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Data Ecosystem Business Models: Value and control in Data Ecosystems

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Abstract

Purpose: Organizations evolve from using and governing data internally towards the exchange of data in multi-organizational data ecosystems. The purpose of this research is to determine a business model framework for actors operating in and/or entering a data ecosystem.

Methodology: To determine a business model framework in data ecosystems. an analysis was made based on how the research fields of "business models", "data governance", "data ecosystems", "data sharing", "business ecosystem" complement each other. A business model framework was created, which was applied to three use case studies in the field of Smart Cities and Urban Digital Twins: The Helsinki Digital Twin, the Rotterdam Digital Twin, and the Smart Retail Dashboard in Flanders.

Findings: The business model of actors in a data ecosystem is determined by value and control factors. Value is determined by the capability to create value through the exchange of data in the ecosystem, and to capture value through revenue (sharing) models and cost (sharing) models. Control is determined by ecosystem control. Governance models on the ecosystem level are required to enable the collaboration and to ensure trust to allow for the willingness to share data. Additionally, data governance on an ecosystem level is required, enabling the data exchange between the actors.

Research Limitations: The model was applied to three use cases in Smart Cities and Urban Digital Twins. Consequently, the data ecosystems concern a high presence of public actors, yet also includes private companies. The applicability needs to be identified in other sectors in further research. Additionally, as the scope of the study was on business models, data governance, data-sharing and data ecosystems, abstraction was made of fields of study beyond these topics.

Value and practical implications: The Data Ecosystem Business Model framework can serve as a guideline for organizations entering a data ecosystem, as well as for actors aiming to establish novel data ecosystems. Additionally, the framework can serve as a high-level overview for further research into the field of business models in data ecosystems.

Keywords: business model, data governance, data sharing, data ecosystem

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Purpose

In different sectors, players are searching for ways to do more with data. The re-use of data in data ecosystems could help create value worth USD 3 trillion per year worldwide (McKinsey,2013) and the OECD estimates that (governmental and private) data sharing can help generate social and economic benefits worth between 1% and 2.5% of GDP (OECD, 2019). Furthermore, the European data strategy aims to create a single market for data that will allow it to flow freely within the EU and across sectors for the benefit of businesses, researchers, and public administrations (European Commission, 2019) and they put forward the proposal of the Data Governance Act to increase the re-use of data. Exchanging data poses different opportunities for companies to create new business models and services as data collaborations can facilitate the discovery of new insights, faster decision making, and increase innovation (Naslund, et al., 2017). For example, in port ecosystems, the sharing of data through the organization NxtPort can optimize the supply chain by matching industrial processes of manufacturers to shipments of logistical companies (NxtPort, 2020). In the medical sector, the exchange of data and equitable benefit sharing of genomic data through the platform LunaDNA can advance medical research (Fox, 2020). For governments and smart cities, it can lead the way to evidence-based policymaking, which is the process of using (big) data in the policymaking process and improving services (Thilo & Verhulst, 2017). The use of commercial data can be utilized to make policy decisions on safety measures during the COVID pandemic, and ultimately also for the economic recovery after the COVID pandemic (Muthukumarana & Perricos, 2020).

Data governance and business models in data ecosystems

Data exchange can occur on an 'intra-organizational scope' on a project- or firm level, for example between departments, or on an 'inter-organizational scope', which encompasses different firms or an ecosystem of firms (Konsynski & Tiwana, 2010). The use of data within an organization is mainly covered within the data governance literature (Khatri & Brown, 2010; Panian, 2010). On an intra-organizational level, data sharing in a data ecosystem results in complexities regarding data ownership and who has decision rights, which results in the need for data sharing policies and agreements (Eckartz, et al., 2014). Additionally, the more actors involved in the ecosystem, the more the creation and allocation of value become difficult, topped with complexities to ensure control of the data (Abraham, et al., 2019). When companies aim to price the data, the valuation remains a daunting task, resulting in complex negotiations (Li, et al., 2019). Besides, when data is shared, different risks occur, such as re-identification risk of anonymized data (Sanderson, et al., 2015) and commercial risk of losing data control or business value. Complying with legal requirements such as the General Data Protection Regulation (GDPR) discourages companies from sharing data (Khuruna, et al., 2011; Sayogo, et al., 2014). Abraham et al. (2019) formulated several further research questions concerning inter-organizational data exchange: How do organizations retain control over their data and design governance in inter-organizational relationships while deconstructing data silos? How are value and trust created in data collaborations?

A novel term utilized in the scope of inter-organizational data sharing and data exchange is "data ecosystems". A **data ecosystem** is a complex network between different actors (Olivieira & Loscio, 2018) where actors use and re-use data for a monetary and/or non-monetary returns between the actors. It is a similar concept to business ecosystems (Adner, 2016) where the main goal is to create a focal value proposition and alignment in the ecosystem. Thus, in the case of data ecosystems the focal value proposition is based on the exchange of data.

In this work, the researchers focused on the following research questions which relate to the business model of data ecosystems:

- *"Which factors determine the business models of organizations operating in a data ecosystem?"*
- *"How is the business model of real-life data ecosystems constructed?"*

The methodology section below describes the literature review and use case application. Next, the

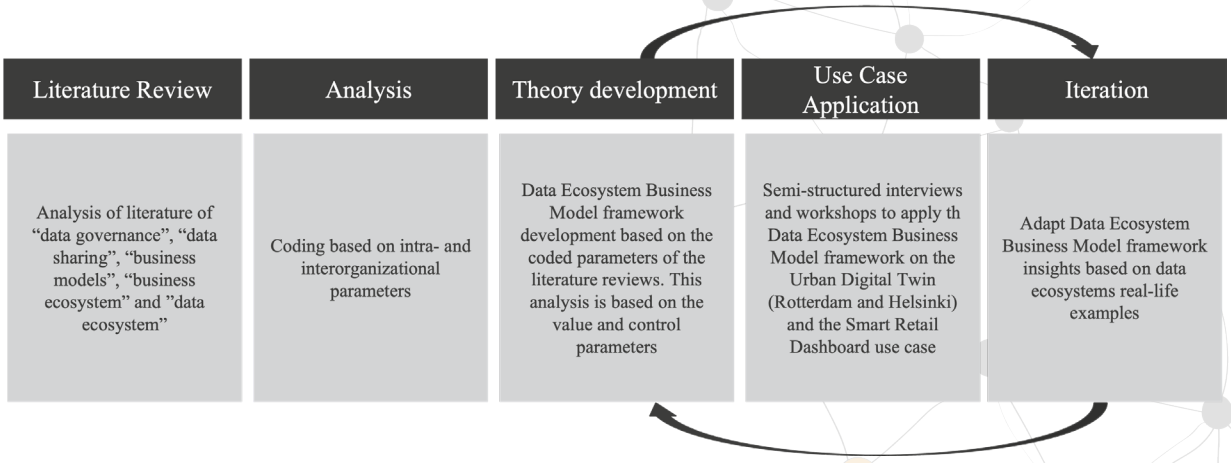

Figure 1: Methodological process

framework, which is based on the literature review, to identify business models in data ecosystems is described. The Business Models for Data Ecosystems Framework is applied in a multiple-case study analysis on two Urban Digital Twins use cases and the Smart Retail Dashboard use case. A discussion on the business model implications of data ecosystems is included. We conclude with the main insights of this work and suggested further research.

