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Raising data availability and quality for improved disruption and carbon footprint management through a novel approach to primary data sharing: Virtual Watch Tower / VWT

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Abstract. The global supply chain and logistics industry is a self-organizing ecosystem consisting of numerous actors that work together to move goods from end to end. The different stakeholders involved are usually interdependent organizations, like freight forwarders, carriers, terminals, and homeland security agencies and information exchange between them is required to coordinate the activities along the individual transport chains. However, the exchange of information has often been analog, flawed, late, and incomplete.

New circumstances, like unprecedented supply chain disruptions, new regulatory requirements around greenhouse gas (GHG) emissions, and generally growing shipper expectations create an urgent need for improved data sharing between actors. New technologies, like digital platforms, networks, and architectures as well as social media, mobile, analytics, cloud, and internet of things (SMACT) have brought some improvements, but not the required holistic digital perspective required or expected. Averages and approximations are usually insufficient to close data gaps, e.g., only primary data allows for accurate GHG emission calculations. Primary data sharing is widely seen as the missing piece of the puzzle. Primary data is data from the source providing an accurate state and picture of a situation. Primary data sharing at scale requires a new form of digital collaboration.

We propose a rethink of digital collaboration as a means for broader primary private data sharing for complete end-to-end datasets and data quality, particularly focusing on the sharing of data associated with both transport plans and progress made in the respective movements of goods for more better disruption and carbon footprint management through more accurate calculations of estimated times of arrival (ETA) and GHG emissions. We introduce an example for digital collaboration in end-to-end supply chains that is focusing specifically on primary data sharing.

The new thinking around digital collaboration manifests itself in the Virtual Watch Tower / VWT initiative (www.virtualwatchtower.org). In 2022, RISE and Singapore Maritime Institute signed a collaboration agreement focused on innovation in shipping. The VWT initiative is the first collaborative project under the umbrella of this partnership. The

VWT is led by RISE, A*STAR, and VTT. VWT is a community-driven, digitally empowered initiative, a cargo owner-driven, and terminal-centric approach for improved supply chain management. It is the users themselves who co-create and co-evolve the solution that they need. The initiative aims to create a community that shapes the digital tool (VWTnet) they need to reach the required higher levels of visibility. This, through primary data sharing across the supply chain ecosystem and between actors (VWT Users) participating in individual end-to-end transports (VWT Shipments). The VWT serves as an object of research to hone the new thinking and understand the implications of its implementation.

1. Introduction – a new form of digital collaboration in supply chains

Although it is often claimed that large-scale cross-industry data sharing brings significant improvements in supply chain and logistics performance and sustainability, the level of data sharing in the industry remains rather low. In individual conversations and workshops that we have organised last year, shippers, who are the customers of the logistics and transport industry, have expressed the need for enhanced transparency and visibility along transport chains. Due to low predictability of the arrival of goods at destination, shippers suffer from high additional unplanned costs and complaints from customers. Specifically, more information about arrivals at intermediary transport nodes would allow actors in the chain to and take corrective action.

Some say that it is policies and laws like the European Union General Data Protection Regulation (GDPR) and competition laws that hamper data sharing. Others mention the contractual architecture of the trade industry. Some believe it is the lack of standards and global alignment or clarity of objectives and future use of the solutions, and again others say that the problem is that actors benefit from limited transparency and information arbitrage. All these points may be valid reasons. But more critical is another question. What changes the game?

Usually, change in the economy is triggered by changes in the ecosystem, like monetary rewards and regulation, like cost advantages, tax breaks, subsidies, and new revenue opportunities, or simply new legal requirements and restrictions. The introduction of AIS is a good example that proves the point. About 20 years ago, the maritime sector underwent a major change when the sharing of information on position, speed, and heading became legally mandatory as a safety requirement. This change resulted in higher safety standards but also created a new market for digital services leveraging AIS data. Recently, severe supply chain disruptions have become the new normal, and environmental and climate protection regulations will increasingly require the sharing of data, e.g., on greenhouse gas (GHG) emissions.

