THE UNIVERSITY OF MELBOURNE

IPIC 2023
9th International Physical Internet Conference
June 13-15, 2023
Athens, Greece

IPIC 2023

Physical twin capability, transparency, and governance - fundamental to PI Proliferation

June 2023

Student: Geoffrey Featherstone (ID:254658)

Supervisors: Prof. Russell Thompson, Dr. Medo Pournader
Committee Chair: Assoc Prof. Felix Kin Peng Hui

PI Impediments

This research focuses on potential impediments to the progression of the Physical Internet:

1. Infrastructure and interface architecture pose potential PI barriers to proliferation
2. Assets must be described by a convention and characteristic hierarchy to route and respond to critical path requirements
3. A Global system and standards are required for multi-user Governance

Introduction

"The evolution of the Physical Internet is highly dependent upon the 'body' (intelligent physical twin) instead of just the 'mind' (digital twin)".

The paper separates the two to focus on the 'infield physical twin' at PI's core:

1. Discuss barriers to proliferation
2. Describe tangible and intangible assets
3. Delineate the semantic orientation of assets, and
4. Define the core portfolios of arm's length governance.

The main contributions of this article are as follows:

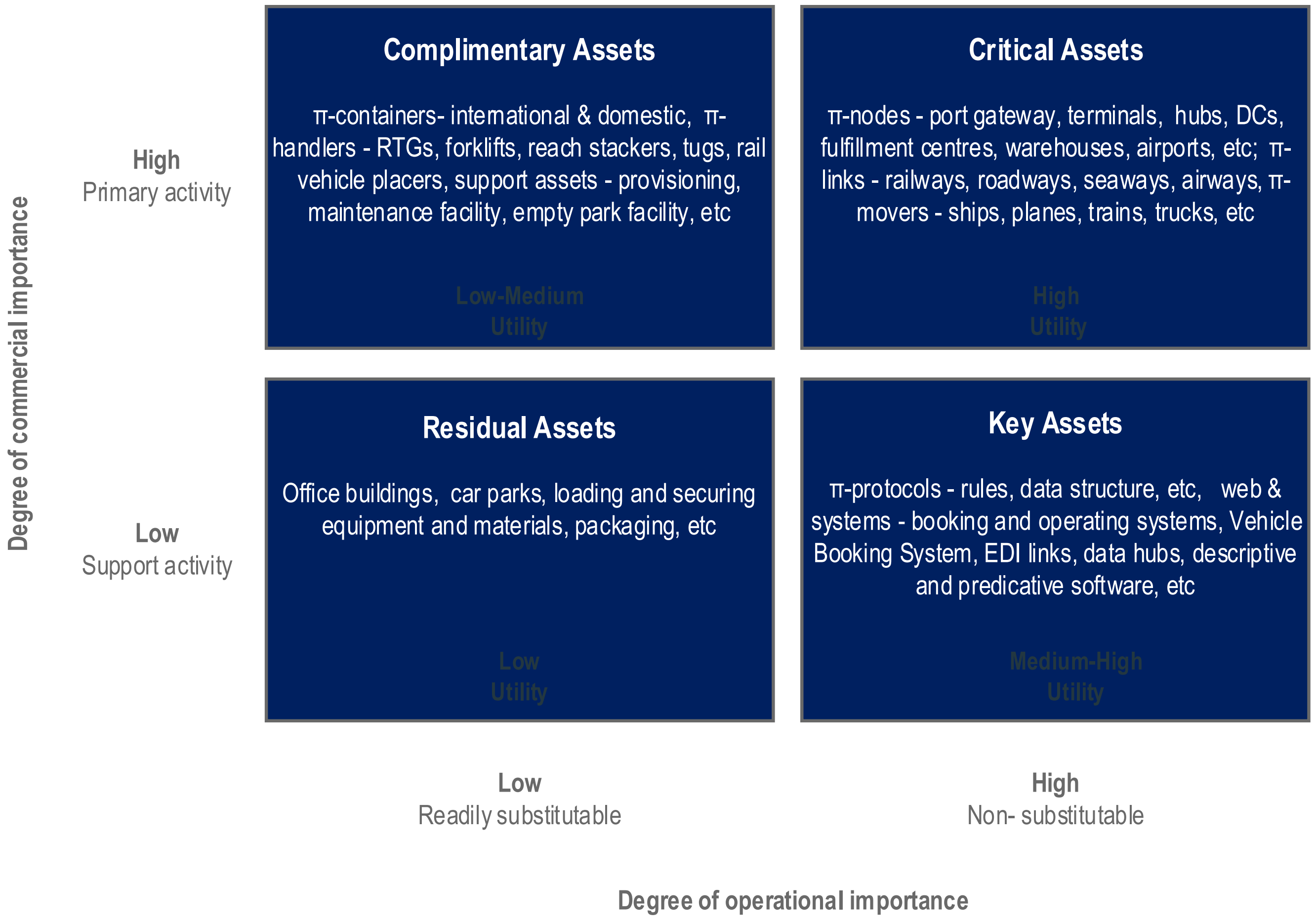
1. Establish a method for determining asset hierarchy,
2. Categorise PI at a group and class level, and
3. Describe an arms-length Governance model

