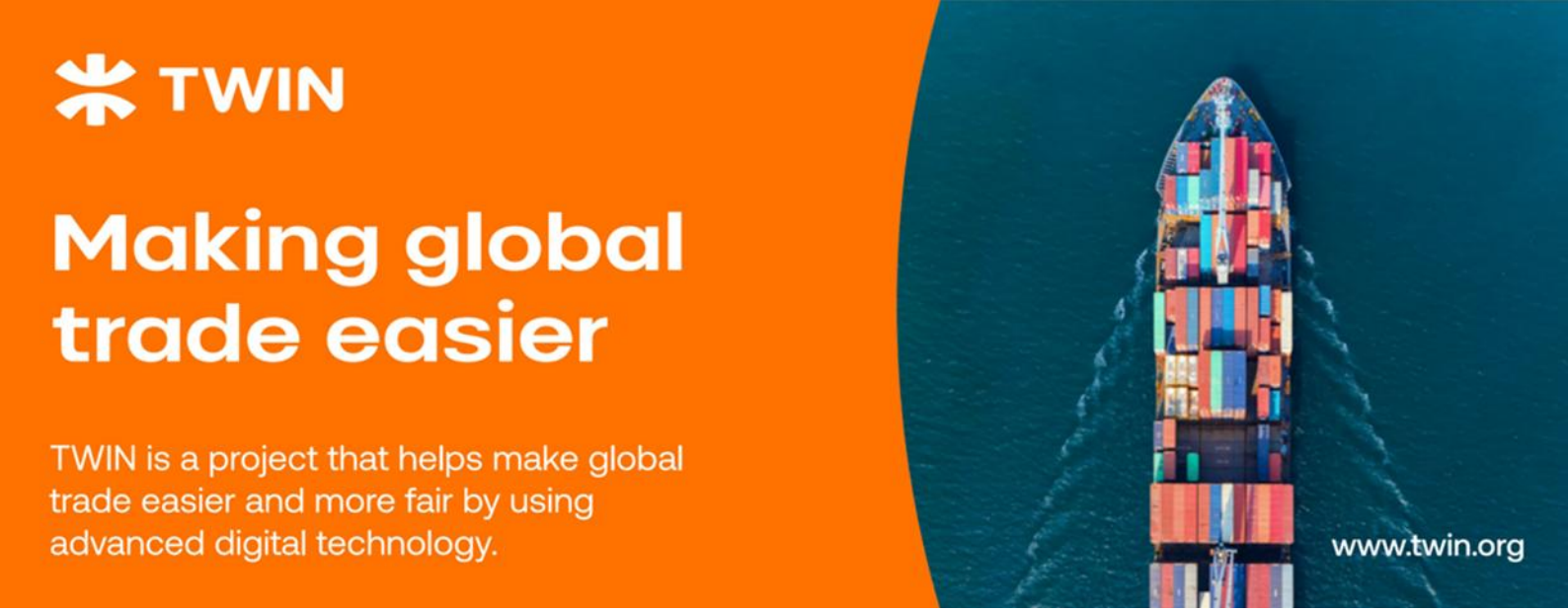

TWIN RESEARCH PAPER

Prepared for Africa Trade Development Forum, Kigali, Dec 2-3, 2024

Version 1 – November 2024

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EXECUTIVE SUMMARY

Global trade, essential to the world economy, is hindered by outdated, paper-driven systems generating 4 billion documents annually. This bureaucracy inflates costs, delays shipments, and restricts businesses. To meet global economic demands, trade must become digital.

In Africa, trade is crucial for economic development but is underperforming due to various challenges. The continent's share of global trade has dropped significantly, and intra-continental trade remains below 5% of its potential. Non-tariff barriers, exacerbated by bureaucracy, triple the average import tariff on the continent.
Only 14% of African trade occurs within the continent, compared to 59% in Asia and 68% in Europe. The African Continental Free Trade Area (AfCFTA) combined with technology could greatly enhance African trade. Technology can address inefficiencies and barriers that impede cross-border commerce.

Blockchain and distributed ledger technology simplify and secure trade transactions, reducing delays and costs. In Kenya, a consortium developed the Trade Logistics Information Pipeline (TLIP), streamlining trade processes and enhancing efficiency. Early trials indicate TLIP could cut some trade costs by up to 20%, improve data transparency, reduce fraud risks, and boost access to finance.

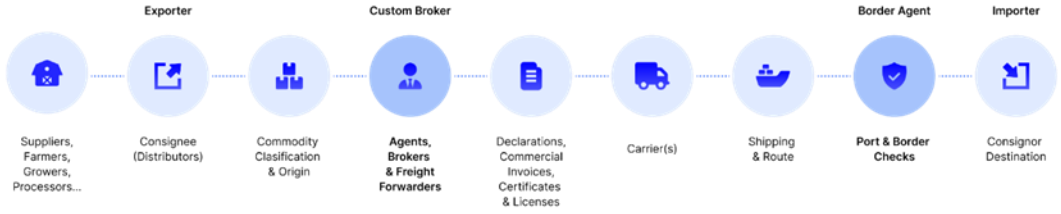
Following this success, the Trade Worldwide Information Network (TWIN) was launched as an open-source, low-cost digital infrastructure. The nonprofit TWIN Foundation, set up by six international trade-facilitation partners, will govern and provide expertise to enhance trade capabilities. It aims to support countries with cutting-edge technologies, ensuring smooth integration and connectivity across borders.

Jens Munch Lund-Nielsen
Head of Global Trade & Supply Chain
IOTA Foundation

1. The Problem of Paper-based Trade

Global trade is a crucial component of the world economy, yet its true potential is often hampered by an outdated, paper-based system. Each year, 4 billion paper documents are produced to facilitate trade, but this overwhelming volume of paperwork can create significant obstacles alongside opportunities.

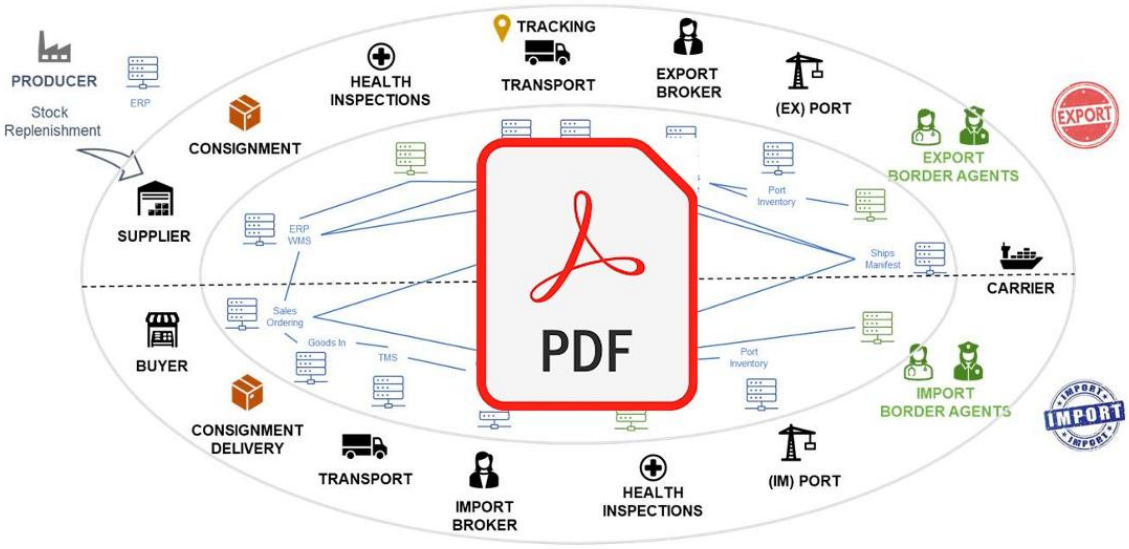
The international trade ecosystem involves multiple stakeholders operating in various roles, including buyers, sellers, exporters, importers, consignors, distributors, retailers, border agents, health inspectors, and market surveillance authorities. Additionally, the system encompasses numerous procedures and regulations, as well as the exchange of diverse documents such as invoices, import/export declarations, phytosanitary certificates, bills of lading, digital product passports, and business process data.