We believe that developments in the past have demonstrated that solutions are getting traction when incentives are in place, i.e., when the reward exceeds efforts and risks, or regulations come into play that force actors to develop new ways of operating. This has been confirmed by the discontinuation of TradeLens due to economic viability in 2022, but the shutdown has also indicated that the main component of such solutions is not the technology, but an inclusive approach driven by a neutral orchestrator. It is commonly accepted that events and developments like COVID-19 and climate change have created new needs that will drive the supply chain and logistics industry towards broader intra-chain and inter-chain data sharing.

In this article, we explore a new form of collaboration, namely how digital tools can be developed by a community to achieve sufficient traction and establish higher levels of situational awareness for shippers but also other actors in the chain allowing for better responses to an unprecedented frequency and magnitude of supply chain disruptions and rising

regulatory requirements in sustainability. Community building and the co-creation and co-evolution of a bespoke digital architecture are at the core of the Virtual Watch Tower / VWT initiative, aiming to improve primary data access.

2. Concepts applied to develop a novel approach

The main concern of shippers is the cost-efficient, and sustainable on time arrival of their goods at the destination. A shared situational awareness across the sometimes highly fragmented chains would make supply chains more predictable and fluid. However, this requires primary data sharing, or more specifically technical solutions and the willingness of supply chain actors to use them, which requires ease of use but more importantly, trust.

Three concepts are foundational to broader data sharing:

- Maritime Informatics
- A system-of-systems (SoS)
- Collaboration and digitalization for balanced economic and societal value creation (CDES)

Maritime informatics [5] emphasizes both, conceiving maritime operations being conducted within a self-organizing ecosystem [5], and providing an expanded viewpoint of the socio-technical nature of the maritime industry as a multi-organizational business. In the spirit of informatics, a holistic view of business practices is promoted by a focus on different system layers [5], the interdependencies between different sub-systems, and conceiving the practice of concern, e.g. the supply chain ecosystem, as a capital creation system [14]. Maritime informatics contributes to understanding how digitalization can improve the maritime industry across shippers, carriers, terminals, ports etc. Maritime informatics addresses three areas of importance to disruption and carbon footprint management [5]: digital collaboration, digital data sharing (DDS) and decision-making, as well as data analytics. Digital collaboration is the practice of collaboration by digital means, emphasizing that actors collaborate by agreeing to the conditions under which authorized sets of data are shared. The data shared forms the foundation for situational awareness established among the parties that are involved [6]. DDS, the sharing of event data is the basis for common situational awareness derived from multiple digital data streams, often reflecting events in different sub-systems dependent on other sub-systems, as a foundation for making better-informed decisions. Data analytics provides capabilities to create intelligence describing what has happened and predicts what may happen going forward. Prescriptive analytics suggest responses to specific challenges. Maritime Informatics focuses on techniques for acquiring, managing, analyzing, and visualizing maritime data. Collaborative Decision Making (CDM) is a concept guiding improvements in digital collaboration building upon the combination of multiple data sources, establishment of common situational awareness shared among involved actors, and agreements on when, what, and how to share temporal-spatial data [12].

Collaboration along the end-to-end supply chain requires an end-to-end (e2e) CDM approach. The concept of *digital collaboration* has been the foundation for a series of efforts in the field of collaborative decision-making (CDM), applied in different settings, such as for coordinated transport within aviation (A-CDM), within maritime transports for coordinated port visits (PortCDM), for coordinated railway transports passing through multiple stations and yards (RailwayCDM), and now end-to-end CDM, forming the foundation for coordinated transport of shipments across multiple nodes and modes of transports. All these different

applications of CDM promise positive effects on efficiency and sustainability in the transport industry.

