This is an electronic reprint of the original article.
This reprint may differ from the original in pagination and typographic detail.

Benseny, J.; Walia, J.; Hämmäinen, H.; Salmelin, J.

City strategies for a 5G small cell network on light poles

Published in:
2019 CTTE-FITCE: Smart Cities & Information and Communication Technology

DOI:
[10.1109/CTTE-FITCE.2019.8894825](https://doi.org/10.1109/CTTE-FITCE.2019.8894825)

Published: 01/01/2019

Document Version
Peer reviewed version

Please cite the original version:
Benseny, J., Walia, J., Hämmäinen, H., & Salmelin, J. (2019). City strategies for a 5G small cell network on light poles. In *2019 CTTE-FITCE: Smart Cities & Information and Communication Technology* IEEE.
<https://doi.org/10.1109/CTTE-FITCE.2019.8894825>

This material is protected by copyright and other intellectual property rights, and duplication or sale of all or part of any of the repository collections is not permitted, except that material may be duplicated by you for your research use or educational purposes in electronic or print form. You must obtain permission for any other use. Electronic or print copies may not be offered, whether for sale or otherwise to anyone who is not an authorised user.

City strategies for a 5G small cell network on light poles

Jaume Benseny¹, Jaspreet Walia¹, Heikki Hämäläinen¹, and Juha Salmelin²

¹ Dept. of Communications and Networking, Aalto University, Espoo, Finland (firstname.lastname@aalto.fi)

² Nokia Mobile Networks, Espoo, Finland (juha.salmelin@nokia.com)

Abstract—Smart city services will be enabled by data-based applications and low-latency, high-capacity city networks. Therefore, cities need a denser mobile network that can support the collection, aggregation, and analysis of sensor data. This article suggests three city strategies to facilitate the deployment of 5G small cells and sensor networks by taking advantage of light poles. To develop these strategies, we analyze value networks for the provision of connectivity and data services in the city context. We identify four value network configurations that can successfully operate the 5G light pole network by providing connectivity services. However, the recovery of investments may take a long time, given the high costs of civil works. To increase the attractiveness of investments, we also identify multiple VNCs that can generate complementary revenues from the exploitation of city data, reducing the payback time. Hence, we propose strategies with high/medium/low city involvement that exploit synergies between connectivity and data services.

Keywords—Smart City, 5G, Small Cells, Light Poles, Value Networks

I. INTRODUCTION

The capacity of mobile networks in cities is increasing through the upgrading and densification of base stations. However, the rollout of 5G small cells might become too costly for mobile network operators (MNOs) since many more sites are needed to provide outdoor download speeds above 300 Mbps. Moreover, new sites may not be easily available in old city centers, city parks, and highly secured places. At the same time, sensor networks face similar challenges as they are becoming ubiquitous in city streets. To address this issue, 5G antennas and sensors could be installed on light poles, enabling a large-scale and hotspot deployment for the 3.5 GHz and the 26 GHz bands, respectively. However, the rollout of 5G light pole networks requires substantial investments (e.g., to connect poles to fiber and power networks) and may affect the technical and business architectures for city connectivity (e.g., enabling new business models in broadband and application hosting markets). To better understand the strategic options for organizing city connectivity services, we conduct a value network analysis (VNA) addressing the following research question: *How city managers can facilitate the deployment of 5G small cells and sensors on light poles?*

Cities hold vast amounts of data from traditional municipal services, new digital services, and sensor networks. However, this data remains closed and fragmented across hundreds of isolated systems. Although some datasets are available through open data, these are typically domain-specific, weakly linked, and not harmonized [1]. Hence, there is a pressing need to increase the usage and value of existing data, thus enabling city managers and stakeholders to better inform decisions and develop new data-based applications [2], [3]. However, the addition of new hosting and computing infrastructure may modify the technical and business architectures for city data services. Further, new business roles

and models are needed for incentivizing data holders to share and merge data. To improve understanding of the strategic options for organizing city data services, we perform a second VNA addressing the following research question: *How city managers can increase the value of city data, enabling data trading and data-based applications?*

This article aims to produce city strategies for deploying 5G small cells and sensors on light poles as well as city-level data infrastructure, thus enabling new smart city applications [4]. These strategies are elaborated by combining VNA results for the provision of connectivity and data services.