Barriers to Proliferation

Barriers to Proliferation

Critical and complimentary assets must evolve into interoperable intelligent assets capable of interconnecting with other agents' key assets.

- Freight is transported via critical assets, supported by complementary, key, and residual assets.
- These assets have relative scarcity and utility in transactions between buyers and suppliers (Cox, Ireland et al. 2001).
- Utility and scarcity are related to the asset's indispensable capability, availability, and substitutability.
- These assets are of operational and commercial importance; therefore, these key determinants must be carefully navigated in the evolution of the physical internet.



THE UNIVERSITY OF MELBOURNE

Tangible and Intangible Assets

Tangible and Intangible Assets

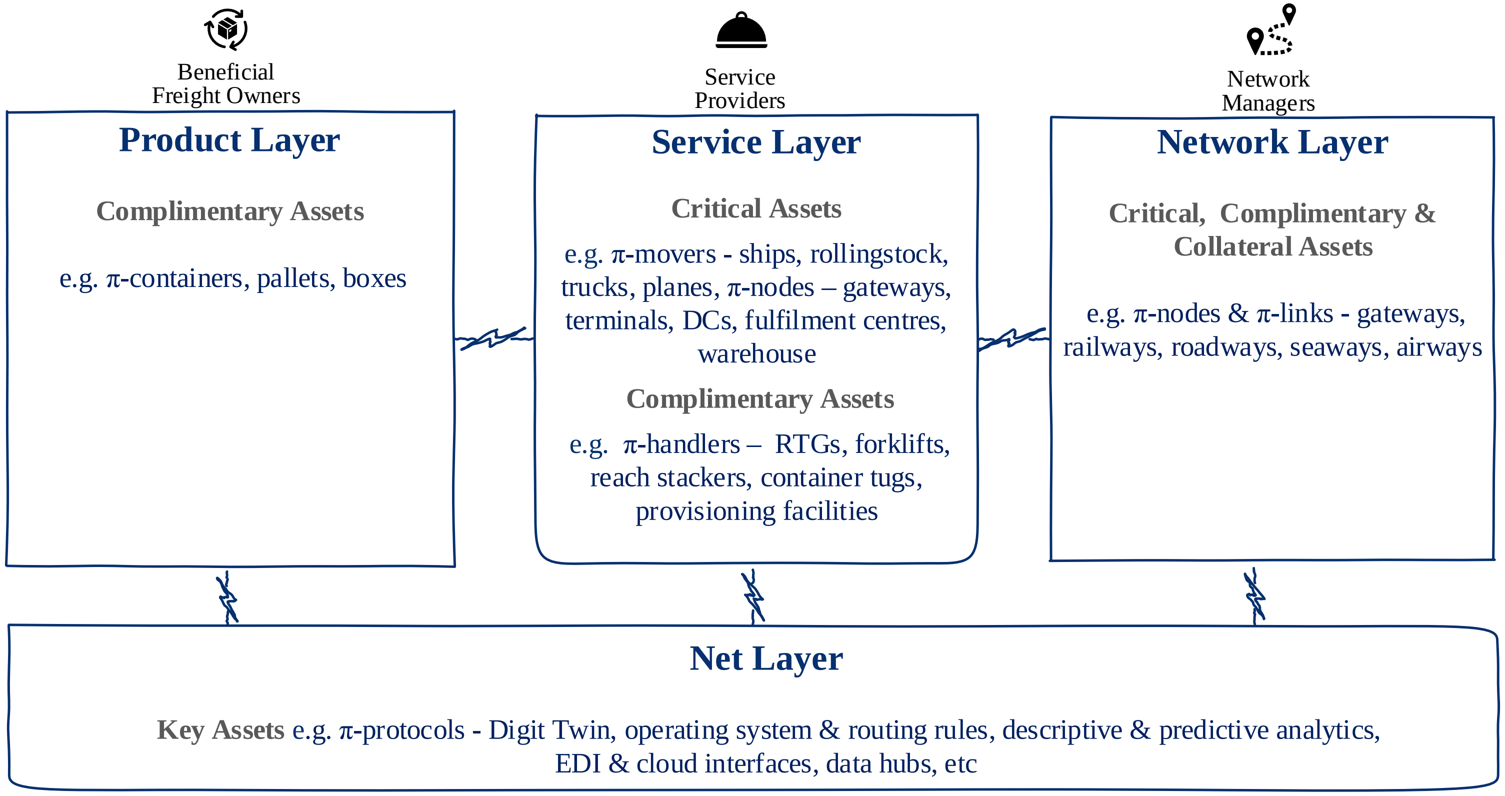
Whilst the asset is tangible in physicality, like a smartphone, it must be able to receive, acquire, process, perform actions, and transmit data from various types of RFID, sensors, and computing systems.