A system-of-systems (SoS) is a collection of different independent, evolutionary, and distributed systems working together to achieve a common goal [3, 4]. SoS principles are increasingly used to solve large and complex problems that single systems cannot solve alone. SoS solutions are scalable so that new systems can easily be added or replace old systems becoming obsolete. It thus becomes a modular and systematic approach to managing complexities. In practice, SoS depend on orchestration mechanisms to manage and maintain the balance between different systems participating in the SoS, also taking care of so-called emergent behavior not considered during the design of the SoS and the participating systems. Maritime informatics and SoS in combination provide contextual meaning to the object of concern which should be the end-to-end transport of goods involving multiple actors in supply and logistics chains.

CDES – Collaboration and Digitalization for Economic and Societal value creation was introduced recently [7], which is a new paradigm that emphasizes that collaboration and digitalization need to work in symbiosis to advance in both areas. The assumption is that there will be no large-scale digitalization without collaboration and vice versa. We advocate that collaboration and digitalization must be mutually reinforcing to generate synergistic gains. We assume a symbiotic relationship between digitalization and collaboration. Neither can exist without the other because they co-determine economic fitness. Successful partnerships co-evolve their collaboration through cooperative digitalization to contribute to an emerging era of digital symbiosis. Consequently, we assert that all industries need to place greater emphasis on the interrelationship between collaboration (c) and digitalization (d), as this powerful duo impacts economic (e) and societal (s) success through enhancing human and social capital and preserving and restoring natural capital. Focusing only on one of both dimensions of each pair, either on collaboration or digitalization or on economic or societal value, leads to suboptimal results. A conscious, holistic approach addressing all four components of the cdes formula ensures durable wealth and well-being for humanity. In particular, the shipping industry has much to gain from a cdes approach because, as a self-organizing ecosystem, it exemplifies massive freedom of association. The new cdes paradigm, with its emphasis on digital data sharing, supports the implementation of virtual watch towers to provide situational awareness of vital assets (e.g., cargo). Collaborative planning and action across multiple watch towers, i.e. different systems, in supply chain networks can facilitate es-outputs, such as supply chain resilience and reduced transport emissions.

3. A real-life example of inclusive digital collaboration

Resulting from the severe supply chain disruptions caused by Covid-19 and significant new pressures exerted by new sustainability regulation the Virtual Watch Tower / VWT initiative was launched in February 2023. In 2022, RISE and Singapore Maritime Institute signed a collaboration agreement. In the scope of this memorandum of understanding (MoU) are those projects that are not possible to be realized without the engagement from parties on both the Nordic and the Singaporean side. The first collaborative initiative under the umbrella of this partnership is VWT, led by RISE and VTT on the Nordic side, and A*STAR on the Singaporean side. VWT was launched as a complementary testbed and space for digital primary data sharing and digital collaboration during Singapore Maritime Week 2023 and a prototype was showcased during Singapore Maritime Week 2024.

VWT's goal is to complement the set of available primary data along end-to-end supply chains. This is aimed to be achieved by establishing a community that co-develops and co-evolves a digital architecture / VWTnet. The co-creation and co-evolution approach led by a neutral orchestrator under the auspice of three national research institutes is expected to ensure adoption. The governance of the solution and data, as well as the preparation of a vehicle to carry the concept forward beyond the project period of initially two years are part of the scope and deliverables of the project. The VWT Community has started to explore two initial use cases.

- Disruption management: prediction and management of variances to transport plans and shocks to supply chains.
- Carbon footprint calculations for end-to-end supply chains.

The work on disruption management has well advanced while the second use case is still in a preliminary stage.

Figure 1 depicts the principal architecture of VWT. This Figure illustrates the foundations of VWT which is the end-to-end transport of goods as the common object of concern involving multiple actors in the supply chain. In the world of VWT everyone is related to everyone. The VWT community members share private data to improve disruption and carbon footprint management. The orchestrator is authorized to obtain data through a power-of-attorney (PoA) signed by the shippers. Analytical services provide intelligence supporting common situational awareness and collaborative decision-making.