Pic 1: complex network of actors needs to exchange and process a wealth of supply chain information

The prevailing approach of sharing paper documents or PDF emails introduces inefficiencies and risks related to document delays, loss, or alteration. Furthermore, when goods undergo multiple transfers or resales, proving their origin becomes increasingly challenging. Government digital infrastructures, such as Single Window Systems, often managed by third-party technology vendors, have made initial strides toward addressing trade digitization issues. However, these systems impose the cost of trusting a single, centralized solution that guarantees data integrity and proper management. They also present a single point of failure.

Single Window Systems are designed for document exchanges with specific governments in individual countries. However, international trade requires interaction with multiple countries and customs agents, forwarders, and transporters, leading to the need to interface with numerous systems and processes. It is unrealistic to expect all global value chains to adopt the same system or vendor, creating resistance among actors—especially when requested data contains sensitive information such as value-related data or trade volumes. Concentrating too much power in a single infrastructure provider makes it an attractive target for malicious actors. Additionally, integrating different digital systems into one proprietary infrastructure without well-defined open standards risks vendor lock-in.



Pic 2 Information interoperability in today's supply chain is largely achieved through emailed PDFs

Moreover, most supply chains are not linear; they consist of varied materials (e.g., the automotive sector includes metals, plastics, and textiles). Even though these supply chain systems are siloed, global trade ecosystems intersect them at multiple points. Consequently, actors must gather data from different parties, increasing complexities related to data verification, authorization, and authentication. This is critical for both government entities (such as border control agencies and market surveillance authorities) and businesses (including customs brokers, freight forwarders, carriers, ports, manufacturers, and recyclers).

As a result, trade becomes more costly, complex, and time-consuming than necessary. A single transaction can cost up to $80,000, involve 27 documents, and take two to three months[1]. These costs are particularly burdensome in regions like Africa[2], where bureaucracy often excludes dynamic small and medium-sized enterprises (SMEs) from participating in trade altogether.

1.2 PDF's are 'Interoperable' But Only Pseudo-Digital

Trade documents are shared in various formats, including Word, Excel, PDFs, XML, and JSON. They are often exchanged through emails and printed copies. While digital exchange exists, upgrades are needed to ensure trust and faster data processing.

[1] https://www.dsi.iccwbo.org/_files/ugd/0b6be5_9a983b7c954d49389dd25a54033bcf78.pdf
[2] https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/African%20Development%20Report%202010%5FCH%201.pdf

Today's supply chains and border management depend on printed originals with signed and stamped verifications. However, the current digital model cannot verify document authenticity or ownership, such as Certificates of Origin or Commercial Invoices. Additionally, it cannot transfer document ownership per the UNCITRAL Model Law on Electronic Transferable Records (MLETR), which is being adopted globally for trade digitisation.

Picture 3: PDFs are a *copy* of the original document or certificate

The **UNCITRAL Model Law on Electronic Transferable Records** (**"MLETR"**) is a uniform model law that has been adopted by the United Nations Commission on International Trade Law (UNCITRAL) in 2017. Its scope is to allow the use of transferable documents and instruments in electronic form. Transferable documents and instruments typically include bills of lading, warehouse receipts, bills of exchange, promissory notes and cheques. National law qualifies a document or instrument as transferable. Transferable documents and instruments allow to request delivery of goods and payment of a sum of money based on possession of the document or instrument. However, it has been difficult to reproduce the notion of possession, which has to do with control over tangible goods, in an electronic environment. The MLETR addresses that legal gap.

Under the MLETR each dematerialised document does not need to be managed in a separate information system, but the same system could manage multiple documents, or also all documents related to a business transactions. This may allow to merge logistics and supply chain, or even commercial and regulatory documents, in a single electronic transferable record.

2. Foundations of Digital Transformation

To be able to replace official printed documents and certificates with digital solutions, a number or design requirements must be fulfilled:

1. **Accessibility**: All organisations regardless of their technical maturity must be able to participate in the digital supply chain, and actors must be able to "opt out" and continue with existing legacy processes.

2. **Trusted** – and independently verifiable: Digital records must be trusted to a level greater than their equivalent paper based signed and stamped documents

3. **Interoperable**: Information must be accessible by all stakeholders including government agencies, small traders and larger players.

4. **Decentralised data control and security:** Control of own data must be equal or better then current practice, where actors hold own document and only share with relevant business partners.

3. TWIN – Trade Worldwide Information Network

The Trade Worldwide Information Network is a digital infrastructure that allow all actors to build digital TWIN's of consignments, shipments and products. TWIN does not replace but complements existing digital systems (siloes), enabling them (in an **evolutive** fashion) to participate in a **wider ecosystem** without compromising data integrity and sovereignty.

The *TWIN* approach and suitability has already been tested and evaluated (TLIP Project in Kenya) against the use case of digitizing consignment certificates in East Africa. Alongside the direct benefit of increasing speed and reducing error of cross-border goods movement, TLIP brings the indirect benefit of creating touch-free information and document sharing. TLIP has been primarily focused on B2G and G2G processes - e.g. all interactions with government and border agencies, but with the potential of seamless integration with private sector platforms of choice through interoperable, open interfaces and open source connectors.

From a technology viewpoint, TWIN aims at improving the efficiency, transparency, interoperability and trust of value chain ecosystems, namely international trade, by means of digitalisation of processes using *Digital Twins, Gaia-X / IDSA Dataspaces, decentralized technologies -Distributed Ledger, Decentralised Storage, Decentralised Identity and Verifiable Credentials*- and associated open APIs and formats based

on open software standards and the recommendations of global trade and economic intergovernmental organizations.

3.1 Main Technical Design Principles

The main technical design principles that guide the TWIN Reference Architecture are:

- **Interoperability** In order to guarantee mainstream adoption "Powered by TWIN" systems and solutions must be interoperable. That way, TWIN value chain ecosystems can grow quickly and smoothly without incurring high integration costs, stimulating participation and removing entry barriers. Interoperability requires addressing the architecture, protocol, payload and policy aspects of TWIN as a software product, in alignment with relevant standards (see below).