- Field assets would preferably have a **power** source, cyber **security**, and **remote transmission capability**.
- Once visible, **Data is ingested into descriptive software**, which overlays the data onto a digital schematic of the assets' design.
- Structured data from IoTs/Intelligent assets are transformed into **viable information describing the asset state and traits**.
- Digital twin must then make sense of data for virtual planning, controlling, coordinating, and monitoring, as well as running diagnostics to **validate the asset's current state against the plan or allowable parameters**.
- Data sources are **merged to form the digital description** of the asset.
- Intelligent asset emulation is the **imitation of the asset and its behaviour**. It visually represents or reproduces the real-time functionality of the intellectual assets. Accurately describing a given asset's state and trait is the basis for precise prediction of **freight momentum**.
- The core system, **simulation of the physical assets' operation** (origin, destination, condition sets) could determine the asset's future behaviour and respond to **physical and process constraints** with given inputs, e.g., capacity, capability statements, or spatial characteristics.
- Predictive analytics could also identify **physical limitations and potential mission threats** that impede the asset's momentum.
- Optimisation and **validation modelling** can be used as findings for recommended actions in a specific situation.

Semantic orientation of assets

Orientation layers

- Products are generally packaged and encapsulated within assets for handling, transportation, and storage.
- Beneficial freight owners typically place orders within a 4PL or 3PL booking system to move encapsulated goods onto a service.
- Critical assets perform transport services, and complimentary assets carry-out handling and support activities.
- These configured assets that perform such services traverse nodes and links within network corridors.



