Asset capability, transparency, and governance - fundamental to PI Proliferation.

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Abstract

This research focuses on identifying and overcoming potential organisational obstacles that may hinder the acceptance and adoption of the Physical Internet. While information and technology systems are well-defined, the physical system is not. Therefore, it is necessary to thoroughly describe the physical system regarding asset utility, functionality, and operational structure. A qualitative approach investigated physical assets' hierarchy, capability requirements, and organisation based ontheir significance and interdependence. These fundamental aspects are critical for synchronising assets, the flow of freight, and accessing real-time data. The literature review concluded that: 1) infrastructure and interface architecture may pose potential barriers to Physical Internet progress; 2) asset characteristics, hierarchy, and freight system orientation are essential in functional design, accurate routing, and matching capacity; and 3) a global system and standards are required for multi-user governance (See Australian Coal Chain example). The paper aims to provide practical approaches to the organisation and asset categorisation, mitigating potential obstacles to PI progression. The research will make theoretical and practical contributions to achieve this goal. Theoretical contributions include adapting the Theory of Complexity to extend its boundaries into the Service Industry by developing a physical system framework. Valuable contributions include contributing to the PI 2030 objectives of optimising network flows and nodes interconnecting across the Physical Internet.

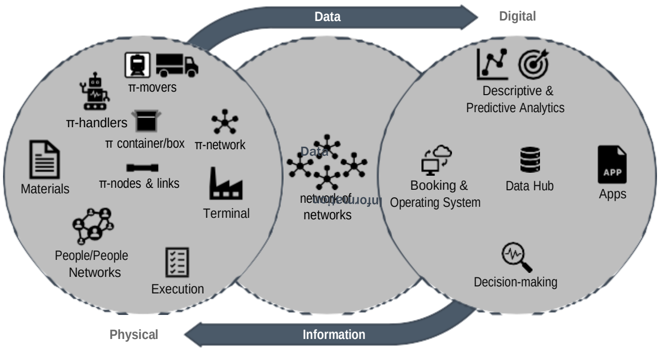
Introduction

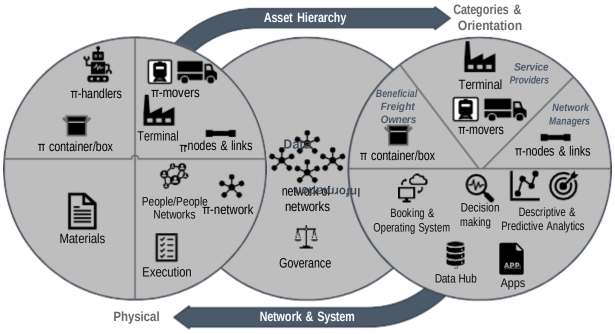
Battles over online information control are often fought at the level of the Internet infrastructure (DeNardis 2012). These arrangements of technical architecture and physical transmission are also arrangements of power. Internet Infrastructure has become a significant factor in access, control, and transparency battlelines. Even before the internet, the telegraph changed human history by separating communications from transportation over vast distances. The physical Internet has the potential to reunite communication and transportation like never before, though it may also be susceptible to similar acceptance and access barriers of the past. For this reason, the paper argues that the evolution of the Physical Internet requires an aligned emphasis on critical assets (intelligent physical assets) and key assets (operating systems). The paper focuses on the assets' hierarchy, operational orientation, and governance structure. The paper sets out to 1. Define the relative hierarchy of assets, 2. Describe PI assets and routing descriptors, 3. Delineate the semantic orientation of assets, and 4. Discuss governance examples. In this regard, the main contributions of this piece are summarised as follows.

1. Establishing a method for determining asset hierarchy,
2. Categorising and orientating the freight system; and
3. Representing governance systems in practice.

The following diagram 1.0 describes the physical vs. digital traits to provide context. However, the paper focuses on the physical asset framework described in the second diagram, 2.0. In the second diagram, the first circle groups the hierarchy of assets, which is discussed in further detail in the following section. The middle-interrelated circle is the global network of networks and governance. The third circle identifies the primary actor groups as 1. beneficial freight owners, 2. service providers and 3. network managers. All three groups are underpinned by their systems. Some actors will affiliate with all three groups, though most will only align with one. The framework establishes an asset hierarchy, descriptors, categories, orientation, and governance. These sections will be described in further detail throughout the paper.