- **Data at the source**: TWIN aims at interworking with existing systems, instead of creating new ones, and facilitating their expansion by integrating off-the-shelf software components and libraries that expose standardised open APIs. As a result, exchange or sharing of existing data, rather than creation of new copies of them, can be achieved. Use of distributed ledger technologies guarantee that exchanged data remains immutable and their source verified, thus increasing accountability and minimizing mistakes and frauds.

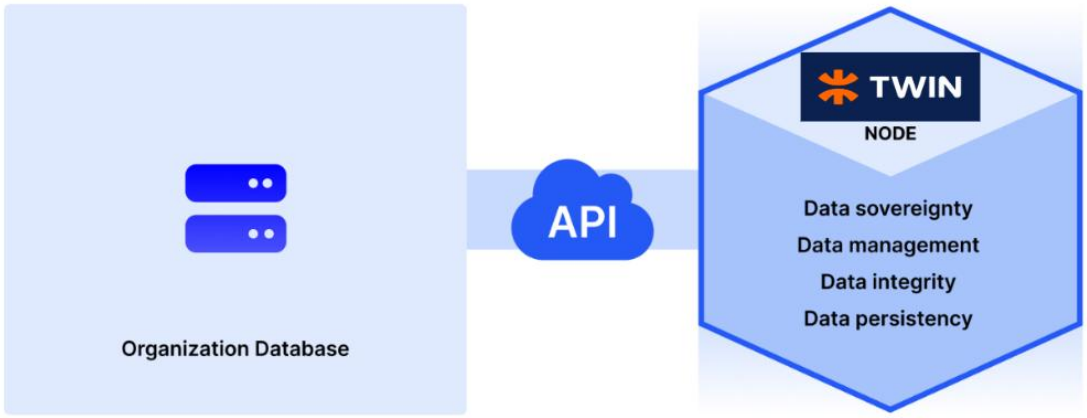
- **Data owner controls access**: It shall be guaranteed that Data Providers have direct control (data sovereignty) on who can access the data they share (and for which purpose), thus enforcing privacy and confidentiality. There are no central actors (i.e., platform owners) with privileged positions. Data Providers can start new relationships (data sharing / exchange) at their own will and thus create an attractive market for solution providers to compete on providing new services.

- **Confidentiality and Privacy**: It shall be ensured data is secure and can only get accessed by the rightful parties on a need basis. Additionally, there should be assurance that the data about value chains, which organizations expose publicly through the ecosystem, cannot be used by other parties (for instance competitors) to their own advantage.

- **Decentralized Data/Document Sharing and Verification**: In accordance with the general principles of decentralized technology, the sharing of data/documents among stakeholders and the subsequent verification of its authenticity and integrity shall be achieved without any man in the middle. Participants shall be able to discover other Participants, and share, exchange and verify data/documents among them, without the intervention of a central, privileged organization or intermediary.

- **Data Minimization & Selective Disclosure**. When it comes to Data/document sharing, it shall be feasible to expose only the minimal amount of data really needed by other trade and supply chain Participants, for instance by enabling selective disclosure at fine granularity levels.
- **Open-Closed alignment with international standards**. For the sake of interoperability, TWIN does not intend to create a new standard but to adopt existing and relevant ones while leaving the door open for extension. On the digital twin representation side of things, TWIN endorses, among others, UN/CEFACT Vocabulary, GS1 Web Vocabulary and schema.org, while being ready to support other Vocabularies following JSON-LD, Linked Data, principles. On the supply chain visibility side of things GS1 EPCIS 2.0, which is extensible by definition. Concerning Digital Identity, the W3C standards, and finally, on the Dataspace / Ecosystem aspects, Gaia-X and International Dataspaces Reference Architecture Model.

The above complexities have been abstracted as capabilities into a TWIN Node, making it easy for all organisations to participate in the network and use its capabilities.



Pic 4: Organisations can connect legacy system with a TWIN node through standard APIs

Each organization will have own database system storing documents and data locally or in their own cloud. Access is available through **TWIN APIs**, with encryption for security. Data will stay within the organization's database for full data sovereignty. However, it can be granularly consumed by permissioned trusted partners. Data is not stored in a central system but in a **fully decentralised network**.

TWIN nodes are built on the **IOTA mainnet**, where hashes of electronic copies of documents are kept for integrity reasons. TWIN also employs **IOTA's Identity Framework** for identity management, regulating access, and verifying document sources.

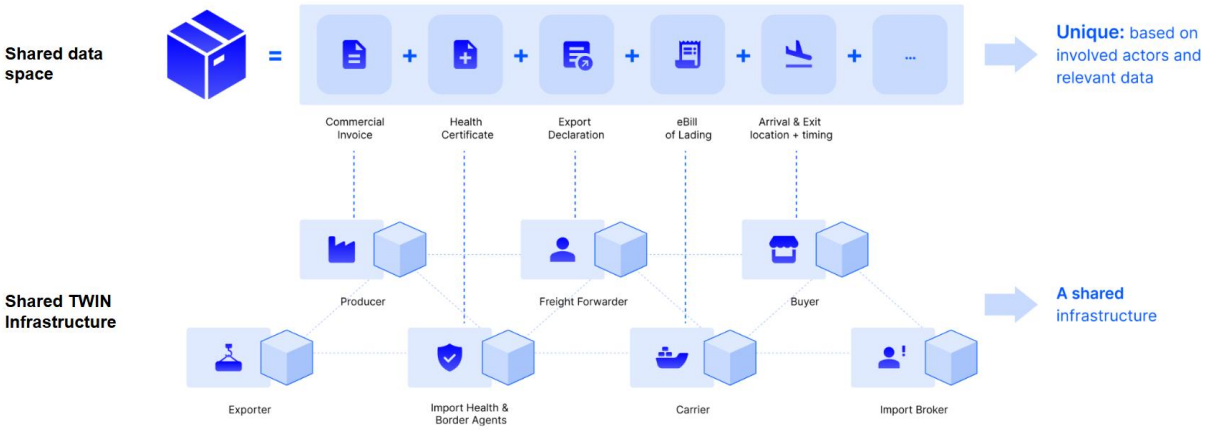
Permission policies and **encryption** ensures that access to data and documents are fully under the control of the owners. TWIN nodes can be easily set up in the cloud or on premise in the organization's own hardware.

The infrastructure is decentralized, requiring each participant to operate a TWIN node, which includes local APIs and an imbedded IOTA node instance. These nodes are interconnected and, given permission, can undertake search discovery and communications.

Third parties not directly integrated with a TWIN Node can connect through a TWIN Community Node and a web-based application, making the network accessible for smaller actors as well.

3.2 Data sharing with TWIN

TWIN allows trade actors to independently manage their data and permissions, enhancing data privacy and control, while building a shared data repository for each shipment and product..



Pic 5: Illustration of how the shared TWIN infrastructure allows ecosystem players to build unique data spaces (digital twin's) of a consignment.