Product Layer
Disaggregated Microservices

✓ Open Access ✗

- Position, Track & Trace, movement
- Encapsulated Characteristics & Condition
- Link to Service/s & Availability
- Link to other Intelligent Assets
- Beneficial Freight Owner Information
- Booking & Billing System
- Data Hub
- Unavailability
- O-D Pair

Service Layer
Aggregated Microservices

✓ Open Access ✗

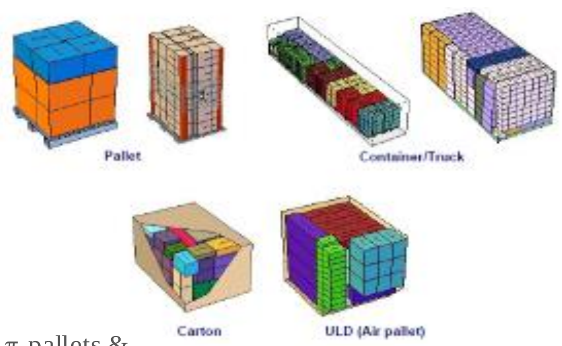
- Position, Track & Trace movement
- Critical & Complimentary Asset capability, capacity, configuration & availability
- Link to other Intelligent Assets
- Booking & Billing System
- Operating & System
- Data Hub
- Condition
- Unavailability
- O-D Pair

Network Layer
Aggregated Macro services

✓ Open Access ✗

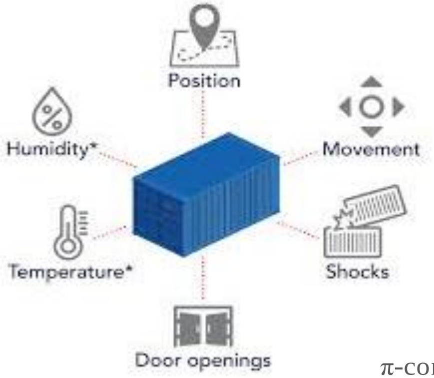
- Position, Track & Trace movement
- Critical Asset / Infrastructure capability, capacity & configuration
- Network Availability
- Access Owner
- Operating System
- Data Hub
- Infrastructure Condition
- Booking & Billing Systems
- O-D Pair

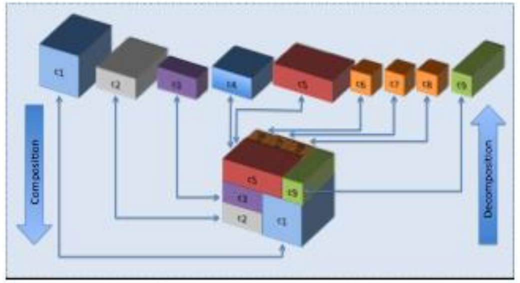
Smart devices, IoT & ITS



π-pallets & boxes

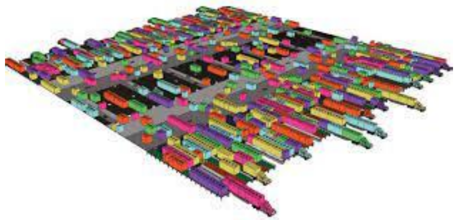
Intelligent Physical objects





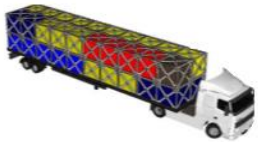
π-containers

Interoperability data seamlessly transmitted with clear ownership & governance



π-node (terminal)

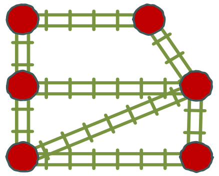
π-handler

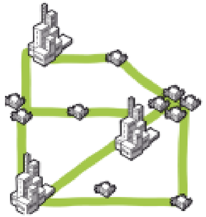


π-movers

Big Data, Descriptive & Predictive Data Analytics, Artificial Intelligence, Blockchain applications, semi-autonomous operations, transhipment technology and handling of assets.

π-node (gateway)





π-nodes & π-links within network

Product Layer

'Product layer' is purposeful as it distinguishes its orientation to 'Services'; this provides a layer directly linked to the agents of goods rather than the agents of services.

