Exploring data space initiatives

Geonovum

Versie	0.52
Status	Workversion
Datum	26 april 2023

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Version management

This document is subject to change. The version management of the document provides insight into change and its topicality.

Version	Date	Name author	Changes
0.1	26-9-2022	Michel Grothe	The first draft version was drawn up. Chapter 1 filled in. First table of contents created. Quick-scan analysis model data spaces added in chapter 2.
0.2	21-10-2022	Michel Grothe	Comment Wideke Boersma, Ine de Visser, Pieter Bresters on v0.1 processed. Description Quick-scan analysis model data spaces elaborated in chapter 1. Chapter 4 OPENDEI. Chapter 8 added the European and national Spatial Data Infrastructure (NGII).
0.3	8-11-2022	Michel Grothe	Description Quick-scan analysis model data spaces completed in chapter 1. Section 1.1 and 1.2 rewritten. Added chapter 2 IDSA and chapter 3 Gaia-X.
0.4	19-11-2022	Michel Grothe	Sections 1.1 and 1.2 rewritten. Added chapter 5 Data Sharing Coalition and chapter 6 iSHARE.
0.5	16-12-2022	Michel Grothe	Comments processed on v0.4 by Wideke Boersma and Ine de Visser. Text and structure changes in chapter 1 and 2.
0.52	26-4-2023	Michel Grothe	Several editorial changes based on UK translation of Dutch original at: https://docs.geostandaarden.nl/eu/VerkenningDataspaces/

Acknowlegdement

This document is a auto-translation offered by the EU Commission from the dutch original at: https://docs.geostandaarden.nl/eu/VerkenningDataspaces/. The translation is offered by the Joint Research Centre , Digital Economy Unit. Many thanks to Alexander Kotsev.

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1. Introduction

1.1 Incentive

Over the past 10 to 15 years, the Netherlands as many other countries worked on a national spatial data infrastructure. In the Netherlands, this resulted in the unlocking of many thousands of spatial datasets and spatial data services on the Internet so that the data can be downloaded for (re)use in different fields of application and application domains. The Dutch spatial key registries for addresses and buildings (BAG), cadastral parcels (BRK), small and large scale topography (BRT and BGT) and the key registry of the subsurface (BRO) are main elements of the national Spatial Data Infrastructure. The Netherlands has made a set of agreements on interoperability and standards and set up registers for concepts and information models and the findability of spatial datasets. Policies and governance within government, business and educational and knowledge institutions have also been designed. And from 2007 onwards, the European Implementation Act of the EC Infrastructure Spatial Information Directive (also known as the INSPIRE Directive) has been established with which Dutch spatial data has also become part of the European Spatial Data Infrastructure. So, in the geospatial data domain, data sharing takes place via the concept of a 'Spatial Data Infrastructure', is an international concept, consisting of a coherent set of data(sets) and metadata, data services, practices, standards, facilities, applications, infrastructure and resources needed to share geo-information.

From the same Europe, a challenging new digitalization and data strategy has been drawn up in recent years. The European Digital Strategy and Data Strategy **[EU-DS]** is intended to be the main driver of the European data economy (see also - in Dutch - the EU Information Guide on Digital and Data Strategy). Through regulation and projects, the EU wants to gain more control over its own data through the development of common EU data spaces **[EU-CDS]**. A 'data space' is aimed at the secure, trusted and sovereign sharing of data within domains and across domains. Several EU data spaces in different domains are foreseen in the (near) future.

So, what is a data space? And what characterizes a data space? And how can we use and apply the data space as a concept in relation to the (national) spatial data infrastructure? These are the questions raised in this exploratory study. We provide insight into the underlying principles and concepts of data spaces from various data space initiatives that have emerged in recent years. We subject a number of data space initiatives to a quick-scan analysis and see which topics get attention and are important building blocks for data sharing in and across various domains.

1.2 Goal of this exploratory study

The increasing European focus on sharing data between private and public parties has been an important reason for this study. Several European and national initiatives work towards realizing the societal and economic potential of data sharing. These data space initiatives have their own focus, for example on collaboration, infrastructure or on the development of use cases. What are the focus areas of these data space initiatives? And what is the position of the Spatial Data Infrastructure as a data space concept in relation to other data sharing initiatives?

This exploratory study has a dual purpose:

1. It provides insight into the guiding data space initiatives in the Netherlands and Europe and their focus areas. It gains insights into the different concepts, actors and building blocks of these data spaces initiatives and (in some cases) how data space initiatives are and can be connected;

2. Gain insight into the position of the European and National Spatial Data Infrastructure in relation to these guiding data space initiatives. The various existing generic data sharing initiatives are working towards realizing data sharing solutions. Understanding the position of the NGII in relation to these initiatives could enable the National Spatial Data Infrastructure (and European equivalent) to better contribute to the European and national data economy. This leads to the question of how the Spatial Data Infrastructure and the generic data space initiatives relate to each other and which aspects the Spatial Data Infrastructure should take within its scope in order to contribute optimally to the data economy.

1.3 Approach

This research was carried out using desk research. The various sources from data space initiatives have been consulted for the quick-scan analysis. These sources have been the main starting point for a quick-scan analysis of the components of various data space initiatives.

The data space initiatives are well under development. Collaborations and coalition formation take place and (technical) elaboration of parts are published. The first experiences with (partial) implementations are also visible. That also means that this exploratory study is not complete and is tracked and updated based on new information and resources made available by the data space initiatives. This makes this exploratory study a 'living' document for the time being.

It is also intended to present the results of this exploratory study and in particular the quick-scan analysis of the individual initiatives to some key stakeholders of the data space initiatives considered.

1.4 Audience

This exploratory study on Data Space initiatives is written for everyone involved in the exchange of spatial data (or location-related data), the application of standards and the National and European Spatial Data Infrastructure. Such as information managers, steering committee members, policy officers, project leaders, consultants, architects, IT suppliers, and individuals who implement spatial data products, standards and specifications in their organisation and want to share these spatial data products with other organizations and data space initiatives in the Netherlands and Europe.

1.5 Reading guide

Chapter 2 provides background information on the quick-scan analysis of data space initiatives in this exploratory study. The data space concept of the International Data Spaces Association is discussed in Chapter 3. Chapter 4 discusses the Gaia-X initiative closely related to the International Data Spaces. The OPENDEI framework is considered in Chapter 5 and in Chapter 6 the framework of the Data Sharing Coalition. Next, chapter 7 explains the iSHARE trust framework for data spaces. Chapters 8 and 9 respectively consider the European and National Spatial Data Infrastructure as a data space initiative.

2. Data spaces initiatives

2.1 Introduction

This exploratory study is related to the development of common data spaces in Europe, which are of strategic importance for the growth of the European data economy. The aim of the European Data Strategy **[EU-SD]** is to enable and stimulate the development of data value chains, while ensuring sovereignty and reliability among European values (see further EU Information on Digital and Data Strategy). As presented in the European Commission Communication of February 2020: "The European Data Strategy is the vision to create internal markets for data, called 'common European data spaces', where both personal and non-personal data, including sensitive business data **[EU-SD]**:

- Can flow within the EU and across sectors;
- Be safe and treated in accordance with EU legislation and relevant standards;
- Accessible and used according to fair, practical and clear rules."

The aim of the European common data spaces **[EU-CDS]** is to enable data from across the EU, both from the public sector and from industry, to be exchanged in a reliable manner and at a lower cost, thereby encouraging the development of new data-driven products and services. Data spaces consist of both the secure technological building blocks and infrastructure as well as the governance mechanisms. These functions are usually organised in:

1. Data platforms — support the sharing and exchange of data;
2. Data marketplace — support of data offerings and data request; and
3. Data sovereignty — support for control and governance of data flows.

2.2 Data space definitions

There are several synonyms for data spaces in circulation, such as 'data ecosystem' or only 'ecosystem', 'data sharing system', 'data federation' and 'federal data system'. In this exploratory study, the term 'data space' is seen as part of the European Data Strategy and the consequent impact on the data economy. We do not intend to have a discussion about the correct definition of a data space, but it is about pinpointing that different data space initiatives exist, each giving a certain meaning and perspective to data sharing. Below are some descriptions of data spaces, such as those carried out by some important initiatives.

International Data Spaces

Distributed network of Data Endpoints (i.e., instantiations of the International Data Spaces Connector), allowing secure exchange of data and guaranteeing Data Sovereignty.

- Shortcut: `IDS`

Source: International data spaces (IDSA)

"The term "data space" refers to a type of data relationship between trusted partners who adhere to the same high level standards and guidelines in relation to data storage and sharing within one or many Vertical Ecosystems."
Source: GAIA-X

A data space is defined as a decentralised infrastructure for trustworthy data sharing and exchange in data ecosystems based on commonly agreed principles.

Source: OPENDEI

"Data Spaces is an umbrella term corresponding to any ecosystem of data models, datasets, ontologies, data sharing contracts, and specialized management services (i.e., as often provided by data centers, stores, repositories, individually or within "data lakes"), together with soft competencies around it (i.e., governance, social interactions, business processes)."
Source: [[Scerri]]

"An infrastructure that enables data transactions between different data ecosystem parties based on the governance framework of that data space. Data space should be generic enough to support the implementation of multiple use cases."
Source: [DSCC-G]

It is not important here to discuss which definition is the right one. It is important to point out that data spaces are about trusted, sovereign and secure data sharing between participants in a federated, distributed manner and on the basis of jointly agreed agreements and control. These aspects of data spaces are reflected in their definitions. The implementation of these aspects in order to achieve genuinely trusted, sovereign and secure data sharing is and will be further developed in various initiatives. With this, these data space initiatives each give a specific meaning to the sharing of data.

2.3 Data space initiatives

In 2023, several data space initiatives exist and are often focused on a specific sector or domain. These initiatives facilitate the sharing of data for their participants, both for customers (consumers) and data providers (producers) in a particular application domain or from a specific sector perspective. Different approaches to creating data spaces have been developed in different sectoral domains. And the maturity of data spaces in one application domain can differ from the maturity of data spaces in the other domains.
In addition to sector or domain specific data space initiatives, there are also some cross-domain initiatives that develop and agree on cross-domain principles, standards or functionalities for data sharing. New or existing data space initiatives, aimed at creating a data space in a particular domain or sector, can once again adopt principles, concepts, functions and building blocks of these cross-domain initiatives.

In this exploratory study, the following data space initiatives are considered and explained through the quick-scan analysis and view:

1. International Data Spaces (IDS);
2. Gaia-X;
3. OpenDEI;
4. Data Sharing Coalition;
5. iSHARE;
6. The European Spatial Data Infrastructure;
7. The Dutch Spatial Data Infrastructure.

2.4 Quick-scan analysis

As a concept, a data space is often considered based on the way in which the data sharing is realized. To this end, an actor model is often outlined with the actors, roles and their interdependence and interactions. And indispensable is also the building block model, which provides insight into the governance building blocks and more technical building blocks of the data space. For this exploratory study, the building block model of OPENDEI was used (Figure 2.1).

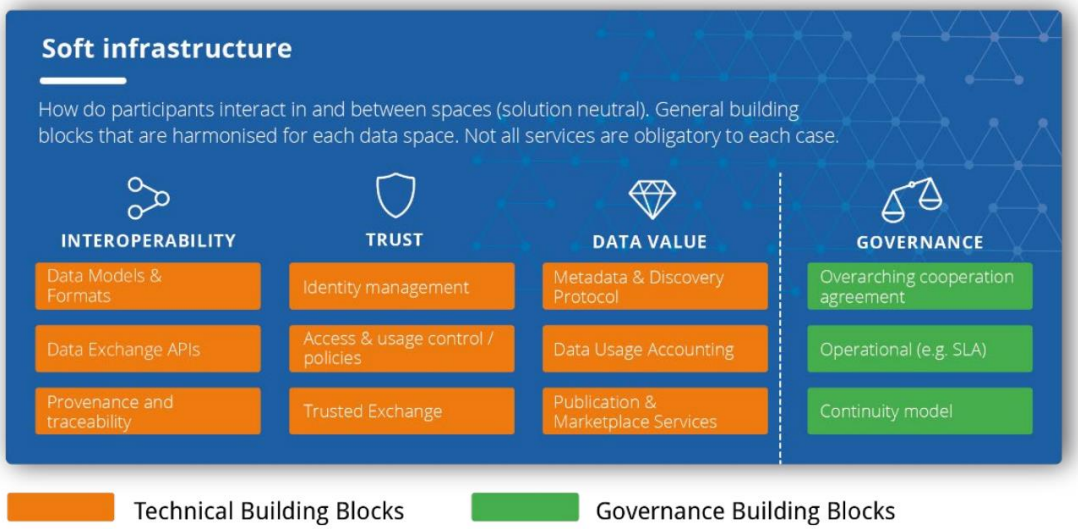

Figure 2.1 — General data space building blocks to OPENDEI ***[OPENDEI-DPR]***

We consider a number of 'data space' initiatives, each addressing a number of basic aspects and components:

1. Domain and cross-domain typology;
2. An overall reference architecture for the data space;
3. Governance, such as model of actors, cooperation agreements and operational agreements;
4. Standards for interoperability on data (models and formats), exchange APIs, origin and traceability of data and metadata;
5. Facilities necessary for the trusted data sharing, such as providing identification and access, use control and trusted exchange (and security);
6. Data value building blocks, such as catalogs, clearing house (logging data transactions), vocabulary and a marketplace (app store).
7. Technical infrastructure.

The OPENDEI model has been applied in a conceptual model (see Figure 2.2), which has guided a quick-scan analysis involving various data space initiatives. With this model, the quick-scan analysis was performed according to the analogy of a previously performed analysis of the Data Sharing Coalition **[DSC-PP]**.

From the OPENDEI model, the four groups of the data space elementary components have been adopted: governance, interoperability, trust and data value. The OPENDEI model is not taken over one by one, but has been expanded with some additional components, such as use cases/value cases and community building. The groups of interoperability, trust and data value are given a technical interpretation in the form of 'technical building blocks' that are reflected in software implementations. In Chapter 5, the OPENDEI model is explained and considered further.

The (position paper) model of the Data Sharing Coalition **[DSC-PP]** has been used for a similar analysis of five data space initiatives. From this model, the domain and cross-domain typing has been taken over and the 'hard infrastructure' (technical infrastructure). The 'soft infrastructure' from the Data Sharing Coalition position paper has been replaced by the OPENDEI model. In the end, the availability of a reference architecture has also been added, because a reference architecture is often overview and insight into the coherence between the components of the data space initiative in question.

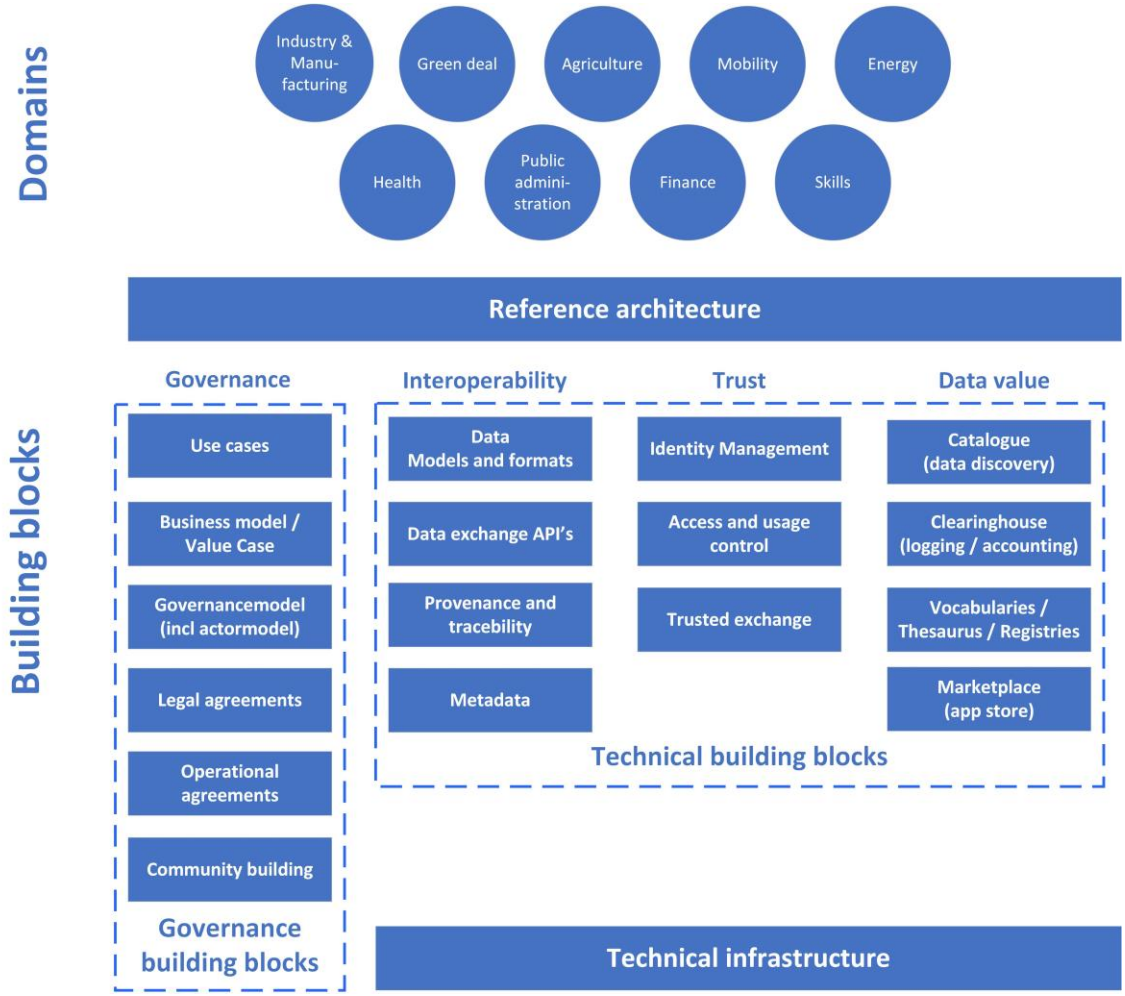

Figure 2.2 — Focus and areas of reflection of data spaces in this exploratory study

Below is a brief description of the basic aspects or focus areas or areas of reflection of the data space initiatives. Comparing the different initiatives by using different concepts (frameworks) and components is not always unambiguous and in some cases difficult to characterize. That is why we briefly describe the elementary parts below without wishing to give a clear description, and we will also mention similar concepts as those used in the various initiatives.

2.4.1 Domain and cross-domain typing

First of all, we consider the domains where a data space initiative is active. For this purpose, the nine data space domains, which are distinguished in the European Data Strategy **[EU-DS]**, have been taken as a starting point: industry (production), green deal, agriculture, mobility, energy, health, public administration, finance and skills (education). Some data space initiatives focus on a

specific domain, and some initiatives focus on multiple or all domains and are therefore domain-crossing or cross-domain initiatives.

2.4.2 Reference architecture

To begin with, various data space initiatives have drawn up a reference architecture, under various headings: Design Principles of Data Spaces (OPENDEI) [OPENDEI-ARCH], Data Sharing Canvas (Data Sharing Coalition) [DSC-DSC], Reference Architecture Model (IDS) [IDS-RAM4] and Architecture (Gaia-X) [Gaia-X-ARCH]. Most of these reference architectures are quite high-over, i.e. a global interpretation of the components of a data space and how they relate and the technical building blocks functionally described. Sometimes a more comprehensive information model (IDS) and the underlying technology have also been described (Gaia-X, iSHARE). Often the actors and their functions and roles are also appointed (actor model), possibly their relationships and data sharing processes are described. And the governance (global) is explained.

2.4.3 Governance

Governance is the set of components or building blocks in data spaces, which must ensure the agreements on control and actors, the valuation, the legal and operational agreements and community building. And it starts with meaningful use cases.

The **Use Cases** building block refers to the presence of elaborate data space use case or application from the point of view of the user. Many data space initiatives work from use cases on the implementation of the data space.

The building block **Business Model** / **Value Cases** (the data valuation method) deals with methods to estimate the value of data shared by organizations in the data space. Often this is about declaring the importance of the business or the value case and/or how a business model can be drawn up. In some cases, a business model is available.

