White Paper

Creating data markets in future smart cities

Authors	Marko Palviainen[1], Ville Kotovirta[1], Liang Wang[2], Riina Luoma[1], Göran Nummelin[2], Antti Mäki[3], Juha Karppinen[4]
Organisations	1) VTT, 2) Nokia, 3) Link Design, 4) Vedia

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Abstract

The evolving smart city infrastructures, such as fast 5G networks, advanced digital platforms and data marketplaces, provide a base for new smart city data markets and new possibilities and incentives for data supply and use. To utilise smart city data maximally, we need markets where citizens, authorities and private companies can sell and buy data, process the data and create added-value data products from existing and new data and develop solutions for data use. In addition to earning direct profits from data sales, data trade can provide other benefits for data sellers, e.g., new partners, new interests in the company's main products, new kinds of business activities and new customers, as a result of data-based solutions.

This paper discusses emerging smart city data economy and presents a conceptual model for it. In addition, the key questions related to data business in smart cities are discussed; a model for local 5G data marketplaces and a four-level categorisation for sellable data products are introduced; and finally, the benefits, obstacles and enablers of data business in the future local data marketplaces are presented.

1 Introduction

There is huge potential and economical value in the data produced in smart cities. A part of this value is already created in companies that produce data for their own purposes or share data in business networks. The emerging smart city infrastructures such as advanced digital platforms, data marketplaces and fast 5G networks will provide new possibilities for data supply and use. Citizens, authorities and private companies can benefit from data trade and create more value from data. The 5G networks provide low latencies, high data transmission capacity and reliable connections. This enables the supply and delivery of near real-time data from sensors to cloud and edge processing to be used in immersive and responsive applications and services, AR applications, digital twins and Machine to Machine (M2M) services.

Smart city data economy creates new incentives for the citizens, authorities and private companies to share data and to act as data buyers and data sellers. The data buyers can purchase data for their own purposes, develop solutions for data use or process the data and sell the processed data to other actors in the markets. In addition to earning direct profits from data sales, data trade can provide other benefits for data sellers, for example, new partners, new interests in the company's main products/services, new kinds of business activities and new customers for the product/service as a result of data-based solutions.

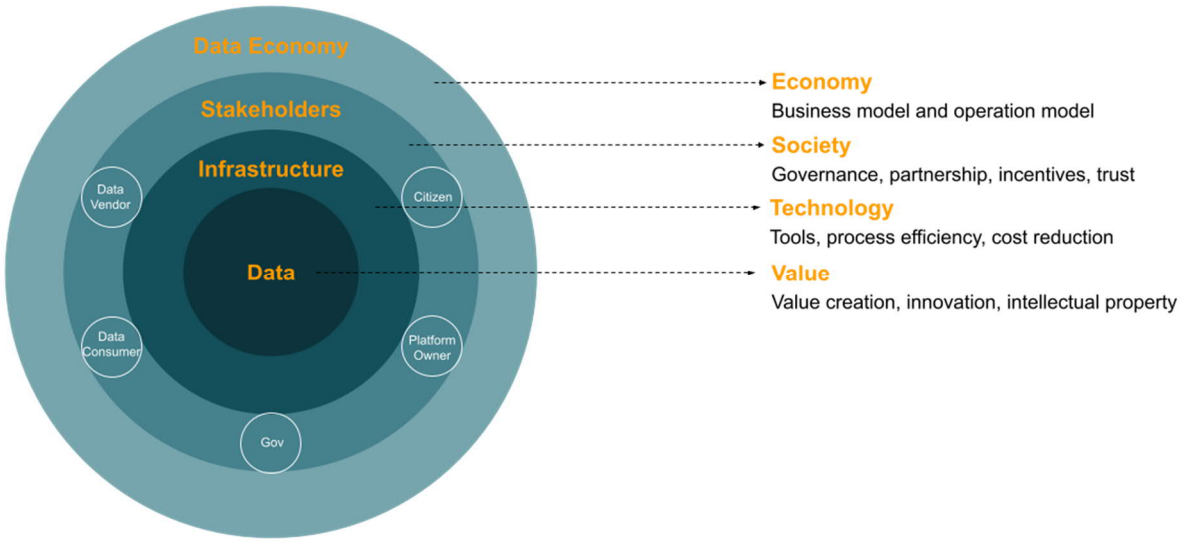

FIGURE 1. A CONCEPTUAL MODEL FOR SMART CITY DATA ECONOMY.

Figure 1 presents a conceptual model for smart city data economy, a bird's-eye-view of the context we are investigating in this paper. The model consists of multiple concentric rings, representing four particular components. From the innermost to the outermost, there are *data*, *infrastructure*, *stakeholders* and *data economy*. Each component corresponds to one perspective of a data marketplace and raises the following questions to be addressed:

- Value – First, the core component is data. This poses a fundamental question on *how to create value from data?* Actually, there are (at least) two approaches for this. First, the value can be created in (business) networks that are created outside data marketplaces. This paper focuses on the second option in which value creation is based on the use of data marketplaces where sellable data products are offered.
- Technology – Second, there must be tools to facilitate preparation of sellable data products and performing various processes in the marketplace. For example, establishing trust between buyers and sellers is a critical step in real-world trades, which is often achieved by contract signing. Similarly, a data marketplace should offer tools to bind data sellers and traders with digital contracts.
- Society – Third, the data marketplace needs to engage various stakeholders by creating effective mechanisms and incentives, e.g., governance, partnership and trust.
- Economy – Finally, the data marketplace must create a scalable business model and an efficient operation model to prove its economic feasibility in the first place.

