrastructure; national labour law constraints	High upfront costs of zero-emission fleets; limited financing options for small operators; uncertain ROI for shared micro-hubs and lockers; high operational and infrastructure costs	Cultural resistance to modal shift; reluctance to share operational data; fear of losing competitive advantage; fragmented priorities across municipalities; acceptance challenges among citizens and operators
LI3A – Smart and synchromodal hubs for hyperconnected urban logistics (ESPLUGUES / Barcelona Metropolitan Area)	S5 – Last-mile delivery	P6 – Lockers network operations	Procedure 1: Smart locker network deployment and management	Platform interoperability: integrating heterogeneous locker provider APIs (access control, status, compartment reservation); reliable IoT connectivity (5G/4G); real-time monitoring without data/format mismatches across lockers and platform modules	Coordinating deployment and maintenance across 14 municipalities; managing installation, commissioning, uptime and daily capacity/occupancy operations (compartment sizing, reservation logic); training for e-van drivers and cargo bike operators	Multi-municipality site approvals and installation permits; constraints on use of public space and electrical/network hookups; privacy/security requirements (surveillance features) varying by municipality	High capex/opex for lockers, connectivity, integration work and maintenance; unclear cost-sharing model among municipalities, LSP and locker providers; ROI uncertainty until usage stabilises	Customer onboarding and behaviour change (choosing locker delivery, pickup habits); adoption friction for less digitally confident users; acceptance by municipal stakeholders (perceived burden, vandalism/security concerns)

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
LI3A – Smart and synchromodal hubs for hyperconnected urban logistics (ESPLUGUES / Barcelona Metropolitan Area)	S5 – Last-mile delivery	P6 – Lockers network operations	Procedure 2: Locker-integrated delivery operations and mobile hub optimisation	Reliable end-to-end integration between routing/optimisation, locker access-code generation, scanning confirmation, notification services and live locker availability; integration limits degrade optimisation quality when data is delayed or incomplete	Coordinating multi-stop locker routes; handling exceptions (locker offline/full, failed access, damaged compartments); managing uncollected parcels (reminders, retrieval dispatch, returns); sustaining service levels across many locker sites and municipalities	Operational constraints on stopping/loading near lockers; rules around parcel holding times and returns; compliance requirements tied to customer communications and data handling across municipalities	Costs to run the network at scale (driver time per stop, exception handling/retrieval trips, support/maintenance); uncertain cost-benefit split among stakeholders as volumes fluctuate	Willingness to pick up within time windows; trust in code/QR access; adoption friction for less digitally confident users; resistance to changed workflows among drivers/operators if perceived as extra steps or added KPIs
LI3B – Smart and synchromodal hubs for hyperconnected urban logistics (Paris)	S5 – Last-mile delivery	PX – Floating Smart Urban Logistics Hub (barge) operations and smart-contract orchestration	Procedure 1: Floating hub (barge) setup and pilot onboarding	Interoperability/incompatibility between tools used by different actors (FLUDIS operational tools, client tools) and the digital orchestration layer; dependence on automation, digital platforms, scanners and labels; persistence of paper-based steps (e.g. handwritten signatures) preventing end-to-end digital flow; digital constraints around real-time data capture and validation especially for CO ₂ /energy monitoring	Synchronisation challenges between hub operations (barge) and last-mile delivery execution (cargo bikes); availability and suitability of physical infrastructure and equipment required for the pilot; operational practices deviating from designed processes (drivers relying on habits over tools); additional handling steps, loading/unloading time and weather/navigation	Ownership, liability and responsibility uncertainties across actors; data sharing constraints (who can access what, under which conditions); constraints from existing contracts and national regulations hindering pooling transformation; lack of harmonised procedures across countries affecting replication	Uncertainty on break-even volumes and whether volumes justify investment; cost of automation and digital upgrades with unclear cost-benefit for the operator; competitiveness of multimodal zero-emission delivery versus traditional road delivery (speed, flexibility, capacity, additional handling time)	Limited awareness and understanding of the Physical Internet concept and its benefits among clients and public authorities; trust issues around sharing strategic process and data information; resistance to change when existing processes work adequately; limited stakeholder engagement in process redesign (clients not directly engaged as redesign partners)