The **Governancemodel** provides insight into how the data space is controlled. For this purpose, a control model is often available with entities and their responsibilities, tasks and roles. An actor model is often part of this. Actors in the data space are the data owners (producers), data providers, data users (consumers) and other intermediaries (brokers, auditors, etc.).

The **Legal agreements** building block consists of the regulations that refer to laws or administrative rules issued by a data space organization, which are used to direct or prescribe the behavior of the participants in the data space. Legal regulations of countries are also covered by the legal agreements. For example, data spaces must take into account various legislative requirements, such as privacy legislation (GDPR), electronic identification legislation (eIDAS), and payments in Europe (PDS2).

The building block **Operational Agreements** is a type of Service Level Agreement (SLA). An SLA is a contract between a data provider and a consumer, or between a data owner and a data provider. It describes the services to be provided by the data provider, together with the standards to be met by the provision of the data services. The data services provided must comply with specified standards, while the consumer of the services has the right to require compliance with these standards.

An operational agreement may also cover other operational arrangements, for example:

- Reporting arrangements, such as reports to be produced as part of the operation of the data space and in accordance with the underlying business models. It specifies the parameters to be recorded and reported for each business actor and data space transaction;

- Billing arrangements. Means of invoicing of data services and transactions provided. In this context, the specification of the billing/charge schedule is important. This indicates how the billing/invoicing should be charged;
- Contracts. They provide a protocol for the execution of contracts between two or more parties (mainly the data provider and the consumer). As such, they specify policies for data usage, legal aspects, SLAs and other agreements in a machine-readable and cryptographically signed manner.

Finally, **Community building** is an important building block in the creation of a data space. A harmonized approach to setting up data spaces is actually more of a coordination and scale problem than a technological problem. To set up data spaces, which give participants control over their data and collaborate with each other in different domains, adequate technology is needed in addition to process knowledge to use it. This means cooperation and coordination with all stakeholders and participants in the data space to arrive at common and supported agreements. Community building facilitates this process.

2.4.4 Interoperability

Interoperability is the group of components in data spaces, which must ensure the agreements on the exchange of data. The following building blocks belong to this category of data 'interoperability': data (models and syntax), data exchange APIs, origin and traceability and metadata.

The building block **Data models and formats** establishes a common format for data model specifications (information models) and data syntax for data exchange (data formats). In combination with the building block for data exchange APIs, this ensures full interoperability between participants in a data space.

The building block **Data Exchange APIs** facilitates the sharing and exchange of data, i.e. data provision and (re)use between participants in the data space.

The **Provenance and traceability** building block of data provides the means for tracing and tracking in the process of data processing and — provision and use. It thus provides the basis for a number of important functions, from identification of the origin of data to audit-proof logging of transactions. It also enables the implementation of a wide range of application-level tracking use cases, such as tracking data products in the data space processing chain.

The building block **Metadata** provides the description of data products in the data space, also called 'self-description' **[IDS-RAM4]** or 'Data Asset Self-Description' **[Gaia-X-ARCH]**. The metadata includes a broad description of the data products and participants in the data space as well as the publication and find mechanisms for data products and participants. Such self-descriptions (metadata) can be both domain-crossing and domain-specific.
Metadata has been added here as part of interoperability, as metadata self-descriptions must also be exchanged. Here too, the exchange of self-descriptions and the achievement of interoperability with data discovery facilities in data spaces (catalogues). This building block has a clear relationship with the building block 'catalog' in the data value category. Metadata of data products is placed in one or more data space catalogues to make data products and participants in the data space findable.

2.4.5 Trust

In various data space initiatives, this category is also known as the 'Trust Framework'. Examples are iSHARE and International Data Spaces. In the 'Trust' category, we also find four building blocks **[iSHARE-S]**, **[DSC-DSC]**, **[Gaia-X-TF]**.

The **Identity Management** building block enables stakeholders operating in a data space to be identified, verified and authorised. It shall ensure that organisations, persons, machines and other actors are provided with recognised identities and that those identities can be verified, including additional information, which can be used by authorisation mechanisms to enable access and use control.

The **Access and usage control** building block ensures the enforcement of the data access and use policy defined as part of the general terms and conditions, which are determined when data products are published (see Marketplace building block below) or negotiated between providers and consumers. A data provider typically implements data access management mechanisms to prevent misuse of its data, while data usage control mechanisms are usually implemented on the consumer side to prevent data misuse. In complex data value chains, both mechanisms are combined by 'prosumers'. Access control and usage control depend on identification and authentication.

The third building block **Trusted exchange** facilitates the trusted data exchange between participants and reassures the participants in a data exchange that other participants are really who they claim to be and that they comply with the agreements made by the data space. This can be achieved on the one hand by organizational measures (such as working with certification/certificates or by verified references) or, on the other hand, by possible technical measures such as remote attestation.

2.4.6 Data value

In the data value category, the value of the data space becomes visible to the participants of the data space. Four building blocks are distinguished: a catalogue for finding data products and participants, a clearinghouse to record transactions, a vocabulary with an overview of the semantics of the data products, and a marketplace to bring together demanders and data product providers. These building blocks are often seen as federated building blocks.

The building block **Catalogue** (data discovery) contains the publication and find mechanisms for data products and participants in the data space, using the general self-descriptions (metadata) of data and participants in the data space. Various terms are used for the catalogues, such as 'metadata discovery' by OPENDEI **[OPENDEI-DPR]**, 'meta data broker' by IDS **[IDS-MDB]** and 'Federated Catalogue' by Gaia-X **[Gaia-X-ARCH]**. Often catalogues also work together and offer opportunities to harvest and exchange each other's metadata or self-descriptions. Agreements and standards also play an important role, such as for exchanging and harvesting metadata.

The **Clearinghouse** building block forms the basis for recording the transactions that record access to and/or use of data by different users (logging). In OPENDEI, this building block is called 'accounting of data usage' **[OPENDEI-DPR]** and in IDS 'clearing house functions' **[IDS-CH]**. The clearing house supports key features for clearing, payment and billing (including transactions for sharing data without the involvement of the marketplace).

The building block **Vocabulaires/Thesarus/Registries** ensures semantic coherence and alignment through the capture of semantics in the data space. For this purpose, the various concepts derived from data models (information models) of the data space are recorded and made available through federated services. In IDS, this role is called the vocabulary provider, and the platform where communities publish and maintain shared vocabulary is called the 'vocabulary hub' [IDS-RAM4]. Other indications for this include glossaries, conceptual libraries, taxonomy, thesauri and semantic registers and ontologies. Here too, a data discovery facility (catalogue) plays a role.

The building block **Marketplace (app store)** includes supporting the online provision of data products and participants under defined conditions. In IDS, this building block is called ‘App Store’ [IDS-RAM4]. This building block supports the publication of offers, the management of processes related to the creation and monitoring of smart contracts (which clearly describe the rights and obligations for data use) and regulates access to data products. Based on the technical needs, the corresponding backend processes for assessment, clearing and billing can be carried out. This building block also facilitates the expansion of data spaces with more data products and participants.

2.4.7 Technical infrastructure

The building blocks described in the previous paragraphs in the OPENDEI model are also referred to as ‘soft infrastructure’. The infrastructure structure here refers to the ‘hard infastructure’ consisting of the hardware and associated software to create interoperability, connectivity and portability between the data providers. Think of aspects and data storage, cloud and edge service provision and network connectivity. Most data space initiatives leave the infrastructure design to the infrastructure providers market and remain independent and can deliver to multiple infrastructure platforms.

3. International Data Spaces

This chapter describes and introduces the use of the concept of 'data space' from the perspective of the International Data Spaces (IDS). In addition to a brief introduction, we describe the essential and supportive building blocks of the IDS data space. The agreements on data sharing are discussed globally and the actors model are briefly appointed.

3.1 International Data Space Association

The International Data Spaces Association (IDSA) is on a mission to create the future of the global digital economy with International Data Spaces (IDS), a secure, sovereign data sharing system in which all participants can realize the full value of their data. IDS enables new 'smart services' and innovative business processes to work across companies and industries, while ensuring that the self-determined control over data use (data sovereignty) remains in the hands of data providers.

The IDSA aims to unlock the data-driven economy of the future by providing a blueprint for secure, self-determined data exchange between trusted partners. This is what is referred to as 'data sovereignty' and it is seen as vital as data access and data exchange quickly become critical success factors for businesses, government and individuals as well as entire economies. So far, companies have kept huge amounts of valuable data that they could not manage, share or monetize on their own terms. The IDSA has defined a reference architecture and a set of agreements that can be used to create data spaces that build trust between partners and a basis for innovative, new business models, products and services.

The IDSA framework and the IDS Reference Architecture Model **[IDS-RAM4]** form an integral part of the EU Data Strategy **[EU-DS]**. The European Commission defines Europe's way forward to the digital economy of the future. A key element of their vision: international data spaces rooted in European values of trust and the self-determination of data use by data providers, which we call data sovereignty. The role of IDSA for the EU data strategy is described in this white paper. Data spaces are the key to the global digital economy.

3.2 IDS building blocks for data sharing

IDS defines standards and specifications for data sovereignty. These standards and specifications describe the technical basis, standards to be used and appointments needed for sovereign, trusted and secure data sharing. The IDS Rulebook **[IDS-PP-RB]** provides an overview of IDS global activities (Figure 3.1).

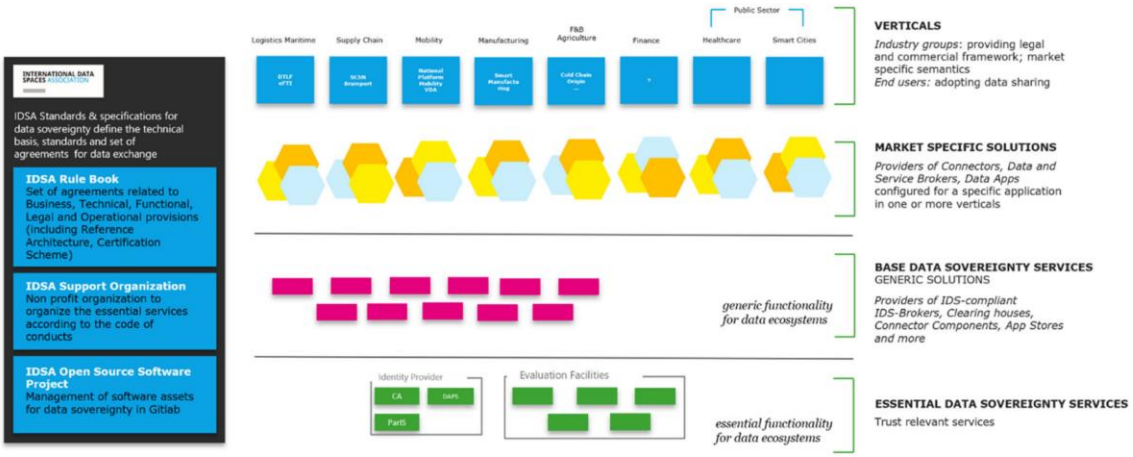

Figure 3.1 — Global overview of the IDSA organisation **[IDS-PP-RB]**

First of all, IDS has three organizational elements:

1. In order to ensure the smooth functioning of the future data economy and its value proposition, all players must adhere to a common governance framework that specifies the functional, technical, operational and legal agreements that structure their roles and interactions within and between the different parts of the ecosystem. The IDS Rulebook [IDS-PP-RB] with rules and guidelines outlines that framework. By following these rules and guidelines, all players can work together to achieve the shared goal of unlocking the full value of the global data economy.
2. The IDSA support organisation is responsible for maintaining the rulebook and supporting its application. The IDSA support organisation helps coordinate key processes and, as a general governance, provides a basis for the realization of internal structures and interfaces with other parties.
3. In addition, the IDSA Open Source project, which developed the software components for the implementation and testing of the essential IDSA components.

The key actors and building blocks of an IDS data space are shown in Figure 3.2 below.

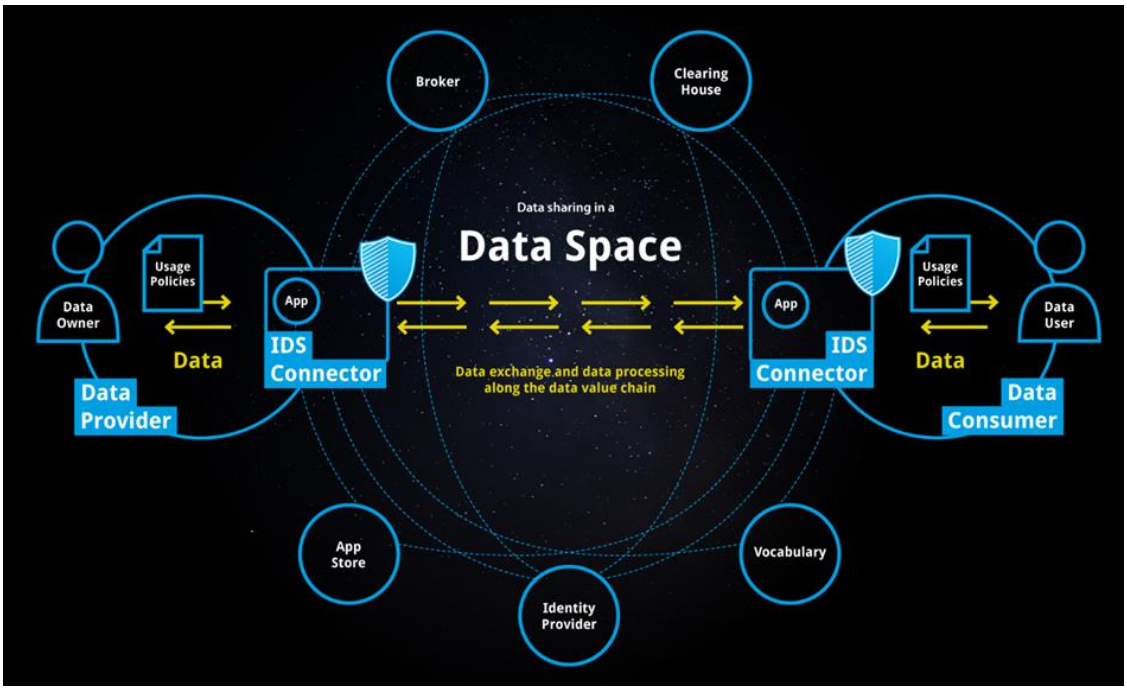

Figure 3.2 — IDS building blocks for data exchange (source: IDSA infographic)

The **data provider** is seen as a 'device' that transfers the owner's data via the IDS connector to the data space. It allows others to use the data while the data owner maintains control over the data: who, how, when, why and at what price. That is data sovereignty, the basis for unlocking the value of data. This is laid down in 'use-policies'.

The **data consumer** is a device that retrieves the data from the owner via the IDS connector and uses it from the data space.

IDS Connectors are the 'data gateways'. The IDS connector is a specific software component that allows participants to link usage policies with their data in a data space, enforce the usage policy and seamlessly track the origin of the data. The IDS connector acts as a gateway for data and

services and as a trusted environment for apps and software. Apps run from the app store in the familiar environment of the IDS connector. Apps perform tasks such as transactions, aggregations, or analysis of the data.
The data connector is the central technical component for secure and trusted data exchange in IDS. The connector transmits data directly to the recipient in a trusted, certified data space, so that the original data provider always maintains control over the data and determines the conditions for its use. The IDS connector uses technology that places your data in a kind of virtual 'container', which ensures that it is only used as agreed upon by the parties involved.

IDS connectors can publish the description of their data products (and endpoints) to an IDS **broker**. This allows potential data consumers to find available data products in terms of content, structure, quality and other attributes. For the same purpose of finding and using the data products vocabulary providers manage a **vocabulary**, which is used to annotate and describe data products (including ontologies, reference data models, metadata elements). Vocabulary providers provide these (domain-specific) vocabularies and their references to the IDS information model, which forms the basis for the description of data products.

The **clearing house** provides decentralized and verifiable traceability of all transactions if necessary. It's the 'counter room.' In addition, this facility provides clearing and settlement services for all financial and data exchange transactions within the data space.

App stores offer data apps. These are applications that can be implemented in IDS Connectors to perform tasks such as transformation, aggregation, or analysis of the data. Data apps can be certified by IDS-approved certification bodies. App stores can be supplied by IDS members and must be certified separately to IDS standards.

Identity providers provide a range of services for creating, maintaining, managing and validating identity information from and for all IDS participants and components. Collective trust in the proven identity of all IDS participants is necessary for the successful functioning of IDS-based data space.

Certified for reliability. A transparent certification process ensures the trust of participants and components within the data space. IDS enables reliable data exchange between certified data providers and recipients, based on mutually agreed rules.

3.3 IDS reference architecture

The IDS Reference Architecture **[IDS-RAM3]** and **[IDS-RAM4]** describes the logical coherence of IDS as data space in five layers:

1. The business layer describes the actors, their roles and interactions. Consideration is also given to the importance of establishing 'identities' and contracts of use for the exchange of data;
2. The functional layer distinguishes the functional aspects of IDS into six categories: trust, security and data sovereignty, the ecosystem of data, interoperability, value-addings apps and the data market;
3. The process layer outlines the important processes of IDS; the process of onboarding in the data space, the data exchange process and process of publishing, using and certifying data apps. Standard process models are available for these processes;
4. The information layer specifies the information model, the domain-independent, common language of the IDS data space;
5. In the system layer, attention is paid to the data connector, and its operation in the system of data apps and data marketplace.

In addition to the five layers of architecture, three perspectives are described on the architectural layers: the perspective of security, certification and control ('governance'). In conjunction, this produces a whole set of components, processes control components for IDS. IDS is not a data space, but a framework for creating data spaces.

An important part of the IDS information layer is the IDS Information Model. The information model contains all aspects that play a role in the data space, their definitions and mutual relationships. The information model supports the description, publication and identification of data products and reusable data processing software, both in IDS 'Digital Resources' or simply referred to as 'resources' or 'sources'. Once the relevant sources are identified, they can be exchanged and consumed through semantically annotated, easily findable services. Apart from these core goods, the information model describes essential components of the international data spaces, participants, infrastructure components and processes.

An important part is the elaboration of the concept of the 'digital resource'. A digital resource 'in the context of the International Data Spaces is a uniquely identifiable, valuable, digital (i.e. non-physical) commodity that can be traded and exchanged between remote participants using the **IDS infrastructure' [IDS-RAM4]**. Central to the exchange of 'digital resources' is the C-model or 'concern model' (see Figure 3.3). A digital source is accurately described in a data space. Through an accurate description of the digital source, data consumers (users of the digital source) are clearly informed for targeted use of the source and prevent misunderstandings. This means that digital sources are adequately described by the data product suppliers. The description shall include at least six categories of attention (the 'concerns'):

1. Content concerns the general description of the data product, type of data product, data format, data sample and the physical size of the data product;
2. Context refers to a description of the entity, the location (such as coordinate reference system) and the time component (validity, date of creation);
3. Concept, such as description of concepts, keywords and types of entities from schematics and ontologies;
4. Communication, such as method of access with data exchange APIs;
5. Commodity or common good, such as quality aspects, provenance (lineage), policy and resource pricing;
6. Community of Trust, which ensures and secure and sovereign exchange of digital resources between data consumers and data providers.

The digital source can only be delivered after the negotiation and a dialogue between the data consumer and data provider. This dialogue sets conditions for the data consumer. The customer must understand the description of this dialogue in order to meet the conditions.