4. TLIP in Kenya – using the TWIN technology

A first version of this architecture was built and tested in Kenya with a larger group of industry and government agencies, lead by Kenya Revenue Authorities and Trademark Africa. It is named the Trade Logistics Information Pipeline (www.tlip.io)

Initial focus was on the flower industry but ensuring all necessary elements to develop TLIP for all commodities and trade lanes.

Example of a user journey for flower export

Flowers consignments from Kenya to Holland are generally initiated when an importer places an order to a local farmer (i.e., the exporter). The exporter then generates an invoice for the importer. Once the invoice is accepted, the importer generates a letter of credit and the preparation of the consignment by the exporter can start.

Using the generated commercial invoice, the exporter registers the consignment on the Single Window System (SWS), a centralized service managed by KENTRADE. As a result, a Unique Consignment Reference Number (UCR) is generated.

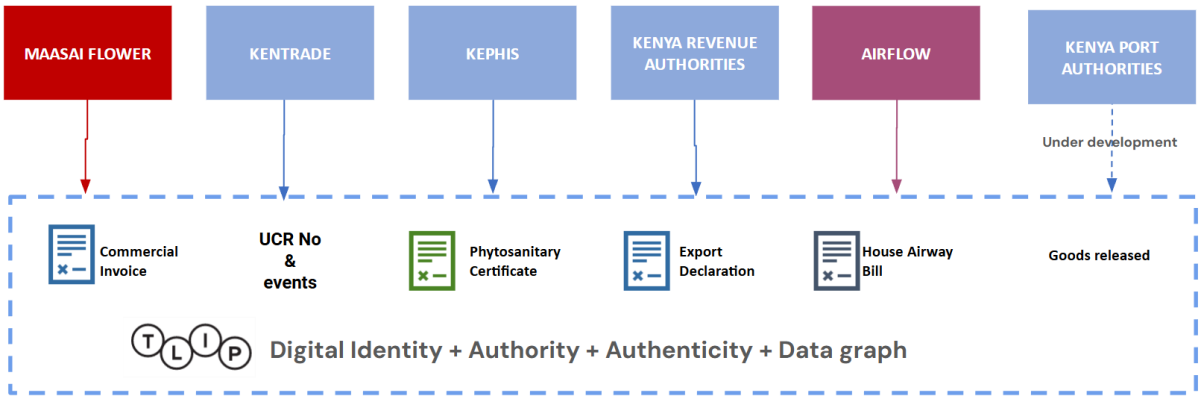
This number is used by the exporter, the importer and any assisting agent/involved authority to reference and aggregate all the documents required for the given consignment.

Generation of the required documents is the result of an interaction between the exporter with a number of other stakeholders.

This includes:

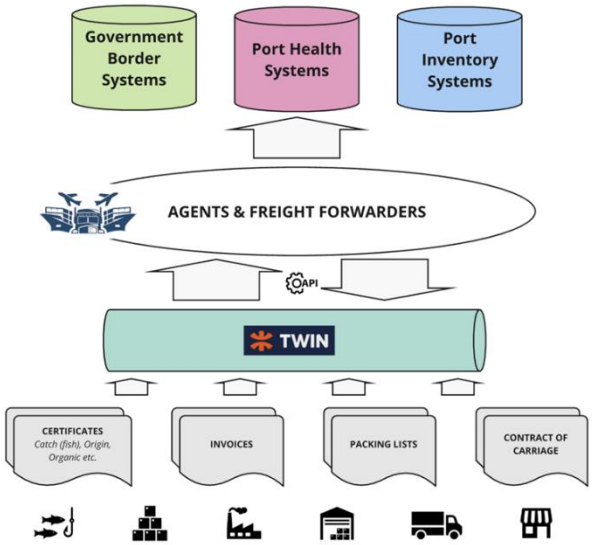
- *Export Certificate (EC),* released by the Horticulture Directorate Office (HCD) and stating the right to export of the exporter;
- *Phytosanitary Certificate (Phyto),* provided by Kenya Plant Health Inspectorate Service (KEPHIS) and confirming that all plants products are in conformity with the requirement of the importing country;
- *Export Declaration (ED),* generated by the Kenya Revenue Authority (KRA) and required by the local customs authorities for processing the export;
- *Certificate of Origin (CoO),* provided by KRA and required by the cross-border customs authorities to process the import.

Using the TLIP platform and underlying infrastructure, exporters can connect to the other stakeholders, to collect and accordingly share these documents. Nodes has been setup with all core border agencies including Kentrade, KEPHIS, and KRA and a web-based interface has been built for traders, transporters and others to access the information.



Today, the system works across all commodities and all registered traders in Kenya can access these documents with their KRA PIN number. The system has not been officially launched yet, as a key security component is still under discussion with KRA, on verifying the ownership of the KRA PIN number, to ensure only authenticated actors can access. Furthermore, dialogues have been initiated with other authorities to onboard including Kenya Ports Authorities as well as Kenya based freight forwarders and international transporters, such as Kenyan Airways

5. TWIN in the United Kingdom



When the UK left the EU customs union, single market, and VAT area in January 2021, the opportunity arose for the UK to create one of the world's most advanced digital trade borders. Faced with a significant increase in the administrative and regulatory requirements for moving goods between the UK and the EU, both sides are developing ways of managing the new complexities of trade administration efficiently. The UK's Electronic Trade Documents Act enables legal recognition of electronic forms of trade documents, while the EU's Entry & Exit System will digitize border crossings by non-EU nationals.

With £450 billion in goods imported into the UK from the EU in 2023, advancements in digital trade infrastructure are crucial to simplify the regulatory environment and

optimize trade procedures. In collaboration with UK Cabinet Office, HMRC, Border Force and DEFRA, trails with flowers, coffee, fish, and poultry have been conducted using the TWIN infrastructure. These trials were initial part of a programme named “Ecosystem of Trust” and has lately been continued under the BTD (Border Trade Demonstrators) programme. These efforts have been led by the *Chartered Institute for Export & International Trade* bringing together a consortium of +40 industry players including companies like DFDS, Nomad Foods and MCP, all representing leading players in their industries.

Trials are ongoing and the feedback from both industry and government agencies are overwhelmingly positive, with the understanding that a digital transformation of existing practices can be time consuming. Recent blogpost of efforts can be view here (June 20th 2024)

6. TWIN Ecosystem

Proving the flexibility of the TWIN technology, a growing number of consortiums and use cases are starting to use the technology, establishing an ecosystem around TWIN. As these efforts grow, the advantage of the technology is that all these ecosystems are immediately interoperable.