Product Layer

Complimentary Assets

e.g. π-containers, pallets, boxes

- Product layers include π-containers, pallets, and boxes, which encapsulate 'Goods.'
- Products are digitally described (weight, cubic size, type - dangerous goods, priority etc.).
- Consignment information includes priority, DGs, sender, receiver and associated locations that link the container to track and trace systems.
- Products (within π-containers) traverse networks (node-link routes) within a digital service packet (within π-movers capacity) from origins to destinations, including intermediate locations.
- Products are amassed at π-nodes, transferred, and atomised via critical π-movers and complimentary π-handlers. A parent model convention could be used to relate the π-containers to the π-movers, i.e., the π-container child is linked to the wagon or trailer, which is linked to the parent asset, the loco or truck, which is linked to the grandparent π-movers, the Train or B-Double.
- Therefore, from a more granular level, boxes are subservient to the pallets, which are subservient to their parent π-container.

Service Layer

'Service layer' is purposeful as it distinguishes its orientation to 'Products and Networks'; this provides a layer directly linked to the agents of services rather than the agents of the goods or networks.

Service Layer

Critical Assets

e.g. π-movers - ships, rollingstock, trucks, planes, π-nodes – gateways, terminals, DCs, fulfilment centres, warehouse

Complimentary Assets

e.g. π-handlers – RTGs, forklifts, reach stackers, container tugs, provisioning facilities

- Services (**E**-services) have a Master ID with subservient IDs, all of which have a Network identifier within a naming convention.
- Master IDs identify the π-movers origin, intermediate hub, destination, weekday, time sequence, priority, and network.
- Subservient IDs are linked to parent IDs, identifying π-container consignments within the service.
- Consignments can have unique identifiers related to the π-mover, π-node, π-handler, service, and network.
- Consignments within π-containers are at a pallet size and are digitally linked to the π-container, linked to a π-mover, linked to a service and a network. Services are essentially a naming convention describing modal (π-mover) capacity and infrastructure usage (π-node & π-link pathing) within corridors, encompassing the logistical distance across a network.
- Critical assets (π-movers) perform services across π-nodes and π-links, with complimentary assets that either support the critical asset or π-handle the π-containers.

Network layer

'Network layer' is purposeful as it distinguishes its orientation to 'Services'; this provides a layer directly linked to the agents of networks rather than the agents of services.

Network Layer

Critical, Complimentary & Collateral Assets

e.g. π-nodes & π-links - gateways, railways, roadways, seaways, airways

- Common user layer
- Private agents are multi-users of the central infrastructure.
- Master networks generally consist of gateway nodes, general nodes, and links within an infrastructure corridor, e.g., transcontinental or land-based penetration lines.
- Networks could have a unique Master ID, with subservient IDs for complimentary and collateral networks.
- Critical networks are digitally mapped via nodes and links to complimentary and collateral networks at nodal point boundaries.
- Each describes the infrastructure's intermodal gateway, corridor, adjoining trans-modal hubs, capacity, and capability characteristics.
- Services can be digitally linked to critical, complimentary, and collateral networks for logistically pathing (π-routing) from origin to destination, including intermediate destinations.
- Relationships between critical, complementary, and collateral networks are described by the point of nodal interface (spatial). Include: headway time, kilometres between nodes (distance), capacity (volume/load/length), and constraints (effort).

Net Layer

'Net layer' is purposeful as it distinguishes its orientation to 'physical field assets'; this provides a layer directly linked to systems, internet, and transmission networks; the systems encapsulate the 'digital twin' which can emulate, simulate, and optimise the product, service, and networks 'physical twin' layers and their interrelationship.

- Key assets are interfacing, booking, operating, diagnostic and billing systems.
- Depending upon their operational and commercial importance, these systems could also be categorised at a critical, complimentary, or collateral level.
- The network, E-services, and associated π-assets can all be digitally twinned to key assets.
- Systems can route services either by nodes or geofenced blocks within links.
- Data transmitted from π-nodes, π-links, and π-movers could be emulated, simulated, and optimised via descriptive and predictive software, e.g., spatiotemporal tracking and tracing, asset condition, capacity, process capability, etc.