Methodology

Figure 1 shows the methodological process followed to answer the research questions below. Based on a **literature review** (Kitchenham & Charters, 2007) the authors identified gaps in the current research to provide a new framework. An initial search focused on the keywords 'data governance', 'business model', 'data sharing', 'data exchange', "data marketplace", "data ecosystem" and "business ecosystem". The search was performed in July and August 2020 and was limited to work in between the year 2000 and 2021 and to academic conference and journal papers. Papers were added when they were mentioned in impactful reviews and papers according to the Snowball Sampling method (Morgan, 2008) and based on their impact on the literature. After identifying referenced papers, they were looked up on ResearchGate[1]. The papers were selected based on whether a taxonomy with determining factors was included in the research. The literature on data sharing, data ecosystems and data marketplaces showed much resemblance and was grouped as terms were used interchangeably. In total, 50 academic works were reviewed (9 in data governance, 19 in business model and business ecosystem and 22 in data sharing, data ecosystem, data marketplace and platform ecosystem literature).

In the **analysis phase**, the literature was coded based on factors determining the 'intra-organizational scope' on a project- or firm level (Konsynski & Tiwana, 2010) and the 'inter-organizational scope', which encompasses different firms or an ecosystem of firms (Konsynski & Tiwana, 2010). The **Theory Development** phase is based on merging and relating key factors in literature (Miles & Huberman, 1994) and resulted in a framework which was developed by applying the division between value and control as proposed by (Ballon, 2007; Walravens & Ballon, 2013). This resulted in the first version of the Data Ecosystem Business model framework (initially named the Data Sharing Business Model Framework), which was published in (D'Hauwers et al., 2020).

After the Data Ecosystem Business Model Framework was **applied to two case studies** in the DUET[2] project as described in (D'Hauwers, et al., 2021) and

[1] An overview of the reviewed papers can be found in the Appendix

[2] *DUET* (Digital Urban European Twins) is a European innovation initiative which leverages the advanced capabilities of cloud, sensor data and analytics in the form of Digital Twins, to help public sector decision-making become more democratic and effective.

the Smart Retail Dashboard[3] project as described in (D'Hauwers, et al., 2021) using the multiple case study analysis approach. The scope of a case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not evident" (Yin, 2014). A multiple case study approach was chosen, as it gives the chance to analyze data within different situations (Yin, 2014). In total 16 semi-structured interviews and 3 workshops were conducted with different players in the distinct ecosystems. The Data Ecosystem Business Model Framework was utilized to create a topic guide for the case studies, and some parameters were selected to develop business model scenarios. In this work, the researchers chose to illustrate the Data Ecosystem Business Model Framework application with the Urban Digital Twin use case and the Smart Retail Dashboard use case. Based on the use case studies, an **iteration of the Data Ecosystem Business Model Framework** was done in September 2021 to include insights on data ecosystems of real-life use cases.

Towards a framework for Data Ecosystem Business Models

This study aims to answer the question "*Which factors determine the business models of organizations operating in a data ecosystem?*". To come to the model, an overview was made of all relevant fields of literature, and which factors they cover to move beyond the boundaries of the organization. The authors aim to link the data governance, data sharing, and data ecosystem literature with the business model literature. Within the business model literature, a distinction can be made between authors that define a business model mostly on the level of the firm (Rappa, 2000; Osterwalder, 2004) while others define it at the network level (Weil & Vitale, 2001; Al-Debei & Avison, 2010; Timmers, 1998). On the network level of the organization, the main questions to be solved are connected with shifting organization boundaries, exploring the relationships that exist between actors in complex value networks and the roles they may play (Walravens & Ballon, 2013).

Thus, the overarching themes in network-level business model thinking are: "Who controls the value network and the overall system design" and "Is substantial value being produced by this model (Ballon, 2007). Given the focus on data sharing in inter-organizational settings, the network-level approach of business modeling provides new insights into the data governance, data sharing, and data ecosystem literature. This led to a framework based on the parameters of value and control (Ballon, 2009) which shows the evolution companies face, and which business model factors need to be identified. The underlying factors which are utilized for this analysis are:

- **Value**
  - *Value creation*: How can a differentiated customer value proposition be created? (Kaplan & Norton, 2004)
  - *Revenue and cost model*: How is value captured based on the use of revenue (sharing) models and cost (sharing) models? (Ballon, 2007)
- **Control**
  - *Value network*: How can organizations control the relationships that generate both tangible and intangible value through complex dynamic exchanges between two or more individuals, groups, or organizations (Allee, 2003)
  - *Data governance*: How is ensured that data meets the needs of the organization? (Panian, 2010)

The data ecosystem literature was grouped on different keywords: data marketplace, data ecosystems, and the platform ecosystem. Business model research which concerns multiple firms (Al-Debei & Avison, 2010) and business ecosystems (Adner, 2016) literature is also covered in the literature review. Data ecosystems are ecosystems in which several actors interact with each other to exchange, produce, and consume data (Olivieira & Loscio, 2018).

[3] *Smart Retail Dashboard* is a project funded by the Flemish government to create a public-private data partnership to develop a dashboard to support local economy policymakers.

Thus, data ecosystems are a type of business ecosystem, where the exchanged value proposition is based on data. Actors in a data ecosystem can be private as well as public. "Ecosystems-as-structure" is defined as a business ecosystem where the actors' interactions serve the fulfillment of a core value proposition (Adner, 2016) or co-created value (Turetken, et al., 2019). A business ecosystem strategy is defined as the alignment structure of the multilateral set of partners that need to interact for a focal value proposition to materialize (Adner, 2017). Each organization aims to position itself in the ecosystem and seeks to capture value, while trading of cooperation with competition. The distribution of value is very complex in the data ecosystem due to the possibility to recombine data (Li, et al., 2019) and due to the intangibility of data (Koutroumpis, et al., 2017). Additionally, a revenue model and pricing model need to be identified, and this needs to be balanced with a cost model to ensure profit (Ballon, 2006; Spiekerman 2019). The value of data is not always recognized between companies, which makes the pricing of data challenging (Spiekermann, 2019; Spiekermann, et al., 2018; Khatri & Brown, 2010). Thus, revenue-sharing models (Fox, 2020; Kembro & Selviaridis, 2015) are challenges in many data ecosystems.