Diagram 1.0 Physical vs. Digital Relationship ***Diagram 2.0 Physical Asset Framework***





The Relativity and Hierarchy of Assets

The internet offers transmission over the airways and lines to hosts and routers. In contrast, 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. Specifically, the characteristics of the physical product as these become Smart, Connected Product Systems (SCPS or a Physical Twin) need to be defined and described (Grieves 2019). The following diagram illustrates a method for determining the relativity of asset utility and scarcity.

Figure 1.0 Asset Relativity and Hierarchy

Degree of commercial importance	Low Readily substitutable	High Non- substitutable
High Primary activity	**Complimentary Assets** π-containers- international & domestic, π-handlers - RTGs, forklifts, reach stackers, tugs, rail vehicle placers, support assets - provisioning, maintenance facility, empty park facility, etc Low-Medium Utility	**Critical Assets** π-nodes - port gateway, terminals, hubs, DCs, fulfillment centres, warehouses, airports, etc; π-links - railways, roadways, seaways, airways, π-movers - ships, planes, trains, trucks, etc High Utility
Low Support activity	**Residual Assets** Office buildings, car parks, loading and securing equipment and materials, packaging, etc Low Utility	**Key Assets** π-protocols - rules, data structure, etc, web & systems - booking and operating systems, Vehicle Booking System, EDI links, data hubs, descriptive and predicative software, etc Medium-High Utility

Degree of operational importance

Note: Example content added to asset sections

Figure 1.0 describes the relativity of assets and sets out a method for establishing an asset hierarchy. Whilst this approach is universal, examples of assets within a corridor are used in this context. This is particularly important, as it may only be viable to describe some digital assets in a freight system, and the ones that are, will be interdependent upon other smart assets and systems. Freight is transported via critical assets, which carry out primary activities and are difficult to substitute or physically imitate. Therefore, it is contended that these assets would be the first to evolve into intelligent assets, i.e., the physical asset to be twinned. Whilst complimentary assets are also a primary activity, they are generally easier to substitute in their current design, though challenging from an intelligent π-container perspective. Therefore, current asset designs may have to evolve as the first step to intelligent tagging systems before hardware and modular software design. Key assets (systems) are becoming more significant in support of field assets and are challenging to substitute due to their path-dependent innovation; this is often the case with operating systems. A potential solution to these barriers is the PI management system (PIMS) concept, which aims to exchange relevant information, such as identifiers, dimensions, and destinations (Tran-Dang, Krommenacker et al. 2020). PI management systems will be vital to transmitting and ingesting relevant data to and from actors operating systems and logistic webs.

Significant global conglomerates own or control enormous physical asset portfolios. These service companies have considerable operational and commercial risks associated with their assets, e.g., international/domestic containers, ships, trains, trucks, planes, terminals, distribution precincts, railways, and roadways, etc. Companies may choose to exploit the utility and scarcity of assets in pursuing higher rents or greater efficiency through innovation (Cox, Ireland et al. 2001). At the core of this position of power is information asymmetry. Whilst open-source data is unavailable and assets are not interconnected, the barriers to entry remain expansive to overcome. These are challenging isolating mechanisms, as interconnected assets and access to open-source data potentially reduce market power. For PI to be successful, it's essential that critical assets can be synchronised across handover points (actor interfaces), so the that the seamless momentum of freight is maintained. This means there must be digital transparency of interconnected assets, whether linked to actors operating systems or open-source systems.

According to Porter (Porter 2008), the Internet has significantly impacted industries that previously struggled with high costs for communication, information gathering, and transactions. In contrast, transporting goods physically is still considered too expensive and harmful to the environment. There are many digital barriers and implementation obstacles, such as the need for more openness, interconnectivity and interoperability (Cichosz, Wallenburg et al. 2020). To address obstacles surrounding proprietary technology and access, three areas of further research are proposed: Firstly, standardising open-source data and access licensing through regulatory influence. Secondly, obtaining non-commercial coordination data (including critical and key assets) from third and fourth-party operators through beneficial freight owner influence. Lastly, developing business models that promote collaboration among industry players and enhance economies of scale by synchronising critical assets, using industry influence.

PI Assets and Routing s

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. The ‘physical asset’ would preferably have a power source, cyber security, computing, and remote transmission capability. Once remote visibility is achieved, data is ingested into descriptive software, which overlays the data onto a digital schematic of the assets’ design. The structured data from assets is transformed into viable information describing its state and traits. The operating systems 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. These data sources are merged to form the digital description of the asset, e.g., ship, container, crane, truck, train, stacker, terminal, warehouse, roadway, railway etc. This intelligent asset emulation is the imitation of the asset and its behaviour. It visually represents or reproduces the intellectual assets' real-time functionality, i.e., location, dimensions, the status of vital systems and provisions. Accurately describing a given asset’s state and trait is the basis for precise prediction of freight momentum.