As of November 2024, the following ecosystems are deploying on TWIN;

#	PROJECT NAME	DESCRIPTION	LEAD ORG	CORE PARTNERS
1	TLIP	Focus on creating a paperless border for import/ export in Kenya. Making all relevant trade documents available as digital verifiable credentials for consignments to traders and industry. Integration is done with KRA, KEPHIS, and Kentrade. Additional efforts to onboard KPA and additional Kenyan border agencies. Test has included flowers, coffee, tea, vegetables. www.tlip.io	TMA, IOTA	KRA, KENTRADE, KEPHIS,
2	SPS - East Africa	G2G exchange of ePhyto certificate for EAC region. Engaging SPS agencies in Rwanda, Uganda and Tanzania to setup an infrastructure for G2G exchange of ePhyto Certificates	TMA, IOTA, KEPHIS	KEPHIS, EAC, Regional governments
3	UK TRADE CORRIDORS	Establish digital trade corridors to/from the UK - enabling industry to digitally coordinate trade efforts + establish digital connections with border agencies. Running multiple pilots with UK government agencies + industry players	CIOE&IT, IOTA, UK Cabinet Office	TETA, MCP, DEFRA, HMRC, FSA, DFDS, MOBIUS, ...

4	Virtual Watchtower Network	The virtual watch tower (VWT) is a networked system-of-systems solution built, used, and governed by a community connected through a digital middleware linking the "VWTs" of the different community members to drive collective intelligence and collaboration across global supply chain networks for better supply chain risk and disruption management. https://virtualwatchtower.org	RISE University (Sweden), A*Star University (Singapore), VTT (Finland)	Industry consortium including Transporeon, PSA, IKEA, MSC, H&M, Hamburg Port Authorities, ...
5	RESULD	Responsible Supply Chains and Logistics Due Diligence (RESULD). RESULD aims to tackle barriers in global trade that stem from paper-based cross-border processes. It will do so by digitising end-to-end fruit and vegetable supply chains between Kenya, the Netherlands, and the United Kingdom.	Docklab, Rotterdam school of Management, Port of Rotterdam	GroentenFruit Huis (Fresh Produce Centre), CargoLedger, Annona, Wageningen University & Research, and Windesheim University of Applied Science and the IOTA Foundation
6	MiSSION	The research project MISSION (MaritIme juSt in time optimiSatION) focuses on developing a communication and logistics platform to optimize maritime traffic, thereby avoiding congestion outside ports and reducing unnecessary high fuel consumption. https://missionproject.eu	SDU University (Denmark)	DFDS, IOTA, + 28 other partners
7	UAE regulatory sandbox	Testing the use of Token-based Identities for corporates for KYC/KYB in relation to trade finance solutions. https://www.tradetechglobal.org	WEF (tradeTech), IOTA	UAE Ministry of trade, ADGM,
8	Smart Food chain	MINIMIZE WASTE IN FOOD SUPPLY: Developing and implementing effective smart packaging technologies to restructure conventional food supply chains. Website.	AIPIA (Active & Intelligent Packing Industry Association)	Tetrapak, Digimarc, Zebra Technologies, T-system, ++

7. TWIN Foundation

A group of international partners has come together to support the development of TWIN that was conceptualised by the IOTA Foundation and TradeMark Africa (TMA). This TWIN partner support group – that is expanding – is comprised of the initial two founding organisations, the World Economic Forum (WEF), The Global Alliance for Trade Facilitation (GATF), Tony Blair Institute for Global Change (TBI), and the Chartered Institute of Export and International Trade (IOE). This like-minded group has worked together with the objective of further developing TWIN as a tool to improve and grow global trade.

The impact hypothesis is that trade can be made more efficient, transparent, predictable, and equitable by using current, emerging, and future digitalisation technology to build a TWIN digital trade networks which seamlessly link actors across the world. TWIN also is a framework - in the form of the *TWIN Foundation* - that will facilitate institutional, national, regional, and global actors to come together to co-create a global network for trade enabled by information technology, a Global Trade Network. The Institute is being established as a non-commercial entity acting in the public interest (or public good), akin to the internet**.** TWIN also operates as a service in that it is the digital infrastructure that provides the core digital backbone enabling institutions, firms, countries, and regions across the world to connect, coordinate, interface, and integrate their trade and logistics activities. Finally, TWIN is also software, it is the base source-code and related digital material developed that will continue to be developed. Currently, it is based on Distributed Ledger Technologies (the IOTA Tangle Platform). In future it may develop to include Artificial Intelligence and other emerging information technologies.

The **Vison Statement** agreed by the partner group is

> '''*To make trade seamless - more efficient, transparent, sustainable, and predictable - through establishing an open digital infrastructure for greater global connectivity, integration, and access*''

The **Mission Statement**

"To continuously re-imagine and innovate an open and trusted, and efficient global digital trade infrastructure - founded on international standards - that is secure, impartial, and interoperable"

Supporting TWIN Foundation's vision are five core **Values**, which are:

1. *Neutrality* - no political, socio-economic, or geopolitical inclinations or associations.
2. *Not-for-profit* – while ensuring its own institutional sustainability, the Institute will adopt a non-profit based approach to supporting both non-profit and for-profit ecosystem builders.
3. *Trust and Transparency* – the Institute will organise and manage the agenda of global trade connectivity in a transparent and accountable manner to stakeholders and the global trade community.

4. *Open Access* – the use of the TLIP technology will be open access to all users, much as Linux operates; and
5. *Living the Information Age* – the Institute will be driven by the desire to identify and address global trade and logistics challenges using digital and automation technologies.

The TWIN Foundation is driven by impact targets and has set out several **key results:**

a) Reducing the time and associated costs to trade across borders and across the world.

Metrics of Success:

- Trade transactions time duration lifecycle; and
- Trade transaction compliance and time-based costs.

b) Reducing the dependency and reliance on paper-based and manual systems to trade across borders and across the world.

Metrics of Success:

- Number of digital documents used in end-to-end trade transactions.
- Ratio of digital documents to paper documents; and
- Number of automated services used in end-to-end trade transactions.

c) Increasing TWIN's global footprint through onboarding and supporting TWIN Ecosystem Builders.

Metrics of Success:

- Number of TWIN Ecosystem Builders.
- Number of countries and geographies covered by TWIN.
- Number of Global Value Chains and Supply Chains covered by TWIN; and
- Number of public and private entities onboarded in TWIN Ecosystems.

d) Building strategic partnerships and alliances with actors within and outside the trade and logistics ecosystem

Metrics of Success:

- Number of strategic partnerships and alliances effected; and
- Number of activities undertaken with partners.

e) *Enhancing and further developing next-generation versions of the TWIN Infrastructure, including incorporating emerging and new technologies*

Metrics of Success:

- Number of functionalities incorporated to the TWIN Infrastructure.
- Number of technologies incorporated to the TWIN Infrastructure; and
- Number of digital services that can be operationalised on the TWIN Infrastructure backbone.

f) *Becoming a financially sustainable Foundation within a three-year period*

Metrics of Success:

- Initial three-year establishment capital and operating costs covered by secured grants.
- Number of income and funding sources operationalised to cover recurring network capital and operating expenses; and
- Funds raised to promote and support non-profit TWIN Ecosystem Builders.

7.1 TWIN Foundation Delivery Mechanisms

To realise the Vision and Mission of the Foundation, and to achieve the strategic objectives and goals, TWIN implementation will be managed and operated using a devolved and distributed mechanism. The basic devolved or distributed unit shall be called a TWIN *Ecosystem*. A TWIN Ecosystem can be at a firm, agency, value chain, trade lane / corridor, national, regional, sub-regional level, or global, level.