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
					impacts affecting daily performance			
LI3B – Smart and synchromodal hubs for hyperconnected urban logistics (Paris)	S5 – Last-mile delivery	PX – Floating Smart Urban Logistics Hub (barge) operations and smart-contract orchestration	Procedure 2: Smart-contract orchestration, event verification and KPI monitoring (barge-to-cargo-bike operations)	Lack of interoperability between systems (FLUDIS tools vs orchestration; 'one client = one tool'; some steps still on paper) blocking reliable event exchange and automation; risk of incompatibility between logistics systems and blockchain-enabled orchestration layer; integration challenges with legacy systems and scanners weakening event capture; reliability issues in real-time CO ₂ and energy data validation/recording (latency, gaps, calibration); risk of delayed smart-contract output validation	Drivers' adaptation to streets/clients bypassing event confirmation steps required for orchestration; limited early data availability slowing modelling accuracy and optimisation during ramp-up	Legal uncertainties around ownership, liability and data sharing affecting how verified events/KPI records are accepted; existing contracts and national regulations limiting how far standardised orchestration processes can be applied; lack of harmonised procedures limiting replication beyond the pilot	Cost of automation and digital upgrades with unclear immediate ROI; unclear break-even volumes creating hesitation to invest in orchestration and monitoring beyond pilot scope; difficulty producing credible performance evidence to convince future clients to scale	Persistent trust issues around sharing strategic data and process information; limited awareness and acceptance of the PI concept and verified workflow logic; resistance to behavioural change for new verification steps; limited stakeholder engagement in process redesign creating adoption risk; operator training needs during transition period; limited upstream supply chain visibility constraining end-to-end verification
LI4 – Intelligent, standard end-to-end chain of custody for carbon emission calculation (Book & Claim)	S3 – Freight forwarding and intermodal transport	PX – Book & Claim operations for collaborative freight efficiency	Procedure 1: Book & Claim system design and setup	Integration with heterogeneous TMS systems while preserving data confidentiality; ensuring data quality, consistency and comparability across operators; robust verification of efficiency gains without direct physical linkage; fragmentation of carbon accounting standards	Translating complex transport realities into simplified credible claim units; aligning different operational rhythms (routes, frequencies, volumes) across operators; managing exceptions and	Lack of established standards for Book & Claim in freight logistics; uncertainty on recognition of claims in sustainability reporting frameworks;	Unclear initial ROI for participants; difficulty pricing claims and efficiency units; risk perception linked to first-mover participation; compliance and implementation costs	Low trust between competing operators; cultural resistance to virtual collaboration mechanisms; need for internal buy-in from legal, commercial and operations teams

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
				and emission reporting frameworks	outliers without undermining trust in the system	compliance with competition law and data protection requirements; unclear regulatory acceptance of new emission accounting methods		
LI4 – Intelligent, standard end-to-end chain of custody for carbon emission calculation (Book & Claim)	S3 – Freight forwarding and intermodal transport	PX – Book & Claim operations for collaborative freight efficiency	Procedure 2: Book & Claim operational execution	Ensuring ongoing data quality, consistency and comparability across heterogeneous operator systems; robust and auditable verification of efficiency gains; risk of fraud or data manipulation; lack of primary fuel/activity data access	Continuous monitoring burden across international custody chains; managing exceptions and outliers without undermining system credibility; sustaining consistent reporting cadence across operators with different rhythms	Fragmented governance of carbon accounting frameworks; unclear regulatory acceptance of new emission accounting methods; data protection requirements for aggregated and anonymised data; ongoing compliance obligations	Compliance and implementation costs with unclear business incentives for ongoing participation; uncertain market demand for Book & Claim units; difficulty maintaining operator engagement after pilot phase	Resistance to moving away from established default emission factors; low data literacy across actors; cultural resistance to systematic monitoring and sharing of operational performance data; fear of exposing inefficiencies
LI5 – Open volume pooled governance for reusable standard modular boxes (GS1 SMART-Box)	S1 – Volume pooling and asset sharing	P1 – Open pool governance for the GS1 SMART-Box	Procedure: Governance design	Lack of interoperability between systems and warehouse setups across countries; dependency on automation and digital tools; integration challenges with legacy systems and scanners; difficulty ensuring compatibility with RFID gates and handheld/fixed scanners across partner systems	Staffing for the neutral Trustee role (new role being piloted with GS1 as neutral partner) requiring training, tools and proper resources; rule-based clearing mechanism still in development;	Legal uncertainty around ownership, liability and responsibilities; data access rules must be clearly defined before operations; hygiene and food safety requirements for	Cost of transition and adoption across the supply chain; high unit value and loss risks in an open pool; costs of automation upgrades for tracking and governance; limited pilot volume raising scalability concerns; unproven business	Stakeholders' acceptance and change management – experimenting with a model that departs from traditional pooling; clear and agreed governance identified as critical