Within 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. Once constraints are identified, optimisation and validation modelling can be used as findings for recommended actions in a specific situation. Both methods have their place in planning asset and infrastructure capacity requirements, geographical configuration, and process capability in response to external changes. Influenced by: (Redelinghuys, Basson et al. 2020).

In PI, there are four primary components: π-containers, π-nodes, π-movers, and π-protocols describing their characteristics and state. The PI network is constructed as a network of logistics based on the interconnection and interoperation of π-nodes following the standardised π-protocols for handling, transporting, and storing π-containers. The globally standardised π-containers conform to physical specifications, with informational features (e.g., identity), and in the digital network transmit data packets. In parallel, the π-nodes represent facilities such as transit centres, distribution centres, and warehouses, which are innovated to enable the smooth flow of freight (Tran-Dang and Kim 2021). Implied rather than formalised are π-links between nodes that are particularly important to π-movers. That is, π-protocols may have rules to route π-movers from the origin to the intermediate location to the destination based on average time or speed over the distance between π-nodes. However, π-movers that spend most of their time on 'links' (e.g., roadway, railway) are constrained by many infrastructure restrictions, such as axle load, length, and kinematic parameters.

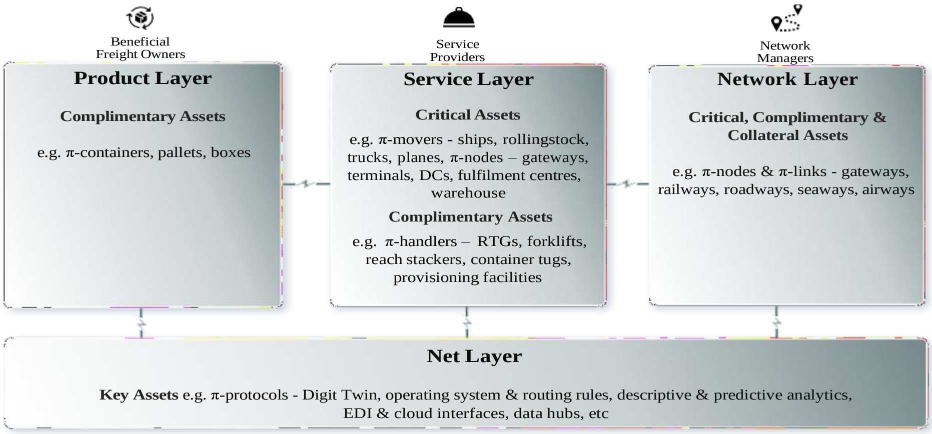
Shaikh and Montreuil's introduction to Services and Protocols for Inter-Hub Transportation in the Physical Internet opens up many research avenues for defining more setting-based parameters to improve the algorithm performance, more extensive simulation-based assessments with scenarios varying notably in terms of demand mix, patterns, and uncertainty; vehicle mix; package size mix; transit time stochasticity; hub availability, capability, and capacity; and tightness of promised delivery times (Shaikh, Montreuil et al. 2021). Generally, the parameters for roadways and railways are not included in the calling conventions and limitations of an actor's operating system. To gain a better understanding of the duty cycle and constraints that impact the level of certainty and responsiveness needed in service design, it is important to delve deeper into potential π-link characteristics. Without including these characteristics as part of the network, distance becomes a crude method for determining the time between nodes.

Whilst most agent operating systems have electronic data interchange, the origin of the data is often a hybrid between human-entered information and data ingestion. In many cases, what is shared is controlled by company policy rather than open source. Therefore, intelligent physical assets will require greater autonomy and utility to interact with various networks via APIs, programmatic applications, operating systems, and other intellectual assets for greater routing accuracy and open-source data. Greater asset capability will also reduce barriers to PI proliferation by providing a potential direct data feed of asset characteristics, spatiotemporal visibility, and diagnostic status. This, in turn, will offer greater transparency for modal synchronisation, emulation, simulation, and optimisation.

Semantic orientation of assets

Once assets can be defined in terms of criticality, and inputs defined for routing, the next logical step is to understand their orientation and categorisation within a network. The following conceptual design has been developed to categorise assets, services, and their primary orientation. Whilst this simplified approach could be universal, a national logistics context is taken for this paper. This contribution supports the ALICE goal of "standard service definitions and information sharing across actors enabling higher efficiency in the use of nodes, services and resources". The logic behind the framework is: that products are generally packaged and encapsulated within assets for handling, transportation, and storage. Beneficial freight owners (BFOs) 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. This simplified view in diagram 3.0 classifies their dimensional orientation.