The control of the ecosystem on a value network level is based to a large extent on the power asymmetry (Mason-Jones & Towill, 1999) between companies, as more powerful companies might enforce smaller companies to share data (Kembro & Selviaridis, 2015). To find alignment in the ecosystem and to agree on common standards of interoperability or value-sharing models, the ecosystem is highly dependent on the power dynamics within the ecosystem, as powerful actors aim to protect their data resources (Kembro & Selviaridis, 2015). Additionally, the control within the data ecosystem depends on the market dynamics, thus the collaborative or competitive nature of the value network (Dahlberg & Nokkala, 2019). The data ownership rights describe who owns and uses the data (Konsynski & Tiwana, 2010; Schreieck, et al., 2016; Lee, et al., 2018). Additionally, the openness of the data-sharing model determines which new entrants can enter the ecosystem, and thus also link to the power dynamics in the ecosystem. Different models of data sharing occur, such as in open closed or hybrid models (Spiekermann, 2019). Customer ownership concerns which players hold direct relations with end customers (Ballon, 2006), which in the case of data could be intermediated through a data intermediary or data could be exchanged directly (Wernick, et al., 2020).

On the data governance level, besides ensuring the quality of data such as in single organization and bilateral data use, the provenance plays an important role, as it enables to trace the history of the data life cycle transparently (Lee, et al., 2018; Koutroumpis, et al., 2017). Data licenses can ensure control over the quality of data by describing whether data can be reused, remixed, adapted, or built upon (Creative Commons , 2019) Thus, it can determine the data rights companies and data subjects may have. Further, Interoperability ensures machine readability (Wimmer, et al., 2018). Data control refers to the control of the essential data resources in the data ecosystem (Curry & Sheth, 2018) which can be controlled by a central actor, or can be decentralized and therefore spread across the multiple actors in the data ecosystem (Guggenberger, et al., 2020; Gelhaar, et al., 2021).

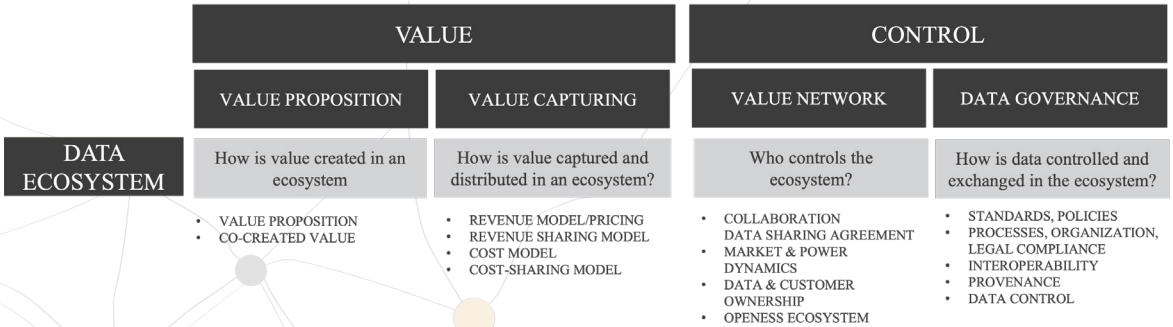

Figure 2: Value and control in Data Ecosystem Business Models

Multiple Case Study analysis: Value and control in data ecosystems

To answer the research question *"How is the business model of real-life data ecosystems constructed"*, the Data Ecosystem Business Model Framework, based on Value and Control (figure 2) was applied to perform a multiple case study analysis of 3 case studies involving cities and private companies:

- A government offering data to engage an ecosystem of co-innovation for companies (Digital Twin Helsinki data ecosystem)
- A government developing a data ecosystem of private and governmental data sources with use cases involving citizens (Digital Twin Rotterdam data ecosystem)
- Private companies developing a data solution for cities (Smart Retail Dashboard Flanders data ecosystem)

Each case study has their own ways of creating, capturing, and distributing value in the ecosystem, which are discussed in the case studies. Each use case also provided an opportunity to zoom into a specific aspect related to the control of the value network and controlling the data exchange in the ecosystem.

Case Study 1: The Helsinki Digital Twin data ecosystem

The Helsinki Digital Twin data ecosystem provides an example of a data ecosystem where a governmental actor provides access to governmental data to enable an ecosystem. Value is created for the city and for the actors in the ecosystem. The model is financed by the city as it helps to reach policy goals. On the control side, it provides insights on the need for data governance in a data ecosystem.

Value creation and capturing

The purpose and value creation of the Helsinki Urban Digital Twin is twofold. A first purpose of the Helsinki Urban Digital Twin is to support the **policy making of the government by including the citizens and ecosystem in the policy process.** One application of the Digital Twin is the Helsinki Energy and Climate Atlas, which is an open web service, built on a semantic Digital Twin model, which can be accessed, used, and shared by citizens and the overall ecosystem. It has four service modules: energy data, solar energy, heat demand, and geo-energy. It can be used by companies, real estate developers, city planners, and building users. Example given, the tool is used by an energy advisory agency that advises people whether to install solar panels or not. Additionally, the tool is used as an information source for energy, heating, and cooling companies to provide a better service.

The added value of the Digital Twin is to gather data from different governmental sources, process data in order to structure the data into a city data model and visualize the data in a real-world environment. The value is captured by the ecosystem, as it enables improved service provision for companies and better decision making. For the city it leads to better services of the city and enables the city to reach climate goals. The service is free for citizens and actors, as the cost is covered by governmental funds.

Additionally, another purpose of the Helsinki Digital Twin is to **drive co-innovation**, which is oriented to engaging the ecosystem to innovate with the data

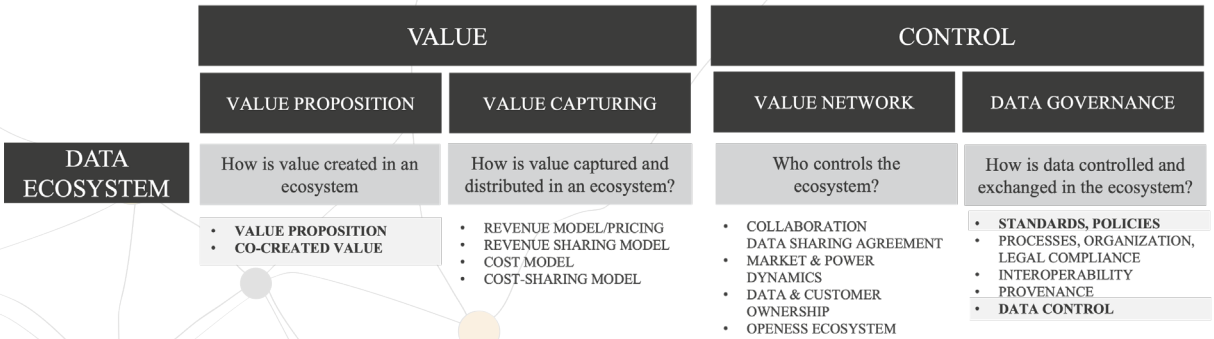

Figure 3: Value and control in the Helsinki Digital Twin

of the urban Digital Twin. This was showcased in a Hackaton where companies could use open data and 5G mobile networks provided by the city, in an augmented reality challenge. The value for the government is mainly to reach policy goals and to engage the ecosystem to innovate. The value is captured as one of the main policy goals of the city is to drive innovation, and they operate under the "open by default' principle. The costs are covered by governmental funds. Startups capture the value as they have access to data and can create new innovations.