This paper discusses the aspects of creating data marketplaces in future smart cities. Section 2 discusses the key questions (*what*, *why*, *who* and *how*) of data economy. Section 3 presents a classification for sellable data products and a model for local and neutrally hosted data marketplaces. Section 4 presents key modules and implementation alternatives for local 5G data marketplaces. Section 5 discusses the benefits, obstacles and enablers that relate to the data business in the local data marketplaces. Finally, concluding remarks are provided in Section 6.

2 Key questions

There are three key actor roles in data business in general (Schroeder, 2016): *data suppliers* create, collect, mash-up and process data for various purposes; *data users* find new possibilities for utilising data in their own business; and *data facilitators* provide technologies and support for finding and exploiting new data. Figure 2 presents the

key questions related to data economy in smart cities from the viewpoint of each of these three actor roles, and the following subsections discuss these questions in more detail.

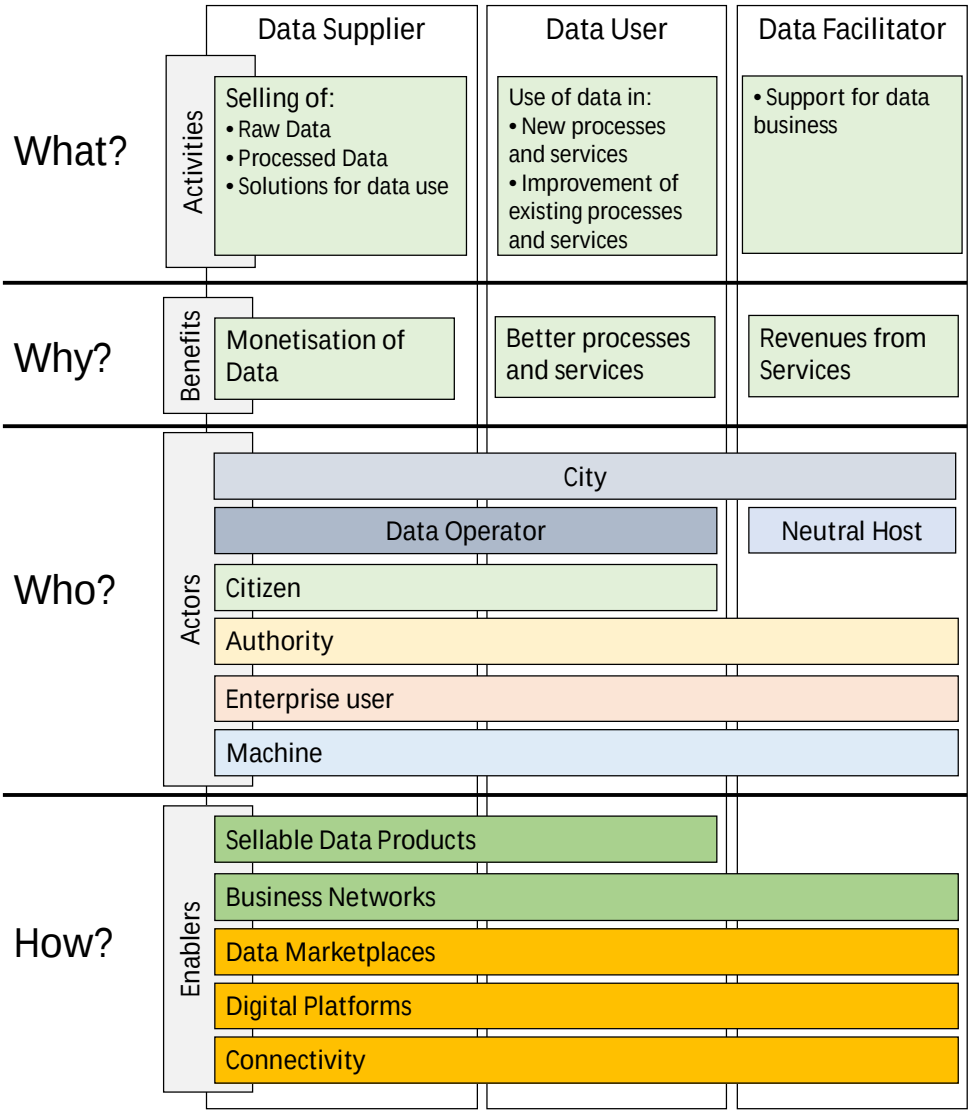

FIGURE 2. THE KEY QUESTIONS RELATED TO DATA ECONOMY IN FUTURE SMART CITIES.

2.1 What?

The core idea of data business is to create value from data by enabling the sharing of data between actors in the markets and to obtain more users for the data. Data providers must consider how value is created and what level of processing is sufficient to generate a unique and high value proposition. This results in many different data suppliers with different capabilities: some may sell only raw data, while some sell processed data or solutions that utilise the data available in the markets. Data users benefit from the sellable data by using it in existing or newly created processes and services. Data facilitators provide support for data business, assist in data productisation or provide technology such as marketplaces for data trade.