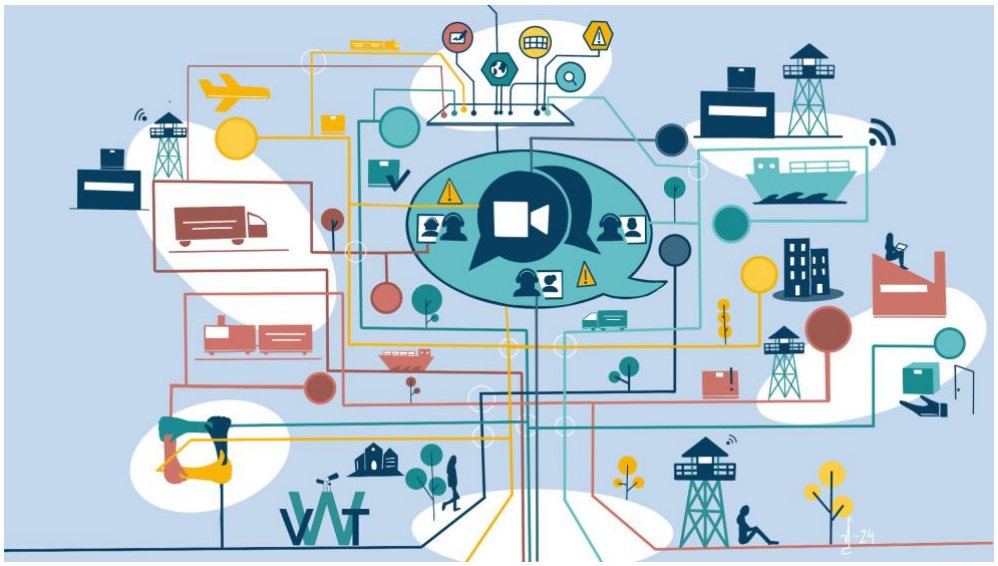

Figure 1: Principal architecture for the Virtual Watch Tower Network / VWTnet (Illustration: Sandra Haraldson)

VWT comprises, first the VWT Ecosystem of different communities, each with specific roles and responsibilities, and second VWTnet, a federated digital technology-agnostic solution designed as a public good [1] and applied on the host/member level enabling data exchanges between different VWT Ecosystem actors or VWT Users. Currently, the VWT Ecosystem consists of three types of communities: VWT Shapers, who co-define the solution, VWT Developers, who build VWTnet, and VWT Users who contribute data. The members of the VWT Ecosystem (continually growing), represent a mix of the supply chain and logistics industry, including shippers, terminal operators, and transport operators, i.e., the providers and consumers of data along transport chains, see Figure 2.

Figure 2: Current partners of VWT per July 2024

VWTnet, which can be understood as the Internet of Towers has structural and functional similarities with the traditional Internet and the Physical Internet [2], the latter exploits the digital Internet metaphor to develop a Physical Internet vision for the flow of goods. VWT enhances the capabilities of Towers, traditionally called transport management systems (TMSs) which are generally provided by commercial actors through primary data access.

4. Methodology – VWT at work, an inclusive community-driven approach

The shipper-driven and terminal-centric VWT creates economic and societal value by solving real-world problems and improving key performance indicators (KPIs) of the triangle of efficiency, reliability, and sustainability. In short, this is achieved by building a community that partners for co-creation and co-evolution of the solutions they need, applying a minimalist and distributed design approach building on the principles of action and design research [10], leveraging previous interoperability efforts (message formats and data standards), proven templates (design instruments), legal instruments (power of attorney and partnership agreements), effective rules and mechanisms data governance and organizational structures to protect and support the community and each member in the leanest and most secure possible way. Commercial actors can build upon VWTnet and offer e.g., AI-powered analytical or public data services (3rd party services).

The VWT community collaborates and co-creates in monthly Living Lab meetings, where progress made between the regular meetings and in specific workgroups is reviewed. Living labs include sprint meetings to make progress in a well-defined area. Following the Living Lab methodology [6, 8, 9, 13], the members of the community create a common understanding of how actors in supply chain networks can collaborate, define objectives for the common object of interest, identify information sharing needs, discuss incentives to share data, and conceptualize and agree collaboration principles. A Living Lab approach is a series of regular meetings and structured way commonly applied at RISE to shorten the time between idea and implementation and paves, through stakeholder buy-in the way for a successful implementation.