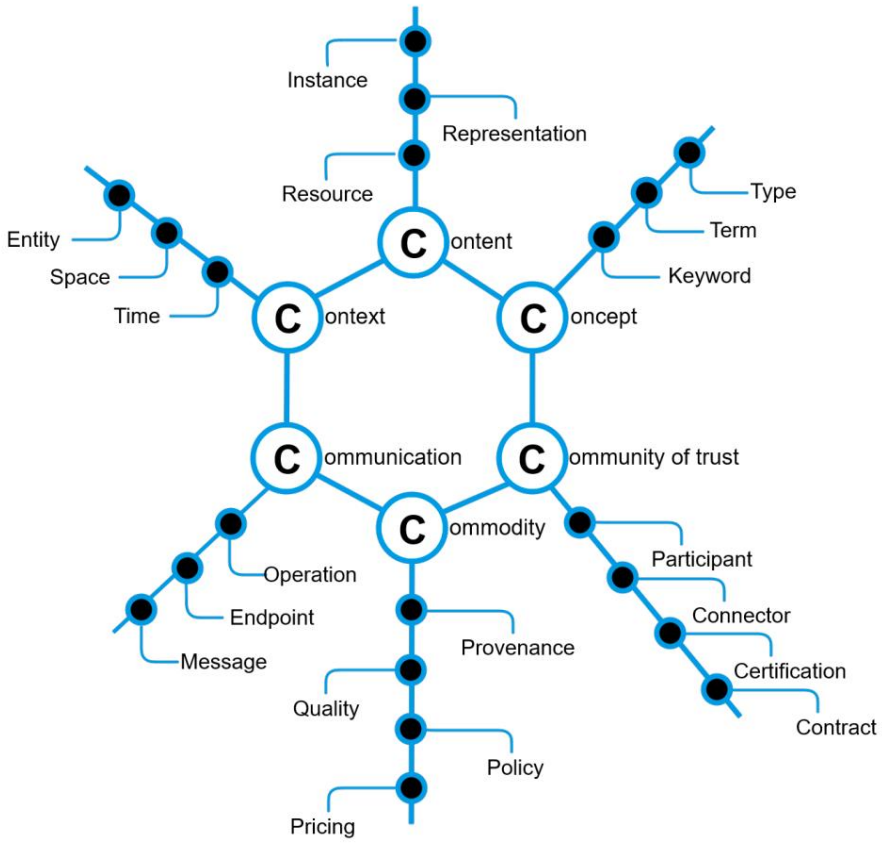

Figure 3.3 — Concerns model for IDS 'resources' ([IDS-RAM4])

The IDS information model is a conceptual representation of the digital source. In addition to this conceptual representation in the IDS reference architecture, the declarative and programmatic representation is also important for the implementation of a digital resource and the various IDS building blocks (see Figure 3.4).

The conceptual representation provides a high-level overview of the most important, largely invariant concepts, without obligation to a particular technology or domain. It focuses on a general audience, as it provides basic information and promotes a shared understanding of the concepts through a textual document and a visual notation. If available, IDS also refers to related elements of the declarative view and a programmatic view, encouraging to look at these alternative implementations.

The declarative view is called 'IDS Ontology' and gives a normative picture of the IDS information model. It has been developed based on the analysis, findings and requirements of conceptual representation. Based on a stack of W3C Semantic Web technology standards and standard modeling vocabulary such as DCAT, PROV and ODRL, it provides a formal, machine interpretable specification of concepts intended by conceptual representation. In addition, it formally describes and defines entities of the IDS in order to be able to share, search and reason the structured metadata of these entities. As such, it includes a complete reference model that allows the distraction of a number of programmatic representations. The IDS Ontology is usually used and instantiated by knowledge engineers, ontology experts or information architects. It defines a fairly minimal, domain-agnostic 'core model' and relies on standard and custom third-party vocabulary

to express head-specific facts. According to common practice, existing domain vocabulary and standards are reused wherever possible, thereby promoting acceptance and interoperability.

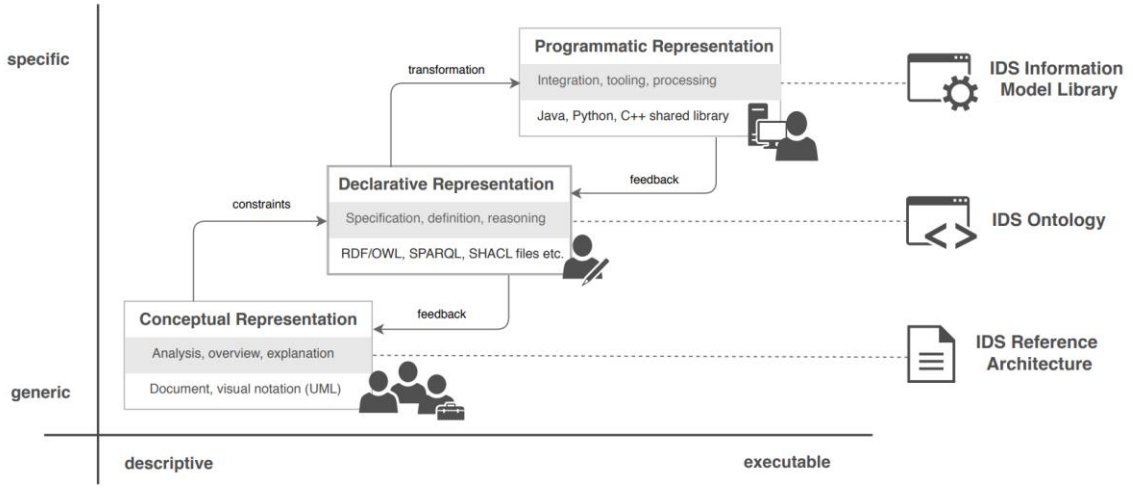

*Figure 3.4 — Three representation perspectives of IDS (**[IDS-RAM4]**)*

Finally, the programmatic representation of the information model focuses on software vendors by supporting seamless integration of the information model with a programmatic infrastructure that software developers are familiar with. It consists of a programming language data model (e.g. Java, Python, C++) that is provided as a series of documented software libraries (e.g. JAR files). The programmatic view provides the best-effort mapping of the IDS Ontology on the native structures of a target programming language. It allows software developers to easily create instances of the information model that comply with the IDS Ontology.

IDS already has several technical building blocks available for the programmatic display. These IDS components, such as a data connector or metadata broker, can be completely rebuilt by using existing resources as a template, or can reuse existing open source components available in the IDS Github repository. Overview of (open source) software implementations of the IDSA building blocks can be found here on github.

3.4 Synthesis

IDS is a widely supported initiative for data space in Europe. IDS focuses on standards and specifications for cross-domain data spaces. The **[IDS-RAM4]** is the reference architecture, which describes the logical coherence of the different aspects of a data space; of actors and their roles, functional aspects and building blocks, the crucial processes, the information layer describing the 'digital resources', and the system layer with data connectors. In various published documents, parts of this global architecture are further elaborated. The focus areas of IDS are included in Figure 3.5.

The information model is a generic cross-domain model, without binding to a particular application domain.

Various use cases illustrate the use of IDS. The IDSA Data Space Radar is the platform for finding use cases to bring data spaces to life and maps all IDS data spaces in one user-friendly tool. The radar covers use cases of different degrees of maturity, from the phase of making a business case to real data spaces; from planned to pilot to fully operational, in various sectors and functional domains.

In a position paper **[IDS-PPBM]**, a method is offered to determine the business model and value case of the data space. IDS does not have a governance model for data spaces, the reference architecture has defined the actors and roles of a data space. A corresponding governance model for the data space is left to the participants of the domain-specific data space.

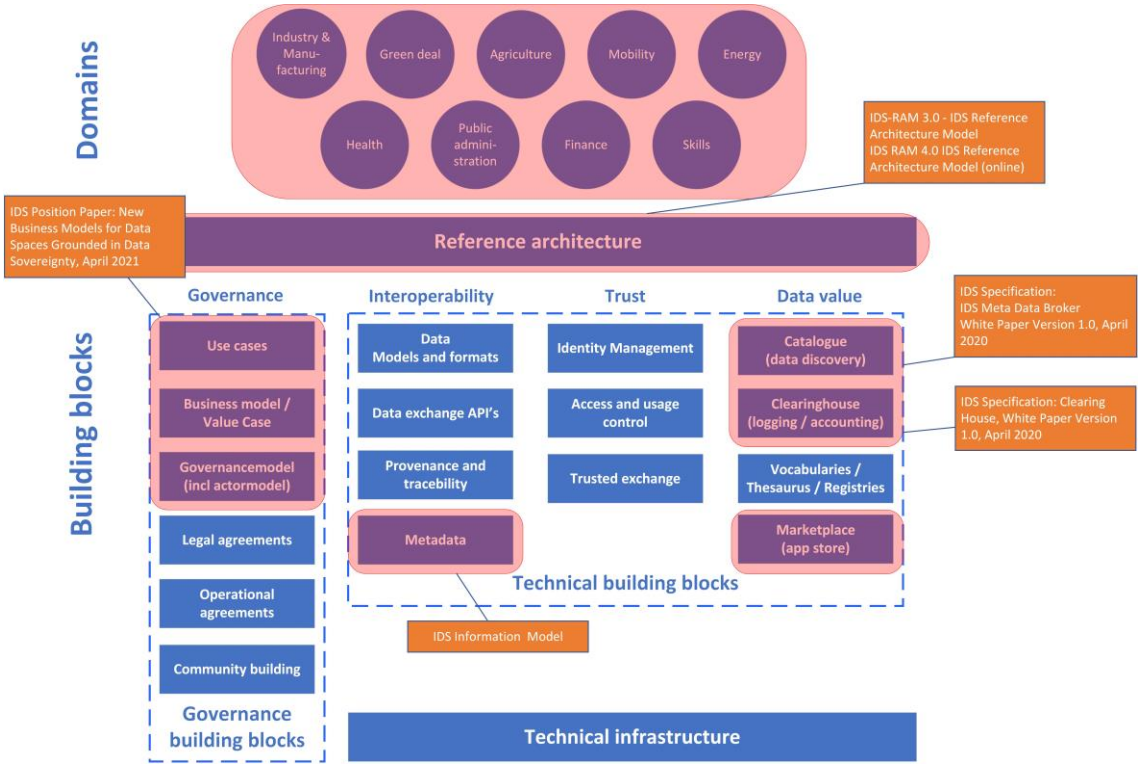

Figure 3.5 — IDS focus areas as data space initiative

In terms of interoperability, the IDS information model does not provide a meta-model for defining data models and formats and data exchange APIs. This has been left to the domain-specific communities and is not part of IDS. Domain modelling is typically based on shared vocabularies and schedules, as provided for example by domain-specific communities Interoperability is offered by IDS by its metadata-model and through the implementation with a data connector. Also, no or little attention has been paid to provenance and traceability, other than the fact that the description of the digital sources must also be taken along with provenance.

IDS has also developed global aspects in the information model for the trust aspect. This has also been elaborated in some position papers, which provide a global insight into the operation of, for example, the 'usage control' **[IDS-PPUC]** and 'certification **[IDS-PPCE]**.

Some of the four data value (technical) building blocks (catalogue, clearing house, vocabularies and marketplace) have also been under further IDS investigations, especially for the building blocks 'metadata broker' **[IDS-MDB]** and 'clearinghouse' **[IDS-CH]**. The various IDS components can also be found on github **[IDS-G].**

On the system layer, the roles specified on the business layer are assigned to a concrete data and service architecture to meet the requirements specified on the functional layer, resulting in what can be considered the technical core of the IDS. From the requirements identified to the functional layer, three key technical components result: the connector, the metadata broker and the App

Store. These are clear IDS focus areas, which refer respectively to building blocks metadata (self-descriptions), the catalogue (metadata discovery) and the marketplace.
The connector, metadata broker and App Store are supported by additional components (which are not specific to IDS but are specified by IDS **[IDS-RAM4]**:

- the Identity Provider (from the perspective of security);
- the Vocabulary Hub (as currently defined outside IDS);
- the Update Repository (i.e. the source for updates of the connectors present) depending on the connector technology used;
- the Trust Repository.

IDS also has open software implementations (building blocks), which can currently mainly be considered as reference implementations. For example, there are some implementations IDS connectors available (see **[IDS-G]**.

4. Gaia-X

This chapter describes and introduces the use of the concept of data space from the perspective of Gaia-X as 'connector between eco-systems'. In addition to a brief introduction, we describe the functional building blocks and distinguish federation services of Gaia-X. The agreements on interoperability and data sharing standards are discussed and the actors model are appointed. And we take a moment to look at the positioning of Gaia-X in relation to the IDS initiative introduced in the previous chapter. Gaia-X and IDS are closely related.

4.1 Gaia-X as a connector between ecosystems

Gaia-X is an European initiative that develops a software framework of control and governance and implements a common set of policies and rules that can be applied to any existing cloud/edge technology stack to gain transparency, accountability, portability and interoperability between data and services. The framework is designed to be implemented on top of any existing cloud platform that decides to adhere to the Gaia-X standard. Gaia-X is not a market operator and will not directly or exclusively operate any of the services required by the framework. Gaia-X services will be created, operated and adopted by market operators, who decide to adopt the Gaia-X standard.

The name of the project Gaia-X corresponds to the high ambitions: named after the Greek goddess Gaia, who was one of the first gods to come out of chaos, Gaia-X is meant to create an order in the digital economy in Europe and claims to serve three objectives:

1. Data sovereignty. European companies and organizations should always have the choice where and with whom they store and process data and where they purchase digital services. Gaia-X wants to avoid monopolies and thus an unilateral dependence on Europe on large non-European platform providers. In particular, SMEs should be able to benefit from market transparency, easy access to services and tailor-made offers;
2. Availability of data. When data becomes the most important raw material, European companies, governments, institutions and citizens need guarantees to exchange data in a reliable, secure and transparent way. Even when this data goes through many hands, systems and phases;
3. Innovation. Gaia-X aims to promote innovation in Europe and strengthen the digital economy. The cloud and edge services collected under Gaia-X support the digital business models of European businesses and give them the opportunity to grow on the basis of this infrastructure worldwide.

Gia-X as a data space concept has the following characteristics:

- A data space is a data integration concept, in which no physical integration of data takes place, but data is federated or distributed;
- The data space concept does not have a common semantic data schedule, but works with vocabularies;
- There is no single source of truth, data can occur more often in a data space (data may be redundant);
- Within a data space, data spaces can exist again (nested data spaces);
- A data space is never finished, and evolves over time;
- In data spaces, data sovereignty is central; the data owner wants to know what happens to his/her data;
- In a data space there is always a relationship of trust between the provider and the customer, via a token.

Gaia-X is therefore seen as a standard that allows data exchange in and between data spaces or 'Gaia-X data ecosystems'. A Gaia-X ecosystem is an organizing principle that describes the interaction of different actors and their environment as an integrated whole, as in a biological ecosystem. In a technical context, it refers to a series of loosely linked actors, which together form an economic community. Gaia-X distinguishes a Data Ecosystem and an Infrastructure Ecosystem, each with a different focus on exchanged data and services (see Figure 3.1).

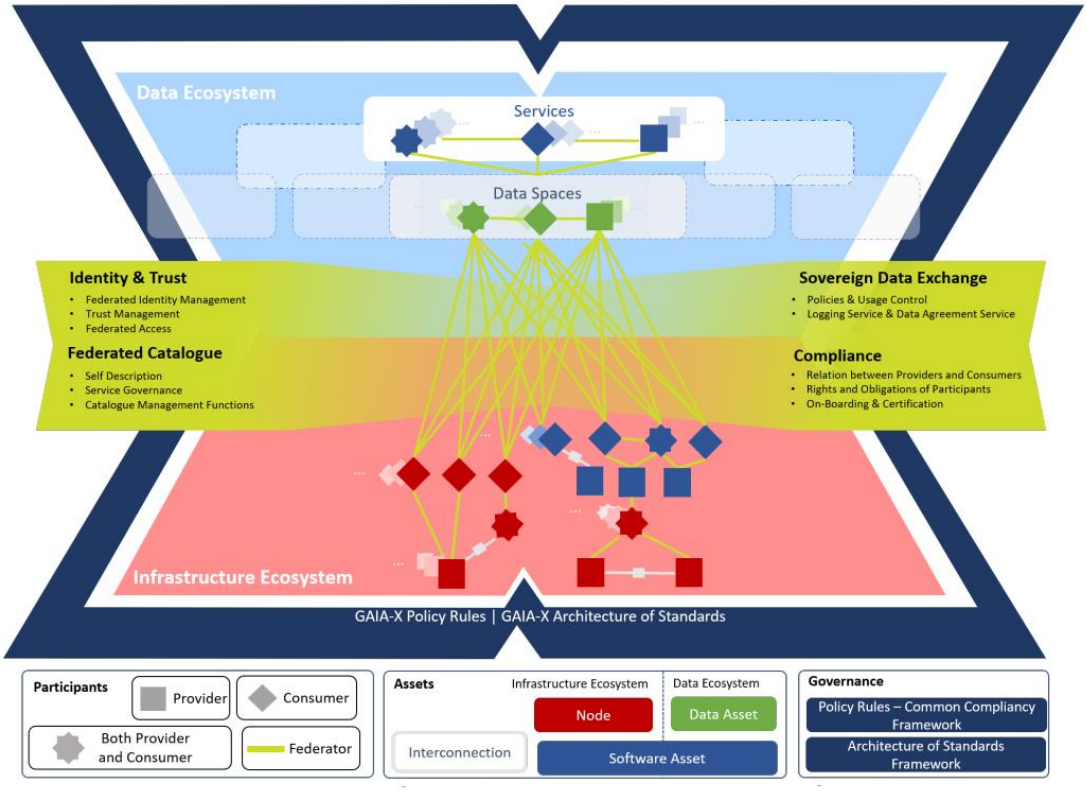

*Figure 3.1 — The Gaia-X ecosystem (***[Gaia-X-REFA]**

Although each of them has a separate focus, they cannot be viewed separately because they build on each other, i.e. they are complementary. The Gaia-X Ecosystem consists of all the individual Ecosystems that use the Architecture and meet the Gaia-X requirements. There may be several individual ecosystems (e.g. Catena-X in the automotive sector) that orchestrate themselves, use architecture and may or may not use the (open source) software of the Gaia-X federation services.

Gaia-X has four types of participants: the providers, consumers, the 'provider and consumer' and some federators. The basic roles of consumer and provider are visualized as different squares, while the federator appears as a connecting layer, which offers various federation services. Federation services provide connections between the different elements and between or between the different ecosystems. Consumers can also act as providers by offering compiled services or processed data through the federation catalogues.

The main three assets are 'data assets' in the data ecosystem, the 'nodes' in the infrastructure ecosystem and the 'software assets' as interconnections between the two.

Governance in Gaia-X includes the policies, which constitute statements of the objectives, rules, practices or regulations of all activities of the participants within the ecosystem. These are laid down in the Common Policy Framework (**[Gaia-X-PRD]**).

4.2 Gaia-X actors and federated services

In the current Gaia-X architecture **[Gaia-X-AD]**, the conceptual model is incorporated with all concepts in the context of Gaia-X and the relationships between them (see Figure 3.2). The Gaia-X core concepts are represented in classes. An entity marked blue shows that an element is part of Gaia-X and is therefore described by a Gaia-X self-description. The upper part of the model shows different actors of Gaia-X, while the lower part shows the relationship with actors outside Gaia-X. The overall pattern of interaction between the actors is also described in the document.

A Gaia-X participant or participant may take on one or more of the following roles: Provider, Consumer or Federator. Provider and consumer represent the core roles, while the Federator allows their interaction(s). A Provider is a participant who exploits resources in the Gaia-X Ecosystem and offers them as services. For such a service, the Provider defines the offer of services including terms and conditions and technical policies. In addition, it offers the service authority with a self-description and associated policy. Federators are responsible for providing federated services. There may be one or more Federators per type of service. Use cases are included in **[Gaia-X-AF]**, illustrating how the Federator roles can be filled. A Consumer is a participant who searches for data services and uses services (service agencies) in the Gaia-X ecosystem to enable digital offers to end users. All participants in Gaia-X have a self-description. These are also the key concepts in the form of mandatory attributes for Gaia-X self-descriptions, which are specified in the Gaia-X Trust Framework (**[Gaia-X-TF]**).

