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Business Model Canvas for Big and Open Linked Data in Smart and Circular Cities: Findings From Europe

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This article introduces a business model for big and open linked data in smart and circular cities, laying the foundation of a new approach that generates societal, business, and public value.

The identification of value sources in smart cities (SCs) remains an unanswered research challenge.[1] The underlying data chains result in the generation of value. Studies conducted mainly in the private sector have identified values, such as increased operational efficiency and new innovations.[2] These are mainly viewed and means to improve profit for companies.[3] In an SC, the value comes from specific sources, such as street lighting services, traffic congestion and seeking free parking slots, air pollution, crime, and waste management. These values underline the sources, while cities can move toward new kinds of public value,[4] such as lower facility charges, increased internal efficiency, and attractiveness. The realization of these public values activates the local government in the value chain to address issues, including positioning, user involvement, and circularity. The preceding synthesizes an SC ecosystem full of opportunities for existing and new value generation and collection. New business models can be created to capture these values.[2]

The SC value chain concerns the full range of activities that generate city smartness, which has yet to be specified.[4] Big and open linked data (BOLD) are a significant "asset" in this value chain.[6,7] Data acquisition from several sources and computational processing is a major requirement for smart service creation and delivery. Value generation from BOLD is still unspecified,

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and several attempts have been undertaken to deal with this issue, including adopting an ecosystems perspective, identifying capabilities, and developing infomediary business models.[8]

A business model canvas[9] describes existing and developing business models, such as sustainability-oriented business model innovation.[10] The objective of this article is to develop a canvas that can be used to describe and develop business models for creating value from BOLD in smart and circular cities (SCCs). Thus, this article aims to provide answers to the following research questions (RQs):

- *RQ1*: What kinds of values can BOLD generate in SCCs?
- *RQ2*: What does the SCC value chain look like?
- *RQ3*: How can a business model canvas depict BOLD value flow in SCCs?

All these questions are important because data and SCCs concern an emerging topic[11] attracting extensive interdisciplinary scientific and societal attention. A multimethod research approach was used to answer them: a literature review was performed to collect information about the value types (RQ1) and formulate the value chain (RQ2). These outcomes were used to generate an extended business model canvas (RQ3), which was tested in a survey with SC experts from a European large-scale project. The survey used a structured online questionnaire, and it was followed by interviews that more deeply investigated the results and revised the business model canvas (RQ3).

BACKGROUND

A business model reflects an organization's core operations and emphasizes the creation of customer value.[9] Today, and especially in the SC context, there is much discussion regarding business model innovation. New business models are variations on a generic value chain underlying all commercial enterprises, and they deal with production and marketing activities.[11] From this point of view, business model innovation can be seen as new product development for unmet needs that could even generate a new customer segment, process innovation, or better way of making/selling/distributing an already proved (existing) product or service (to existing and/or new customer segments). Business model innovation can also be seen as the introduction of a novel building block and even the transformation of a single step within the development/delivery process.[11]

In contrast, an SC can be defined as urban innovation, generally though not always information and communications technology (ICT) based, that deals with challenges, including sustainability, climate change, efficiency, and enhancing the quality of local life.[1] The creation of societal value is a key concern. For the purposes of this article, the unified conceptual model (UCM) is adopted (Figure 1) because it summarizes many other conceptual models and depicts business issues that can support the treatment of our topic. The UCM complies with the circular city definition,[13] according to which a city promotes the transition from a linear to a circular economy in an integrated way across all its functions in collaboration with citizens, businesses, and the research community. The UCM shows that a city's hard facilities are combined with instances of soft and hard infrastructure to generate and deliver different services according to specific governance processes. Moreover, it shows the important roles of data and people in SC service delivery.

The emergence of ICT enables cyberphysical integration in an urban space: the natural environment, local stakeholders, ICT, processes,