Net Layer

Key Assets e.g. π-protocols - Digit Twin, operating system & routing rules, descriptive & predictive analytics, EDI & cloud interfaces, data hubs, etc

THE UNIVERSITY OF MELBOURNE

Supply Chain Governance

Coal Chain Governance Case

1. Recommendation from O'Donnell Review 29th July 2007, Australian Competition Authority.

    - *A **central coordinator role is created** to oversee and, if necessary, coordinate all activities that span the whole supply chain. The position would oversee master plans to ensure that future capacity is in line with forecasts, facilitate industry consideration of …investment, and oversee short-term planning and the establishment of business rules for daily optimisation of system capacity.*

2. Australian Competition and Consumers Commission (ACCC) determination on "a queue management system designed to address the imbalance between the demand for coal loading services at the Dalrymple Bay Coal Terminal and the capacity of the Goonyella coal chain". 29th February 2008.

    - ***Appointment of people to coordination roles**, and a rail contract renewal process.*

3. CEDA Queensland Export Infrastructure Conference. The ACCC's role in coal chain logistics. Dr Stephen King, Commissioner. 15th July 2008, Brisbane.

    - *"There is **significant complexity in managing the supply chain from both strategic and operational viewpoints**".*

4. Coal Network Capacity Co. CENTRAL QLD COAL NETWORK Initial Capacity Assessment Report. 27th October 2021 Version: 2021 ICAR

    - *UT5 specifies two types of Capacity Assessments…1. Definition of Deliverable Network Capacity, and 2. System Capacity. For the **Independent Expert** Initial Capacity Assessment, only the Deliverable Network Capacity is required to be assessed.*

Governance Outcome

1. Integrated Logistics Company (ILC). The Central coordinator to oversee and, if necessary, coordinate all activities which span the entire coal chain.
2. HVCCC's purpose and vision reflect a focus and role within the evolving circumstances of the Hunter Valley Coal Chain Members. HVCCCs' objectives are to plan and coordinate the cooperative operation and alignment of the Coal Chain to maximise the volume of coal transported through the Coal Chain at minimum total logistics cost…Accordingly, HVCCC's purpose is to Independently optimise the end-to-end coal chain to serve Members' collective needs best.
3. Independent Expert (IE) undertakes dynamic Deliverable Network Capacity Analysis based on a dynamic model, sets out the System Operating Parameters (SOP) for each Coal System having regard to how each Coal System operates in practice and develops an Initial Capacity Assessment Report (ICAR) that sets out Deliverable Network Capacity (DNC), assumptions, constraints, and Existing Capacity Deficits (ECDs). The IE conducts Dynamic Simulation Modelling using the AnyLogic modelling software to determine the DNC of the CQCN and each Coal System.
4. Coal Chain coordination companies 1. Coordinate operational planning, 2. Independently report on SC performance, 3. Declare critical asset availability, 4. Model system capacity, 5. Lead investment reviews across supply chains, 6. Establish and maintain system goals, process, and rules, and 7. Resource these functions via industry contributions. The coordination companies have no jurisdiction over commercial contracting between Agents and must comply with all relevant federal and state competition laws and regulations.

Conclusion

Conclusion

At the core of effective logistics and supply chain operations is the ability to synchronise the momentum of freight movements to reduce dwell and unnecessary exchanges; at the core of the Physical Internet is an Intelligent Physical Twins (IPT), which must remain central to this goal.

Observations from the research indicate that the solutions to potential PI impediments include:

1. The interoperable and interconnected capability of intelligent physical twins to transmit open-source data to digital twins; this will result in greater asset utility (use-value) and avoid manual inputs into operating systems; assets will remain a source of scarcity without this capability.
2. Definitions of asset categories and classes will establish a standard system and industry language; it will also better define a hierarchical focus for collaboration and interconnection of agents.
3. The demarcation of orientation layers will provide clarity for different industry sectors, developers and simplify overarching governance.
4. An arms-length Governance approach simplifies the path to industry acceptance whilst avoiding the commercialisation of the central elements of the PI model. It is argued that collaborative, interconnected and interoperable structures should not cross commercial boundaries.
5. Business models can evolve through autonomous IPT interactions, network economies of scale, digital transparency and accessibility to corridor links, nodes, and modes.

THE UNIVERSITY OF MELBOURNE

Thank you

Your comments and suggestions are very welcomed