2.2 Why?

Data business provides direct business benefits for data suppliers that will earn revenue from supplied data and for data users that can access data more easily and cost-efficiently from data marketplaces and digital platforms. The sellable data can be a critical enabler for new processes or products or an enabler for improving existing

processes or products. Being able to combine data from different sources in such a market can both create new revenue streams and facilitate new insights into previously unseen possibilities.

2.3 Who?

The future smart city data economy will be based on different actors that can occupy the data supplier, data user and/or data facilitator roles. For example, the following kinds of actors can participate in the local smart city data economy:

a) Cities – In our vision, the future cities will have local data marketplaces. The cities will be neutral actors that regulate the use of their data marketplaces and can act as data suppliers, data users and data facilitators in the future smart city data economy.
b) Neutral hosts – Neutral hosts are data facilitators that provide infrastructure services, such as fast 5G connectivity, data platforms and local data marketplaces to facilitate data economy in smart cities.
c) Data operators – Data operators are data users and data suppliers that buy data and produce sellable value-added data products for other actors in the marketplaces.
d) Citizens – Citizens can be data users or data suppliers of sellable data. For example, citizens can sell selected parts of their personal data for selected data users or contribute to crowd-sourcing applications in supply of sellable geo-spatial data in city environments.
e) Authorities – Authorities can act as data suppliers or as data users. For example, the public sector can provide sensor data of urban environments and live data feeds about traffic, public transportation and public spaces as sellable data that enables data buyers, such as private companies, to benefit from the data and to use the data in improving of their processes or services. The authorities can benefit from sellable data products available in the data marketplaces produced by other actors in the city, e.g., purchase weather or air quality data, and use it in services that are provided for different actors in the city.
f) Enterprise users – There can be private companies that sell data to markets or buy data to improve their business and services. Furthermore, there can be enterprises in the data facilitator role providing technologies and support for data business.
g) Machines – The role of machines will increase in data trade. In addition to human users, there will be fully or semi-autonomous systems, such as autonomous vehicles, robots, buildings, applications, software systems and services, that connect to data marketplace APIs (Application Programming Interface) and use or produce sellable data automatically.

2.4 How?

Fast network connections, digital platforms, and data marketplaces will be key enablers for smart city data economy. Digital platforms are often referred to as “electronic marketplaces” that facilitate the exchange of goods, by using pricing strategies and enabling the platform participants to co-create value between each other and create a “network effect”, which is when a good or service acquires more value for its user as more users adopt it (Fruhwirth, Rachinger, & Prlja, 2020). Data marketplaces (DMPs) offer a data exchange infrastructure by acting as intermediaries that create a link between data providers and data buyers (Spiekermann, 2019). 5G networks offer low latencies and high data transmission rates and enable the use of local, cloud and edge computing in sensor data processing and the creation of highly responsive applications for near real-time situational data.

Regarding trust, security and privacy, the marketplace should focus on creating flexible mechanisms so that it can be customised to different local context. Different cities may have different legal and regulatory constraints, which further require us to implement different policies using the mechanisms offered by a marketplace.

The creation of value from data requires that the data suppliers supply sellable data products that fulfil the requirements of data users. For example, the Data Market Simulation (DMS) approach assists data suppliers to optimise vehicle-based supply of sellable data and creation of value from data; evaluating vehicle routes and the quality of data that the vehicles on these routes will produce; and reviewing how well the routes will serve the potential data users before beginning the supply of data in cities (Palviainen, & Kotovirta, 2022).

Data suppliers can use the following four methods for creating value from data (see the four-level categorisation for data products in Figure 4):

1) Data productisation – First, extracting value from data that is not yet provided as sellable data in a marketplace requires productisation for the data. This can produce level 1, 2 or 3 sellable data products available to data marketplaces.
2) Data sharing *(Level-1 Data Products)* – Second, in the case where value creation is based on sharing of sellable data as it is. The data users will then perform the needed processing for the data or develop solutions for the use of the data.
3) Data processing *(Level-2 Data Products)* – Third, in the case of a sellable processed data, the value creation is based on the processing of data that prepares data, information, knowledge or insights from data for a certain purpose to create value for data users.
4) Development of solutions for data use *(Level-3 Data Products)* – Fourth, there can be applications and services that create added value for data users by facilitating the use of data, e.g., visualising data.

3 Model for local data marketplaces

Cities are neutral actors that regulate the use of the physical marketplaces where people regularly go to purchase sellable goods (see, Figure 3). In our vision, future cities will also create digital marketplaces that are analogous to physical marketplaces, but operate in a digital realm. For example, there can be digital marketplaces for digital goods, such as sellable data products. These local data marketplaces can be designed for data trade that exploits the benefits of fast 5G networks in data supply and use.

The hypothesis is that by introducing local data marketplaces, we motivate opening up existing data, productising of data, creating new data and taking data into use in data-driven services. This will pave the way for a society where the potential of existing data is used to benefit different actors in cities. Data marketplaces bring "the crowd", the citizens, authorities and private companies, to one place and make sellable data visible, enabling parties to search data for their requirements and create new value from data. Both the human users and machines can participate in data trade, and there will be sellable data products for human users and for machines.