Control of the Data governance

In this use case, a major focus of the city concerns the data governance regarding policies and data control. The **data source is mainly governmentally owned data**. The data is often generated and collected by the government, and when needed **purchased from private companies**. In this case, the government also needs to decide on which data can be **open, and which data cannot be shared with the wider public**. Reasons for not sharing the data can be because the data is sensitive, can pose negative effects on society when it comes into the wrong hands or simply because there are no use cases. To open data, a **classification of data** is required which determines which data can be **opened**, and which data needs to remain **closed.** This depends on the confidentiality, correctness, and availability of the data. This depends also on the type of data, as **governmental data** is often seen as data which needs to be 'as open as it can be', whilst some data can be too sensitive to share (e.g. in the case of water piping data this can only be shared on a certain level). In the case of commercial data, the sharing of the data depends on the conditions of the company. In the case of personal, privacy-sensitive data this needs to comply with the GDPR, and some cities even require to set up an ethical commission which needs to determine whether the data can be shared based on what will happen with the data and which data is required.

Table 1.

Use Case	Actor	Value proposition	Value captured	Revenue Model
Energy & Climate Atlas (energy data, solar panels, CO2 emissions...)	Real estate companies, researchers, city planning, citizens...	E.g., Solar panels: give advice by real estate companies to improve renovations E.g., Information for energy, heating, and cooling companies	External: Improved service provision for companies, better decision making Internal: Improved services of the city, reach climate goals	Free for citizens and actors Cost covered by governmental funds
Hackathon and co-innovation	Universities, startups, citizens	Access to data to innovate e.g. open data and 5G challenge, to use geodata to build an AR application	External: access to data, create new innovations Internal: Provide data, create innovation, "open by default' principle	Free for users City provides a prize for challenges Cost covered by governmental funds

Table 1: Value creation and capturing in the Helsinki Digital Twin

Case Study 2: The Rotterdam Digital Twin data ecosystem

The Rotterdam Digital Twin data ecosystem provides an example of a data ecosystem where a governmental actor aims to create an infrastructure for data exchange between private and governmental actors. Value is created for the city and for the actors in the ecosystem. The model is initially financed by the city as it helps to reach the policy goals. On the control side, thus use case provides insights on the need for ecosystem governance in a data ecosystem.

Value creation and capturing

The Rotterdam (Netherlands) Digital Twin is in the process of setting up the **digital infrastructure for a data ecosystem** in Rotterdam to bring different actors together through the Digital Twin and the Open Urban Platform by sharing data within the ecosystem. The Digital Twin is mainly used to engage the ecosystem, with different use cases. There are use cases where the city provides data, and other use cases where the city provides a platform for data exchange.

The data sources for the Rotterdam Digital Twin are based on both governmental data and data from the ecosystem. Therefore, Rotterdam aims to set up a data ecosystem called the **Open Urban Platform.** In this data ecosystem, the role of the city is to connect different actors, to develop the platform, to own the platform, and to invest in the initial stages. Once the platform is operational, the city and the data ecosystem will be able to act as a data provider, developer, user, and customer of the digital data ecosystem. Thus, the data sources of the urban Digital Twin will be governmental data, as well as private data from the data ecosystem gathered from the open urban platform. The added value for the data providers will be to sell their data, and for the data consumers that they will have access to data they previously do not have access to.

The initial use cases of the Rotterdam Digital Twin engages with the ecosystem, as it provides data insights for different players in the ecosystem to make their own decisions (e.g., information on building permits…), and to engage citizens in participation in urban construction processes (an AR application on construction sites, citizen participation by allowing to give feedback). The added value of the Digital Twin is to **gather data** from different governmental and private sources, **process data** to structure the data into a city data model and **visualize the data** in a real-world environment. The value is created externally to the citizens, as the citizen can provide feedback and receive feedback on projects in the city, and they can also engage more with the digital twin. For the government, this can improve decision making, improves processes and reduces cost for future use cases. For companies, this can improve processes. For data providers, this can become a novel revenue source. As the use is primarily **provided for free to the citizens**, the **revenue model is initially based on creating internal value** and use without a direct financial exchange. The costs are covered from the Digital Twin department paid from **governmental funds**.

In the long run, the financing and revenue model of the Rotterdam Digital Twin will probably change. Initially, the city pays for the technological infrastructure and for the structuring and gathering of data. As it concerns public value, the Digital Twin could use governmental funding for the opening of the Digital

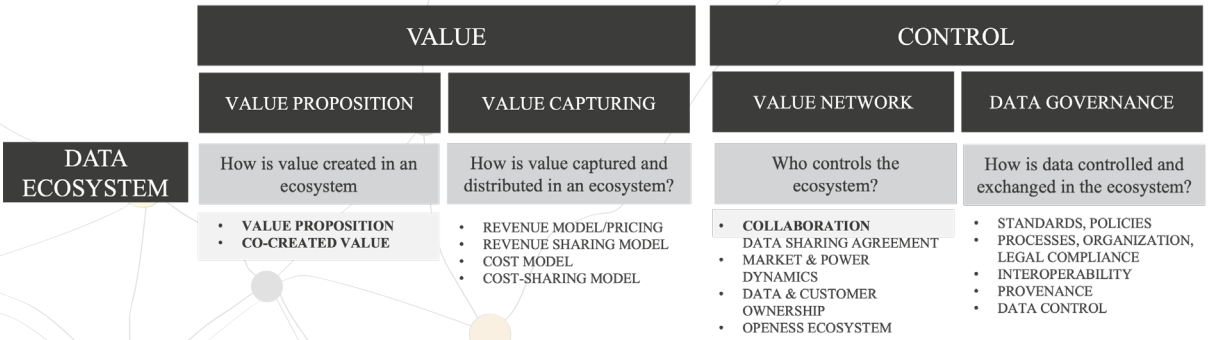

Figure 4 Value and control in the Rotterdam Digital Twin

Table 2.

Use Case	Actor	Value proposition	Value captured	Revenue Model
Building Permits	Citizens who want to request a permit	Quick feedback on whether a citizen will receive a permit	Citizen: quick feedback Government: reduced governmental time spent, better service	Free for city Costs covered by Digital Twin department
Participation	Citizens who want to give feedback on urban project	Informing citizens about urban development projects	Citizen: Better visualisation of the city project Government: Improved decision making, receive feedback from the citizens	Free for citizen Costs covered by Digital Twin department

Table 2: Value creation and capturing in the Rotterdam Digital Twin

Twin and the Open Urban Platform to the ecosystem. In the future and for some use cases, the ecosystem could also be paid for data by other actors in the ecosystem if the value mainly returns to them.