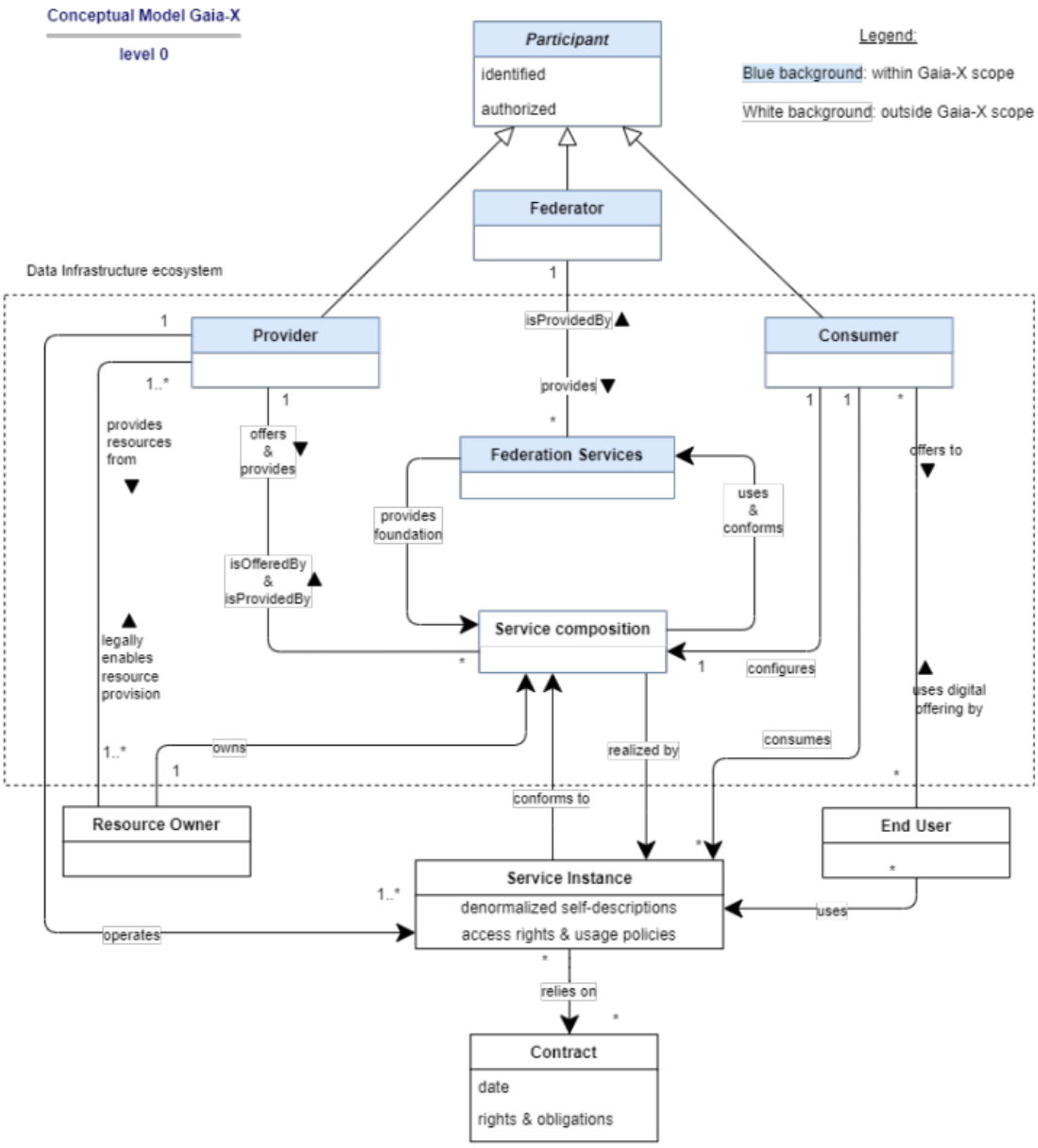

Figure 3.2 — Gaia-X conceptual model

The **Gaia-X Federated Services [Gaia-X-FS]** are services necessary for the operational implementation of a Gaia-X data ecosystem. Gaia-X distinguishes four groups of federated services, which are needed to enable federation of resources, participants and interactions between ecosystems. These four groups of federated services focused on identity and trust, compliance services for sovereign data exchange and a federated catalogue containing self-descriptions of the participating organizations and their services.

The Gaia-X Federated Services represents the minimum technical requirements required to set up and operate a Gaia-X ecosystem. Based on technical specifications, the federated services are developed on the basis of open source code. These open source software components are available to everyone and can be used directly or as inspiration for their own implementations. This is also known as the GXFS Toolbox. They are developed into operational services and are continuously improved by the Gaia-X community. On gitlab you can find the open source code of the implementation of various Gaia-X federation services.

To ensure Gaia-X a higher and unprecedented level of trust in digital platforms, and to make trust an easy-to-understand and adopted principle, Gaia-X has developed a 'Trust Framework' — formerly known as Gaia-X Compliance and and Labelling Framework **[Gaia-X-LF]**, **[Gaia-X-FCC], [Gaia-X-PRD]**, which ensures data protection, transparency, security, portability and flexibility for the ecosystem, as well as sovereignty and European control. The Gaia-X 'Trust Framework' **[Gaia-X-TF]** is the set of rules, which define the minimum basis to be part of the Gaia-X ecosystem. These rules ensure a common governance and the basic levels of interoperability between individual ecosystems. In other words, the Gaia-X ecosystem consists of participants and services, which follow the Gaia-X requirements of the trust framework. The trust framework uses verifiable references ('credentials') and a linked data representation. The set of computable rules known as the compliance process is automated and verified.

4.3 Synthesis

Gaia-X is a widely supported initiative for data spaces in Europe. Gaia-X focuses on standards and specifications for cross-domain data spaces. The **[Gaia-X-AF]** is the reference architecture, which describes the logical coherence of the different concepts of a Gaia-X data space; of actors and their roles, the functional aspects and building blocks in the form of federated services, the definition of the self-description of sources and the comprehensive trust framework with trust anchors, policy rules and labels. In various published documents, parts of this global architecture are further elaborated. The focus areas of IDS are included in Figure 3.3.

The Gaia-X model is a generic cross-domain model, without binding to a particular application domain. In a large number of use cases, the operation of a Gaia-X data space is explained in various application domains. In various Gaia-X lighthouse projects, the operation of the Gaia-X building blocks is now being tested, such as Catena-X for the automotive industry, AGDATAHUB for the agri-business in the Mobility Data Space for the mobility domain.

In Gaia-X there is a limited actor model, the actors and their roles are globally appointed. Implementation of the data space takes place during the implementation of the data space. In addition, Gaia-X has a governance model, in which the Gaia-X Association plays an important role. However, much is not yet known about how the Gaia-X data space is controlled.

Community building is an important organizational pillar of Gaia-X. Gaia-X is a common European project: it brings people from different companies, research institutions, associations, governments and politics together to work towards a common goal. Together, they build on the broadest spectrum of expertise to co-create the future of digital infrastructure for Europe.The organizational structure of Gaia-X is built on three pillars: the Gaia-X Association, the national Gaia-X Hubs and the Gaia-X Community. Within that there are several working groups and committees. The exchange within, between and outside these pillars with other stakeholders (e.g. European Commission, international initiatives) is ensured.

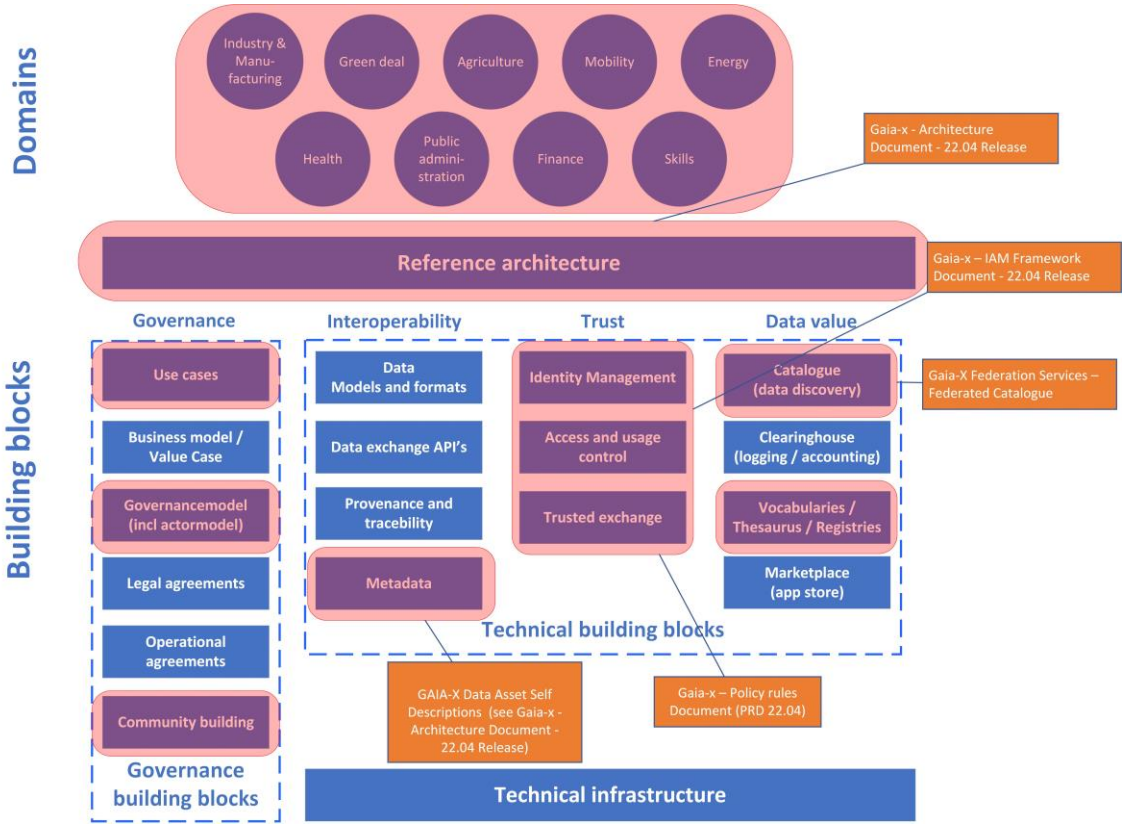

Figure 3.3 — Gaia-X focus areas as data space initiative

In terms of interoperability, Gaia-X does not provide a meta-model for defining data or exchange APIs. Domain modelling is typically based on shared vocabulary and schedules, and provided by domain-specific communities. This has been left to the domain-specific communities and is not part of Gaia-X. Interoperability has been elaborated in the form of the self-description (metadata) of resources. Also, no or little attention has been paid to 'provenance' and 'traceability'. Self-descriptions are guarantee trusted and sovereign exchange of data and can also be adapted by domain-specific data space initiatives.

For the trust aspect, Gaia-X has worked out various aspects of the architecture and technical specifications are also available. The technical specifications provide detailed insight into the functional and non-functional aspects of various building blocks needed. Technical specifications have been drawn up and developed for the building blocks 'catalogue', 'clearinghouse' and 'marketplace': those for the 'Federated Catalogue' **[Gaia-X-FC]**, the Data Exchange Logging Service and Continuous Automated Monitoring **[IDS-CH]**, and the 'Portal **[Gaia-X-POR]**. Technical specifications have also been drawn up for various supporting components: the 'Personal Credential Manager', the 'Organisational Credential Manager', Services API.

Implementations of some of the technical specifications are available. The available (open source) software components (reference implementations) can be found on github **[Gaia-X-G].**

4.4 Gaia-X versus International Data Spaces

In the previous two chapters, International Data Spaces (IDS) and Gaia-X are briefly explained from terminology, concepts, actors and reference architecture.

A 2021, a position paper **[IDS-PPGXIDS]** identified the differences and similarities between the two. In October 2015, the Fraunhofer Society initiated the International Data Spaces (IDS) project, formerly Industrial Data Space, funded by the German Federal Ministry of Education and Research. This is supported by the non-profit International Data Spaces Association (IDSA), which actively contributes. In 2022, the IDSA consists of 138 members from all over the world, who together define the IDS standard for data sovereignty. The members of the IDSA come from different industries and offer use cases where the IDS architecture is applied in their corresponding domain, which already presents an analogy with Gaia-X. Gaia-X is a fairly new initiative with a first high-level architecture and a demonstrator-like Minimal Viable Gaia-X has been developed, while the IDS architecture is much more mature and has already been tested by various systems in science and industry. This has resulted in a high-level alignment between these two initiatives.

An IDS position paper **[IDS-PPGXIDS]** from 2021 provides a first overview of the coherence between the architectures of Gaia-X and IDS. The comparison shows that Gaia-X is not as mature as the IDS initiative, but follows the same vision to spread data sovereignty and create an ecosystem of trust for data sharing. The IDS initiative and the IDS Reference Architecture Model (IDS-RAM) offer various concepts and solutions that contribute to Gaia-X's overall vision and to the concrete Gaia-X architecture requirements. On the other hand, Gaia-X offers concepts, which include the storage of data and cloud-related elements, that can complement the IDS architecture **[IDS-PPGXIDS]**. The conceptual mapping results in the following high-level relationship:

- The Gaia-X Federational Catalogue consists of the IDS Broker, Vocabulary Provider and Information Model;
- The Federation Service of Sovereign Data Exchange comes from IDS Usage Control and Clearing House.
- The Gaia-X Federation Service of Identity &Trust benefits from the IDS Identity Provider and Dynamic Attribute Provisioning Service (DAPS);
- Gaia-X Nodes are aligned with IDS Connectors as gateways;
- The Gaia-X Data Ecosystem is the place where IDS Data Provider and Data Consumer are located conceptually;
- The IDS Service Provider, IDS App Store Provider and App Provider are located in the Gaia-X Infrastructure Ecosystem.

5. OpenDEI

5.1 Introduction

OPENDEI aimed to identify gaps, encourage synergies, support regional and national cooperation, and improved communication between EU projects implementing the EU Digital Strategy. OPENDEI delivered a very readable position paper 'Design principles for data spaces' in May 2021 **[OPENDEI-DPR]**. Several other data space initiatives and organizations have contributed to the OPENDEI position paper, such as IDSA and Gaia-X. The position paper describes the principles for creating data spaces, and is also a conceptual model of the necessary agreements and generic building blocks for creating a data space. OPENDEI has set up a framework for a 'soft infrastructure' which is a kind of reference architecture on (functional) main components and buildings blocks. Where possible, reference is also made to standards to be applied. In addition to an actor model, there is a suggestion for a governance model based on the European Governance Act. Attention is also paid to the importance of a business model. The position paper underscores the importance of data spaces and the sovereign sharing of data in the future EU data economy. It was developed under the coordination and direction of International Data Spaces Association in collaboration with more than 40 data spaces initiatives and experts from the industrial domain, representing more than 25 organizations from 13 EU Horizon 2020 projects and related initiatives. This has provided a first approach to design principles for data spaces and agreements on the building blocks for a 'soft infrastructure' and the governance of data spaces.

5.2 OPENDEI principles and building blocks

5.2.1 OPENDEI Principles

OPENDEI has four principles:

1. Data sovereignty. The ability of a natural person or organisation to have exclusive self-determination in relation to its economic data goods. This is the innovative and transformative concept that underlies data spaces;
2. Level playing field on data. Newcomers do not experience insurmountable barriers to entry due to monopolistic situations. When there is a data level playing, players compete on quality of service and not on the amount of data they manage. A level playing field for data is a crucial prerequisite for creating a fair economy for data sharing;
3. Decentralised 'soft infrastructure'. The data sharing infrastructure is not a monolithic centralised IT infrastructure. It is a collection of interoperable implementations of data spaces that meet a uniform set of agreements across all dimensions: functional, technical, operational, legal and economic. The principle of data sovereignty follows functional and non-functional requirements of interoperability, portability, findability, security, privacy and reliability;
4. Public-private governance. Good governance is essential for the design, creation and maintenance of the level playing field for data sharing. All stakeholders should feel represented and involved. These include users (persons, organizations) or providers of data services, as well as their technology partners and professionals.

5.2.2 OPENDEI building blocks

OPENDEI has developed a building block model for data spaces, which is frequently used in various initiatives. The OPENDEI generic building blocks are included in Figure 4.1. These building blocks have also been taken as a starting point in this study for determining focus areas in various data spaces initiatives. The building blocks are explained in more detail in paragraph 2.4.

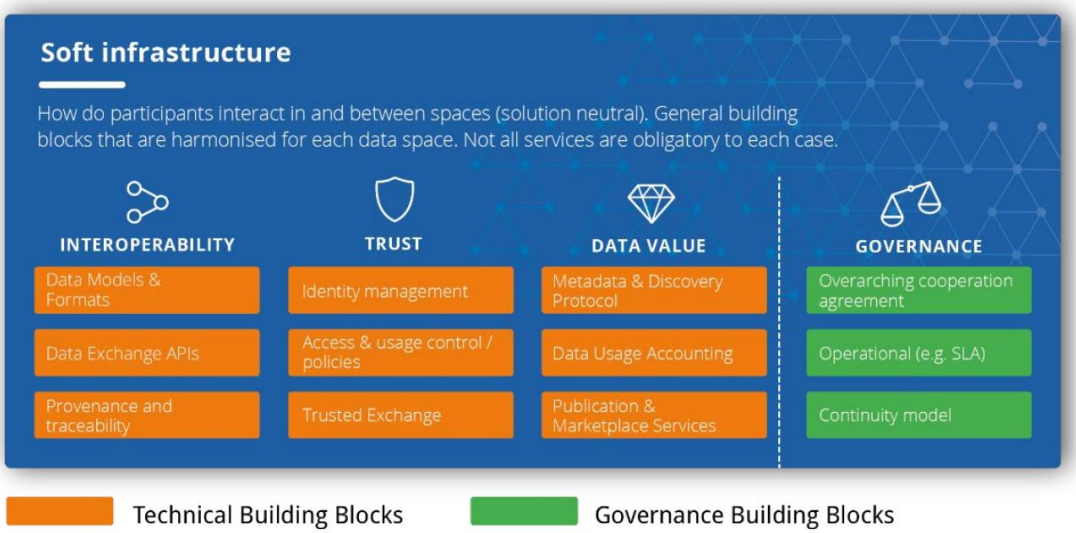

Figure 4.1 — OPENDEI data space building blocks

5.2.3 Actor model

The building blocks will eventually have to be implemented and managed by actors. This also requires an actor model (and a control model). In terms of the actor model for setting up the 'soft infrastructure', OPENDEI relies on the actor model of IDSA and simplified this actor model. OPENDEI distinguishes four groups of stakeholders in data spaces: the data acquirer or data owner, the data provider, the data processor and the marketplace operator. Figure 4.2 illustrates the relationships and interactions between these stakeholders and the data flow that takes place between them.

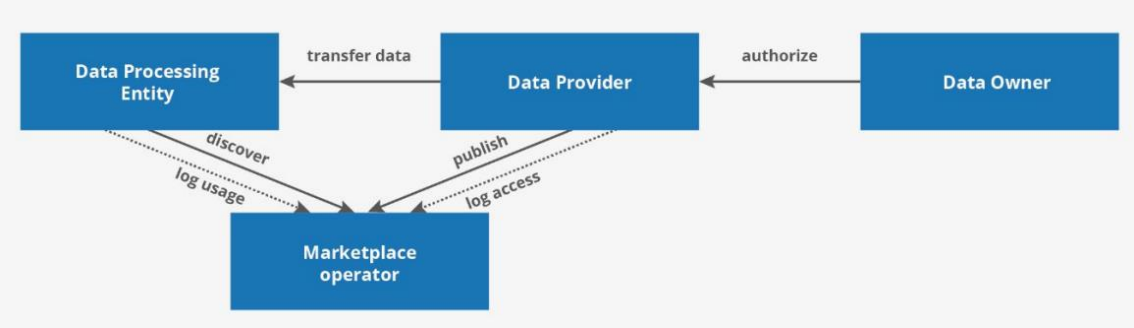

Figure 4.2 — OPENDEI actor model

A **data owner** is an entity that has the power to decide how its data can be used by third parties. Depending on the service and solution and the business model set up, this entity may collect data (manually or using systems) or use third-party tools and services to obtain data. Data can be stored on-premise, on the edge or in the cloud. Data owners may decide to keep their data private for internal use (for improvement of own processes, creation of new business value for commercial benefit, etc.) or to share it publicly or with a limited number of third parties. In the event that data is made available in one form or another to third parties (usually done with the help of a data provider), this includes rights and obligations (data usage policy) and general terms and conditions. Data owners can make data available free of charge to third parties (for example, to promote science and innovation with open data) or offer for payment, depending on the business model.