This article is organized as follows. Section 2 describes the method. Section 3 analyses stakeholders. Section 4 and 5 report VNA results for connectivity and data services, respectively. Section 6 proposes city strategies. Section 7 draws conclusions.

II. METHOD

We investigate the city provision of connectivity and data services by employing twice the VNA method, i.e., first for connectivity and then for data services. We iteratively apply the VNA method, including feedback from unstructured interviews at each iteration. We interviewed experts involved in the LuxTurrin5G project from Finnish cities, network equipment vendors, MNOs, and SMEs.

The VNA method enables the study of business ecosystems by comparing alternative Value Network Configurations (VNCs). We generate VNCs by conducting: (1) stakeholder analysis, (2) identification of technical components in the technical architecture and business roles in the value network, (3) assignment of roles and components to stakeholders, and (4) VNC comparison and plausibility check. We draw VNCs following the notation in Fig. 1. More details on the VNA method can be found in [5].

III. CITY STAKEHOLDER ANALYSIS

TABLE I summarizes city stakeholders, their assets and needs for the provision of connectivity and data services.

Fig. 1. VNC Notation

This work is done in the LuxTurrin5G project funded by Business Finland and the participating companies (<https://www.luxturrin5g.com/>)

TABLE I. CITY STAKEHOLDERS

Stakeholder	Assets
City	Light poles, Fiber and power networks, Municipal data, Data center
Mobile Network Operator (MNO)	Spectrum licenses, Nationwide mobile network, Fiber network, Telco cloud
Fiber Network Operator	Fiber network
Power company	Power network
Hosting provider	Application hosting infrastructure and services
Service provider	Application, business data
IoT company	Sensor network, sensor data
Citizen	Personal data

IV. CITY CONNECTIVITY ANALYSIS

A. Business roles and technical components

We identify technical components and business roles in the provision of city connectivity services, as shown in TABLE II.

B. Single MNO-driven VNC

The city assigns the long-term exploitation rights of light poles to a single MNO, possibly enforcing minimal coverage obligations for 3.5 GHz-based connectivity. In this VNC, the MNO either controls fiber networks, or it is willing to invest in civil works heavily. The city covers the costs of the pole structure, while the MNO covers the 5G antennas and the civil works for connecting poles to existing fiber and power networks. The MNO reuses the core network functions from

Fig. 2. Single MNO-driven VNC

existing WAN deployments, offering broadband services to citizens through WAN and MAN, as shown in Fig. 2. For this VNC to be feasible, the single MNO should obtain a larger fraction of the allocated 3.5/26 GHz bands than the competing MNOs. At this point, the single MNO has the monopoly of the small cell connectivity. However, in the spectrum license, the regulator may enforce MVNO (Mobile Virtual Network Operator) access, allowing other MNOs to use the 5G light pole network (i.e., MAN).

The MNO leases pole space for third-parties to deploy sensors and provides backhaul and power services like tower companies. The city leases some of this pole space to deploy privacy-sensitive sensors (i.e., video cameras, infra-red sensors), thus substantially expanding street surveillance. Given the large volume of collected data by city-controlled sensors, the city subcontracts its management to the MNO. Consequently, the MNO expands existing telco cloud infrastructure, which becomes the default hosting site for city application and data (i.e., *City hosting* in Fig. 2). In addition, this MNO deploys the only edge hosting network in the city, serving application providers requiring low-latency and IoT players requiring local computation (i.e., *Edge application hosting contract* in Fig. 2). For this, it takes advantage of 5G selective traffic routing [6], as shown in by the Data Path 1 and Data Path 2 in Fig. 2.

C. Joint MNO-driven VNC

The city assigns pole exploitation rights to a joint MNO venture, possibly enforcing coverage obligations. The city covers the cost of the pole structure while other costs are shared among the venture participants. The venture exploits the 5G light pole network similarly to the single MNO in the