A TWN Ecosystem will include an entity defined as the TWIN Ecosystem Builder, TWIN Ecosystem Integrators, and TWIN Ecosystem Users. In some Ecosystems, the three entities may be a single institution or firm – e.g. firm-level ecosystems; but in most cases these will be distinct entities. *TWIN Ecosystem Builders* are entities who design and implement this TWIN basic units. They are classified as both non-profit and for-profit. *TWIN Ecosystem Integrators* are software-based entities specialised in areas of business operations that are part of services within a trade and logistics environment, for example trade financial technology firms (fintech), smart logistics and smart trade compliance firms. Their objectives will be to bolt-on smart and digital services on the TWIN Ecosystem for non-profit and for-profit motives. *TWIN Ecosystem Users* are entities whose trade transactions and activities will be enhanced and rely on TWIN Infrastructure. They will be classified as either public or private entities. Supporting the various ecosystems will be the TWIN Foundation.

8. The IT Architecture of TWIN

This section provides overview of the IT architecture of TWIN. A more detailed and comprehensive Whitepaper will be issued by year end (2024) and become accessible on both www.twin.org and www.twindev.org. The later website will also provide all relevant documentation needed for software developers that wants to use the TWIN software, build API integrations with the TWIN nodes etc.

8.1 Overview of architecture

The architecture gravitates around a "**TWIN Node**", an agent that enables participation in a TWIN Ecosystem. A "TWIN Node" realizes all the infrastructure (hardware infrastructure, processing, data store and object store, DLT, etc.) and platform software services necessary to support the main TWIN functionality, i.e. the exchange of data and documents about items of interest concerning different value chains. TWIN Nodes can be run within the data centers of Participants or a Participant can be onboarded and authorized to make use of the services offered by a third-party provided TWIN Node (Node as a Service).

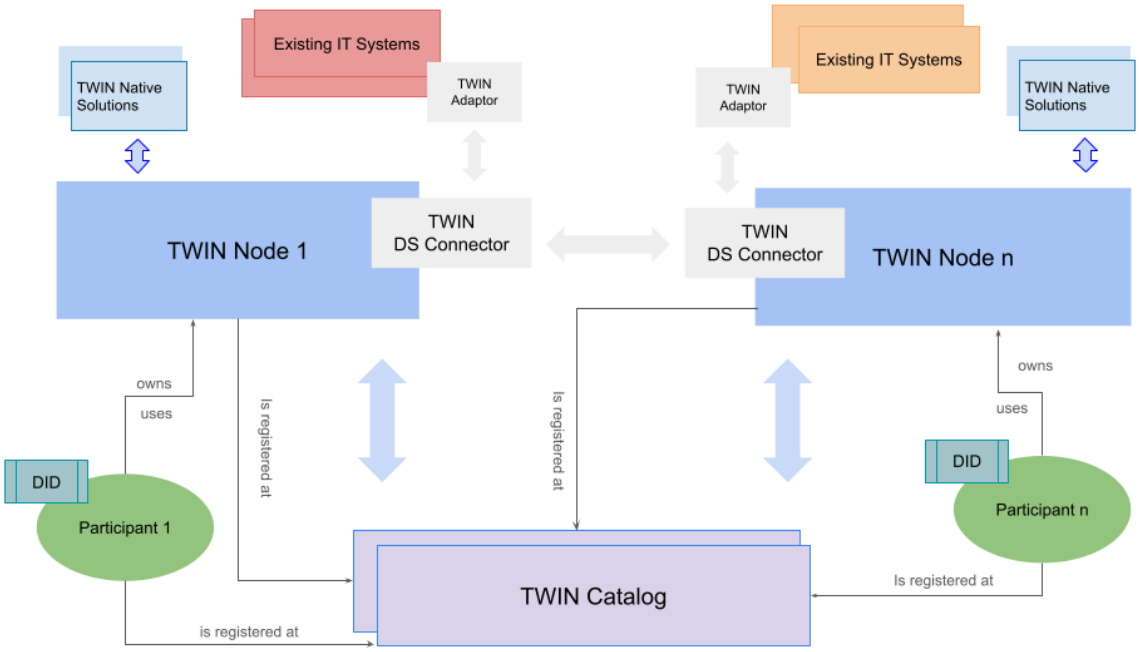


Figure 6 TWIN Node(s) and their interactions

General-purpose extensions can be deployed directly on a TWIN Node ("*TWIN Apps*"), for instance, to implement a custom protocol or format for a certain supply

chain subdomain. There can also be “white label apps” that provide an entry-level functionality. Furthermore, on top of a TWIN Node different “Powered by TWIN Solutions” and existing or legacy IT systems might appear. “Powered by TWIN Solutions”, also known as TWIN Native Solutions, can interact directly with a TWIN Node through open, REST APIs. Such solutions can be of different nature, for instance, custom dashboards that allow users to monitor the status of consignments of interest, automated checkers for consignment clearance at borders based on Artificial Intelligence, analytics tools, trade finance tools, etc. Existing or legacy IT systems could be Single Window Systems already owned by Governments, Trade Operations systems, ERPs, Custom Broker Solutions, Automated Compliance Checkers, etc. Finally, third party platforms might also participate in an ecosystem, namely IoT platforms supplying real time data points while trade items move.

The interaction among different “TWIN Nodes” happens through a **TWIN Dataspace Connector,** whereas existing IT systems can interact with “TWIN Nodes” through a **TWIN Adaptor** that in turn speaks to a TWIN Dataspace Connector. This scenario can be better conceptualized through the example depicted below, involving cross-border data/document exchange in international trade (one of the typical use cases of TWIN, but not the only one).

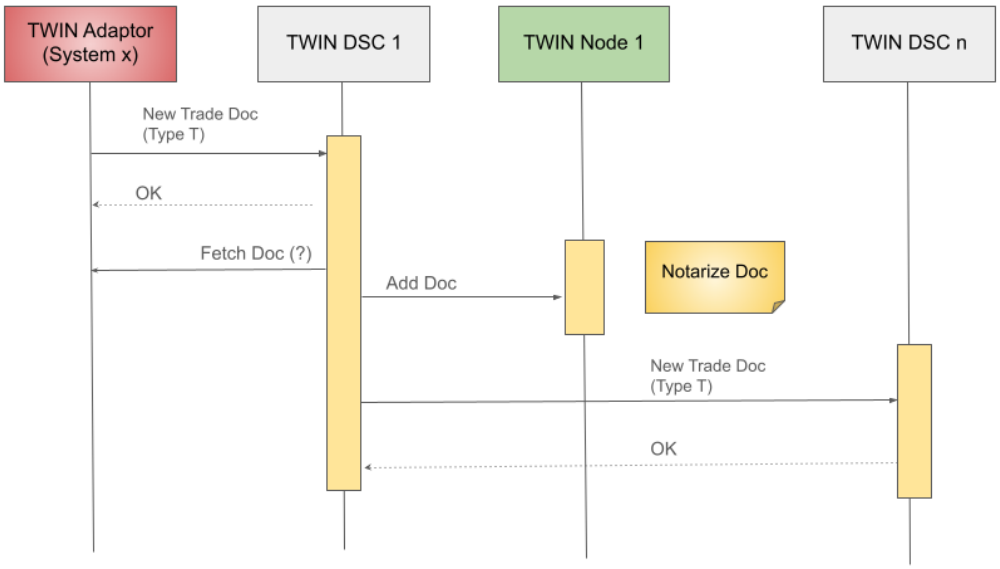


Figure 7 Scenario of interaction in a typical cross-border document exchange

When a trade document is issued, an “external, existing IT System”, that has implemented a “TWIN Adaptor”, can publish this activity information (as an event)