Diagram 3.0 Orientation layers



Since the development of the physical internet is of a physical dimension, the asset orientation proposes four distinctive layers or categories of this dimension; the diagram starts at the smallest physical unit, linking to the largest unit, the system network, and the digital network. The approach provides vertical and horizontal synergies in four distinct functional domains to create intra-dimensional and inter-dimensional visibility across different supply chain dimensions.

1. **Product layer:** Product layers include π-containers, pallets, and boxes, which encapsulate ‘Goods.’ Products are digitally described (weight, cubic size, type - dangerous goods, priority etc.). The 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, at a more granular level, boxes are subservient to the pallets, which are subservient to their parent π-container. The term ‘Product layer’ is purposeful as it distinguishes its orientation and relationship with ‘Service Assets’; this provides a layer directly linked to the *actors of goods* rather than the *actors of services*.

2. **Service layer:** Services (E-services) have a Master ID with subservient IDs, all of which have a Network identifier within a naming convention. The Master IDs identify the π-movers origin, intermediate hub, destination, weekday, time sequence, priority, and network. The subservient IDs are linked to parent IDs, identifying π-container consignments within the service. These 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. The term ‘Service layer’ is purposeful as it distinguishes its orientation and relationship with ‘Products and Networks’; this provides a layer directly linked to the *actors of services* rather than the *actors of the goods or networks*.

3. **Network layer:** The layer is separated as this layer is generally a common user layer. That is, private actors are multi-users of the central infrastructure. Vertically or horizontally structured major infrastructure is usually subject to network access legislation. Master networks generally consist of gateway nodes, general nodes, and links within an infrastructure corridor, e.g., transcontinental, or land-based penetration lines. These networks could have a unique Master ID,

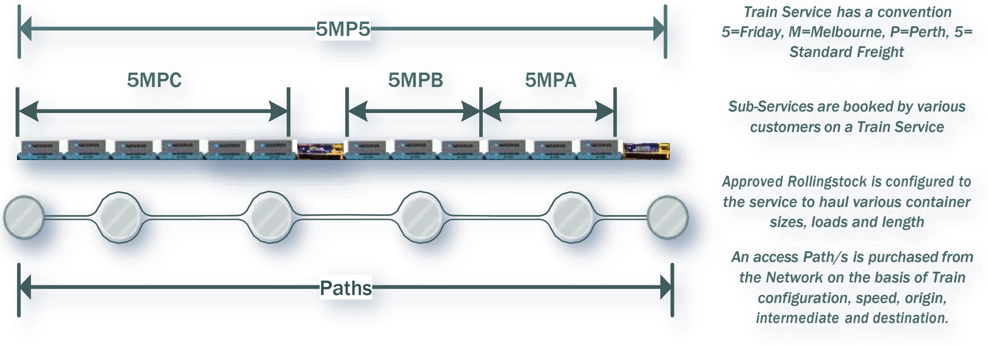
with subservient IDs for complimentary networks. Critical networks are digitally mapped via nodes and links to complimentary networks at nodal point boundaries (Interception or Tran scalar). The point of nodal interface (spatial) describes relationships between critical and complimentary networks. Each describes the infrastructure's intermodal gateway, corridor, adjoining trans-modal hubs, capacity, and capability characteristics. Services can be digitally linked to critical and complimentary networks for logistically pathing (π-routing) from origin to destination, including intermediate destinations. They include headway time, kilometres between nodes (distance), capacity (volume/load/length), and constraints (effort). The term ‘Network layer’ is purposeful as it distinguishes its orientation and relationship with ‘Services’; this provides a layer directly linked to the *actors of networks* rather than the *actors of services*.

4. **Net layer:** 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 and complimentary level. The network, E-services, and associated critical field π-assets can all be digitally linked 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, and process capability. The term ‘Net layer’ is purposeful as it distinguishes its orientation and relationship with ‘physical field assets’ within the service layer. The net layer is directly linked to external *systems, internet, and transmission networks*; the systems encapsulate software that can emulate, simulate, and optimise the product, service, and networks ‘physical field’ layers and their interrelationship.