Control of the Open Urban Platform

In setting up the Open Urban Platform, the city takes an active role in the the first phase of setting up the platform. Afterwards, the city will need to identify whether the governance of the Open Urban Platform might need to be transferred to the ecosystem itself. Working with a completely different model which gives more control to the ecosystem, requires a drastically changing role of the government. It needs to move from a more passive role towards taking an active role in the ecosystem and positioning the government and the data ecosystem actively. It requires a governance model for the ecosystem and a role definition for the government. Different activities will be required to facilitate the supply and demand of data in a marketplace, and additional services (such as data storage, geocoding…). Additionally, there is a role for marketplace governance who guards the balance between the commercial exploitation and the societally responsible behaviour of actors in the ecosystem. If the Urban Digital Twin is offered to the ecosystem as an infrastructure for the end users, questions arise on who gains value, who adds value and who owns the results of the outcome of the Urban Digital Twin. Therefore, when opening the Digital Twin to the ecosystem there can be questions on what the role of the city government, beneficiaries and contributors of the Urban Digital Twin are.
Additionally, an Urban Digital Twin with a surrounding data ecosystem needs a governance model which ensures trust in the ecosystem. The data ecosystem needs to be willing to open the data, require clear data ownership rules, which ensure control over the data resources, and to set up conditions based on which the data can be shared. To set this up, collaboration models need to be set up regarding the ownership of data, access to data, and open standards adoption by the ecosystem.

Case Study 3: The business model of the Smart Retail Dashboard data ecosystem

The Smart Retail Dashboard data ecosystem provides an example of a data ecosystem where a consortium of private actors aims to create an offering for data exchange from private actors towards governmental actors. Value is thus created for the cities in the retail sector. This use case provides insights on the need for developing a sustainable revenue and cost (sharing) model in a data ecosystem, and on the control side, it provides insights on the need for ecosystem governance related to the openness of the data ecosystem.

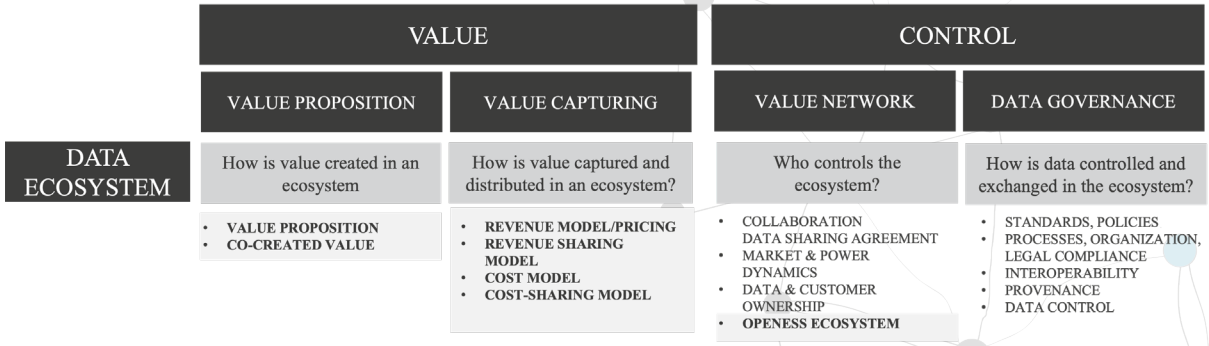

Figure 5: Value and control in the Smart Retail Dashboard

Value creation and Capturing

The aim of the Smart Retail Dashboard is to support policy makers in Flemish cities to make decisions based on urban data sources. The Smart Retail Dashboard is a collaboration of private companies which offers a data platform with combines and visualizes governmental and private data of telecom providers, financial data providers.

The primary focus will be on four use cases (attract retailers to the city, develop a retail strategy, event management and City Marketing). The value of the Smart Retail Dashboard comprises of ensuring that public authorities can make decisions based on actual data. To provide this value, the different actors combine smart city information and data such as transaction data, passer-by, visitor profiles...

Table 3.

Use Case	Actor	Value proposition	Value captured	Revenue Model
Event Management	Policy Maker responsible for city events	Identify the ROI of an event organized by the city (impact on purchases at local retailers)	Government: Able to assess ROI on events Retailers: Events lead to higher purchases	Different models are possible: freemium, subscription model, cost-sharing model Paid in a cost sharing model by cities and by Flemish government
City Marketing	Policy Maker responsible for City Marketing	Identify profiles of visitors in the city to adapt the City Marketing	Government: Assess ROI on City Marketing Retailers: Increased number of visitors in the city	
Retail Strategy	Policy Maker responsible for Retail Strategy	Adapt the retail strategy of the city based on data of purchases and visitors	Government: Develop a Retail Strategy based on data Retailer: Retail Strategy leads to higher profitability	

Table 3: Value creation and capturing in the Smart Retail Dashboard

Revenue and cost (sharing) models:
In the case of the Smart Retail Dashboard, the revenue model of the Smart Retail Dashboard is of a major concern to enable a sustainable business model, as cities have limited budgets and the total addressable market is reasonably small. The model will be based on a basic data offering in a subscription model, with additional possible services of consulting, additional in-depth data, and standardized additional reports.

Three different models were developed to provide an answer to this challenge (a license model, a cost-sharing model, and a freemium model). In the license model, the cities pay 100% of the license cost for access to the dashboard with access to basic standardised reports. Due to the limited budgets of the cities, this model may not be realistic. In the cost-sharing model, the cities pay a percentage of the access to the dashboard and the use cases. Given the societal value of the Smart Retail Dashboard, governmental support of higher governments (on the Flemish level) is included in this model. In the freemium model, the users receive free access to the dashboard and the license cost would be paid by the higher governments. Cities would pay for additional services such as reports, additional data, and consulting.

An example of the revenue model and value network of the Smart Retail Dashboard is shown below. The cities receive access to a basic offering (including the license, access to platform and standardized report). If desired, the city can receive an additional offering in depth data, for which it will pay a premium. The fee will be paid to the platform provider of the Smart Retail Dashboard, who redistributes the fee within the consortium. The redistribution between the different data providers is based on the amount of data it provided based on a contribution percentage of each partner. If insufficient data is available, data providers from outside of the consortium can be added, and they receive a fee per provided data.

Control: Openness of the ecosystem
The market conditions show that many data providing actors of the Smart Retail Dashboard operate in the ecosystem in a competitive environment. Thus, different players may not trust to share data with each other. To overcome this lack of trust in the ecosystem, an ecosystem governance model is required for who can enter the collaboration. To develop a governance model for the ecosystem, three different scenarios arose based on **'open, hybrid or closed'** (Spiekerman et al, 2019) collaboration models.