Fig. 3. Joint MNO-driven VNC

TABLE II. BUSINESS ROLES AND TECHNICAL COMPONENTS FOR CITY CONNECTIVITY SERVICES

Technical components	Business roles	Description
App/sensor server	Internet/City/Edge hosting	Server-side applications are deployed on Internet/City/Edge hosting depending on requirements. While Internet hosting implies that the hosting location is undetermined, the city hosting happens in a known local data center. Edge hosting is outside the pole in neighbor-level micro datacenters for low-latency applications.
WAN Core/Access	WAN Core/Access provision	Core and Access Network Functions for managing the existing nationwide MNO network, i.e., wide area network (WAN), as defined by 3GPP.
MAN Core/Access	MAN Core/Access provision	Core and Access Network Functions for managing the 5G light pole network. The Metropolitan Area Network (MAN) Access uses bands on the 3.5 Ghz and 26 GHz, albeit these may change depending on the country.
App client	Usage	Client-side applications are used via smartphone.
Sensors	Data collection	Data is collected by sensors

previous VNC. However, in this VNC, the venture provides broadband services through the MAN and roams customers to existing MNO infrastructure when WAN access is required (i.e., a *Roaming agreement* is established as shown in Fig. 3). Since 3.5 GHz (and possibly 26 GHz) licenses were allocated to MNOs, they agree for the venture to combine spectrum.

D. City-driven VNC

The city bears the cost of poles, 5G antennas, as well as civil works and establishes coverage targets. The city creates a neutral host operator company to commercially exploit the 5G light pole network using spectrum on the 3.5 GHz and the 26 GHz bands. Local spectrum licenses are either administratively allocated (e.g. in Germany 100 MHz of the 3.5 GHz band were reserved for local use) or leased by MNOs (e.g. in Finland the 3.5 GHz license may force MNOs to issue a local license if local actors are underserved), aiming to attract investment by local players [7]. MNOs compete based on service quality since they can acquire more resources from the neutral host operator via 5G network slicing (e.g. to offload outdoor traffic and delay the construction of new macro cells). The operator also serves internal use cases or even provide broadband services (i.e., via wireless-fixed access). For this, the city controls its own core network functions (i.e., *MAN Core* in Fig. 4).

The operator leases pole space for sensor deployment by IoT companies. Further, it manages the city-owned privacy-sensitive sensors, which produce a large data volume, forcing the expansion of the municipal datacenter, possibly constructing a new data warehouse. The operator deploys

Fig. 4. City-driven VNC

edge hosting infrastructure. Optionally, it could enable routing to third-party edge hosting, encouraging investment by hosting providers.

E. Power company-driven VNC

The city assigns pole exploitation rights to a power company. The power company has access to power and fiber networks since it has deployed them at the same time or because it creates a joint venture with a fiber network operator. The power company exploits the light pole network via a neutral host model like in *City-driven VNC*. It also uses light poles as electric vehicle charging stations.

F. Results from city connectivity analysis

First, we identify *MAN Access*, *MAN Core*, and *edge hosting infrastructure* as new components in the city technical architecture. Further, we identify *MAN Access provision*, *Core provision*, and *edge hosting* as new business roles in the city value network. More importantly, we identify a new actor, i.e., the neutral host operator, which allows non-MNO actors (i.e., city, power company) to exploit the 5G light pole network. Second, we summarize and compare the key technical and business factors of VNCs, as shown in TABLE III. Finally, the city's decision to subcontract the management of privacy-sensitive data implies that either MNOs or the city will control the new data warehouse where city application and data are hosted. This decision has implications on the next VNA analysis for the provision of city data services.

V. CITY DATA ANALYSIS

A. Business roles and technical components

We identify technical components and business roles in the provision of city data services, as shown in TABLE IV. Also, we create data categories, as shown in TABLE V.

B. Google-driven VNC

Google collects vast amounts of data from its applications (e.g., search, email, maps), from open APIs, and from service providers' web pages. Google increases the value of individual datasets by aggregating them together, increasing volume and widening the scope, as shown in Fig. 5.

City stakeholders are not willing to share additional data with Google since Google could create a competing service, leaving them out of business. At the same time, Google is not willing to share the aggregated data with city stakeholders since it would risk an increase in service competition. Hence, Google remains the leading provider of smart city applications. Thus, Google provides new applications that

TABLE III. CONNECTIVITY VNC COMPARISON

	Single MNO-driven VNC	Joint MNO-driven VNC	City-driven VNC	Power company-driven VNC
Resources of VNC driver				
3.5/26 GHz license holder	Single MNO	MNOs	MNOs and the city	MNOs and the city
Backhaul & power	Single fiber network	Multiple fiber networks	Fiber & power networks	Fiber & power networks
Broadband				
MAN competition	Monopoly*	Monopoly	Service-based	Service-based
MAN-WAN access	Regulated MVNO	Roaming	5G slicing	5G slicing
Pole space lease				
Privacy-non-sensitive sensors	Lease to anyone	Lease to anyone	Lease to anyone	Lease to anyone
Privacy-sensitive sensors	Lease to city	Lease to city	Owned	Lease to city
Application hosting				
Edge hosting competition	Monopoly	Monopoly	Monopoly**	Monopoly**
City hosting location	MNO cloud	MNOs cloud	Municipal data center	Municipal data center