Decisions, including the direction of development, the invitation of new members, and the overall way of working are taken in VWT consortium meetings where each member has equal voting rights. This governance principle underlines the neutrality and inclusive nature of VWT. As trust is the foundation of data sharing, VWT was initiated by two national, state-owned, not-for-profit research institutes, Swedish RISE and A*STAR's IHPC in Singapore, safeguarding the neutrality of the orchestrator. The two initiators were later joined by Finish VTT, another

national research institute. The leadership team with representatives from the three research institutes is responsible for the day-to-day management of VWT. The geographic expansion of VWT builds on involving national research institutes as stepping-stones towards setting up complementary clusters consisting of a representative mix of supply chain actors.

5. Discussion – designing and developing a prototype

The supply chain industry has access to a broad set of solutions hinging around the concept of transport management systems (TMSs). The workflow management is well supported by the various solutions, but the willingness of primary data sharing remains challenging. VWT aims to close the gap through an inclusive and federated approach driven by a neutral orchestrator body run by three research institutes (see Figure 3).

Category	Existing solutions	VWT
Concept	Use a digital solution	Co-create a digital solution
Governance	The solution providers decide	Community shapes the solution
Focus	Digitalization	Digitalization through collaboration
Technology	The platform provider decides on the technology stack	Technology-agnostic approach, community members can contribute solutions
Core design principle	Focused on a commercially promising area	Minimalist (data, tools, governance, structure, etc.), but holistic
Digital solution	Product, mostly enterprise-grade software with broader functionalities and features	Enabler (at the core standards and protocols) of primary data pushing and collaboration (internet of towers)
Situational awareness	Track and trace building on a mix of device-driven accurate visibility or system-driven waypoint-based calculated visibility	Pushing of primary data
Approach to data sharing	Gather as much data as possible and commercialize it	Minimalist data push approach unlocked by a power-of-attorney (PoA)
Modal scope	Diverse, with many providers focusing on one or few modes of transport	Multimodal focus in end-to-end supply chain networks
Setup and architecture	Usually, a centralized system using fully controlled central infrastructure	Decentral/federated system-of system approach, using user infrastructure (no central infrastructure exists)
Control	Data is temporarily stored, e.g. three or six months; analytics are performed in a central component	The user stores the data and has full control; analytics are performed at user level
Data storage location	Centralized storage by the platform owner	Distributed storage by users
Core features	Diverse, including workflow management, visibility, alerts to solve specific problems in the chain	Primary data access: visibility, alerts, and pop-up situation rooms to improve the KPI triangle of efficiency, reliability, and sustainability
Offer	Broad range of services and features	Narrow: data pushing mechanism, minimalist tower

Disruption management	Generate alerts (descriptive, predictive) and prescriptive analytics (suggesting solutions)	Generating visibility and alerts for collaborative action
CO2e emissions	Focus on calculating CO2e emissions	Focus on primary CO2e data for more accurate calculations
Positioning	New solution to fill a gap or replace existing products	Complements existing solutions
Adoption of the solution	Marketing and sales push	Organic growth through community building and adoption through co-evolution
Incentive to participate	Relevant and competitive offering	Membership to a co-creating community
System ownership	Owned by individual usually commercial parties with vested interest	Co-created public good backed by neutral parties, such as research institutes

Figure 3: Factors differentiation VWT from existing solutions

While VWT is well-differentiated from traditional TMSs and other digital solutions, it shows similarities in design with some architectures, like IOTA's TLIP. The Trade Logistics Information Pipeline / TLIP, a collaborative infrastructure for the secure exchange of data and documents was launched as a response to the same challenges as the VWT initiative; "To facilitate sustainable trade by creating a neutral, open, collaborative, trusted and interoperable digital ecosystem" [16]. A closely related movement, building on similar foundations as TLIP and VWT, is International Data Spaces (IDS) that also has applications in transport management. In the development of VWTnet, IDS isan additional source of inspiration [15].