Three fundamental elements in the smart city data economy can be identified: data products, regulation and frameworks, and smart city infrastructure. These elements are briefly discussed in the following paragraphs:

Data products – In physical marketplaces, there is a demand and supply for unprocessed groceries, such as carrots and apples, and for highly processed groceries, such as ready-made meals with cutleries (see, Figure 4). The future data marketplaces will offer sellable data products for different demands. The degree of processing will greatly vary in the data products, and there will be a demand and supply for *raw data (Level-1 Data Products)*, for *processed data (Level-2 Data Products)* that is prepared for a certain purpose or demand, and for *solutions (Level-3 Data Products)* such as applications and services that enable human users or machines to use data for different purposes.

Regulation and frameworks – There must be trust between sellers and buyers in the data trade. The future cities are neutral actors that can regulate the trade of data products in their data marketplaces and provide frameworks

for data trade to lower the threshold of starting supply or use of sellable data via data marketplaces (see, Figure 3). For example, these frameworks can determine well-defined APIs, data models, and licencing models to assist both the supply and the use of sellable data in smart cities. Regulatory frameworks, like GDPR and GAIA-X in the EU, will provide a higher-level frame inside which the neutral actors will function.

Smart city infrastructure – The physical marketplaces require city infrastructure, such as roads and electricity supply and water supply and sewerage. Similarly, the digital data marketplaces require smart city infrastructure for data gathering, data delivery, data processing and data use. First, the smart city infrastructure, such as smart lighting poles in a city, can contain sensors to capture street-level sensor data of city regions. Second, the fast and reliable networks, such as 5G networks, are needed to offer low latencies and high data transmission rates for data delivery and for enabling the use of local, cloud and edge computing in data processing and the creation of highly responsive applications for near real-time situational data. Third, advanced digital platforms, processing components and algorithms are needed for data processing.

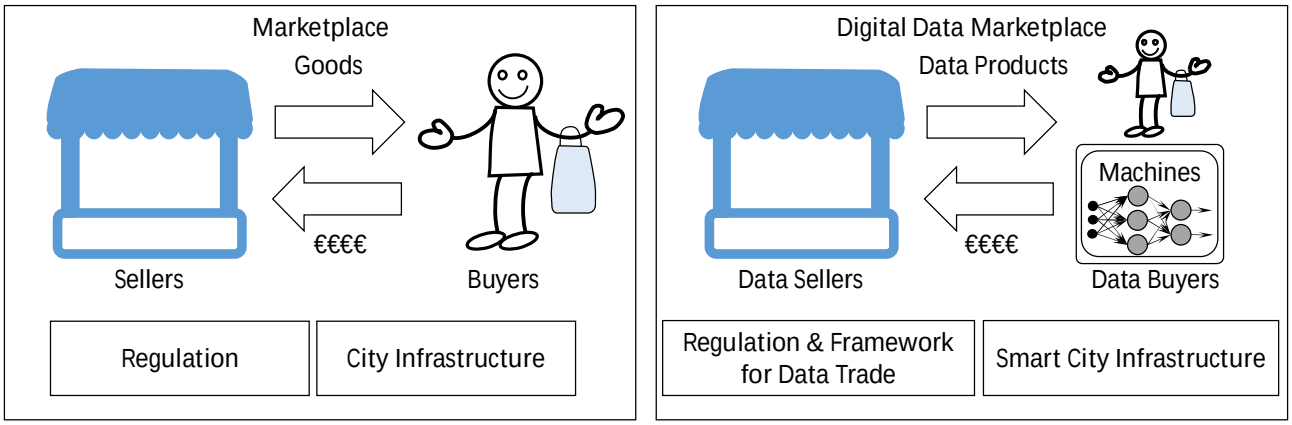

FIGURE 3. MARKETPLACE FOR PHYSICAL GOODS AND DIGITAL DATA MARKETPLACE FOR SELLABLE DATA PRODUCTS.