through the “TWIN DS Connector” of a target “TWIN Node”. Such a “TWIN Node”, then, can record the existence of this new trade document, possibly fetch it (through the “TWIN Adaptor”, published by the origin system) and validate its authenticity, while preventing potential tampering (through a fingerprint, for instance). A “TWIN DS Connector” also offers a subscription interface that allows other “TWIN Nodes” to subscribe to activities of their interest (if they are allowed as per authorization policies, described using a standard and interoperable language such as W3C ODRL). For instance, a destination country’s “TWIN Node” can subscribe to another, external “TWIN Node”, so that it is notified when new value chain activity concerning such a country is available, thus increasing efficiency and transparency.

TWIN DS Connectors and TWIN Adaptors are actually Services and Data Resources and must be registered on the TWIN Catalogue so that Participants can discover them when needed. The registration shall be accompanied with metadata including, for instance, the jurisdiction for which data / documents is provided, the associated policies, the type of document/data items provided, etc. All those descriptions are represented using Linked Data Vocabularies, namely, Gaia-X, the GS1 Web Vocabulary, the UN/CEFACT BTS Vocabulary or Schema.org.

In a nutshell, TWIN Nodes can share data or documents among themselves. This data exchange is performed through open interfaces, realized by the “TWIN DS Connector” that each TWIN Node must support. Each business or government can own one or more TWIN Nodes. Each application may decide to interface with a particular TWIN Node according to internal policies, etc. At any point in time a TWIN Node can be enquired concerning information about a particular item in the supply chain (for instance, a consignment), and can, on a need basis, delegate on other TWIN Node(s) (discovered through the TWIN Catalogue), actually acting as a Broker.

Finally, physical, edge devices (such as RFID Readers, scanners, printers, mobile sensors, ...) can also be part of the TWIN infrastructure, as they connect the physical world of trade items to the digital world, improving automated identification and data capture tasks. Devices manufactured by Zebra Technologies (namely fixed RFID Readers exposing the Zebra IoT Connector and Android scanners) have already been successfully tested to interoperate with TWIN through their corresponding Edge Connectors (see below).

8.2 Anatomy of a TWIN Node

The figure below describes schematically the anatomy of a TWIN Node:

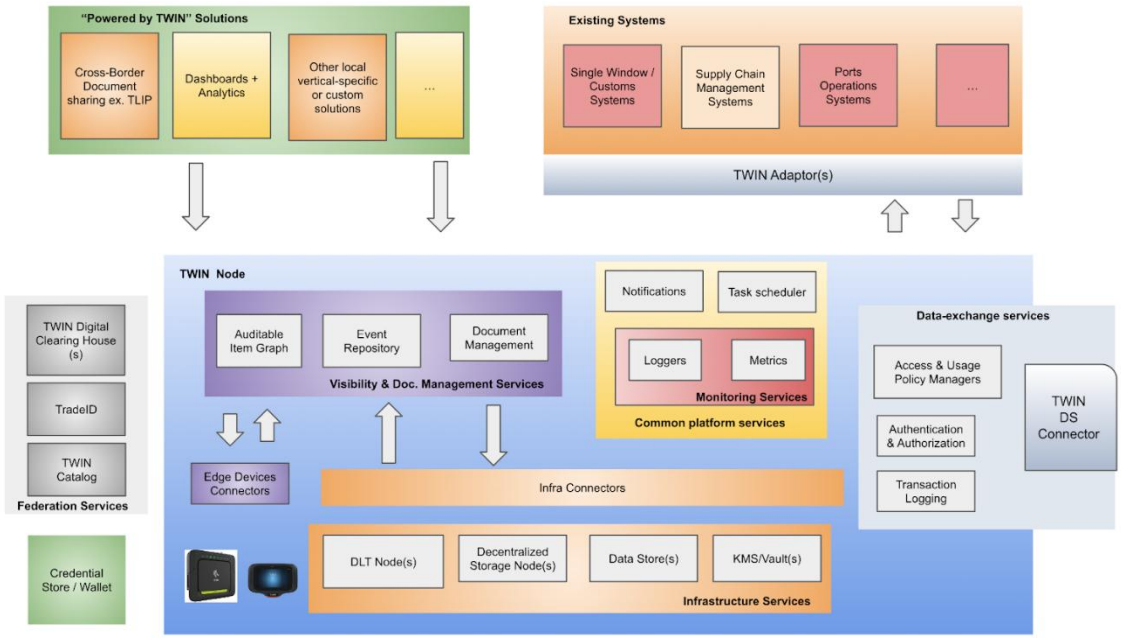


Figure Anatomy of a TWIN Node and service categories

A TWIN Node is composed by different software services classified under the following categories:

- **Enabling & Federation Services**, which realize the clearance, publication and discovery of participants and the services they publish, so that federated / decentralized interactions can take place. The *TWIN Catalogue*, depicted by the figure above, is a key component as it has all the information about Participants, Services, Data Resources and their policies (represented using W3C ODRL). Authorization policies, depending on each ecosystem's governance, might also apply to these services, for security and privacy reasons.
- **Visibility Services,** encompassing auditable (through IOTA DLT Connectors) object representations as a digital twin through its properties, relationships, business events (GS1 EPCIS 2.0) and related resources (for instance, associated documents or external data resources). These services are

application-agnostic, based on open standards (notably Linked Data Vocabularies from schema.org, GS1, and UN/CEFACT) and REST APIs.

- **Document Management Services**, that facilitate document storage (multi-version), document resolution, document traceability and authenticity (possibly on-chain through NFT tokenization), data extraction and document transformation, including multiple representation as per different industry standards (W3C VC, eInvoice, eBill of Lading, etc.). Document transfer, as per MLETR, via IOTA DLT tokenization, is also under the scope of these services.
- **Data Exchange Services**, these are services that facilitate data (or document) exchange among the different ecosystem participants. The main enabler on the "TWIN Node" side is the "TWIN Dataspace Connector" which publishes REST endpoints that allow participants to publish and subscribe to "supply/value chain activity and events" information.
- **Infrastructure (Software) Services**, these services realize the software infrastructure needed for a TWIN Node to operate, namely, public, permissionless distributed ledger technology, object storage and datastores.
- **Infrastructure Connectors,** they are generic technical core components of the architecture that abstract away the specific interfaces of infrastructure services from the rest of services present in a TWIN Node, so that there is loose coupling and improved flexibility concerning the underlying infrastructure, avoiding vendor lock-in. One remarkable Infrastructure Connector is the *IOTA DLT Connector*, key for trust and data verification within a TWIN ecosystem.
- **Common Platform Services**, these are general purpose, reusable services that provide horizontal functions. Task scheduling, notifications, metrics and monitoring are some of the most remarkable ones.
- **Edge Connectors** They are connectors that bridge the physical world of trade items with their corresponding digital twin. Through *edge devices* (RFID readers, mobile scanners, etc.) and via Edge Connectors, data can be captured seamlessly, object presence can be recognized, recorded and attested on TWIN and access to trade item information held by TWIN can be improved (for instance by reading or printing barcodes).