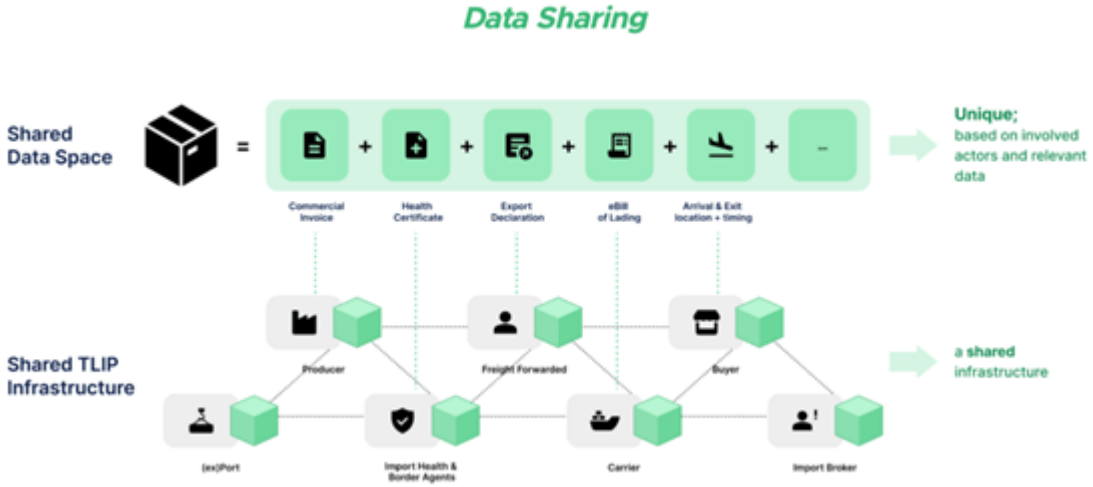

Figure 4: data sharing explained [11]

Each actor has access to a TLIP node that abstracts away the complexity of securing data integrity, data sovereignty, and permission management (Figure 5). Thus, allowing these actors to build unique data spaces for consignments, shipments, or products where each stakeholder might hold different parts of the information of the lifecycle (Figure 4).

Relevant architectures for similar purposes compared to VWT, such as TLIP, will be diligently studied when building the VWTnet solution.

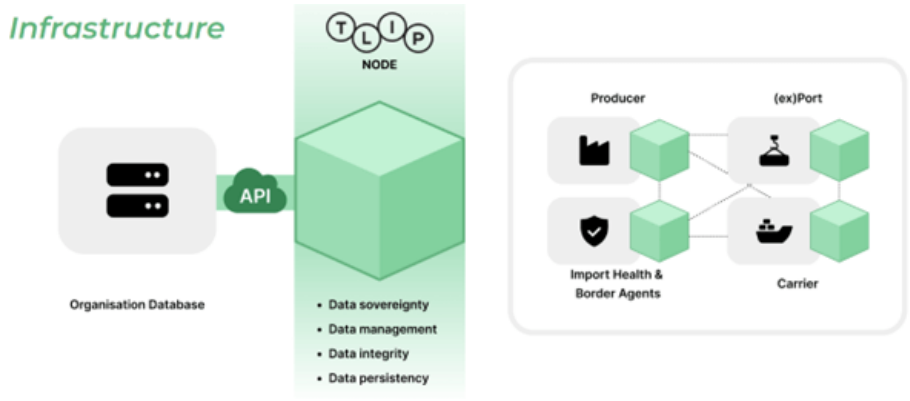

Figure 5: Infrastructure explained. Each actor has access to a node, either own node or a community node for smaller actors, that can convey trusted data between siloed organisational databases [11]

Currently, the VWT Community is building a version of VWTnet based on the TLIP architecture as the vehicle to provide access to primary data.