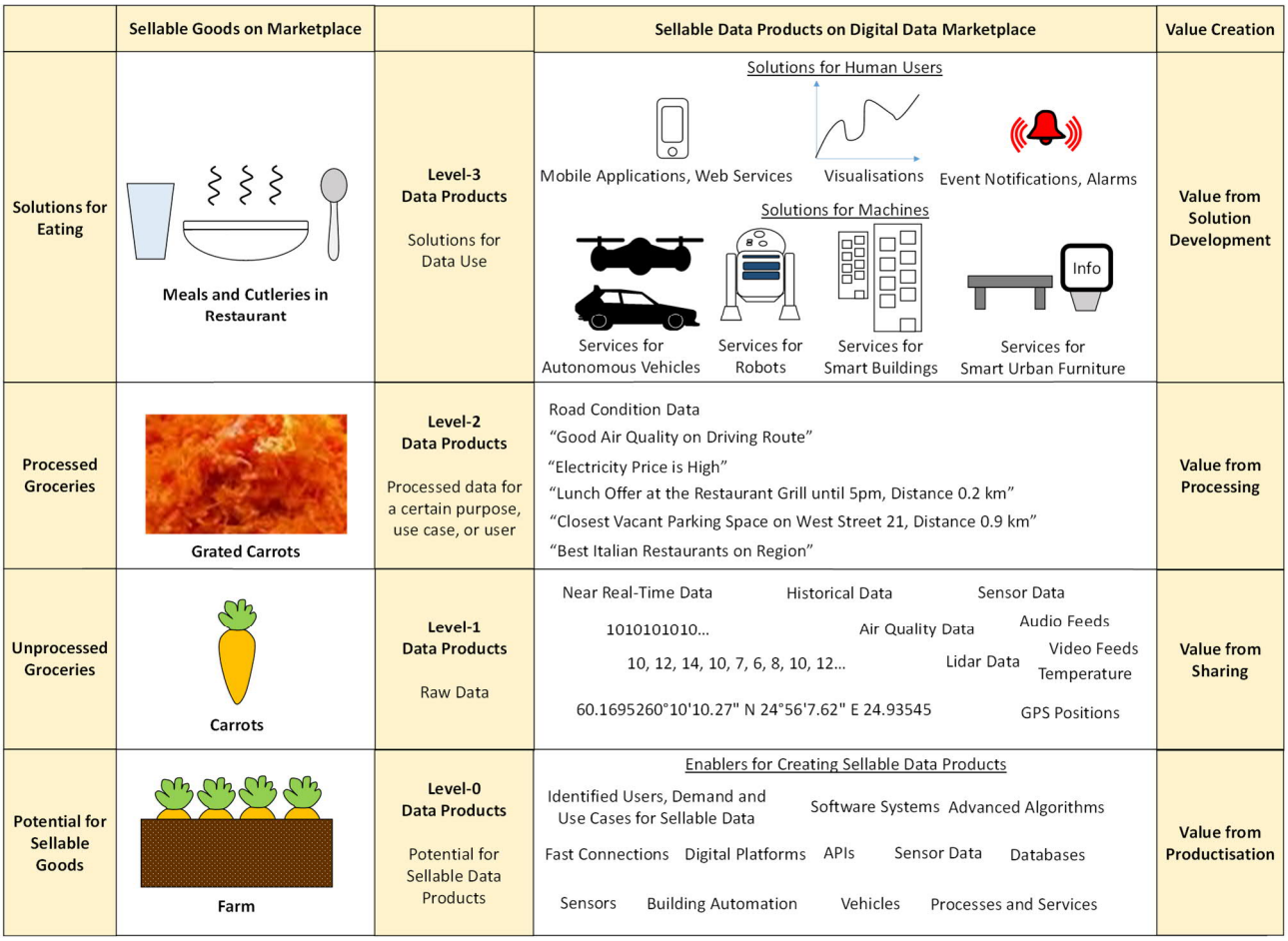

FIGURE 4. FOUR-LEVEL CATEGORIZATION FOR SELLABLE DATA PRODUCTS IN A SMART CITY DATA ECONOMY.

4 Key modules for local 5G data marketplaces

A local and neutrally hosted digital data marketplace can be called a 5G data marketplace (5G-DMP) if it is especially designed for applications utilising 5G networks with low latency, high bandwidth and high reliability. It serves people, e.g., citizens, service and business developers, data owners and data users, but also promotes creation of automatic data economy where machines and software components in various devices (mobile apps, vehicle software, building automation) search for, sell, buy and use relevant data without human intervention. This is especially relevant in 5G-enabled, real-time applications, when there is no time to wait for human decisions, e.g., in autonomous traffic.

There are numerous aspects to be considered in the implementation of 5G-DMPs. The following paragraphs discuss the key elements needed in 5G-DMPs:

Core functionality for data trade – First, a 5G-DMP should have a core part with APIs to provide basic functionalities for data trade, such as registration to the data marketplace, publishing of sellable data products, buying of data products and management of data product catalogues (see, Figure 5).

Support for static and live metadata – There is a need for *static metadata* that describe the static properties of sellable data products and for *live metadata* that provide fresh information about dynamic properties (e.g., quality of data, volume of data, and availability of data) of sellable data products. The actual data can also be located in a distributed fashion, where the metadata also need to provide information on how to access those.

Extensible metadata structures – There can be very different sellable data products in the marketplace that provide raw data, processed data or solutions for data use. Data can come from different application domains, and there can be sellable data products for time-dependent and geospatial data. This all requires extensible metadata structures that have core elements to describe general information (name, pricing and terms of use, etc.) for each sellable data product and extension elements to describe information that relates to a certain data product, its application domain, the type of data product and possible service parameters.

Extension modules – There might be a need for optional *extension modules* to extend the core of the data marketplace for different purposes. For example, there can be the following kinds of extension modules:

1) Configuration modules – can adapt the data marketplace for a data trade in a certain city, for specific application domain or for certain users or user groups. These modules can adapt the visual appearance of the data marketplace, tailor the logos and texts in the user interface, display the sellable data product in a specific way in the user interface and configure the map views to the desired city. There can be a huge number of sellable data products in the data marketplace. The configuration modules can define application domain-specific categories for traffic, energy and weather data products that assist in the managing of data products in the data marketplace. For example, the user interface can use these categories and display these application domain-specific data products in illustrative ways that assist the data user in the browsing and selection of domain-specific data products.
2) User interface modules – are tailored UI components for data selling and data buying for specific user groups. For example, there can be specific UIs that are created for citizens and different UIs designed for authorities or enterprise users.
3) Data processing modules – enable data processing inside the data marketplace. For example, there can be sellable data that is not allowed to be delivered to the data buyer to be processed by the data buyer, but it is only allowed that the data is processed in the data marketplace or by the data seller by using agreed upon algorithms and processing components, and only the processing results are delivered to the data buyer.
4) Data curation modules – support curation of sellable data in the data marketplace.
5) Data platform integration modules – make the data platform's data visible in the data marketplace and assist data sellers in publishing the data platform's data as sellable data products in the data marketplace.
6) Data market integration modules – integrate the neutral data marketplaces to other data marketplaces so that part of the sellable data products are made available in other marketplaces, or sellable data products in other marketplaces are made available in the local neutral data marketplace.
7) Data traceability modules – trace a data product created in one data marketplace and shared in other marketplaces. For example, when a data supplier decides to completely remove a data product offering, the deletion in one marketplace has to propagate to other marketplaces that offer the same data products.