A **data acquirer or data provider** is an entity responsible for collecting and preprocessing data and providing it to others on behalf of a data owner (often as part of a business-related service

provided to a data owner). For example, a company that provides asset monitoring services (e.g. for fleet management) uses tracking devices and collects data about the customer's vehicles (time data, location data, etc.). Although the data is collected, processed and stored by the data provider for the benefit of the customer (i.e. the data owner), the later use of the data usually remains under the control of the customer. Recently, new business models have emerged on the basis of which data providers offer their services at reduced prices in exchange for the ability to use their customer's anonymized data to further improve existing services or create new services that generate new business value. The data provider provides the data owner with technical means to enable reliable data exchange with other participants in the data space (including monitoring of data usage, if requested).

A **data processor** is an entity responsible for and interested in using certain types of data to create new services offered on the market. The spectrum of such services is very broad, ranging from domain-specific use cases to cross-domain applications. The value of the data used to create new services depends on the accuracy of the data, the availability (i.e. the number of data providers that this data provides) and how important they are to the processing algorithms used. It is usually pre-estimated and agreed, which to some extent limits the data owner's ability to achieve maximum monetization of his data, because they do not have an understanding of the additional value created on top of their data and/or the value the new services have for users. Since data usage control is based on conventional contract documents drawn up by the parties involved, resulting in dependency on manual/back office activities, the use of data is further complicated, thereby slowing down the full exploitation and monetization of data.

A **data marketplace operator** is an entity that provides different types of infrastructure (e.g. soft infrastructure, cloud hardware, data processing tools). In addition, it is responsible for the management of the market by providing support services, defining terms and conditions and deciding on admission and withdrawal of datasets or participants. As the importance and potential of data is increasingly recognized, data marketplaces emerge as a new type of business offering. Their goal is to enable data usage in a seamless and automated way, bypassing the need for complicated back office contracts and agreements. A data marketplace can be cross-domain or domain-specific (i.e. dealing with data relevant to specific use cases and industries). Their main task is to make data easily findable (based on a set of standardized data models) and to provide transparent tracking of all data-related transactions (whose data used at what time to revenue generated from sharing data). Data marketplace operators should put in place mechanisms to ensure compliance with data usage policies (e.g. with regard to the time and number of data on which the data were used, or areas where certain data cannot be used).

5.2.4 Governance model

Public-private governance is one of OPENDEI's four main principles. OPENDEI has launched a global governance model based on the EU Data Governance Act. The Data Governance Act (DGA) confirms the idea of a multi-entity governance structure. For European data spaces, it is recommended to designate for each data space a (domain) authority for governance and to have a central authority overseeing all aspects of the data space related to the interoperability of data space, i.e. the de facto 'soft infrastructure'. This central authority will communicate with all specific authorities for the individual data spaces. This governance of soft infrastructure requires governance at three levels (strategic, tactical and operational level) to operate closely with each other. The EU DGA specifies the European Data Innovation Board (DIP) as the strategic authority. OPENDEI proposed the establishment of an authority at tactical and operational level, the Data Exchange Board (DEB). Figure 4.3 below shows this governance structure.

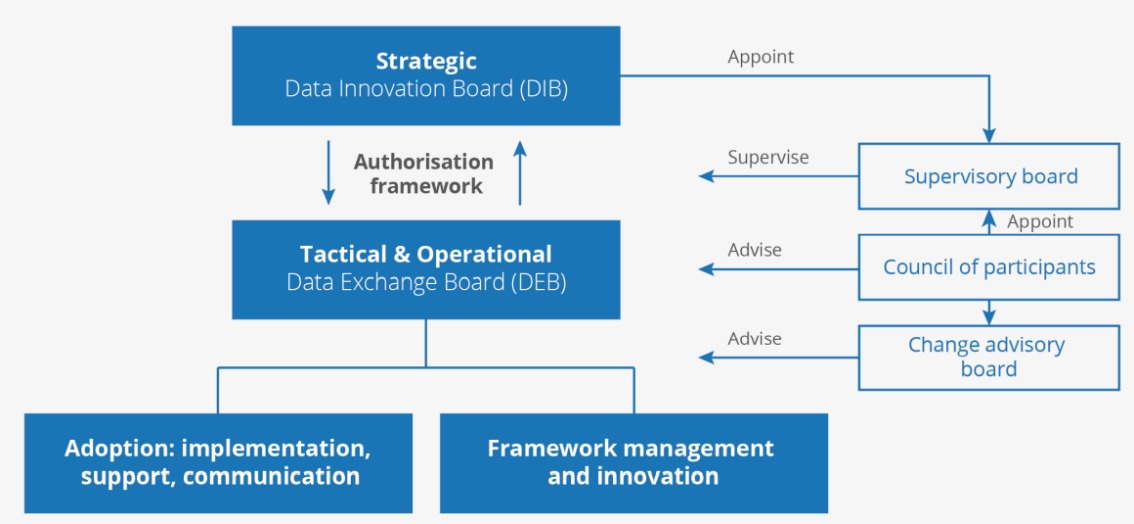

Figure 4.3 OPENDEI Governance structure for soft infrastructure

With DGA, the EU establishes a Data Innovation Board (DIB), which advises on the practices under this law, on standards and interoperability. OPENDEI endorses this and makes the suggestion to set up a Data Exchange Board (DEB) in addition to the DIB for data spaces governance. According to OPENDEI, the DEB will have two main activities:

1. Taking care of the authorization framework; and
2. Handling everything related to European data spaces that are live and adopted (i.e. implementation, support, communication).

The DEB itself will have a two-fold structure. A central role will be given to the 'Council of Participants'. This board could consist of representatives of certified and permanent parties. The Participants Council is entitled to appoint the members of the Supervisory Board (together with the DIB). The DEB will have its own staff. Some of these personnel must be made up of representatives of the governance organizations of the individual data spaces. The organisation responsible for the governance of each data space will appoint a part of the representatives to staff the DEB. In addition, the participants of any data space representatives can send representatives to the Supervisory Board, the Participants' Board and the Change Advisory Board. The organizational structure of the governance entities of the individual data spaces should be similar to this overall governance structure. OPENDEI also advises to define a strategic, tactical and operational level for the governance of the individual data spaces, with each level being controlled by organizational bodies consisting of representatives of participating organizations.

5.2.5 Data space domains

OPENDEI has also explored data spaces in the field of industry, energy, health and agri-foo and which specific aspects play in these data spaces domains. In addition to this, OPENDEI has been active on several other topics:

- Platform development. OPENDEI has carried out a comparison of reference architectures **[OPENDEI-ARCH]** for data spaces and identified open source reference implementations for data spaces (open source catalogue), enabling a uniform industrial data platform;
- Building data ecosystems. Enabling an innovation and cooperation platform, forging a European network of DIHs, contributing to the Industrial Skills Catalogue and Observatory;
- Large-scale data space pilots for industry, energy, health and agri-food. Contributing to a digital maturity model, creating a set of assessment methods and a benchmarking tool for migration pathways.

5.3 Synthesis

As an EU project, OPENDEI has focused on supporting data spaces in four domains: industry (production), energy, health, agriculture (agri-food). OPENDEI has created reference architectures for these domains. In the position paper 'Design principles for data spaces' **[OPENDEI-DPR]**, OPENDEI has provided global insight into important building blocks for data spaces. The building blocks are broadly and functionally described in terms of governance, interoperability, trust and data value. A detailed elaboration of these building blocks has not been given. Only the elaboration of the creation of business model and value cases for the domains as well as the impetus for creating a governance model and actors model are appointed as a focus area. Hence, these elements are highlighted as focus areas in Figure 4.4 below.

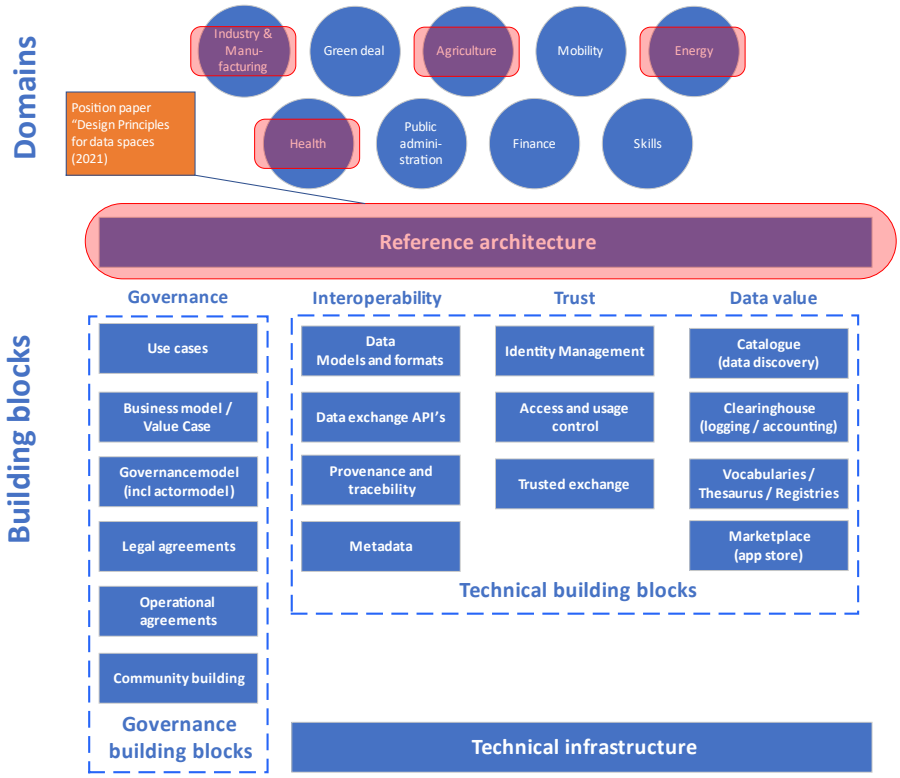

Figure 4.4 — Focus areas of OPENDEI

6. Data sharing coalition

6.1 Introduction

There are several data sharing initiatives that focus on a specific sector or domain. The Data Sharing Coalition aims to build on existing data sharing initiatives to strengthen them in unlocking the value of sharing data in and across their domain. The Data Sharing Coalition aims to stimulate cross-domain data sharing under the control of the rightsholder, by enabling interoperability between domains. The Data Sharing Coalition is an international initiative in which a wide variety of organizations collaborate to allow data sharing between existing data spaces. By enabling interoperability between existing and future data spaces with data sovereignty as a core principle, parties from different sectors and domains can easily share data with each other, unlocking significant economic and societal value. The Data Sharing Coalition realizes several cross-domain use cases. In these use cases, organizations from different domains together define and realize a use cases that offer new value thanks to (cross-sectoral) data sharing.

The coalition started in January 2020 with the support of the Ministry of Economic Affairs and Climate in the Netherlands. The expected lifetime of the project phase of the coalition is until 2025. By 2025, the Data Sharing Coalition is expected to have transferred its results and activities to an entity that operates and manages a trust framework that facilitates cross-domain data sharing. The first phase of the Data Sharing Coalition is a study of the harmonization potential to enable cross-domain data sharing. This is explained in the Data Sharing Canvas, which lists the main elements and actors of cross-domain data sharing.

6.2 Data sharing canvas

The Data Sharing Coalition currently has two clear focus areas: the development of the Data Sharing Canvas as a kind of reference architecture for sharing data and supporting it with the insights and experiences from use cases.

The Data Sharing Canvas is the conceptual model for realizing a trust framework for cross-domain data sharing **[DSC-DSC]**. The Data Sharing Canvas is intended to provide an overview and indication of the topics needed for data sharing and their implications. The Canvas is not intended to be exhaustive or to elaborate on these topics in detail. The Data Sharing Canvas also provides the global guidance for future work of the Data Sharing Coalition, but does not yet provide a basis for binding agreements or (technical) requirements for data sharing. To this end, DSC foresees a task for the DSC trust framework to be realized. On the basis of a BLOFT model, the DSC trust framework is described. The BLOFT model is shown in Figure 5.1.

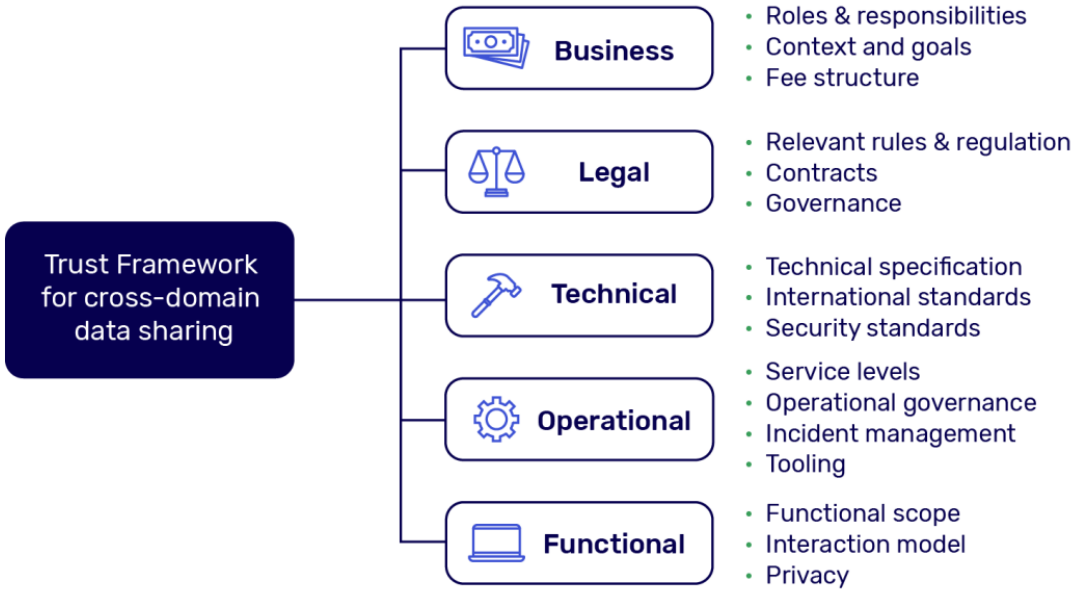

*Figure 5.1 — BLOFT model for DSC trust framework **[DSC-DSC]***

The Data Sharing Canvas is the current conceptual framework, which gives input to the Blueprint and the final DSC trust framework. The Data Sharing Canvas sets out the principles for data sharing, as well as the important concepts and topics. The topics are described broadly and conceptually by guiding principles, concepts, actors, harmonization through the proxy model and the specific focus on the following topics: terms and conditions, identification authorisation authentication (IAA), legal aspects, information security, data exchange, operational agreements, business models and control, data standards and metadata. These topics are explained conceptually.

An important role has been laid down for the proxy model; a concept similar to the IDS data connector, which should make it possible to connect a data sharing agreement between a consumer and provider of one domain with the other domain. To enable interoperability between domains and future scalability, each domain needs a proxy according to DSC. Proxys are systems, which must be used by each domain with the function of translating between domain-specific specifications and common harmonised inter-domain specifications. This is necessary to achieve interoperability and trust between domains. Figure 5.2 shows the proxy concept of DSC. This actor model also shows which actors are in scope of DSC. With the domain proxy, four actors are within DSC scope: the Data Service Provider, the Data Service Consumer, the Rightsholder and Domain Proxies.

The **data service provider** is defined as the actor, who offers a data service to the consumer of the data service. In the use case archetype, described in **[DSC-UCIG]**, the data service provider may only provide the data service if the rightsholder has given explicit consent. The data service provider defines the data service and the associated terms and conditions. A **data service consumer** is defined as the actor using a data service provided by the data service provider. The consumer must take note of the data service offered by the provider and accept his terms and conditions before the consumer can initiate the data service. The **rightsholder** is defined as the entity, which has rights to data. The rightsholder approves the data service, allowing the data to which they have rights to be shared by the provider to the consumer.

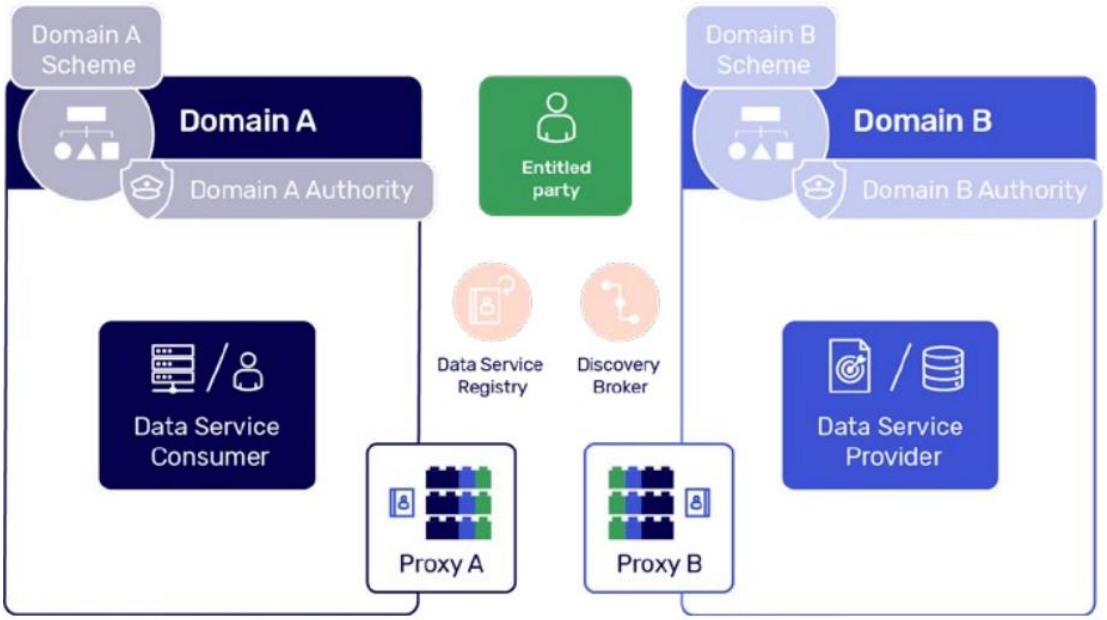

Figure 5.2 Proxy as intermediary between data service consumer and provider ([DSC-UCIG])

In the future, the Data Sharing Canvas will be further substantiated with insights derived from practical use cases for sharing data that the Data Sharing Coalition has realised. The Data Sharing Canvas lays the foundation for a soft infrastructure to share data between sectors. This infrastructure lowers barriers for organisations that want to share data to build trust and technical interoperability with their data sharing partners.

In addition to the Data Sharing Canvas, the Data Sharing Coalition offers an obvious method to set up a data space; creating a use case for data sharing. For this purpose, the DSC has developed three supporting methods. It starts with the 'Use case playbook' **[DSC-UCPB]**. This is the 'kickstarter' or the roadmap for a data space initiative. This roadmap accelerates new use cases for data sharing by offering a step-by-step approach to generating, assessing and realizing the data space (from the idea or initial initiative). It guides the user through the various steps, such as determining the context and scope, the valuation, complexity of interactions and final determination to proceed to realization. The focus of this roadmap is to provide a comprehensive and structured process to develop the use case for data sharing. The roadmap introduces five steps of use case development and provides a concrete objective, approach and resources for each step. Templates are provided to support different steps, which are taken in chronological order.

As a second step of use case development, the 'Blueprint' offers an elaboration of the Data Sharing Canvas a practical, useful approach to starting the development of a data space **[DSC-UCBP]**. The blueprint covers all relevant topics and insights from the Data Sharing Canvas and offers a good starting position for realising a data space. For this purpose, it is made clear in three phases which design choices are made for the relevant topics. These phases are: .

1. Scope and ambition. Why do you want to make data sharing possible and how do you benefit from this? Relevant topics to discuss are: context, purpose, guiding principles and functional scoping;
2. Develop the agreements needed to enable the necessary functionalities. Relevant topics to discuss are: business topics (e.g. tariff structures), legal topics (e.g. governance), operational topics (e.g. risk management), functional topics (e.g. user experience) and technical topics (e.g. technical specifications);

3. Determine the required functionalities to enable your use case. The relevant topics to discuss are: roles and responsibilities, functional components and the interaction model.