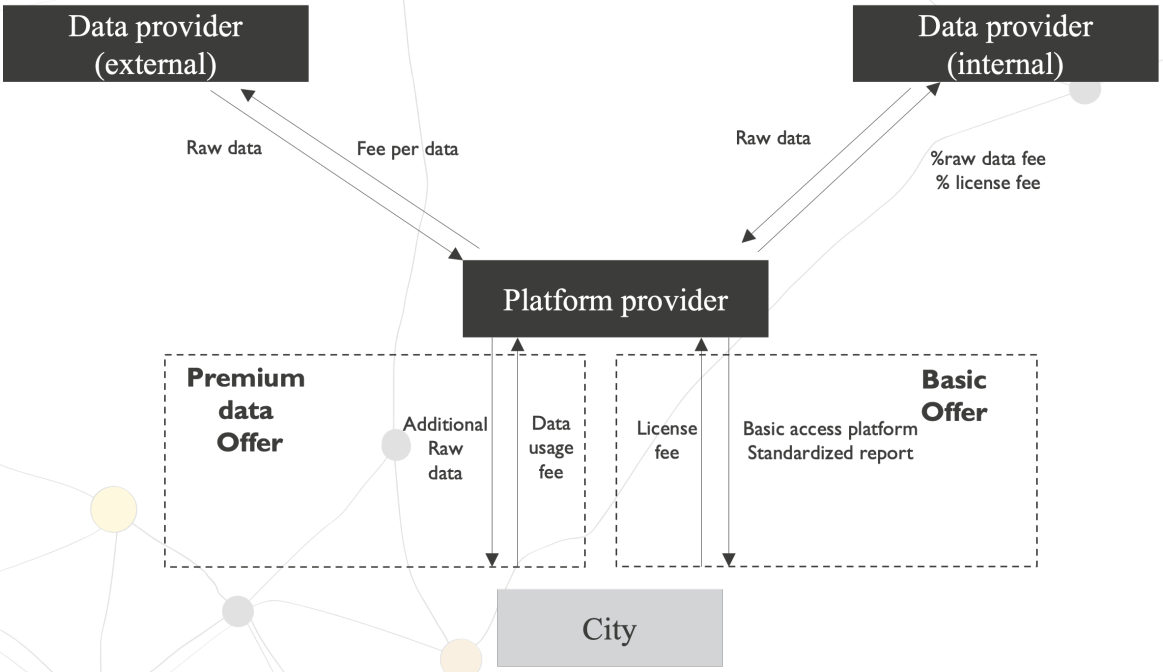

Figure 6: Value network of the Smart Retail Dashboard data offering

In the **open model**, all data owners can join, and receive a fee based on the percentage of their data contribution to the final offering. In the **closed model**, a limited amount of data providers creates a consortium. The consortium is composed of complementary players, who do not compete but collaborate. The data providers receive a fee based on the percentage of their data contribution to the final offering to the cities, as is negotiated in the beginning of the collaboration model. In the **hybrid model**, a limited amount of data providers creates a consortium. The consortium is composed of complementary players, who do not compete but collaborate. The data providers receive a fee based on the percentage of their data contribution to the final offering to the cities, as is negotiated in the beginning of the collaboration model. Yet, through subcontracting additional data providers could be added to the consortium, either on a short term – or long-term basis.

Implications on Business Models of actors entering data ecosystems

If value through data cannot be created and captured sufficiently within organizations, one may need to move beyond the borders of single organizations. Thus, the need for a data ecosystem arises. The business models for entering data ecosystems have implications on different actors: either actors who aim to **establish a data ecosystem** (such as the Rotterdam government use case) or actors who want to determine whether they want to **enter an existing data ecosystem**. This could be as an actor providing data or receiving data, depending on the use case. This may concern governmental and/or private players.

To enter data ecosystems, actors will need to ask questions which can be guided by the Data Ecosystem Business Model Framework. One needs to establish whether value can be created when entering or setting up a data ecosystem: Can the internal data of the individual actors be utilized to create value of data internally within the organization? Or is there a value for exchanging data in a data ecosystem? Will the company require to receive data from other actors, or will it be able to share data? It could be observed that all case studies initially created value through the definition of use cases involving governments, companies, and citizens to kick start the ecosystem. Within these use cases, value needs to be created for all different actors. If there is no value created for one actor in the data ecosystem, the use case will not materialize as no alignment can be found between the actors for a common focal value proposition of the ecosystem.

The actor will need to establish whether value can be captured by entering a data ecosystem. Are there revenue (sharing) and cost (sharing) models which are applicable? In the different use cases, governmentally funded use cases for creating a data ecosystem were required to build a sustainable model (Helsinki, Rotterdam) to kick start the ecosystem. Value can be captured in monetary terms (paying a fee for data in the case of the Smart Retail Dashboard) or non-monetary (e.g., free access to data). In the latter, as value is captured by the government for reaching policy requirements, the governments pay for the development of the use cases in the cities of Helsinki and Rotterdam. The example of the Smart Retail Dashboard and in the future Rotterdam show that there is a need for developing revenue sharing models and cost sharing models between private and public actors. The distribution of value within the ecosystem is a major field of further research, as could be observed in the Smart Retail Dashboard use case.

When the value creation and capturing questions are answered, an actor needs to determine whether it can control its current position in the market by entering a data ecosystem. Additionally, actors aiming to establish a data ecosystem, will need to consider questions regarding ecosystem governance. Can the other actors in the ecosystem be trusted? What are the power dynamics, customer ownership and data ownership tendencies in the ecosystems? Can data be shared with the partners in the ecosystems, or are there competitors with whom data cannot be shared? Is there a need for developing ecosystem governance models in the data ecosystem, and is the company willing to abide to the existing governance models? In the Rotterdam and Smart Retail Dashboard use cases, it became clear

that trust within the ecosystem will need to be created. Companies or governments may not want to share the data with competitors and/or will not want the data to be reshared. Additionally, when setting up a data ecosystem, new roles for the government and private actors arise, requiring novel governance models. One aspect within the governance models is the openness of the ecosystem, which has major implication on the models to collaborate as the Smart Retail Dashboard use case has shown. In closed ecosystems the actors choose with whom the data is shared, while in open ecosystems this creates additional challenges for data sharing governance.

Last, the control over the data resources will need to be ensured as well as the efficient exchange of data. Can agreements be made within the data ecosystem regarding the usage of data? Is the data sufficiently structured and shareable or are interoperability standards required within the ecosystem? If there are existing agreements, is the company willing to adopt the standards, and what are the implications on the existing data governance within the company? This has business model implications, as it may require actors to change their current way of handling data. The example of Helsinki has shown that looking into with whom the data can be shared is of a high importance, as some data may be sensitive due to privacy, competition, or security reasons. Thus, the sharing of data in data ecosystems requires the acceptance of agreements and standards within the ecosystem, which may result into changing certain internal policies of actors.