* Service-based competition is expected after the regulator enforces MVNO access on the single MNO

** The neutral host operator could enable infrastructure-based competition by allowing routing from the MAN Access to third-party edge hosting.

TABLE IV. BUSINESS ROLES AND TECHNICAL COMPONENTS FOR CITY DATA SERVICES

Technical components	Business roles	Description
App server	Single-domain (SD) /Multi-domain (MD) service provision	While the single-domain service provision role employs server-side applications covering a single domain (e.g. weather forecast), the multi-domain service provision role employs server-side applications covering multiple domains (e.g., weather, transport, pedestrian flow).
App client	Service usage	Client-side applications are used via smartphone.
Sensor	Data collection	Data is collected by sensors.
DB	Single-domain (SD) /Multi-domain (MD) data storage	After data aggregation, while the single-domain data storage role employs a DB covering a single domain (e.g. weather forecast), the multi-domain data storage role employs a DB covering multiple domains (e.g., weather, transport, pedestrian flow).
File transfer program	Data buying/selling	Data is sold or bought through retail human-conducted transactions. Data is physically exchanged by using file transfer programs.
e-commerce solution	Data trading	Data is sold or bought through the e-commerce solution minimizing the need for human intervention in data transactions. In addition, this solution includes a self-service data ordering system for data buyers to create customized orders, selecting data from multiple sets. The e-commerce solution can calculate the price of orders depending on the exploitation rights of each data set.

TABLE V. DATA CATEGORIES

Data categories	Description
Municipal data	Data from traditional municipal services, e.g., land/building ownership, which is hold by the municipality. Municipal data does not include sensor data.
Sensor data	Data collected by sensors. Privacy-sensitive sensors include video cameras, infra-red sensors, bluetooth/wifi trackers, etc. Municipal data is excluded.
Personal	Data about individual citizens that is collected during the usage of Internet Services (e.g. Gmail, Facebook). Personal data excludes municipal and sensor data.
Stakeholder data	Business, personal, and privacy-non-sensitive sensor data that is hold by city stakeholders, excluding the municipality.
City data	All previous data categories

combine weather, road utilization, business opening hours, and personal data.

C. City-driven VNC

The city can drive different VNCs depending on the category of the commercialized data. The following VNCs show different development stages for city data exploitation.

a) City-driven VNC for municipal data: The city invest minimally in the integration of departmental DBs on a per use case basis, extracting small multi-domain datasets. The city

creates a city data company to commercialize these datasets which are traded through retail transactions, following the model of national statistics offices. Modest revenues are obtained since prices are defined to cover the cost of individual requests. An example of a retail transaction is data on city infrastructure evolution that is sold to construction companies via pay-per-download pricing, as shown in Fig. 6. These datasets aggregate data on land/household ownership, records on building construction/ renovation, etc. These datasets can update/improve municipal applications for building inspection.

b) City-driven VNC for sensor data: The city controls multiple sensor networks. To aggregate the large volume of incoming data, the city invests in new DBs for *MD data storage* supporting high-performance big data analytics. The city data company offers wholesale access to aggregated sensor data and cloud-based analytics services. A large number of transactions is possible, thanks to the *e-commerce solution* since transactions do not require human intervention. Thus, the city data company scales up the business model of national statistics offices, multiplying the obtained revenues. Prices are no longer defined based on request cost but to facilitate data market development and to cover city financial needs. An example of a transaction includes a parking company that acquires access to a real-time video stream showing its parking lot via a *flat-rate subscription*, as shown

Fig. 5. Google-driven VNC

Fig. 6. City-driven VNC for municipal data

Fig. 7. City-driven VNC for sensor data

in Fig. 7. Data from privacy-sensitive sensors should be traded after removing links to individual citizens, e.g., by using blurring functions on citizens' silhouette, by sharing results from event detection algorithms. Internally, the city informs citizens on the real-time availability of city-owned parking and city planners can estimate future parking space.