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
					operational readiness validation required across all pilot partners	specific product types (eggs, direct food contact); existing contracts and national regulations may hinder pooling governance design	model for reusable open-pool packaging	success factor; resistance to behavioural change; limited stakeholder engagement in process redesign
LI5 – Open volume pooled governance for reusable standard modular boxes (GS1 SMART-Box)	S2 – Warehousing and storage	P2 – Standard transport and warehousing best practices with the GS1 SMART-Box	Procedure 1: Theoretical flow (physical specifications, palletising and traceability standards)	Reliably identifying assets across different warehouse setups (barcode orientation, scanner placement, EPCIS events); lack of harmonised palletising standards, stacking rules and box variants needed for automation; compatibility with RFID gates, handheld/fixed scanners and cross-docking configurations	Upgrading scanners, conveyors, robots and manual handling stations across diverse partner sites; defining and validating Standard Operating Procedures across multiple partner environments; workforce adaptation and training requirements	National differences in operational rules (warehouse safety norms, pallet-height limits, labour regulations) making cross-border best practices difficult to unify; potential food safety compliance requirements for certain product types	CAPEX for automation tuning, scanning infrastructure, warehouse reconfiguration and pallet optimisation tools; ROI projections uncertain pending pilot validation	Resistance to change from existing staff habits and routines to new scanning and standardised palletising procedures; workforce training requirements across multiple partner sites
LI5 – Open volume pooled governance for reusable standard modular boxes (GS1 SMART-Box)	S2 – Warehousing and storage	P2 – Standard transport and warehousing best practices with the GS1 SMART-Box	Procedure 2: Operational flow (filling, palletising, transport and DC inbound handling)	Reliably identifying and tracking assets at each touchpoint (barcode orientation, scanner placement, EPCIS event generation and linkage); ensuring consistent RFID/barcode scanning performance during transport and unloading across different operator setups	Consistent application of palletising standards and load-securing rules at supplier sites with varying capabilities; managing stacking stability and equipment compatibility during transport; coordinating	National differences in road transport and warehouse safety regulations affecting cross-border operational flows; compliance with hygiene requirements for specific product types during transport	CAPEX for scanning infrastructure and EPCIS tooling upgrades at supplier and DC sites; uncertain ROI pending pilot scale validation	Resistance to change from established packing and loading routines; workforce training needs at supplier and logistics provider sites; habit-based deviations reducing data quality in event logs

Logistics Innovation (LI)	Service	Process	Procedure	Technological Barriers	Operational Barriers	Regulatory & Policy Barriers	Market & Economic Barriers	Societal & Organisational Barriers
					inbound handling at the Distribution Centre			
LI5 – Open volume pooled governance for reusable standard modular boxes (GS1 SMART-Box)	S4 – Cross-docking	P3 – Standard in-store best practices with the GS1 SMART-Box	Procedure 1: Theoretical flow (store zoning, EPCIS events, SOP design and reverse logistics)	Difficulty integrating SMART-Box handling into existing store-level systems; compatibility issues with store scanning devices and replenishment systems; EPCIS event integration with INLECOM tracking tools; ensuring system compatibility across all retailer formats	In-store workflows require alignment between brands, retailers, poolers and carriers to shift from SRP/cardboard to modular reusable boxes; defining standard processes for receiving, storing, replenishing, returning empties and handling damaged/soiled boxes across all store types	Hygiene, safety, food-contact compliance, storage height and handling procedure requirements may slow adoption of new reusable formats; potential variation in requirements across national retail regulations	Costs for adapting in-store equipment, rearranging shelf infrastructure, updating scanning devices, training staff and adapting replenishment systems; uncertain ROI at store level given the number of adaptations required	Store teams and operations managers may resist changed routine workflows; cultural shift required from single-use packaging to reusable modular boxes; sustained change management effort needed across all stores
LI5 – Open volume pooled governance for reusable standard modular boxes (GS1 SMART-Box)	S4 – Cross-docking	P3 – Standard in-store best practices with the GS1 SMART-Box	Procedure 2: Operational flow (arrival, backroom, shelf replenishment, empty box return and pooler collection)	Difficulty integrating SMART-Box scanning and identification into existing store-level systems (barcodes, RFID) at all operational touchpoints from arrival to empty handover to pooler	Coordination required between store staff (receiving, replenishment), backroom management, and pooler driver for FIFO rules, folding, sorting and timely collection of empties; managing exceptions for damaged or dirty boxes	Compliance requirements on hygiene and food-contact safety during in-store handling; national retail regulations on storage height and procedures varying across pilot countries	Cost of training and managing changed workflows across all store staff; investment in dedicated backflow zones and updated scanning devices at store level	Store teams and operations managers may resist routine changes; drivers and staff may revert to familiar habits; sustained enforcement of new procedures required to ensure data quality in the reverse logistics loop