Finally, the 'Use Case Implementation Guide' **[DSC-UCIG]** gives the last move. It will inform, inspire and accelerate domains in data sharing and support them in setting up data sharing activities. The implementation guide is based on open standards and aligned with existing data sharing standards and implementations. To this end, the implementation guide provides an overview and explanation of how principles of the International Data Spaces (see chapter 3) and the trust framework iSHARE (see next chapter 7) can be applied for the implementation of a DSC data space. For this purpose, in the use case implementation guide concepts of actors and roles borrowed from IDS and for the trusted exchange of data, elements have been borrowed from iSHARE, such as machine-to-machine authentication and the OAuth flow. To prepare for future interoperability, the requirements in the use case implementation guide are, as far as possible, based on the iSHARE implementation and infrastructure, aligning with the specific context of the implementation guide. The DSC trust framework has been announced, but not yet available.

6.3 Synthesis

The Data Sharing Coalition initiative is Dutch initiative with an international focus. DSC focuses on cross-domain data sharing between data spaces.

DSC has developed a reference architecture for cross-domain data sharing, called the Data Sharing Canvas. The Data Sharing Canvas is an important focus area of DSC and provides global insight into the important topics for data sharing. These are the topics that will be further elaborated in the announced DSC trust framework. A detailed elaboration of these building blocks to enable the implementation of the building blocks is not yet available. DSC, on the other hand, has paid a lot of attention to the implementation of use cases and value cases. The Blueprint helps organisations to apply the Data Sharing Canvas to set up a use case for data sharing. The development of DSC towards implementation is reflected in the Use Case Implementation Guide. The Implementation Guide uses IDS's actor model and iSHARE's implementation concepts as a trust framework. The development of use cases and the value case can safely be appointed as the focus area of DSC. Hence, these elements are highlighted as focus areas in Figure 5.3 below.

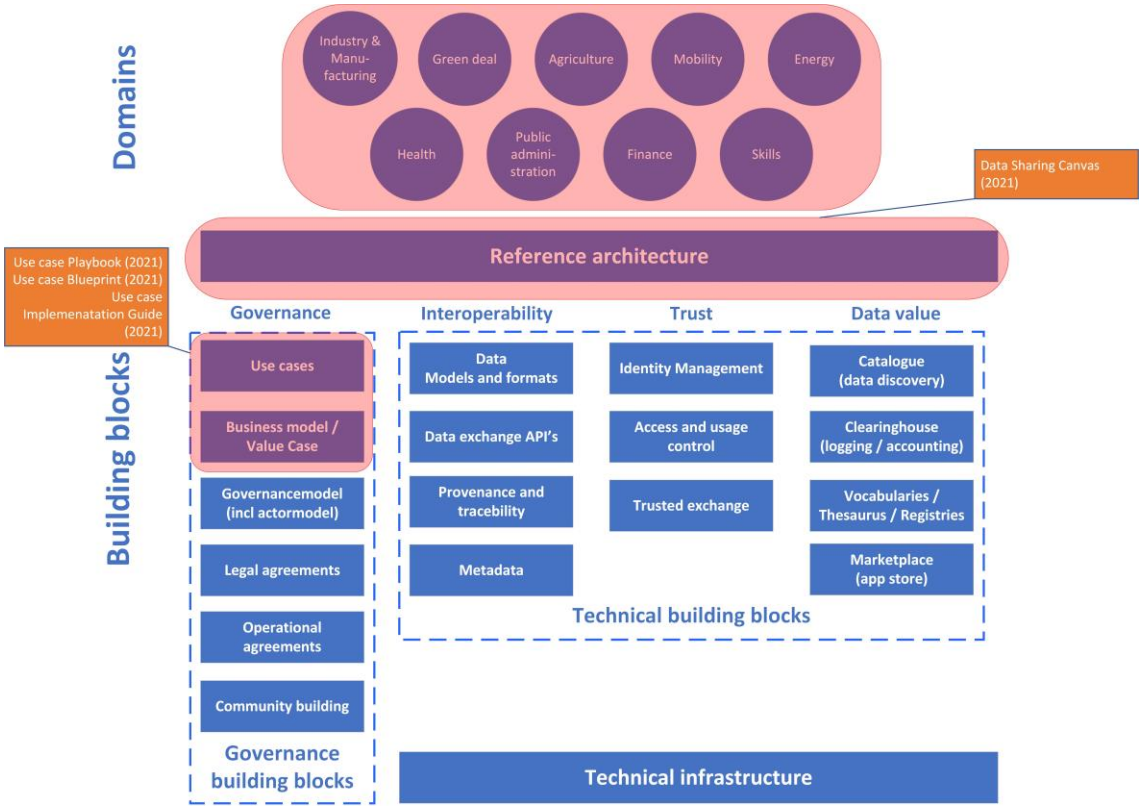

Figure 5.3 — Focus areas of Data Sharing Coalition

Finally, the Data Sharing Coalition has developed a position paper **[DSC-PP]**, which outlines DSC's collaboration and relationship with the other data space initiatives. This position paper was also a guideline for the analysis carried out in this underlying exploratory study.

7. iSHARE

7.1 Introduction

iSHARE is a Dutch initiative that works with a trust framework for data spaces. iSHARE offers an implementation of confidential data sharing in a data space using open standards. iSHARE also provides reference implementations for the associated data provisions.

By using iSHARE's trust framework, data providers have the certainty that organisations that have access to data services are legally covered by the confidentiality agreement and remain in the license issued with the data. In addition, the data provider has the certainty that only data, which the data provider has authorised, will be shared with the data provider who also authorised the data provider. iSHARE is a fully federated structure and legal framework, enabling trust, data protection and data sovereignty within data spaces.

iSHARE originated in the logistics sector in the Netherlands from the question of why organizations share little or no data with each other. From the first phase in 2016, iSHARE was built with the help of many co-creation partners. The co-creation partners have different backgrounds: from the private and public sectors, organizations of different sizes, different modalities, both providers and recipients of data, etc. This variety of organizations ensures that the iSHARE trust framework has become widely applicable.

7.2 iSHARE trust framework

7.2.1 ISHARE actor model for trust

The iSHARE trust framework is a uniform set of agreements for Identification, Authentication and Authorisation (IAA), including tooling needed to implement the appointment system. The iSHARE framework describes an actor model with six roles that, depending on the situation, interact with each other on the basis of the iSHARE 'scheme agreements' (see Figure 6.1) **[iSHARE-GOVF]**.

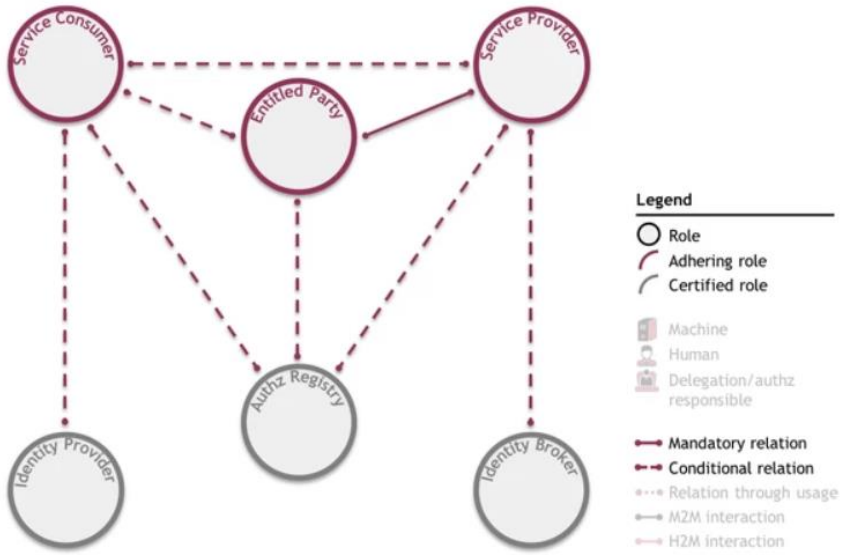

*Figure 6.1 — iSHARE actor model (**[iSHARE-GOVF]**)*

Each role has a certain function in the schedule and carries certain responsibilities. Each party, which plays a role in the iSHARE trust framework, must be iSHARE holder or iSHARE certified:

1. Parties, who play an 'adhering role', provide and consume services under iSHARE. These parties comply with the iSHARE terms of use;
2. Parties, who perform a 'certified role' provide the facilitation functions, on which the 'pending parties' can rely in the provision or consumption of services. In order to be certified, these parties must not only demonstrate compliance with the iSHARE conditions of use, but also meet a number of role-specific criteria.

The **service consumer** is performed by a legal entity, who uses a service, such as data services, as provided by a service provider. A consumer can be represented by a machine (his system) or a person, appropriately called the 'machine service consumer' and the 'human service consumer'. The **service provider** is provided by a legal entity that provides a service, such as data, for consumption by a service consumer. This legal entity provides the result of a service that the service consumer(s) need.

The role of **entitled party** or rightsholder is performed by a legal person, who has one or more rights to a service provided by a service provider, for example on dates. The data owner is an example of a rightsholder. These rights, or claims, are laid down in a legal relationship between the rightsholder and the service provider.

The **identity provider** is a legal entity whose tooling identifies and authenticates people (and in particular human service consumers, who represent service consumers). An identity provider provides identification data for people and provides credentials (i.e. a password or electronic keycard) to people. Based on this identification information, people identify and authenticate for the service providers. The identity provider retains the information about authorizations of persons representing a consumer service, i.e. information that indicates which persons are authorized to act on behalf of a service consumer. Based on this information, the identity provider can verify whether a person representing a legal entity is authorized to purchase a service and the identity provider can confirm to the service provider whether this is the case. As a result, service providers can outsource the identification and authentication of people, as well as tasks related to the management of people's authorization and delegation information, to an identity provider (rather than implementing their own tooling).

If service providers choose to outsource identification and authentication to more than one identity provider, they can connect to an **identity broker** instead of multiple identity providers. Different people can have IDs with different identity providers. Also, service providers may need to connect to different identity providers. To ensure that service providers do not need a relationship with each identity provider separately, an identity broker has been introduced. The identity broker is a legal entity, which gives service providers access to different identity providers and allows people to choose with which identity provider they identify and authenticate themselves throughout the iSHARE System.

The role of **authorization register** shall be fulfilled by a legal entity, which provides solutions to the contracting parties for the storage of delegation and authorization information. An authorization register has information on delegations to service consumers; i.e. information that indicates which parts of the rights of a rightsholder have been delegated to a service consumer. On the basis of this information, the authorization register can verify whether a machine representing a legal entity is authorized to purchase a service and the authorization register confirms it to the service provider. As a result, the contracting parties may outsource tasks related to the management of

authorization and delegation information to an authorization register (instead of implementing their own tooling).

7.2.2 Use case example Modality Reporting

To illustrate how iSHARE enables familiar data sharing using the above actor model, a use case example is included below. To explain this mechanism of trusted data sharing, we use the following iSHARE use case example in case of CBS that wants to request (statistical) data for its modality reporting from a trusted importer of televisions who are also participants in the iSHARE satellite (see Figure 6.2).

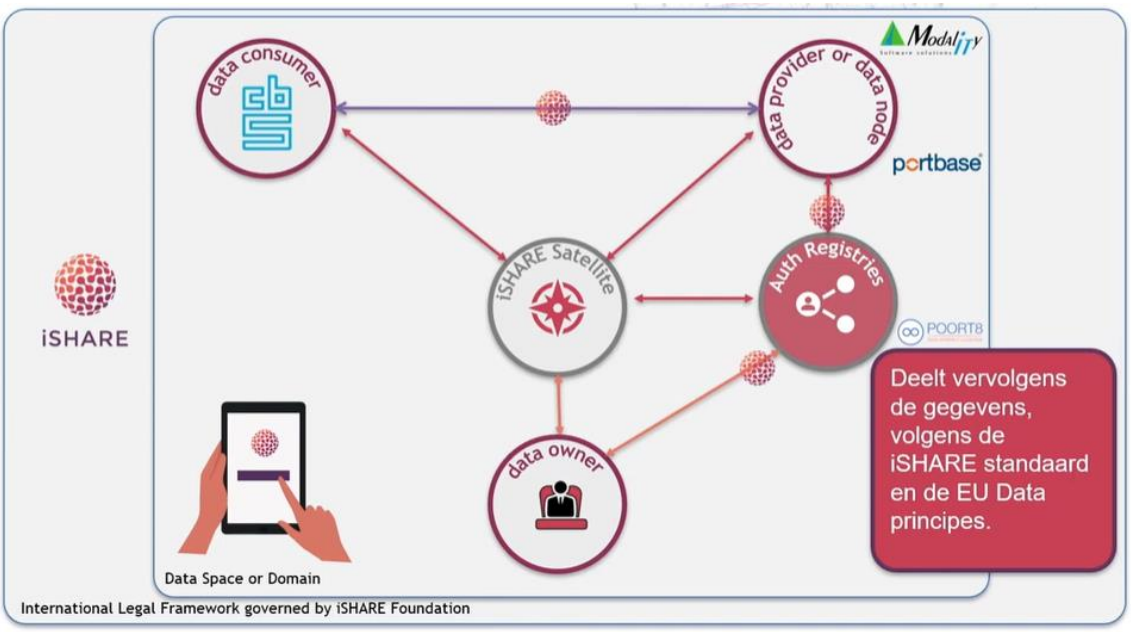

Figure 6.2 - iSHARE use case modality reporting CBS

The following steps are taken to share the data:

1. CBS needs data from data owner T (importer of Televisions) for its modality reporting and does not know whether the data owner T is affiliated with iSHARE and whether the data is available in the iSHARE network;
2. CBS has checked in the iSHARE network whether the data provider is connected for the respective service (the data for modality reporting) and where the information from the data provider T is available. For this, CBS consults the iSHARE Satellite.
3. The iShare Satellite informs CBS which data provider can retrieve the data from. This is data provider 'Modality'.
4. CBS asks the data provider 'Modality' whether CBS may have the data of data owner T. CBS asks the data provider Modality for the data.
5. The data provider 'Modality' first checks whether CBS is a reliable data consumer and Modality passes the following 'tests': A. Modality check with the Satellite whether data consumer CBS is in the iSHARE network and b. Modality check with the Satellite whether data owner T is in the iSHARE network;
6. Modality then checks in the authorisation register of Poort8, where the authorisations of the data owner are located, whether the requested data service of owner T may be shared with the data consumer CBS (and what attributes; certain fields may be shared).
7. If yes, Modality as a data provider provides the data service to data consumer CBS;
8. If the authorisation register does not give permission, the data provider Modality asks the data owner T whether it wants to provide the data service to CBS. If the owner wants to, then owner

T informs the authorisation register and the registry is updated under the terms of the T, so that the data consumer CBS gets access to the data.

9. As a data provider, Modality delivers the data to data consumer CBS.

The iSHARE Satellite is at the heart of the iSHARE trust network, as coordinator and governance core in a data space. Therefore, the iSHARE Satellite is managed by coordinating organisations within a data space, which serves and gives participants access. The iSHARE Satellite has the role of **scheme manager** and ensures:

- Admission; trusted registration of participants that have been validated;
- Withdrawal: permanent termination of participants who have crossed borders or ignored warnings;
- Warnings, suspension and exclusion;
- Changes and updates: registering additional data to participants, such as additional data spaces, additional data fields or new authorisation registers.

Within the iSHARE Sattelite (also known as iShare Node), administrators can register participants with:

- Their unique ID (EORI numbers in accordance with EU identification) and
- EIDAS identification;
- A public key (only for service providers and consumers and certified parties);
- Signed terms of use and any additional terms and conditions and of Chamber of Commerce documentation to ensure that the contract is legally signed.

For the management of participants, iSHARE has a web interface on the Satellite Node or APIs available for automated registration.

7.2.3 Standards

Since iSHARE is a cross-domain data space trust framework, registration is done according to the terms and conditions of iSHARE in all data spaces with iSHARE as a trust framework. Organizations, which are part of the iSHARE network, the data owners, data providers and data consumers, have all signed the same Non-Disclosure Agreement and Terms of Use. Each party is validated by the iSHARE Satellite in the registration process to ensure reliable onboarding. Through the federated authorization register, data owners consent to data attributes available from data providers, specifically to selected data consumers using licenses. In this collaboration scheme, based on iSHARE technical specifications, parties can really put data to work, where the data is also stored with SaaS providers in the iSHARE network or on their own services of data owners. iSHARE's technical specifications and API architecture are based on the following components:

- PKI and digital certificates; For the authentication of parties and machines, iSHARE uses PKI and digital certificates;
- HTTP via TLS (HTTPS); iSHARE uses the commonly used HTTP protocol for its communication, including TLS to encrypt the communication;
- RESTful APIs; iSHARE uses the RESTful architecture style to structure APIs and HTTP calls;
- JSON/JWT; Data exchanged in the iSHARE context is structured using the JSON standard. Where irrefutability is required, JSON Web Tokens (JWT) are used;
- XACML. Delegations are structured according to a JSON port of the XACML standard.

The combination of the above standards and protocols leads to a certain dynamic between the roles in the iSHARE framework. Essentially, service consumers acquire a token that allows them to access certain services from certain service providers. The roles specified in the iSHARE framework are loosely based on the OAuth standard. The OAuth2.0 protocol is a policy management implementation technology with access tokens, based on generic web service calls in the form of APIs. It follows a two-stage approach, first obtaining an access token from the service provider, based on approval by the rightsholder, with which the data service can then be retrieved by the

consumer from the data provider. Policy enforcement options are only required for the data provider.

The concept of iSHARE satellites combined with the iSHARE standard authorisation registry role in data spaces is also based on IDS's reference architecture **[IDS-RAM4]** and completes the value proposition of complete trust and certainty on a legal and technical basis for data spaces participants.

The governance of iSHARE is regulated in a Dutch foundation, founded in 2018, which regulates the control of iSHARE. Participating parties to iSHARE can - by entering into an agreement with this foundation - join the network of trust based on the iSHARE agreements system. A party that accedes works according to the arrangements of the system. To this end, it integrates the API specifications into its software and demonstrates compliance with the system's agreements. In order to formally accede, it signs a so-called 'Accession Agreement' with the iSHARE Foundation. The control of iSHARE scheme lies with the iSHARE Foundation is laid down in the governance model of iSHARE (see Figure 6.3) **[iSHARE-GOVF]**. The iSHARE satellites (data spaces) appoint the members in the iSHARE governance structure and the data spaces that use iSHARE as a trust framework are placed in the iSHARE governance structure and through that structure influence the further development and representation of the importance of data spaces.

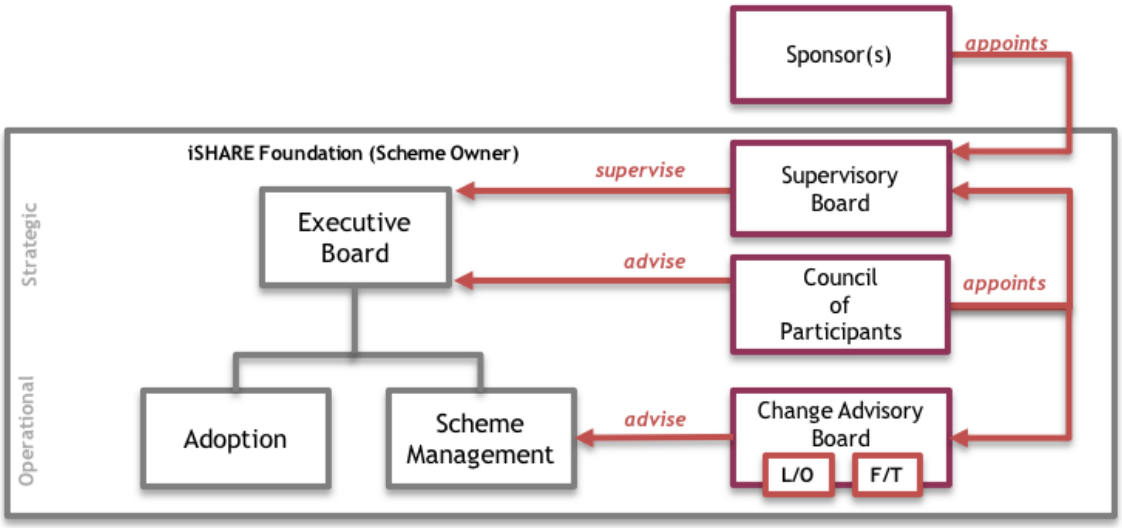

*Figure 6.3 — Organisation of iSHARE (**[iSHARE-GOVF]**)*

7.3 Synthesis

OPENDEI has developed the concept of data space in terms of a soft infrastructure consisting of 12 building blocks. The OPENDEI building block model shows that data sovereignty and trust and the three related building blocks 'Identity Management', Trusted Exchange' and 'Access & Usage Control/Policies' are an important and integral part of the data space concept. Together they are called the trust framework. iSHARE positions itself in this category of trust (see figure 6.4).