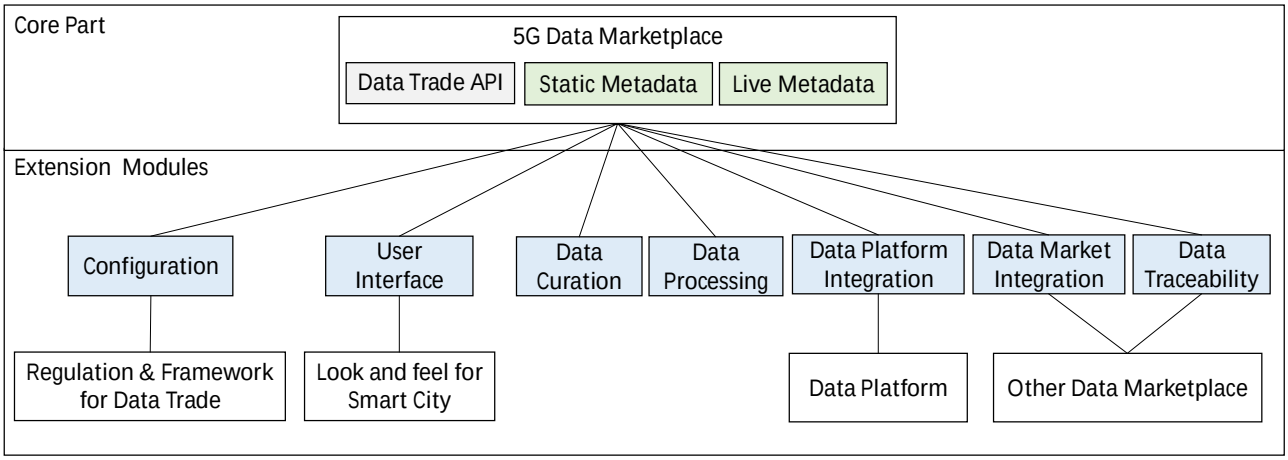

FIGURE 5. A 5G DATA MARKETPLACE (5G-DMP) THAT CONSISTS OF CORE MODULES AND OPTIONAL EXTENSION MODULES THAT ADAPT THE MARKETPLACE FOR DIFFERENT PURPOSES.

5 Benefits, obstacles and enablers

The data marketplaces support creation of new value from existing data and motivate the creation of new data. The data suppliers earn revenues from selling of data products, and the data users benefit from accessing raw data, processed data or solutions that assist in the data use. However, before the benefits can be realised, some obstacles need to be overcome with the help of the enablers of the smart city data economy. The possibility of starting beneficial data business in a city is defined by the balance between obstacles and enablers (Figure 6). The aim is to lower the threshold for data business by boosting the enablers, such as smart city infrastructure, 5G connectivity and automation in data trading. The following subsections discuss the benefits, obstacles and enablers related to the local smart city data economy in more detail.