Conventions within Layers

Within the orientation layers, actors develop service conventions that provide granular information such as the operator, nodal pairing, service type, load type, service allocation, deployment weekday, sequence of the day, and direction. A train number reporting system in railway operations provides the service description within the network. These services are mapped on train line diagrams across a network to describe the paths between nodal pairs and where services will cross or dwell against a given schedule. The following figure provides an insight into rail conventions.

Figure 2.0 Rail Convention System



Train Service has a convention 5=Friday, M=Melbourne, P=Perth, 5= Standard Freight

Sub-Services are booked by various customers on a Train Service

Approved Rollingstock is configured to the service to haul various container sizes, loads and length

An access Path/s is purchased from the Network on the basis of Train configuration, speed, origin, intermediate and destination.

Figure 2.0 represents an Australian Intermodal rail network convention, where customers book services, which are sub-sets of capacity allocation within the overall train service. The train service has Rollingstock configured within a train for a particular path from origin to destination. The point of the Illustration is that π-movers (the train) can have various configurations to match the requirements of a service and associated access requirements. Services are routed via train paths with varying capacities (nodes & links) across a rail corridor. Therefore, the system in PI terms has π-containers, π-movers, π-handlers, π-nodes, π-links, and system π-protocols within a π-network. Links being railway sections between nodes that have various constraints, such as axle loading, asset length, and kinematic dimensions.

A node is either a connection point, a redistribution point, a passing point, or a communication point in the rail network. Similarly, in the digital network, computers or devices are modems, hubs, bridges, switches, etc., which are part of a network[1]. In an Internet sense, data is transmitted from nodes that define the bi-directional flow of information packages streaming wirelessly between two communication devices. In the physical world, frictionless (digital) and friction-intense (physical) activities exist in parallel. That is, contained goods are electronically booked to services. Services are electronically booked on critical assets (π-mover), and complimentary assets (π-containers) are electronically routed from nodal origins to traverse links to nodal destinations. In contrast, the physical activity system is friction-intense with loading (π-handlers) at nodal points (π-node), crossing via seaway, railway, roadway, or airway links, to arrive for freight unloading amassment or goods atomisation at the nodal points. The distinctive difference between electronic transmission to physical transportation is that π-movers undertake the physical effort of hauling volume over distance. Routing the physical may be more challenging than routing the data packet, as the activity system has many varying functions. Kaup and Ludwig's paper proposes π-transporters as routing entities whose software representatives negotiate freight handover points in a cloud-based marketplace. They further argue that implementing such a marketplace also allows the integration of software representatives for stationary π-nodes, which contribute to their location and capacity utilisation levels for the market (Kaup, Ludwig et al. 2020). Alternatively, a straightforward method more widely adopted in routing is via nodes or potentially geofenced link-node blocks, which may be more logical regarding fixed geographic locations.

Defining asset criticality, determining inputs for routing, and establishing layering/category conventions will pave the way to more granular inputs, focus, and associated transparency. This is important, as coordination and collaboration can significantly improve effectiveness and sustainability in transitioning from individually managed supply chains to open supply networks[2].

Supply Chain Governance Case

As discussed, understanding the criticality of assets, their role, route requirements, and how they are categorised and layered within an overall network is necessary to achieve greater system granularity. However, without good governance, supply chain cooperation and collaboration are somewhat limited to contractual requirements that do not exist between all actors across the network.

Coal Chain Governance has significantly matured over the last 25 years in Australia. The same cannot be said for Intermodal and Bulk freight movement. These sectors do not generally have central coordination across multiple actors and, in most cases, have minimal system protocols. The global adoption of PI will require enormous cooperation and collaboration. It will require layers of development to calibrate the current state, explore directional and transitional options, then create a future state. Addressing members requirements, navigating stakeholder collaboration, and associated business models will eventuate in significant governance layers at a product, service, network, and digital system level. The Alliance for Logistics Innovation through Collaboration in Europe is leading collaborative efforts. ALICE is based on recognising the need for an overarching view of logistics, supply chain planning and control, in which shippers and logistics service providers collaborate closely to reach efficient logistics and supply chain operations[3]. The following insights on 'governance precedents' are included to contribute to the 'ownership and governance' initiative within the Systems and Technologies for Interconnected Logistics stream.

