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Exploring the Future of Urban Logistics Through Physical Internet Implementation Using Delphi

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Background & Motivation

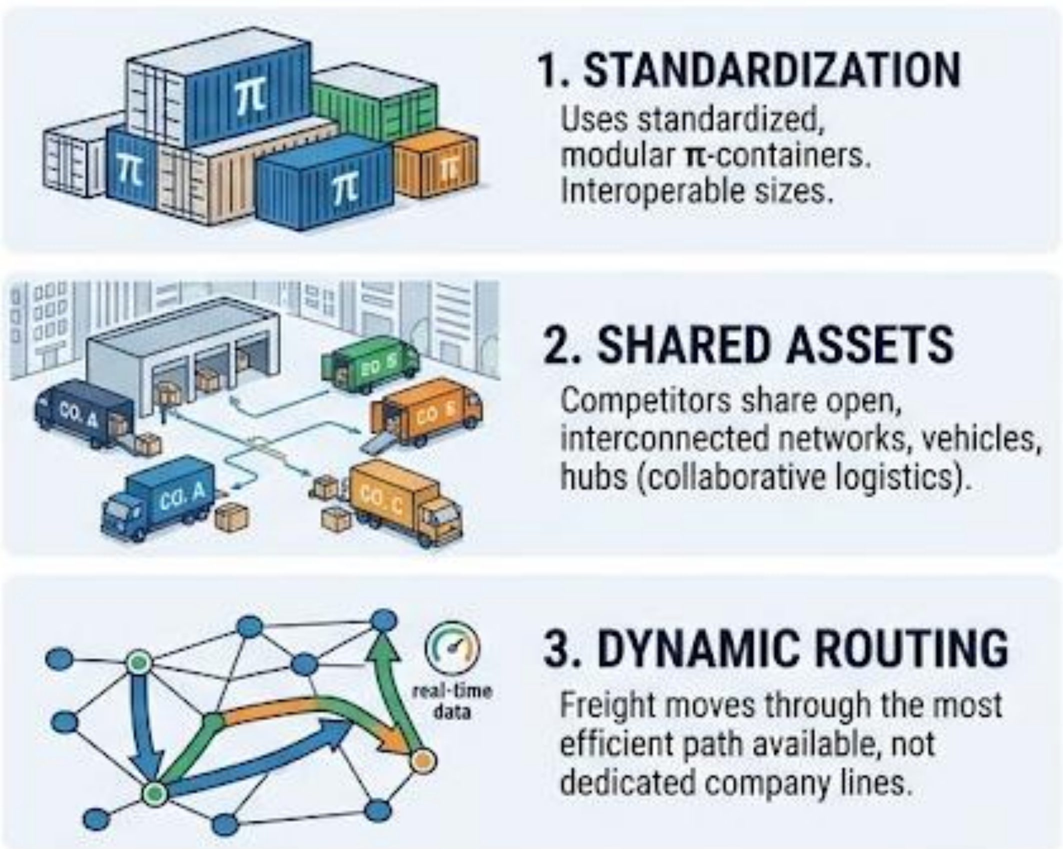
E-commerce growth
Fragmented B2C demand
Higher congestion & parcel km

VS

Sustainability goals
CO_2 neutrality targets require cleaner, more coordinated urban freight

The shift from consolidated B2B to fragmented B2C deliveries increases congestion, vehicle-km and per-parcel emissions. Fast shipping further lowers load factors and raises carbon intensity.

Physical Internet (PI)
A hyperconnected logistics paradigm inspired by digital internet interoperability, using standardised and open, shared logistics networks.



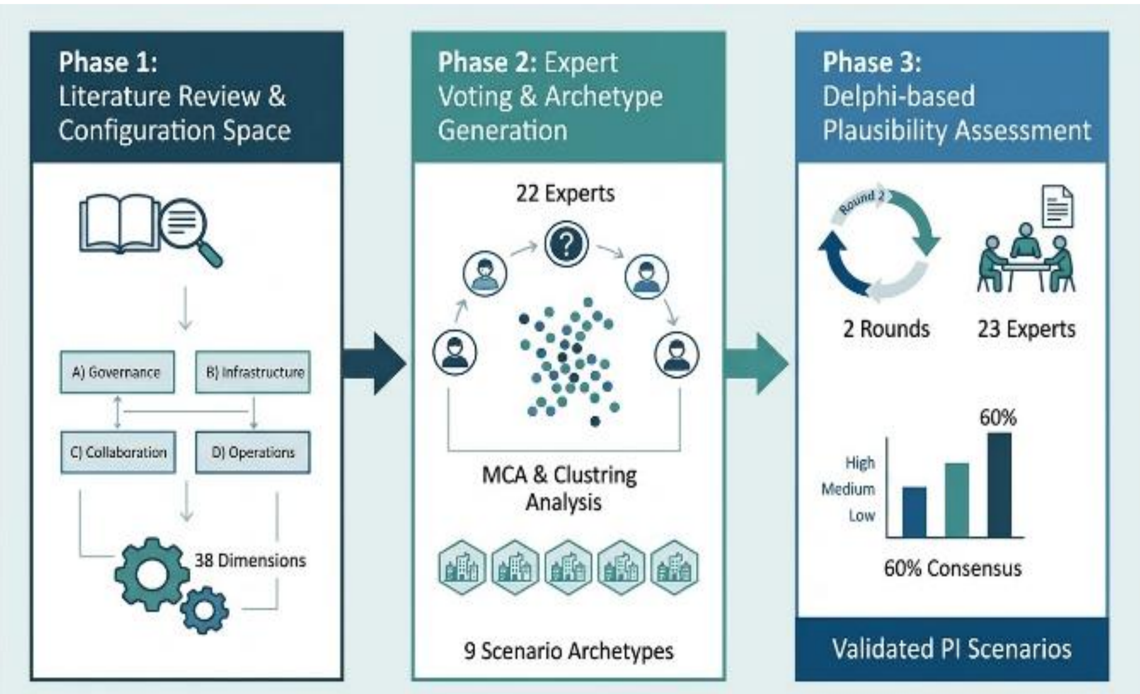
Potential impact | ↓25% costs | ↓32% CO_2