All TWIN software services offer REST APIs using JSON(-LD) as the data representation format. There is a high level of flexibility when deploying those services (packaged as Docker containers), from a monolithic deployment to a full micro-service split.

In addition to the above referred software infrastructure, a TWIN Node must execute within a hardware infrastructure that encompasses computing, storage and networking resources. Such a hardware infrastructure might be virtualized (IaaS) and be offered by cloud providers in conjunction with PaaS (containerization, clusterization, i.e. Kubernetes, etc.) capabilities. Nonetheless, TWIN Nodes including the TWIN software infrastructure services (datastores, DLT, etc.), are also ready to be executed on-premises when required by organizations. In a nutshell, TWIN is not bound to any cloud provider nor hardware platform. The deployment view of the architecture is out of scope of this report and will be discussed in a future white paper.

8.3 TWIN Trust Framework

Introduction and key definitions

According to Gaia-X, a **Trust Framework** establishes the rules that ensure minimum requirements are met for security, privacy, identification management and interoperability through accreditation and governance. These operating rules provide a common framework for ecosystem participants, increasing trust between them. The TWIN Trust Framework revolves around following concepts:

- **Identity** Set of attributes related to an entity.
- **Decentralized Identifier** (DID). A type of entity identifier that is globally unique, resolvable with high availability, and cryptographically verifiable. DIDs are used to identify Participants within a TWIN Ecosystem.
- **Verifiable data registry** A role a system might perform by mediating the creation and verification of identifiers, keys, and other relevant data, such as verifiable credential schemas, revocation registries, issuer public keys, and other rules. Example verifiable data registries include trusted databases, decentralized databases, government ID databases, and distributed ledgers. Often there is more than one type of verifiable data registry utilized in an ecosystem.

- **Credential** A set of one or more claims made by an issuer.
- **Credential Dataset** defines the data (claims) about a subject that is to be included in a Credential.
- **Credential Format** Data Model used to create and represent Credential information. This format defines how various pieces of data within a Verifiable Credential are organized and encoded. TWIN supports both JWT and JSON-LD (using the W3C VC Data Model).
- **Verifiable Credential** A tamper-evident credential that has authorship that can be cryptographically verified. Verifiable credentials can be used to build **verifiable presentations**, which can also be cryptographically verified.
- **Credential Issuer** (or Issuer): An entity that issues Verifiable Credentials.
- **Holder** An entity that receives Verifiable Credentials and has control over them to present them to the Verifiers as Presentations.
- **Verifier** An entity that requests, receives, and validates Presentations.
- **Verifiable Presentation** A tamper-evident container of data derived from one or more verifiable credentials, issued by one or more issuers, that is shared with a specific verifier by a holder.
- **Credential Status List** A mechanism used by a Verifiable Credential issuer where a verifier can check to see if a credential has been suspended or revoked.
- **KYC** Know your Customer. It is a process intended to verify the identity of new Participants. There can be multiple mechanisms and providers of KYC services.
- **Wallet**: An entity used by the Holder to request, receive, store, present, and manage Verifiable Credentials and cryptographic key material.
- **Trust Anchor** Conformity Assessment Bodies or technical means accredited to be parties eligible to issue attestations about specific claims. The way accreditation of Trust Anchors work can depend on each TWIN Ecosystem's rules. There can be even regular Participants, for instance certain prominent organizations such as freight forwarders, that also play the role of Trust Anchors.

- **Participant Attribute** The identities of Participants in a TWIN Ecosystem rely on signed attributes, which can be requested and exchanged to gain individual trust from other participants. Participant Attributes might also be extracted from Verifiable Credentials which subject is the Participant itself.

Description

In alignment with Gaia-X, TWIN adheres to a **Trust Framework**, which enables the attestation of Participants' attributes and their seamless onboarding and interaction without prior knowledge among them. The final aim is to ensure that all Participants in a TWIN Ecosystem are adhering to the policy rules agreed between the Participants of the Ecosystem itself.

The Trust Framework revolves around the following rules:

- Participants are identified by a *W3C DID* hold in a Credential Wallet, either directly controlled or kept in custody by a third-party. Even though TWIN is not bound to any particular DID method, it provides off-the-shelf support for IOTA Identity, thus DLT infrastructure acts as a verifiable data registry.
- Participants' Attributes are attested by other Participants (**Trust Anchors**) through W3C Verifiable Credentials. Trust Anchors can be accredited by other Trust Anchors.
- Trust Anchors are defined by each TWIN Ecosystem. While there can be ecosystems with pre-defined, prominent Trust Anchors (for instance government agencies or private institutions, banks, etc.), other ecosystems might be more lenient when it comes to attestation. For instance, an existing, compliant Participant might attest to the attributes of Participants it wants to interact with.
- Participants must be compliant with each ecosystem's rules. Once a Participant has been attested to possess certain attributes it must acquire a **Compliance Credential** through a TWIN Clearing House (which can be implemented by a TWIN Node). A **TWIN Clearing House** must check for Compliance as per the rules of each ecosystem. Compliance Credentials are the pass needed to appear under the TWIN Catalog.

Ideally, TWIN Clearing Houses should be based on Smart Contracts, but it is not a hard requirement.

- Ecosystem rules which include participation rules, schemas, vocabularies, etc. must be registered on a **TWIN Registry** and be accessible to any TWIN Node and Clearing House.
- External Trust Service Providers through their controlled trusted data sources are allowed to be part of the TWIN Trust Framework. When an accredited Trust Anchor is not capable of issuing cryptographic material nor signing claims directly, then a TWIN Ecosystem can accredit one or more **Notaries**, which will perform a validation based on objective evidence from a Trusted Data source (offered by a Trust Service Provider) and will issue an attestation. Notaries are converting "not machine readable" proofs into "machine-readable" proofs.

Example: The European Commission provides several APIs, including one to check the validity of EORI number (i.e. the EC plays the role of Attribute Service Provider). Unfortunately, those APIs are not returning Verifiable Credentials. Hence a TWIN Notary can perform EORI verification using the European Commission API as the Trusted Data source for EORI validation.

- Compliance credentials and their evidence (also represented as Verifiable Credentials) are subject to **revocation**. As revocation lists are DLT registry entries, they can reach TWIN Nodes and be effective immediately. As a result, bad actors can be dismissed and offboarded from a TWIN ecosystem in a very efficient and effective manner.