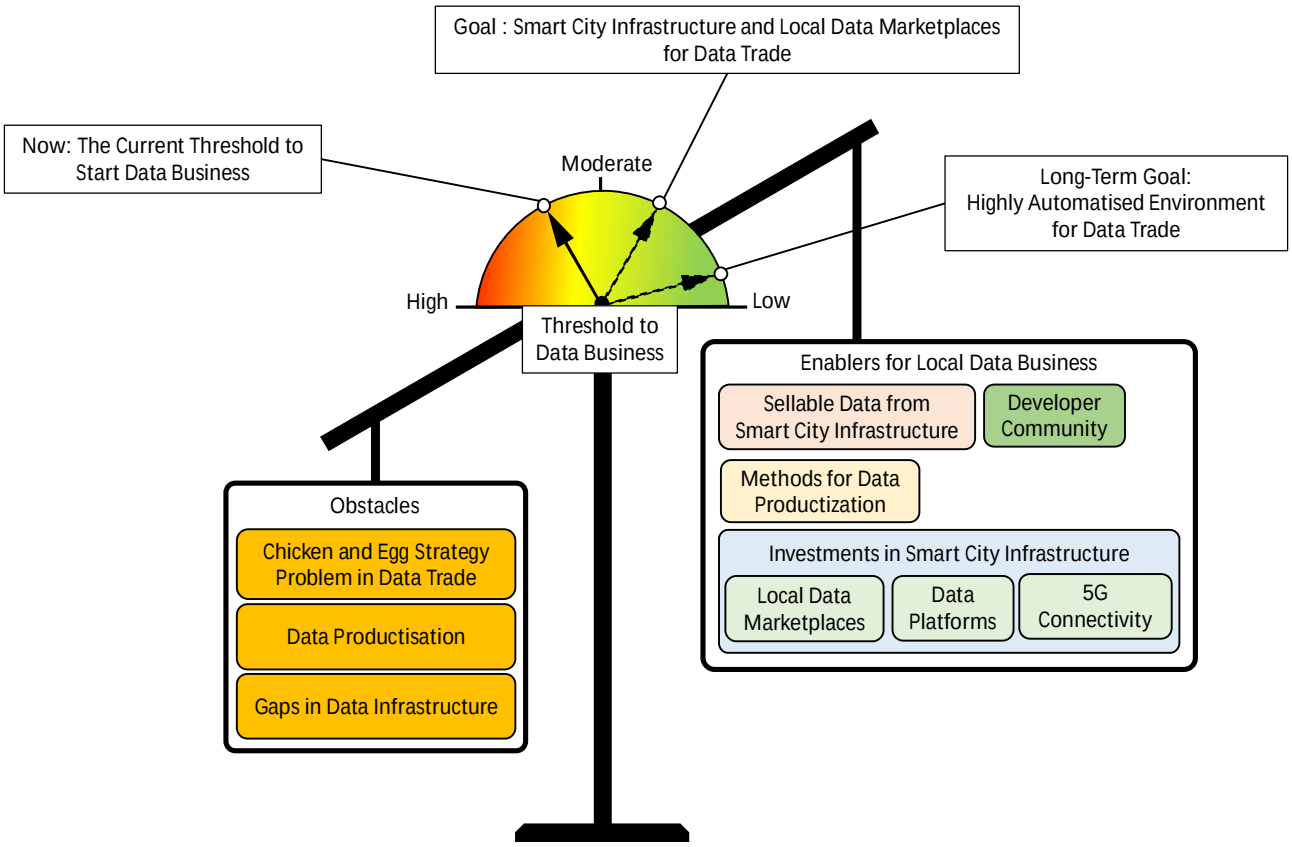

FIGURE 6. THE BALANCE BETWEEN OBSTACLES AND ENABLERS IN DATA BUSINESS IN SMART CITIES. THE LOCAL DATA MARKETPLACES, DATA PLATFORMS AND 5G NETWORKS AND INVESTMENTS IN SMART CITY INFRASTRUCTURE WILL LOWER THE THRESHOLD OF PARTICIPATING IN DATA BUSINESS IN THE FUTURE.

5.1 Benefits

The local 5G data marketplaces (5G-DMPs) boost the sharing of data and creation of business networks in cities and provide enterprises with more possibilities to act as *data suppliers, data users* and *data facilitators*. The local data marketplaces will provide direct and indirect benefits for the future smart cities. For example, 5G-DMPs can do the following:

- Engage the local community via data business – The sellable data can make it possible to improve safety and quality of life in cities, to provide better services and processes for citizens, and to create more value from data. The local data marketplaces provide democratic opportunities for data trade: for example, citizens can act as sellers of data and benefit from their data or act as data buyers and use sellable data in various kinds of applications and services. The 5G data marketplaces promote creation of local data markets and data business ecosystems, where different stakeholders, like citizens, authorities, enterprises, data providers and service developers, act in data seller, data buyer or data facilitator roles correspondingly.
- Enhance urban services – The data marketplaces can provide cities with easier access to data, where rights exist / apply and reduce the cost of offering urban services. Many urban services, such as city maintenance, transportation or safety-related services, can benefit from the data products in marketplaces. For example, citizens and enterprise users can participate in data supply and publish sellable situational data, such as road condition data, that assist street maintenance, such as ploughing, prevention of slipperiness, street cleaning and maintenance of pavement and traffic signs.
- Accelerate data economy with multisided platform – A local 5G-DMP provides a centralised marketplace for sellable data in a city where data buyers and data suppliers meet and trade. The market provides two

important benefits. First, it assists the discovery of sellable data products related to the city. Second, it provides a centralised marketplace for the data buyers in a city that assists in obtaining the critical mass of data buyers for the data products that are related to the city. This makes it easier for new data suppliers to initiate the supply of data that is not yet available in global DMPs. The data suppliers can join the local data ecosystem and start supplying new, rival or supplementary data products in the data marketplace, getting profit from the data business.

- Enrich global data marketplaces with unique local data – A local 5G-DMP can act as a marketplace for the data produced in the smart city infrastructure. For example, data produced by the sensors available in the smart lighting poles in a city can be offered as sellable data products in the local 5G-DMP that enables the local and global actors to benefit from the data.

5.2 Obstacles

The following paragraphs discuss the three key obstacles that raise the threshold of starting local data business in smart cities (see Figure 6):

Chicken and egg strategy problem in data trade – The local multisided data marketplace faces the chicken and egg strategy problem in the beginning. Data suppliers are not willing to put data on sale if there are no data users, and data users are not using the marketplace if there is no data available. Thus, the development needs investments to push either or both sides forward and initiate, hopefully, a positive feedback loop. The data produced in the smart city infrastructure, such as in the sensors in the smart pole network, can provide a partial solution for the chicken and egg strategy problem. This data can be provided as sellable data that will bring a starting point for local data business and more data users to the local data marketplace. Now, if there are enough data users in the data marketplace, it is easier for data suppliers to join the local data ecosystem and start earning from the data trade.