Conclusions

To define the ongoing evolution towards data ecosystems, a literature review in the fields of data governance, data sharing, business models, and data ecosystems was performed, describing the interdependencies between the different streams of literature. This led to a Data Ecosystem Business Model Framework based on value and control, which includes the parameters of value (how is value created and captured) and control (controlling the value network/ecosystem and data governance). The multiple case study analysis provides empirical analysis of business models of data ecosystems showcasing the factors in three use cases in the Rotterdam Digital Twin, the Helsinki Digital Twin and the Smart Retail Dashboard.

The Data Ecosystem Business Model Framework can be utilized to help to define an alignment strategy between the actors to go towards the same direction by providing an overview of the factors that need to be considered. It shows the need for creating individual business models with value proposition & revenue (sharing) models for each organization that fits the overall ecosystem strategy. Value needs to be created and captured within use cases for the data ecosystem to materialize and for alignment to occur. Additionally, it shows the need for control of the data ecosystem, as governance models are required to develop organizational models in the ecosystems, as well as to develop trust among the partners in the ecosystem to be willing to share data. Lastly, data governance models are required to ensure data can be controlled and exchanged within the ecosystem.

A limitation of this study is that it is applied to case studies in the fields of smart cities and digital twins. As a result, the use cases all deal with ecosystems where governments play an important role. Further research will need to investigate whether these findings can be extrapolated to other data ecosystem with a higher presence of private actors. Another limitation concerns the fields of literature that have been covered. This work concerns data governance, data ecosystem, business models, data sharing literature, and makes abstraction of legal and technical challenges.

Further research is required to determine the underlying business model implications of data ecosystems. Examples of important areas of study are the value of data, the willingness to share data in data ecosystems, revenue sharing models and value distribution models, governance models for enabling trust, the openness of data ecosystems, ... The Data Ecosystem Business Model Framework can serve to further scope this ongoing research.

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Appendix: Overview of analyzed literature

Table 4.

Paper	Intra-organizational	Inter-organizational
(Ballon, 2007) (Control and value in mobile communications)	Not applicable	Control: Value network - Functional architecture Value: Financial model - Value configuration
(Walravens & Ballon, 2013) (Business models for smart cities)	Not applicable	Control: Value network - Functional architecture - Governance Vale:: Financial model - Value configuration – Public Value
(Mahadevan, B., 2000) (Business models for internet-based e-commerce)	Not applicable	Value stream, Revenue stream, Logistical stream
(Alt & Zimmerman, 2001) (Business models)	Mission, Structure Process , Revenues	Not applicable
(Applegate, 2001) (Emerging e-business models)	Concept, Capabilities, Value	Not applicable
(Rappa, 2000) (Business models on the web)	Sustainability, Revenue stream, Cost structure, value chain positioning	Not applicable

Table 4: Data governance

Table 4. *(Continued)*

Paper	Intra-organizational	Inter-organizational
(Weil & Vitale, 2001) (Migrating to eBusiness models)	Revenue Strategic objective Competencies	Roles & relationships, Flow (information money), Customer segments & channel
(Chesbrough & Rosenbloom, 2002) (Business model and capturing value)	Cost structure Competitive strategy	Value proposition, Market segment, Value chain, Value network
(Osterwalder, 2004) (Business model generation)	Key resources, Key activities, Key partnership; Revenue stream , Cost, Customer segment & relationship Channel, Value proposition	Not applicable
(Morris, et al., 2005) (The entrepreneur business model)	Competence, Positioning, Revenu, Value Ambitions	Not applicable
(Bonaccorsi, et al., 2006) (Hybrid business models in open source software)	Products & Service, Customer Cost structure, Income, Network, Network externalities	Not applicable
(Johson, et al., 2008) (Reinventing your business model)	Profit formula (revenue, cost), Resources, Processes, value proposition	Not applicable
(Grefen, et al., 2013) (Turetken, et al., 2019) (Service dominant business model radar)	Not applicable	Co-created value proposition, Actor value proposition; Actor co-productivity activity, Actor cost-benefit
(Weking, et al., 2018) (industry 4.0 – A business model pattern framework)	Target customers, Value Proposition, Value Chain, Key elements, Value capture, value chain	Not applicable

Table 4: Data governance

Table 4. *(Continued)*

Paper	Intra-organizational	Inter-organizational
(Solaimani & Bouwman, 2012) (alignment business model and business process)	Value, Information, Process	Not applicable
(Wirtz & Daiser, 2017) (Business model innovation: conceptual framework)	Target customer, value proposition, value constellation, Macro, and microenvironmental dimensions	Not applicable
(Al-Debei & Avison, 2010)(Unified framework of the business model concept)	Not applicable	Value proposition , value architecture, value network, value finance
(Wiener, et al., 2019) (Data business model framework	Not applicable	Value proposition Value architecture,V value network , Value finance
(Adner, 2016)(Adner, 2017) (Ecosystem-as-a-structure)	Not applicable	Alignment structure, multilateral, set of partners, focal value proposition

Table 4: Data governance

Table 5.

Paper	Inter-organizational	Intra-organizational
(Allen, et al., 2014) (data governance and data sharing in health)	Not applicable	Data Sharing Agreement Who will share or access the data? What types of data? Why?
(Martens, 2020) (The economics of the business to government data sharing)	Not applicable	Market type, Single data source VS. multiple data sources, Quality of data, Transaction costs
(Eckartz, et al., 2014) (A decision model for data sharing)	Not applicable	Ownership of data, Privacy legalities value of data and revenue, Data quality, Data standards
(Kembro & Selviaridis, 2015) (Information sharing across multiple supply chain tiers)	Not applicable	Trust, Benefit-sharing, Information quality, Dominant player/power structures, Confidential information
(Richter & Slowinski, 2019) (The Data Sharing Economy:)	Not applicable	Platform ownership - Openness, Trus , Revenue, Match supply, and demand
(Koutroumpis, et al., 2017)(Potential of data marketplaces)	Not applicable	Provenance (control and quality) Transaction costs
(Spiekermann, 2019) (Data Marketplaces: Trends and Monetization of Data Goods)	Not applicable	Transformation architecture, Market access, Value proposition Revenue model, Price model, Integration , Market positioning
(van den Broek & van Veenstra, 2015) (governance in inter-organizational data collaborations)	Not applicable	Type of data sharing, Characteristics, Coordination mechanism, Control over data