An overarching view on logistics, supply chain planning and coordination was recognised as a need in Australian Coal chains in the 90s. However, it was not fully realised until Industry and the Australian Competition and Consumers Commission intervened in breaking crucial impasses that the industry faced. Collaborative efforts generally broke down over gaining consensus on capacity and

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[1] https://afteracademy.com/blog/What-is-a-network-and-what-are-the-nodes-present-in-a-network

[2] https://www.etp-logistics.eu/roadmaps-3-2/global-supply-network-coordination-and-collaboration-2/

[3] https://www.etp-logistics.eu/

associated commercial compensation. Capacity alignment of the critical asset was at the centre of disagreement in all cases. As a result, several reports were commissioned, and recommendations were implemented. The following extracts provide insight into the legislative change that occurred to coordinate physical assets better logistically and across supply chains.

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. A co-located workgroup containing resources from the rail providers and DBCT port would facilitate optimising the application of resources to service DBCT port*[4].

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.

   *The ACCC notes that some progress has been made towards implementing the recommendations in the O'Donnell Review, including the commencement of a business improvement program across the supply chain, the procurement of locomotives, the **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. This complexity is primarily a function of the number of entities directly associated with it. Eight coal producers are operating across the 13 mines…In addition, there are regulatory, commercial and shareholder interfaces with the Queensland Competition Authority (QCA), ACCC, Port Corporation of Queensland (PCQ) and the State Government"[5].

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

   *Requirements of 2017 Access Undertaking (UT5), as approved by the Queensland Competition Authority (QCA), requires Capacity Assessments of each of the Central Queensland Coal Networks to be performed, ... 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.*

Following the Governments intervention, coordination groups were established with clear expectations, roles, and resourcing. They include:

1. Integrated Logistics Company (ILC). The Central coordinator will oversee and, if necessary, coordinate all activities spanning the entire coal chain. The ILC would operate under the core principles of remaining independent and encouraging cooperation between participants for the betterment of the supply chain. The ILC has an appointed board made of industry stakeholders, has a Memorandum of Understanding (MOU), and has appointed an independent coordinator.; it has a leadership team and an Integrated Logistics Centre in Mackay, QLD, and has also incorporated Integrated Logistics Company Pty Ltd[6].

2. Hunter Valley Coal Chain Coordinator is an independent body overseeing activity along the world's largest and most complex coal chain. HVCCC's purpose and vision reflect a focus and role within the evolving circumstances of the Hunter Valley Coal Chain Members.

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[4] https://ncc.gov.au/images/uploads/DeRaRrSu-008.pdf

[5] https://www.accc.gov.au/system/files/The%20ACCC%27s%20role%20in%20coal%20chain%20logistics.pdf

[6] https://www.ilco.com.au/background-of-the-ilc

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 by the agreed collective needs and contractual obligations of Producers and Service Providers. Accordingly, HVCCC’s purpose is to Independently optimise the end-to-end coal chain to serve Members’ collective needs best[7].

3. The appointment of an Independent Expert Coal Network Capacity Co by the Queensland Competition Authority. 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[8].

In summary, the 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, processes, and rules; and 7. Resource these functions via industry contributions. The coordination companies have no jurisdiction over commercial contracting between actors and must comply with all relevant federal and state competition laws and regulations. However, the coordination company structure significantly influences transparency of declared capacity, operating parameters, performance accountability, and clarity of where investment across the chain is required.

Across these Governance regimes, collaboration models vary from arms-length to prescriptive collaboration requiring significant digital transparency, interconnection, system rules, capacity declaration, and performance data. The fine line is determinations about the greater system good vs exposure of marketplace commerciality. A greater focus on factors required for synchronisation, rather than factors of commerciality, may be better suited to lowering barriers to PI entry and proliferation.

With transformational change comes disruption. This disruption could come in the form of 1. intelligent physical assets capable of providing direct computing and data transmission to open-source systems, 2. Business models that improve the economies of scale across multiple actors, 3. Greater asset and corridor transparency and accessibility to open-source networks.

Conclusion

Observations from the research indicate that the solutions to potential PI impediments include: 1. The interoperable and interconnected capability of intelligent physical assets to compute and transmit open-source data to systems that encapsulate digital twin software; this will result in greater asset utility (use-value) and avoid manual input into operating systems; asset data will remain a source of scarcity without this capability, 2. Definitions of asset categories and classes will establish a standard system and industry language and better define a hierarchical focus for collaboration and interconnection of actors, 3. The demarcation of orientation layers will provide clarity for different industry sectors and 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. 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 are Intelligent Physical Assets, which must remain central to this goal.

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[7] https://www.hvccc.com.au/about-us/

[8] http://qcaprod.australiaeast.cloudapp.azure.com/wp-content/uploads/2021/11/coal-network-capacity-co-initial-capacity-assessment-report-redacted.pdf

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