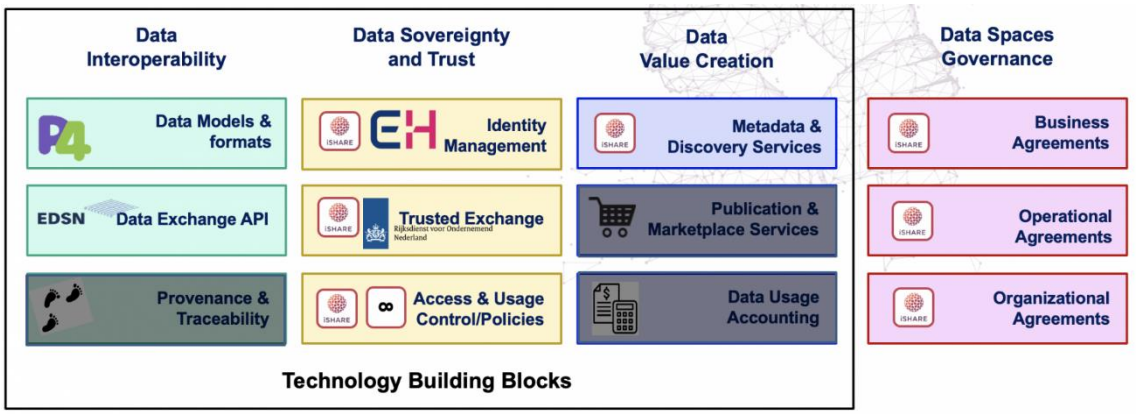

Figure 6.4 — Focus areas iSHARE in relation to the OPENDEI model (source: iSHARE)

iSHARE originated in logistics, but also generically applicable. Meanwhile, iSHARE is spreading its wings to other application domains (see figure 6.5).

As iSHARE reference architecture is iSHARE Scheme. The iSHARE scheme includes, among other things, the model of actors. The specific rather centrally organized governance model is also included in iSHARE scheme.

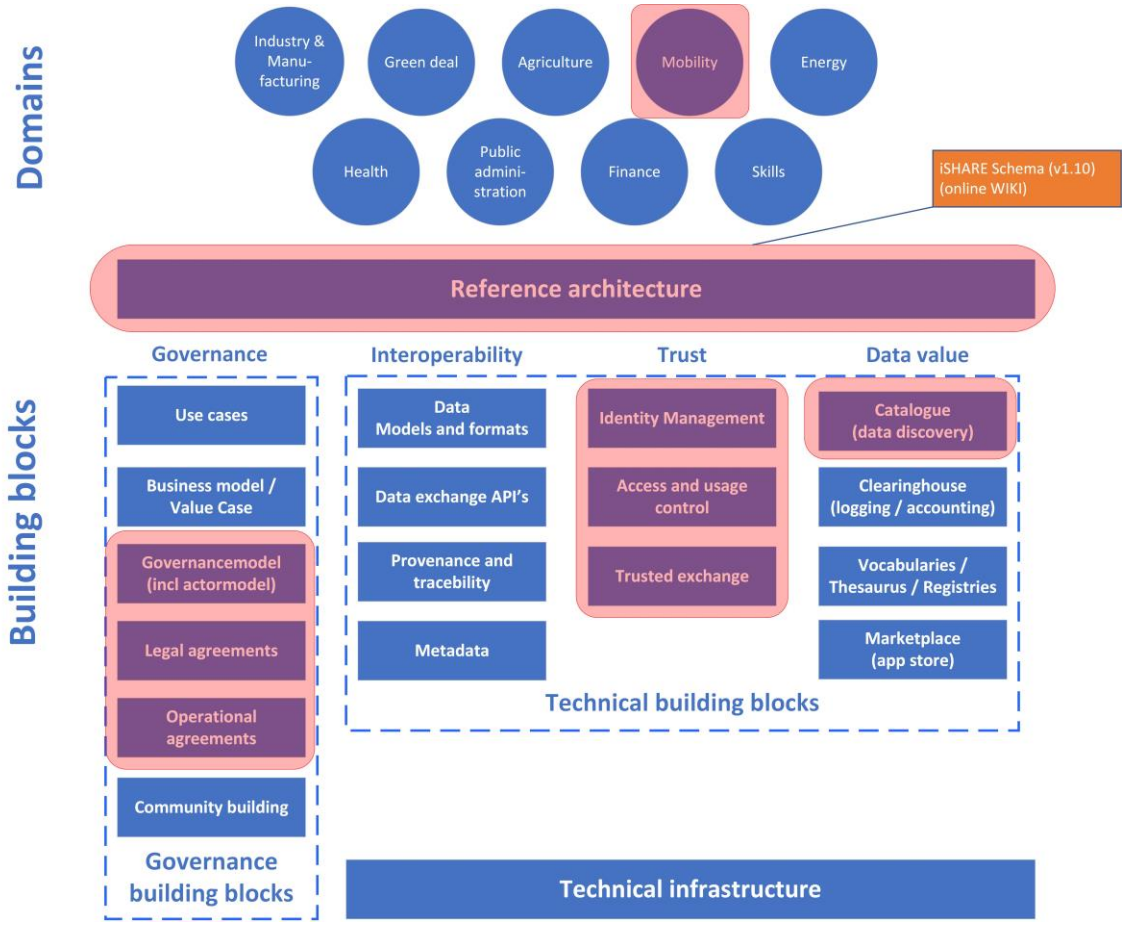

Figure 6.5 — iSHARE Focus Areas

The main focus area of iSHARE is the fully elaborated trust framework consisting of the pillars identity management, policy and access control and trusted exchange of data.

Examples of implementations of the three trust building blocks can be found on github.

iSHARE also implements the development of data spaces in line with the International Data Spaces and Gaia-X. In doing so, iSHARE works closely with the international community on data standards and other building blocks for data spaces to stimulate these data spaces across Europe. A further explanation of the iSHARE initiative as a trust framework for data spaces compared to some previously discussed European data space initiatives IDS (Chapter 2), GAIA-X (Chapter 3) and OPENDEI (Chapter 4) is set out in **[TNO]**.

The recently launched i4Trust EU project should also contribute to further alignment between iSHARE's trust framework and some European data space initiatives. With grants, I4Trust stimulates the creation of data spaces in various domains and aims to accelerate the data economy with data spaces in Europe.

8. The European spatial data infrastructure

This chapter describes and introduces the use of the concept of data spaces from the perspective of the European spatial data infrastructure. We highlight the 'data foundation', the agreements on standards for interoperability, the building blocks and facilities in the European spatial data infrastructure, which has been realized over the last 15 years on the basis of the European INSPIRE Directive.

8.1 The European spatial data infrastructure

8.1.1 The INSPIRE Directive

One of the most unknown, but now implemented data spaces in the European Union, is the European spatial data infrastructure created after the introduction of the European INSPIRE Directive in 2007. The European INSPIRE Directive improves the availability, quality, access to and exchange of location-based data on the environment in Europe. For example, data such as the location of administrative borders, water systems, agriculture, industry and transport networks and the geographical distribution of air quality and noise, but also of population, plant and animal species and health at a location. INSPIRE - an abbreviation of 'Infrastructure for Spatial Information in the European Community' - obliges public data providers in the 27 European Member States to make location-based data on 34 environmental themes digitally findable, usable and interchangeable. In order to make this possible, the data shall be made available in a standardized manner so that the data connects seamlessly within and between Member States and speaks the same, comprehensible language. This creates a network of services or services on the Internet, making public location-related data much better, more uniform and more comprehensible accessible to government, citizens and businesses.

As part of INSPIRE the Netherlands have made available approximately 200 main spatial datasets to the European spatial data infrastructure in a standardized and harmonized way. These datasets are findable, viewable (metadata and view service) and downloadable (direct download and indirect bulk download). The data can be found in the Netherlands in the national georegistry, which also serves as a national access point for the EU geoportal. The European Geoportal is the central catalogue where all Member States communicate their data products (datasets and network services) for the European spatial data infrastructure. The European spatial data infrastructure has been established as a data space as the whole of agreements laid down in legislative, conceptual and technical documentation. INSPIRE works with formal agreements on how data should be described uniformly between organizations in different Member States (including detailed modelling conventions for drawing up information models, application diagrams and exchange formats), which are applied for data product specifications for 34 themes (see figure 8.1). With these 34 themes a specific generic spatial and broad cross-domain perspective on data about the environment is offered. INSPIRE is initiated and maintained by the EU Directorate General Environment.

Figure 8.1 – Themes of the European spatial data infrastructure

8.1.2 The INSPIRE Principles

The European spatial data infrastructure established with the INSPIRE Directive is based on the following set of principles:

- INSPIRE aims to make environmental data freely available through the Internet in a high-quality way, both to the public and to citizens and businesses;
- INSPIRE is a spatial data infrastructure for sharing environmental data based on a comprehensive set of standardization agreements for geo-information exchange;
- The infrastructure idea is based on the one-time collection and storage (at the source) and the ability to combine different environmental datasets from multiple sources to the many users and their applications via the location;
- INSPIRE is not about collecting environmental data. INSPIRE asks public organizations to make available data in a uniform structure. it is also not necessary to collect or acquire (new) data for INSPIRE;
- The environmental data is easy to find and it is clear how the data can be used for a particular purpose and under what conditions and conditions of use the data are made available;
- The INSPIRE method works with and on international open standards regarding three building blocks: 1. network services in the form of web services, 2. data models for uniform seamless data exchange across member states and 3. discovery metadata for both network services and data;
- INSPIRE is functionally simple and 3-fold: 1. discovery and search for data, 2. view and evaluate data for it's purpose and 3. download and use data;
- INSPIRE offers agreements on restricting access to data. Specific rules remain in place for EU institutions.

8.1.3 The INSPIRE functions

For users, INSPIRE has a fairly clear design (see figure 8.2) and INSPIRE has been kept functionally simple with 3 functions: discovery-view-download. This is also known as the publish-find-binding principle of service oriented architecture. The user can search for the data via the discovery service, such as a national catalogue, the EU portal or their own applications. The user evaluates the suitability of the data based on the characteristics and descriptions of the dataset (metadata) and/or by viewing the dataset in map form (view service). If the user considers the data suitable for its purpose, the data is downloaded for use (download service), or called as a spatial data service

(spatial data service). The spatial data service allows for a more specific query on the dataset (e.g. geocoding of an address, a calculation between two points, etc.). The user gets access to the data via his own business application(s). The business applications must be suitable for this, i.e. support the INSPIRE standards.

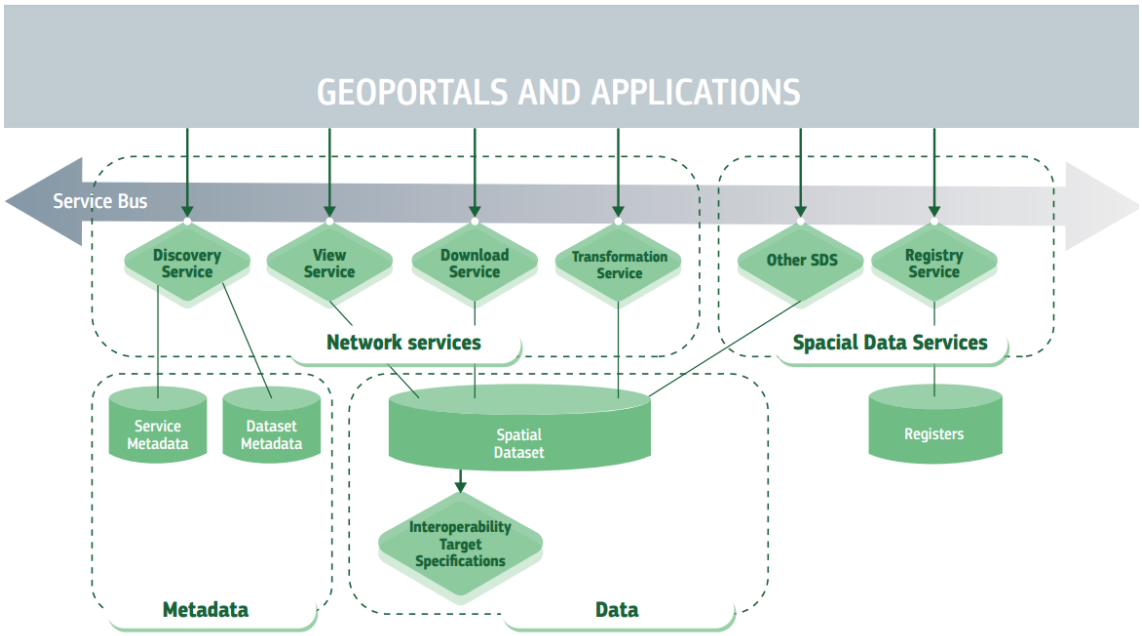

*Figure 8.2 — Reference architecture INSPIRE ([**JRC126319**])*

For data providers, the architecture is more complex, in particular due to the data transformations (e.g. coordinate system and data model transformations), which need to be implemented to deliver INSPIRE compliant data. In addition to the catalogue (discovery metadata), some generic, supporting facilities, such as a registries, are also needed.

8.1.4 The INSPIRE methodology

The INSPIRE methodology consists of a set of formal agreements – a kind of the quality framework - on various aspects of the spatial data infrastructure. This framework consists of three pillars (see figure 8.3):

1. A legislative framework consisting of the Directive and mains Acts;
2. Architecture, methodology and conceptual documentation;
3. Technical documentation.

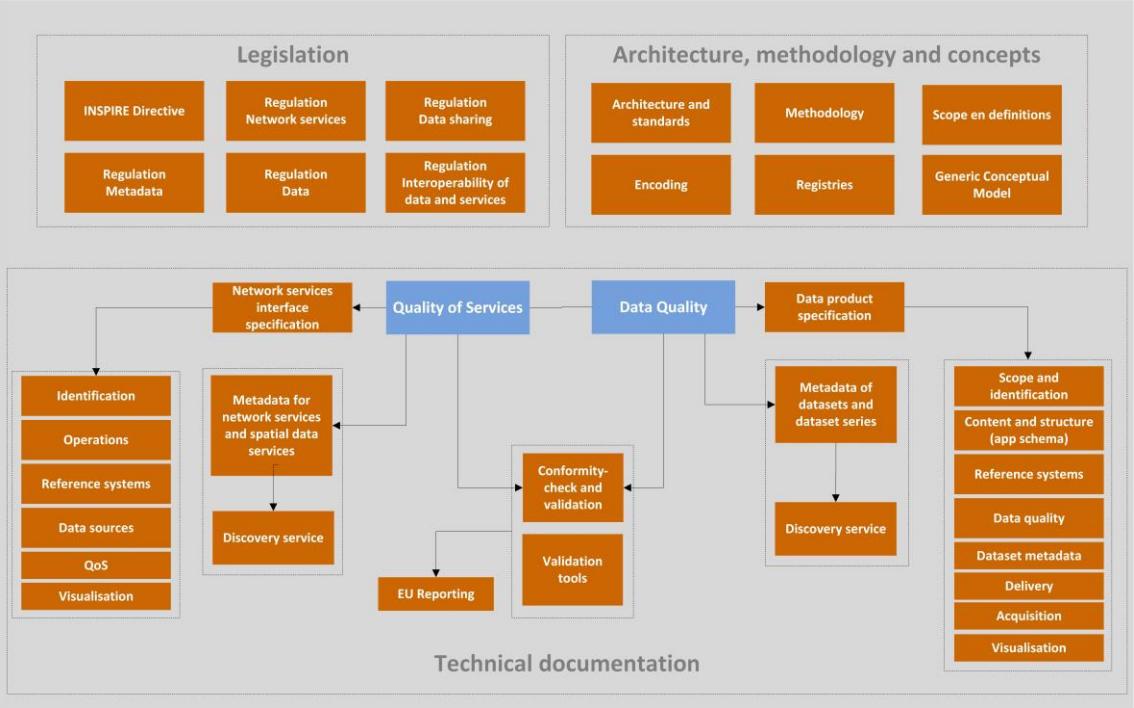

Figure 8.3 - Quality framework European Spatial Data Infrastructure INSPIRE

The following agreements are part of the entire quality framework:

1. Formal agreements on scope, concepts to be used, generic conceptual model for data models, methodology, technical architecture and standards, and data encoding;
2. Formal arrangements on how data should be described uniformly between organizations in different Member States (including detailed modelling conventions for drawing up information models, application schemes and exchange formats), which are applied for data product specifications for 34 themes;
3. Formal agreements on functionality for exchanging data through principles of service oriented architectures and standardized service interfaces;
4. The (quality) description of datasets and services with metadata, so that the search-view-download paradigm and principles of service-oriented architectures is supported;
5. The possibility of conformity testing for EU reports based on abstract test suites;
6. INSPIRE has an approach with distributed responsibilities and in combination some generic, central facilities, in particular registries;
7. INSPIRE has an approach to abstract models and guidelines and detailed (technical) manuals;
8. These formal agreements have been/are drawn up by the stakeholders in the 27 member States (users and data providers) themselves. This provides support and resolves substantive discussions about content, models and standards;
9. INSPIRE has an implementation roadmap.

All documentation, agreements and governance related to the 'Infrastructure for Spatial Information in the European Community' can be found in the INSPIRE knowlegde base.

8.2 Synthesis

Figure 8.4 shows the focus areas, which have been important in the creation of the European spatial data infrastructure or the geo-information data space based on the entire INSPIRE legal framework.

First of all, INSPIRE can be considered a cross-domain initiative that offers a spatial data space for different application domains. The 34 themes of INSPIRE touch different application domains, such

as the green deal (many different themes), mobility (theme transport networks), Energy (theme energy networks and facilities), agriculture (theme agricultural facilities) and public administration (themes addresses and buildings, cadastral parcels, administrative units).

INSPIRE is strong on data interoperability agreements: scope, concepts to be used, generic conceptual model for data models, methodology, technical architecture and standards, and data encoding. Several specifications for networks services (among discovery, view en download services) and spatial data services cover the topic of data exchange API's. INSPIRE describes in technical implementation rules how to set up the data exchange APIs. These formal agreements on functionality for the exchange of data through principles of service oriented architectures and standardized service interfaces are fully established.