Data productisation – The use of data marketplaces requires knowledge, skills and effort for data productisation that prepares sellable data products to data marketplaces. For example, there are many business, technical and legal aspects to be solved in data productisation. First, the data owners need to have an understanding of the data business and data markets and answer questions such as "*How many users would buy our data products in the used data marketplace(s)?"* and "*How much effort and investment does it take to provide the data as sellable data products in a data marketplace?* Second, there are many technical challenges to be solved in data productisation. For example, the data suppliers must determine metadata that describe the sellable data products in a data marketplace and support the use of the data products in various use cases. Then, depending on the type of data product, the data suppliers must develop APIs and data models for data products and possibly solutions for using the data of the sellable data products. Third, legal aspects, such as determination of SLAs and the terms of use for the sellable data products, must be solved, too.

Gaps in data infrastructure – The data business requires an infrastructure such as the sensor, network or data marketplace infrastructure for data trade in smart cities. The following lacks can be found in data infrastructure:

- Insufficient sensor infrastructure – First, an insufficient sensor infrastructure can cause lacks to the geographical coverage and quality of sellable sensor data. For example, there can be available air quality data and parking lot data for certain city regions only; or then the insufficient quality or accuracy of the sensor data limits the use of the data in certain services and applications.
- Insufficient network infrastructure – Second, there can be gaps in the network infrastructure preventing the fluent delivery of data from data sellers to data buyers and distributing the data processing to local, edge and/or cloud computing units. High latencies in network connections, low bandwidth or unreliable

network connections can cause obstacles for the data trade and prevent the use of near real-time sellable data in applications and services.

- Complexities in data engineering – Third, the data is scattered to very different information systems in a smart city. The actors in smart cities use a great number of different digital devices, applications and services in their everyday life. As a consequence, the actors' data are not available in a single source but the data are scattered to multiple information systems. In addition, lack of APIs prevents the use of part of the data as sellable data.
- Complexities in data marketplaces' interoperability – Fourth, the data suppliers can use different data marketplaces for data trade. Without integration of data marketplaces, a data user must register in all of these separately and use marketplace-specific search and payment methods for purchasing the needed data products from different marketplaces, which slows down the finding and purchasing of relevant data products in a city. In addition, a data user may need to register in different data marketplaces when moving from one smart city to another.

As can be seen, there are challenges that are common for all cities and challenges requiring city-specific solutions. For example, the data productisation is a common challenge in data business, but building of a data infrastructure for a city can require solutions that must be tailored for the needs of the target city.

5.3 Enablers for local data business

Taking steps towards broad data business in smart cities requires solutions to offer a foundation for local smart city data economy and support the supply of sellable data and use of sellable data in the future cities. The following paragraphs discuss the key enablers promoting data business in smart cities (see, Figure 6):

Investments in smart city infrastructure – First, the smart city data economy requires investments in smart city infrastructure. For example, these investments can make it possible to build a smart city infrastructure that provides data marketplaces, data platforms and 5G connectivity for data business. Building of the smart city infrastructure requires investment, but will also provide direct and indirect benefits for the different actors in a city.

Sellable data from smart city infrastructure – The smart city infrastructure will produce raw (e.g., sensor) data and processed data, that are provided as sellable data, as a starting point for local data business, bringing more data users to the local data marketplace and creating incentives to join the marketplace.

Methods for data productisation – Development of sellable data products requires new methods for data productisation. First, there is a need for methods and tools that assist creation of data product ideas and concepts, for example, to detect demand and use cases for new data products. Second, it should be easy to develop a minimum viable data product for a data marketplace for experimenting if there is market demand for the data product. If it seems that there is market demand for the data product, there can be several iteration rounds to develop it further, according to data buyer feedback. This way, new data products are better serving the market needs, and data suppliers are not investing in products that are not successful.

Developer community – It is crucial to have creators for new unseen services and data products. This requires a developer-friendly environment and a developer community to support the creation of solutions for data use in smart cities. For example, it is important that the 5G data marketplace provides well-defined and clear APIs for data trade, example code for using these APIs that assist in the creation of basic operations in target systems/platforms, and developer tools to assist in the creation of data products and data-driven services.

6 Summary

The 5G data ecosystems offer new possibilities for data supply and use and enable both machines and human users, such as citizens, authorities and business users, to benefit from data trade and to create more value from data. The future smart cities will benefit from local data marketplaces that are designed for data trade, that exploits the benefits of fast 5G networks in data supply and use. The hypothesis is that by introducing these local 5G data marketplaces (5G-DMPs), we motivate the opening up of existing data, productising of data, creating data that is not yet available in global DMPs and taking this data into use in data-driven services.

The local data marketplace faces the chicken and egg strategy problem in the beginning. Data suppliers are not willing to put data on sale if there are no data users, and data users are not using the marketplace if there is no data available. Thus, the development needs investments to push either or both sides forward and initiate, hopefully, a positive feedback loop. The data produced in the smart city infrastructure, such as in the sensors in the smart lighting pole network, can provide a partial solution for the problem. This data can be provided as a sellable data in the local data marketplace, which will bring more data users to the marketplace. If there are enough data users in the data marketplace, it is easier for data suppliers to join the local data ecosystem and start supplying new, rival or supplementary data products in the data marketplace.

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