c) *City-driven VNC for stakeholder data*: The city aggregates municipal and sensor data since it already implements the *City-driven VNC for municipal data* and the *City-driven VNC for sensor data*. In addition, the city data company offers to city stakeholders the possibility to increase the value and monetization of their data by aggregating datasets together in a neutral infrastructure and by adding the company as a new sales channel, respectively. For example, a weather forecaster brings weather data by signing barter or a revenue-sharing agreement, as shown in Fig. 8. European Union citizens may also bring personal data by enforcing portability rights on Internet service providers (e.g., Google), as defined by the General Data Protection Rights (GDPR).

The *e-commerce* solution allows data buyers to acquire a combination of datasets which have been brought by different stakeholders. Through a self-service ordering system, prices for the selected datasets are combined into a single invoice. Note that each dataset may have a different pricing structure, including open data, barter, pay-per-download, flat-fee

Fig. 8. City-driven VNC for stakeholder data

subscription. A large number of transactions is possible since human intervention is not required, increasing data revenues and enabling stakeholders to create data-based applications. An example of a data transaction includes an insurance company acquiring a flat-rate subscription to have unlimited access to multi-domain data, as shown in Fig. 8.

D. MNO-driven VNC

MNOs hold service usage data from broadband and machine-to-machine (M2M) subscriptions, and they control substantial hosting infrastructure. They create a joint venture data company to organize the aggregation of stakeholder data, increasing data monetization via wholesale trading. Thus, stakeholders, including the city, may join the venture. The resulting VNC looks similar to Fig. 8. Venture participants may exchange data internally, prioritizing the improvement of their own applications, before data can be traded openly.

E. Results from city data services

First, we identify a new *DB* that stores multi-domain data and an *e-commerce* solution, as new elements in the city technical architecture. We also identify *data trading* and *MD data storage* as new business roles in the city value network. More importantly, we identify two new actors, i.e., the city and the MNO-driven joint venture as data companies, which can aggregate and trade multi-domain data. Second, we

TABLE VI. DATA VNC COMPARISON

	Google-driven VNC	City-driven VNC	MNO-driven VNC
Enabling resources of VNC driver			
Data hosting capacity	High	Low	Medium
Categories of managed data	Personal, Service usage	Municipal, Sensor (from privacy-sensitive sensors)	Service usage
Service dev. and data analytics competence	High	Low	Medium
VNC data trading outcomes			
Ability to attract stakeholder data for trading	Low	High (neutral infrastructure)	Medium
Willingness to use managed data for trading	Low	High	High
Achieved volume of data trading	Low	High	Medium
VNC data-based application outcomes			
Ability to attract stakeholder data for apps	Low	High (neutral infrastructure)	Medium
Willingness to use managed data for apps	High	High	High
Enabled data-based apps	New Google apps	New stakeholder apps	Improvement of existing apps

summarize and compare the key technical and business factors of VNCs, as shown in TABLE VI. Third, based on these results, we indicate that multiple data VNCs can co-exist for aggregating and trading city data.

VI. CITY STRATEGIES

We propose city strategies by combining a connectivity VNC with one or more data VNCs, as shown in TABLE VII.

Low city involvement: The city assigns long-term exploitation rights of light poles to a single MNO or a Joint MNO venture, which we hereafter refer to as the MNO(s). Although the city bears the cost of pole structures, it takes a passive role in the network rollout heavily relying on the MNO(s). Deployment is slow since the MNO(s) prefer first to update 4G sites. Concerning city data, the city invests minimally in integrating departmental DBs, generating small data sets. At the same time, a joint venture data company is created by MNOs to monetize data via wholesale offering. Since the city lacks the infrastructure to aggregate and trade municipal and sensor data, it establishes a revenue-sharing agreement with the MNO-driven joint venture data company. As a result, new smart city applications may arise predominantly provided by existing service providers. In this strategy, MNO(s) benefit from synergies in the provision of connectivity and data services since they reuse infrastructure (i.e., mobile/fiber networks, telco cloud) and competences (i.e., 3GPP, infrastructure operation). In addition, they ensure control over edge hosting infrastructure.