Table 5: Data Sharing/ Data ecosystem/ Data marketplace

Table 5. *(Continued)*

Paper	Inter-organizational	Intra-organizational
(Stahl, et al., 2016) (A classification framework for data marketplaces)	Not applicable	-Hierarchical vs market based -Ownership (private, consortia, or independent)
(Lee, et al., 2018) (Data governance for platform ecosystems)	Not applicable	Definition criteria, Data use case Conformance legalities: Data ownership and access, Contribution estimation, provenance, Monitoring
(Dahlberg & Nokkala, 2019) (Willingness to Share Supply Chain Data in an Ecosystem Governed Platform)	Not applicable	Trust, Control of processes, Data quality, Risk (commercial, technical)
(Schreieck, et al., 2016) (Design and governance of platform ecosystems–key concepts and issues for future research.)	Not applicable	Roles - Control Pricing and revenue sharing - Competitive strategy Boundary resources Openness - trust
(Autry, et al., 2014) (Multiplexidy in the supply chain)	Not applicable	Dyadic vs. Multiple relationships Relational and process-based linkages
(Caridi, et al., 2014) (Virtuality and complexity in supply chains)	Not applicable	Dyadic vs. Multiple relationships Visibility (access/share data supply chain) Virtuality (collaborate supply chain) Complexity supply chain
(Tachizawa & Wong, 2014) (multi-tier sustainable supply chains)	Not applicable	Multi-tier supply chain Power, dependency, distance, industry, knowledge resources

Table 5: Data Sharing/ Data ecosystem/ Data marketplace

Table 5. *(Continued)*

Paper	Inter-organizational	Intra-organizational
(Kembro, et al., 2017) (Information sharing in multiple supply chain tiers)	Not applicable	Information quality, cost IS, power asymmetry, governance/dominant player, trust, benefit allocation, metrics, goals, confidential information
(Pavlou, 2002)(Online marketplaces with institution-based trust)	Not applicable	Trust: Based on Perceived risk, past performance, andtransactiono,n intentions
(Oliveira, et al., 2019) (Data ecosystems: systematic mapping study)	Not applicable	Technical knowledge, complexity tasks, actor participation, organizational structure, privacy & confidentiality
(Azkan, et al., 2020) (Service dominant logic on data ecosystems)	Not applicable	Value co-creation (key offering, value, value capture), Actors (role); Operations/data flow; Data assets; Architecture (type, resources, access), Governance (structure, security, usage)
(Curry & Sheth, 2018) (Topology data ecosystems)	Not applicable	Control of data key resources (central vs decentral); Type of interdependence (reciprocal, pooled)
(Guggenberger, et al., 2020) (Types of ecosystems)	Not applicable	Ecosystem purpose, relational structure, system configuration, system dynamics
(Gelhaar, et al., 2021) (Taxonomy of data ecosystems	Not applicable	Economic (domain, purposeorganizationon); Technical (infrastructure, openness); Governance (interdependence, control)

Table 5: Data Sharing/ Data ecosystem/ Data marketplace

Table 6.

Paper	Intra-organizational	Inter-organizational
(Ballon, 2007) (Control and value in mobile communications)	Not applicable	Control: Value network - Functional architecture Value: Financial model - Value configuration
(Walravens & Ballon, 2013) (Business models for smart cities)	Not applicable	Control: Value network - Functional architecture - Governance Vale:: Financial model - Value configuration – Public Value
(Mahadevan, B., 2000) (Business models for internet-based e-commerce)	Not applicable	Value stream, Revenue stream, Logistical stream
(Alt & Zimmerman, 2001) (Business models)	Mission, Structure Process , Revenues	Not applicable
(Applegate, 2001) (Emerging e-business models)	Concept, Capabilities, Value	Not applicable
(Rappa, 2000) (Business models on the web)	Sustainability, Revenue stream, Cost structure, value chain positioning	Not applicable
(Weil & Vitale, 2001) (Migrating to eBusiness models)	Revenue Strategic objective Competencies	Roles & relationships, Flow (information money), Customer segments & channel
(Chesbrough & Rosenbloom, 2002) (Business model and capturing value)	Cost structure Competitive strategy	Value proposition, Market segment, Value chain, Value network

Table 6: Business models/ Business Ecosystems

Table 6. *(Continued)*

Paper	Intra-organizational	Inter-organizational
(Osterwalder, 2004) (Business model generation)	Key resources, Key activities, Key partnership; Revenue stream , Cost, Customer segment & relationship Channel, Value proposition	Not applicable
(Morris, et al., 2005) (The entrepreneur business model)	Competence, Positioning, Revenu, Value Ambitions	Not applicable
(Bonaccorsi, et al., 2006) (Hybrid business models in open source software)	Products & Service, Customer Cost structure, Income, Network, Network externalities	Not applicable
(Johson, et al., 2008) (Reinventing your business model)	Profit formula (revenue, cost), Resources, Processes, value proposition	Not applicable
(Grefen, et al., 2013)(Turetken, et al., 2019) (Service dominant business model radar)	Not applicable	Co-created value proposition, Actor value proposition; Actor co-productivity activity, Actor cost-benefit
(Weking, et al., 2018) (industry 4.0 – A business model pattern framework)	Target customers, Value Proposition, Value Chain, Key elements, Value capture, value chain	Not applicable
(Solaimani & Bouwman, 2012) (alignment business model and business process)	Value, Information, Process	Not applicable
(Wirtz & Daiser, 2017) (Business model innovation: conceptual framework)	Target customer, value proposition, value constellation, Macro, and microenvironmental dimensions	Not applicable

Table 6: Business models/ Business Ecosystems

Table 6. *(Continued)*

Paper	Intra-organizational	Inter-organizational
(Al-Debei & Avison, 2010)(Unified framework of the business model concept)	Not applicable	Value proposition , value architecture, value network, value finance
(Wiener, et al., 2019) (Data business model framework	Not applicable	Value proposition Value architecture,V value network , Value finance
(Adner, 2016)(Adner, 2017) (Ecosystem-as-a-structure)	Not applicable	Alignment structure, multilateral, set of partners, focal value proposition

Table 6: Business models/ Business Ecosystems

About the Authors

Ruben D'Hauwers is a PhD candidate in the field of Business Models in Data Ecosystems. He worked as a researcher at imec-SMIT, VUB since 2014, with a focus on investigating business models in the fields of smart cities, SMEs and sustainability. He holds a Master in Business Engineering of the University of Ghent and a Master in Innovation Management from the Antwerp Business School. Prior to working at imec-SMIT, VUB he worked as a business developer in Belgium and Myanmar for AIESEC and SBE nv.

Dr. Nils Walravens works as an Advisor Smart Region and Digitization at VLAIO. Prior to working at VLAIO, he worked for 14 years at imec-SMIT, VUB as a senior researcher focused on open data, smart cities and business models. He holds a PhD which focused on "Public value creation from 'smart' mobile application initiatives for Brussels and local governments". He graduated as a Master in Communication Sciences – ICT and globalization from the VUB.

Prof. Dr. Pieter Ballon is the Director of the research group SMIT (Studies on Media, Innovation and Technologies). He was appointed the first Brussels Smart City Ambassador and is also the International Secretary of the European Network of Living Labs. Prof. Ballon holds a PhD in Communication Sciences and an MA in Modern History. Since 2009, he has taught Communication Sciences at the VUB (Free University of Brussels). His expertise lies in the Smart City area for both Brussels and the Flanders Region, on the subject of which he has recently published the book "Smart Cities : hoe technologie onze steden leefbaar houdt en slimmer maakt".