The gap
Digital technologies are advancing faster than the physical, economic and collaborative setups needed to realise PI at scale.

Research question

"What are the most plausible PI configurations for urban logistics systems by 2050, as assessed by industry and academic experts?"

Methodology



Configuration Space

Four primary sectors, each decomposed into contrasting optimistic/pessimistic implementation options:

A. Governance & Planning
Long-term orientation · Cross-department integration · Data intelligence · Stakeholder engagement · Funding · Regulatory adaptability

B · Urban Space & Physical Infrastructure
Curbside management · Public-space allocation · Microhub siting · Network density and access

C. Collaborative Logistics
Multimodality · Platform integration · PPP intensity · Trust / data sharing · Collaboration breadth

D. Sustainable Operations
Future mobility · Implementation pace · Transparency · Analytics · Automation · Resilience

Key contrast
Each dimension was operationalised as a binary pair: progressive / integrated (Option 1) versus conservative / fragmented (Option 2).

Archetypes

Nine Scenario Archetypes

A1 Tech-progressive, ops-conservative — HIGH
City monitoring; slow governance; limited data sharing
Tech: **High** | Collab: **Limited** | Gov: **Slow**

A2 Fully integrated next-gen network — N/C
Proactive governance; unified AI platforms; synchromodal
Tech: **V.High** | Collab: **Full open** | Gov: **Proactive**

A3 Tech-advanced private ecosystem — HIGH
High automation; closed incumbent-controlled assets
Tech: **V.High** | Collab: **Closed** | Gov: **Private**

A4 Cautious commons — MED
Open shared assets; conservative tech; static rules
Tech: **Low** | Collab: **Open/shared** | Gov: **Conserv.**

A5 Centrally focused, excl. managed — N/C
Advanced urban core facilities; exclusive concessions
Tech: **High** | Collab: **Exclusive** | Gov: **Central.**

A6 Basic infra, minimal innovation — LOW
Low-cost retrofits; sparse nodes; rudimentary data
Tech: **Low** | Collab: **Minimal** | Gov: **Reactive**

A7 District-led, fragmented gov. — MED
Localised experiments; no metro interoperability
Tech: **Med** | Collab: **Fragmented** | Gov: **Local**

A8 Transition: shared network — HIGH
Common data platforms; moderate automation; stepping-stone
Tech: **Mod.** | Collab: **Shared** | Gov: **Collab.**

A9 Advanced tech, excl. sparse nodes — N/C
Predictive AI in few high-capacity private sites
Tech: **V.High** | Collab: **Exclusive** | Gov: **Sparse**

DELPHI: High plausibility | Medium | Low | No consensus

Key Findings

- **Bounded ecosystems preferred**
  Closed or semi-open private configurations were seen as more plausible than a fully open city-wide PI.
- **Collaboration is the main barrier**
  Trust, incentives, liability and competition concerns dominate scaling barriers.
- **Transitional models are viable**
  A8 suggests shared physical networks plus common data layers can act as a stepping-stone.
- **Minimal innovation is insufficient**
  A6 cannot meet future sustainability or service requirements.
- **Fully open PI is not ruled out**
  A2 lacked consensus but was not rejected; longer-term institutional change could still enable it.

Policy Implications

For tech-forward / collaboration-light futures (A1, A3)
Early interoperability requirements can reduce lock-in and lower barriers for SMEs. Procurement should reward open API standards even inside private platforms.

For shared-network trajectories (A8)
Transparent data-governance frameworks, shared-access procurement and regulatory sandboxes can support system-wide efficiency gains.

For district-led innovation (A7)
Horizontal learning mechanisms and metropolitan scaling tools can reduce fragmentation. Coordinated investment is essential for climate targets and service quality.

Conclusions

- ✓ A 4-sector, 12-component, 38-dimension configuration space with 76 options was developed for PI-led urban logistics.
- ✓ Expert voting plus MCA clustering yielded 9 internally coherent archetypes; Delphi validated 6 with 60% consensus.
- ✓ High plausibility: private tech ecosystems and transitional shared networks.
- ✓ Low plausibility: minimal innovation.
- ✓ The key barriers are organisational and institutional—especially trust, incentives, liability and competition.
- ✓ The findings help cities and firms prioritise investments, design governance frameworks and sequence sustainable logistics transitions.

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