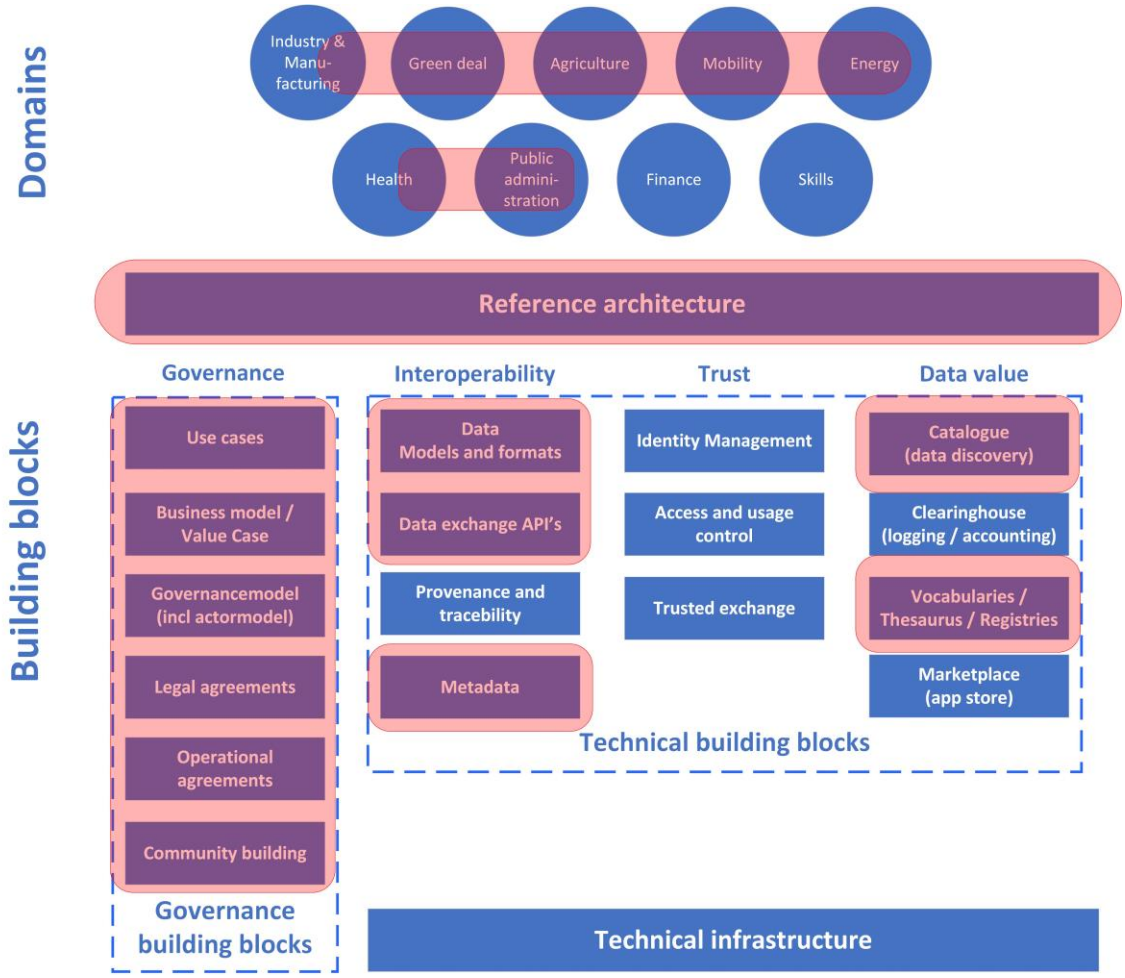

Figure 8.4 - Focus areas INSPIRE as a data space initiative

And discovery metadata is covered extensively as well. A (quality) description of datasets and services with metadata has been developed, so that the publish-find-bind principle of service-oriented architectures is supported. There is also the possibility for consistency testing for EU reports based on abstract test suites.

To make datasets findable, INSPIRE has an approach with distributed responsibilities in combination with some (de)central facilities: metadata catalogues (searching via geoportals) and various supporting European and national registers (dictionaries/vocabularies, CRS register).

The implementation of INSPIRE was accompanied by an implementation roadmap and governance structure. The agreements were drawn up by the stakeholders in the EU. Support is thus obtained and content discussions about content, models and standards are resolved (use cases, business models and community building). Implementation is left to Member States and public organisations in the Member States.

INSPIRE expressly does not impose any requirements regarding a trust framework, like identity management, acces and usage control or trusted exchange. It does either not prescribe contracts and/or policies other than making them known in the metadata. The European Commission itself is the guardian of the data space through the legal framework and manages some generic facilities such as the European catalogue for all EU-wide data discovery, various supporting registries and a governance structure. All available at the INSPIRE knowlegde base.

8.3 The next step: towards the green deal data space

An evaluation has recently been published on the creation and realization of the European spatial data infrastructure. Following this review of the INSPIRE Directive, INSPIRE will be revised. This will be in close connection with the new GreenData4All initiative to be proposed.

The GreenData4All aims to make it easier to share data between public and private parties and with the general public. GreenData4All will offer updated rules on geospatial environmental data and access to environmental information in Europe. This should support data-driven innovation and evidence-based decision-making. The GreenData4All related data will be placed in the Green Deal data space. Additionally, two supporting studies have been published that give insight in the further adoption and integration of the European spatial data infrastructure in and towards the green deal data space (**[JRC126319]**, **[JRC126750]**).

Recently several legislative proposals have been made in the framework of the European Digital Strategy and the Data Strategy (see also - in Dutch - the EU Information Guide on Digital and Data Strategy). These recent established EU legislative and regulatory agreements work on the implementation of spatial data infrastructure and green deal data space. Several developments are going on to shape the green deal data space. There is currently not enough information about what the green deal data space will look like. It is therefore too early to clearly characterize and identify the areas of reflection of the green deal dataspace.

EU High value datasets

Furthermore, the recently adopted EU Open Data Directive, published at the end of February 2022, is a major cornerstone in the European Data Strategy **[EU-DS]**. The Open Data Directive gives the EC the possibility to impose open data obligations on all Member States at the same time (i.e. without transposition into national law) with an Implementing Regulation. Such an implementing regulation specifies how and under what conditions the mandatory open data should be published, and provides in an annex the EU High Value Data list. Data, which is mentioned on the EU High Value Data list, must be published as open data by all Member States, if available, and made accessible via APIs. In the coming years, the list will be periodically supplemented by the EC, with new data domains and possible expansion within already named domains.

The first list of High Value Data sets includes obligations for six spatial data domains: geospatial, earth observation and environment, meteorological, statistics, companies and mobility. The obligations add an open data obligation for geo-data, earth observation/environment and mobility to a series of INSPIRE themes (25 of 34 INSPIRE themes). And a proposal for a new list of themes is also expected in 2023, for which new obligations will follow in a few years' time. These new themes may include energy, health care, government and public services, language, climate change, law and justice, and the economy.

The role of federated data sharing initiatives is increasingly intertwined with the broader perspective on international developments in the context of the European Data Strategy and related European initiatives for the development of reference architectures. Therefore, this broader perspective on federated data sharing and data spaces is an important part of this exploratory study, covering three different perspectives from data spaces based on the OpenDEI model: the perspective of governance, interoperability, trust and data value will become more and more of importance for data sharing as common EU data spaces **[EU-CDS]** will evolve.

9. The Dutch spatial data infrastructure

This chapter describes and introduces the use of the concept of data space from the perspective of the spatial data infrastructure in the Netherlands. We highlight the 'data foundation', the agreements on standards for interoperability, the building blocks and facilities in the national spatial data infrastructure.

9.1 The spatial data infrastructure in the Netherlands

The spatial data infrastructure is actually an international concept, which over the years has been implemented in the Netherlands through legislation, agreements and governance, standardization and implementation of central and decentralised facilities and data platforms offered by mainly public organizations.

The Ministry of the Interior and Kingdom Relations, responsible for the national Spatial Data Infrastructure, sees the national spatial data infrastructure as a data foundation among social challenges and sectors that use it **[GeoInfo]**. First of all, the national spatial data infrastructure consists of several aspects and components (figure 8.1): data collections, facilities and the work processes to keep them in order (blue blocks in figure 8.1). Among these are the things that create conditions: agreements and standards to achieve a coherent whole, governance to be able to make the joint agreements, funding to enable realization, management and maintenance, and legislation and regulations to define the main lines in a way that binds parties. In the arrow on the left the connecting story and on the right the control on the whole.

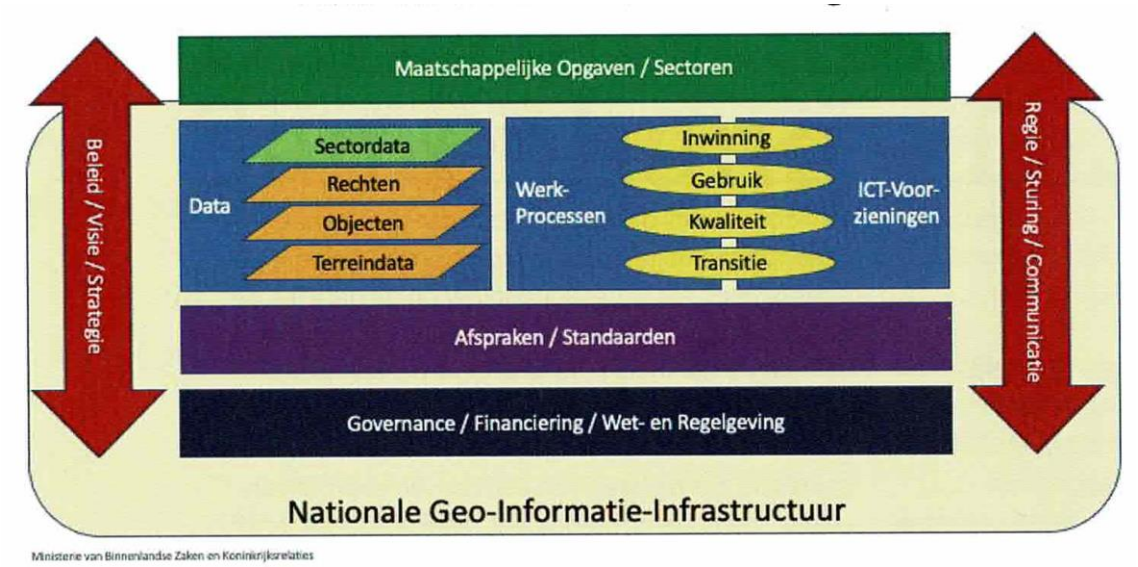

*Figure 8.1 — National Spatial Data Infrastructure (**[Geo-Info]***

The National Spatial Data Infrastructure (NGII) includes geospatial key-registrations, facilities such as PDOK, and agreements and standards, which are regulated by law in a number of cases. A number of registrations that do not have the status of key-registration but are widely used could also be attributed to this. A policy vision has recently been drawn up to achieve a national geo-data foundation (see further paragraph 8.3). However, no clear limitation of the NGII has been agreed. Users actively participate in the direction of infrastructural registrations and facilities, contribute to funding, and often make a substantive contribution, for example in the role of data owner and data provider by making feedback to the basic records.

The NGII as a public infrastructure is governed by the Ministry of Internal Affairs and Kingdom Relations. The current Minister of Housing and Spatial Planning is responsible for geo-information and geo-information policy. The GI Council, in which all public parties are represented (various national governments, provincial and local authorities), is the main advisory body for the responsible Minister of Housing and Spatial Planning. The policy of the NGII is laid down in a policy document GeoSamen, a joint initiative of government, business and research and educational institutions. The companies are represented through the GeoBusiness NL trade association and the research and educational institutions by the Dutch Centre for Geodesy and Geo-Informatics (NCG).

Also part of the NGII is the legislation and regulations. Geo-information is embedded in legislation in different ways. For the NGII, especially the Dutch spatial key-registrations and the European INSPIRE Directive (see chapter 8) have been guiding the establishment of the NGII, with requirements for the standardized disclosure of all kinds of geo-information for environmental applications in the physical living environment. This has also led to the creation of the National Georegister in 2007, which has now recorded more than 8,500 datasets to improve access to public geo-information. This is done by various data facilities, such as PDOK hosted by the Dutch Cadastre and the satellite data portal hosted by the Netherlands Space Office.

Geo-information standardisation in the public sector is also well-invested and awarded to an independent knowledge institution (Stichting Geonovum) and for the specific Dutch geodetic infrastructure at the Dutch Cooperation Geodetic Infrastructure (NSGI). The attention to the correct use of coordinate reference systems in geo-information (systems) is invested at the Dutch Cadastre (as manager of 'Rijksdriehoeksmeting'), Rijkswaterstaat (as manager of 'Normaal Amsterdams Peil') and the Hydrographic Service (primarily focused on the marine part of the Netherlands).

9.2 Synthesis

Over the past 15 years, the national spatial data infrastructure has emerged as an ecosystem of many parties and has led to agreements on all aspects of geo-information sharing: the spatial key-registrations, many spatial datasets with APIs for access, catalogues for discovery and standards for interoperability, whether or not laid down in legislation. Governance is also set up. Figure 8.2 shows the different areas of consideration of the NGII as a data space initiative.

The NGII has a cross-domain perspective, without binding to a particular application domain but to various domains, in which the geographical impact of actors, objects, activities and systems play a role. The operation and application of the NGII can be seen in the various application domains. It concerns use in a wide range of areas, such as infrastructure management and maintenance, water management, mobility, nature protection, energy transition, industry, spatial planning, housing, agriculture, taxation and public administration.

An unambiguous description of what the Dutch national Spatial Data Infrastructure is actually not available. For example, the NGII does not have a uniform reference architecture, in which the coherence of the underlying building blocks is described.

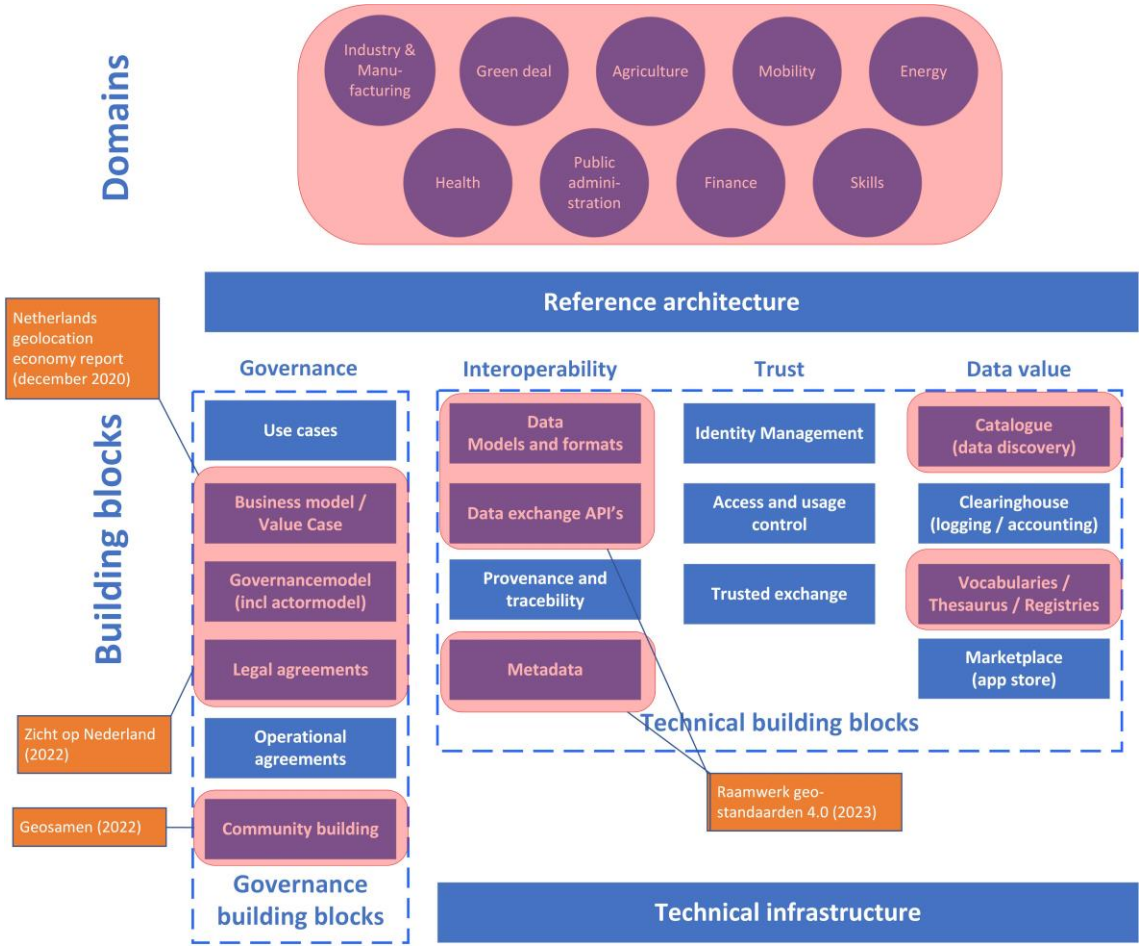

Figure 8.2 — Focus areas dutch SDI as data space initiative

In 2020, the NGII received a 'business model' with the report 'Netherlands geolocation economy report' **[BZK-GeoL]**. This report provides insight into the Dutch geo-data economy and the impact of spatial data has on the Dutch economy. The report addresses four topics:

1. Development of a national geospatial infrastructure strategy;
2. Geospatial industrial development strategy;
3. Encourage research and educational institutions and involvement with industry;
4. International cooperation and geospatial hub.

The report provides a brief overview of some geo-data technologies and the benefits of use. This is followed by an analysis that reflects the 'geospatial readiness' of the Netherlands vis-à-vis other countries. The Netherlands scores 4th in 2019. In 2022, an update of the international 'geospatial knowlegde infrastructure readiness' index appeared and the Netherlands remained fourth position after USA, the United Kingdom and Denmark **[GW]**.

In the recently published policy vision 'Zicht op Nederland', the transition from the NGII to the geo-data foundation for the living environment is foreseen to get a grip on the major social challenges in the Netherlands **[BZK-ZoNL]**. The NGII and its data sources, agreements and standards and facilities form the data foundation on which public parties can build their necessary information. It not only provides a high-quality, reliable and shared image of the living environment. It also functions as a reference point with which other data can be connected, which is crucial for the wider dataset — both sectoral, national and European. In 'Zicht op Nederland' it is found that the NGII has been created over the past 20 years by the most relevant basic data base regimes for government-wide use. The core of this is the six basic records, which contain the most commonly

used data from the physical environment. Together with various other relevant data, standards, agreements and provisions, they form the NGII, which provides the data foundation on which government organisations base their policy, decision-making and implementation tasks.

Legal agreements, which play a role in the NGII, are legal and applicable to data sharing, such as the INSPIRE and the Open Data Directive. In accordance with this legislation, there are different obligations for public authorities and public bodies to share and make spatial data accessible. There is no legal basis under the NGII. Several laws give the NGII a legal meaning.

The standardization of the NGII is regulated by various agreements. These include data standards (information models and formats), access via APIs, as well as metadata and coordinate reference systems. Standards for provenance and tracebility are not specifically created. Interoprability and standardization of the NGII is regulated by the following agreements:

- Geo-standards are offered in the Forum standardisation (for the 'apply-or-explain' list of standards for the Dutch government);
- The Dutch geo-standards framework identifies the current geo-standards for data (information models), metadata, APIs, exchange formats, visualization and coordinate reference systems;
- Process agreements on standardization are laid down in BOMOS and management documentation;
- Alignment with (inter)national standardization organizations, i.e. OGC, ISO (TC211), W3C and INSPIRE, Dutch NEN (via working group NEN3610);
- As a organisation for the management of the Dutch geo-standards, the Geonovum foundation is appointed.

From the perspective of 'data value', the NGII has clearly elaborated and implemented two aspects in the Netherlands: catalogues for data discovery are generally accepted by public organizations to make geo-information findable for (re)use. Nationally, this has resulted in a national georegistry, in which approximately 8,500 datasets and/or data services can be found from various public organizations. The national georegistry is linked to the open data portal of the government, also to the European geoportal. The NGII has various vocabularies, thesauri and registers, such as the concept library for information models, technical register for geo-standards and a qualifying register for organisations with INSPIRE datasets. A clearinghouse for logging transactions or an app store (marketplace) does not know the NGII. However, the NGII has various facilities, which provide access to geographic datasets via APIs, including the aforementioned PDOK and the satellite data portal.

In the NGII, no or hardly specific agreements are included for the trusted sharing of data. A specific trust framework is missing. Based on the strong public nature of the NGII, the implementation of the trust framework is based on the generic agreements in the public sector. The public 'open data' policy has been guiding, so that a trust framework has not come off the ground or has not been necessary, such as setting up identity and access management and usage control based on various policies. This does not alter the fact that there are certainly use cases, in which trusted parts of geo-information are the order and implemented. In practice, data deals are already closed. For example, the Water Boards have signed a deal with a company that collects satellite data to make that data available as open data. And the VNG is working on supply agreements with Chamber of Commerce, housing corporations and energy companies to make their data reusable by municipalities. The use of data from third parties, especially non-government, becomes crucial for good public governance. In order not to invent the wheel every time, the government does well to make agreements with these third parties about the use of private data. An exploratory study **[Geonovum]** illustrates how the government could best address this.

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