The jury is out on whether VWT can live up to the expectations and become the breakthrough initiative in digital primary data sharing. But enthusiasm among the VWT Ecosystem members persists and the project is on plan. The VWT milestone plan and progress report is captured in Figure 6.

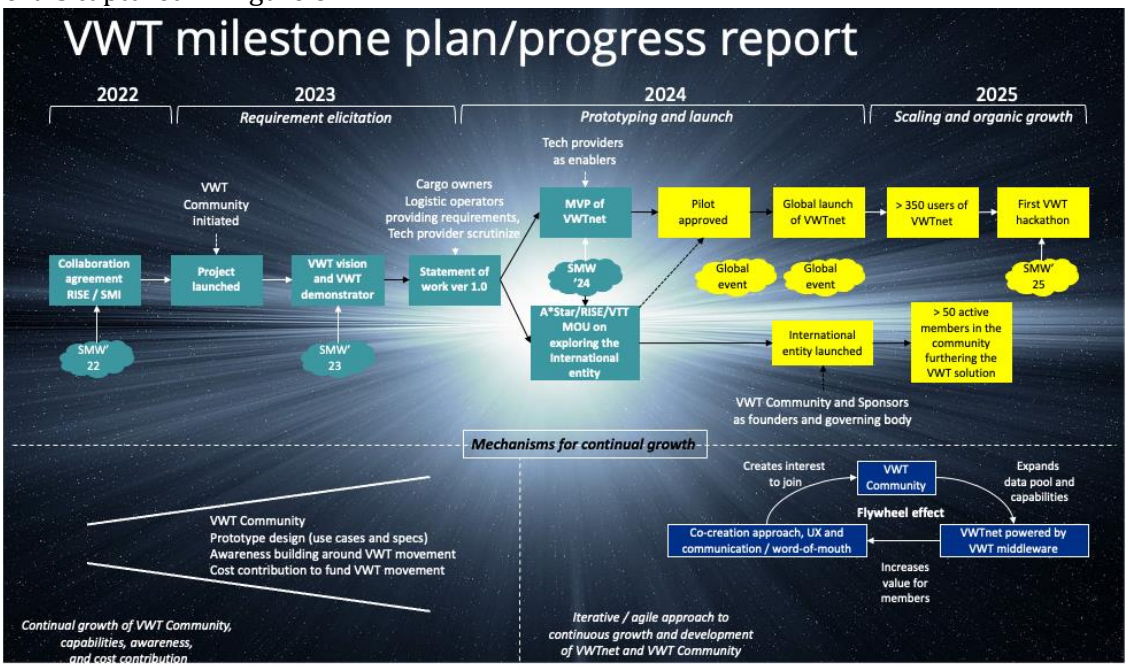

Figure 6: The VWT milestone plan and the main mechanisms for continual growth.

Success will depend on the ability to scale the community and leverage existing digital tools possibly converging development efforts and ecosystems that exist across the supply chain and logistics industry. We are observing a proliferation of developments for example in trade and transport facilitation and management tools which overwhelm the users and hinder adoption. While there will always be multiple solutions, each of the winners needs a critical mass of users and service providers. VWT is designed as an ever-evolving two-sided marketplace bringing users and service providers together.

6. Conclusion and future work

Considering the major challenges the supply chain and logistics sector is facing, primary data sharing is a prerequisite for continuous success. Without it the industry will not be able to respond to the expectations and requests of their stakeholders. VWT is a novel approach to cut through the conundrum of protecting own interests while solving common problems.

VWT represents a new form of collaboration between actors in the end-to-end supply chain and logistics ecosystem. This collaboration needs to be orchestrated to maintain the balance between actors, situations, and scenarios in the ecosystem. A venue for further research within the VWT community is the need for different types of orchestration mechanisms to manage the inherit dynamic behaviors and complexities across the ecosystem.

The initial project ends at the beginning of 2025. Then, the effort needs to be carried on by subsequent action. While driving the work on furthering the prototype the team is working on establishing the setup that guarantees the future of research and development around a solution that creates not only economic but also societal capital.

Acknowledgement

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