Medium city involvement: Like in the low city involvement strategy, the city assigns pole exploitation rights to the MNO(s). However, the city enforces coverage obligations in exchange for (1) public work subsidies, (2) favorable access conditions to city-owned fiber/power networks, (3) subcontracting the management of on-pole privacy-sensitive sensors, and (4) subcontracting the hosting of data infrastructure. Therefore, MNOs and the city collaborate. On the one hand, the city data company maximizes the value and revenues from city data by concentrating its aggregation in a neutral infrastructure and by automating its wholesale trading. Further, revenues are used to subsidize rollout civil works. On the other hand, MNOs increase the utilization levels of existing connectivity and data infrastructure while ensuring control over edge hosting.

High city involvement: The city takes a major investor role in the rollout of 5G light poles. The city defines coverage targets, acquires 5G antennas, and partners with power companies to connect poles to fiber and power networks. To recover the investment, the city creates a neutral host operator company generating revenues from 5G slices, pole space leasing, and broadband subscriptions if local licenses are available. Concerning city data, the city data company

maximizes the value and revenues from city data by centralizing its aggregation and automating its trading, as in the medium involvement strategy. In contrast to other strategies, the city coordinates the activities of the neutral host and the city data company. For example, depending on the investment capacity, the city might prefer to first invest in data infrastructure and wait for revenues before constructing connectivity infrastructure. Furthermore, the city might incentivize investment in edge hosting infrastructure by allowing routing to third-party edge hosting.

VII. CONCLUSIONS

This article produces city strategies for deploying 5G small cells and sensors on light poles as well as city-level data infrastructure, enabling new smart city applications. We conduct VNA for the provision of connectivity and data services. We identify new technical components for the city connectivity and data architectures as well as new business roles in the broadband, hosting, and IoT/data markets. These components and roles can be controlled by new actors, including the city-driven neutral host operator for connectivity, and the MNO-driven joint venture data company as well as the city data company for data services. We produce three city strategies with low/medium/high level of city involvement. In the low city involvement strategy, the city heavily relies on a single MNO or a joint MNO venture, slowing down the network rollout. In the medium city involvement strategy, the city enforces coverage obligations to the MNO(s) while subsidizing rollout civil works. Subsidies are funded via data revenues from a city data company that trades municipal, sensor, and stakeholder data. Finally, in the high city involvement strategy, the city takes a major investor role for the construction of the 5G light pole network and the data infrastructure, coordinating investment and commercialization activities between the city data company and the neutral host operator.

ACKNOWLEDGMENT

We thank the cities of Espoo and Turku for valuable discussions. We thank Alexandr Vesselkov for the thorough article revision. This work is done in the LuxTurrin5G project funded by Business Finland and the participating companies. Sunny Vijay contributed to this work with his Master Thesis.

REFERENCES

- [1] E. Ahmed *et al.*, "The role of big data analytics in Internet of Things," *Comput. Networks*, vol. 129, pp. 459–471, Dec. 2017.
- [2] Municipality of Copenhagen, "Cita Data Exchange - Lessons Learned from a public/private data collaboration," 2018.
- [3] S. Barns, "Smart cities and urban data platforms: Designing interfaces for smart governance," *City, Cult. Soc.*, vol. 12, pp. 5–12, Mar. 2018.
- [4] J. Salmelin, M. Heino, H. Hämmäinen, and J. Hemilä, "Building key enablers for a Digital Smart City," 2017.
- [5] T. Casey, T. Smura, and A. Sorri, "Value Network Configurations in wireless local area access," in *2010 9th Conference of Telecommunication, Media and Internet*, 2010, pp. 1–9.
- [6] 3GPP, "3GPP TS 23.501 V15.4.0 Technical Specification Group Services and System Aspects; System Architecture for the 5G System; Stage 2 (Release 15)," 2018.
- [7] J. Benseny, J. Töyli, H. Hämmäinen, and A. Arcia-Moret, "The mitigating role of regulation on the concentric patterns of broadband diffusion. The case of Finland," *Telemat. Informatics*, vol. 41, pp. 139–155, Aug. 2019.

TABLE VII. CITY STRATEGIES

City involvement	Connectivity services	Data services
Low	Single MNO/Joint MNO-driven VNC	City-driven VNC for municipal data and MNO-driven VNC
Medium	Single MNO/Joint MNO-driven VNC	City-driven VNC for municipal, sensor, and stakeholder data
High	City-driven VNC	City-driven VNC for municipal, sensor, and stakeholder data