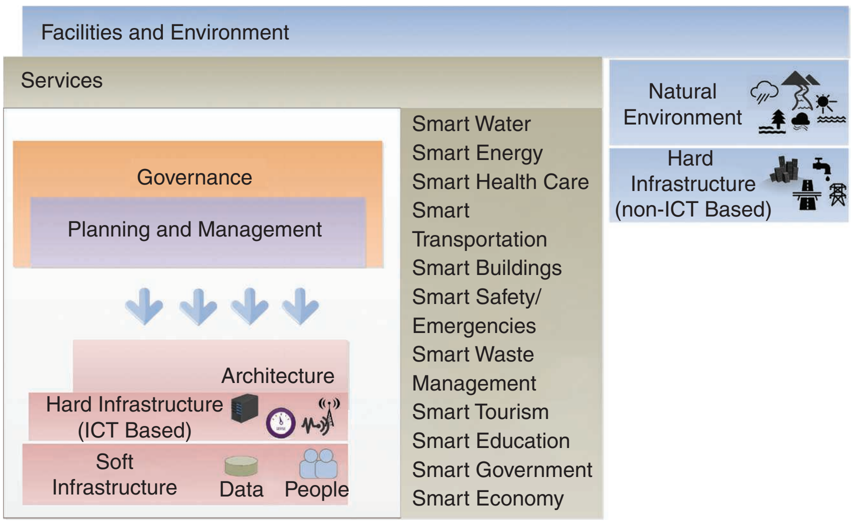

FIGURE 1. The adopted UCM.[1]

products, and services are interconnected and circular instead of having linear flows. This integrated environment concerns the SCC ecosystem, and it is also labeled "multiactor value" due to the engagement of several players (for example, data producers, data processors, data reusers, and data consumers).[14] Prosumers can be producers and users of data. City utilities enable different actors to develop and employ business models with ICT, which leads to sustainable urban renovation[15] and integrated business models,[16,17] while monetary and nonmonetary values have been circulated for SCs.[18]

The business model concept in an SC still lacks in-depth investigation. For the purposes of understanding the relationship between the terms "smart city" and "business model," a literature review was performed using scientific resources in late 2020 (Table 1). The review process combined the keywords "smart city," "business model," and "big and open linked data." The results followed a "screening process," which left out duplicates; irrelevant works; articles discussing SCs, business models, or data alone; and conference articles that evolved into journal publications and editorials.

In the end, approximately 50 articles were studied in detail, returning useful information: business models in SCs differ according to the value producer and focus on different types of value generation (Table 2), which provides the answer to RQ1: SC industry vendors own value that deals with the delivery of their products and services in cities and pursue creative engagement models, local governments own city infrastructure and consider nonprofit values (for example, local well-being), and local stakeholders serve either as smart infrastructure developers/owners/deployers or smart service providers within the city. The literature findings address the computational aspects of this article's problem, too: indicatively, Mulligan and Olsson[42] discuss the architectural evolution required to enable SC business models, while Cohen and Kietzmann[43] show the importance of SC organizational units that can transform planned values to tangible outcomes.

CITY UTILITIES ENABLE DIFFERENT ACTORS TO DEVELOP AND EMPLOY BUSINESS MODELS WITH ICT, WHICH LEADS TO SUSTAINABLE URBAN RENOVATION AND INTEGRATED BUSINESS MODELS.

The preceding values and previously documented multiactor value ecosystem results in the SCC value chain (Figure 2) that provides the answer to RQ2, as follows:

- Smart service suppliers are the players that collaborate to offer service components (for example, data and sensor suppliers and records suppliers).
- Smart service intermediaries give access to resources and processes/analyzed resources.
- Smart service consumers are the value's beneficiaries.
- Smart service prosumers consume services as beneficiaries and supply the service with additional resources (for example, feedback, crowdsourcing, and new data sensing).
- SC owners and strategic partners/stakeholders establish SC objectives and challenges (for example, monitoring environmental indexes and measuring safety performance).

The BOLD acronym emphasizes open data, linked data, and big data, which highlights the necessity for sharing data for large audiences, connecting the need to relate data sets and respecting big data volume, velocity, variety, and, additionally, the value, variability, and veracity of data. BOLD enables the use of data for predictive analytics to improve decision making and the use of resources in SCs. Various types of value can be created, and they can be for a particular group of citizens, a person, or society. Different stakeholders can perceive various types of value from data, addressing

TABLE 1. The literature findings.

Source	Results	Articles after "screening"
Science Direct	569	[4], [18]–[35]
Scopus	150	[15], [36]–[40]
Google Scholar	6,140	[4], [41]–[50]

TABLE 2. The identified SC values.

SC Service	Value
Smart transportation	Traffic reduction Traffic congestion decrease Traffic safety Response to traffic emergencies Fleet route improvement Emissions reduction Fuel and time savings Easy parking slot location/guidance Parking monitoring/response to violations Real-time location and schedules Vehicle sharing Selection of optimal mobility means
All SC services	Telecommunications availability
Smart safety	Crime measurement and alerts Response to crime effects Privacy enhancement
Smart tourism	e-Ticketing/e-booking services for sports and culture
Smart health care	Digital health and care accessibility
Smart education	Digital public libraries Distance/self-learning opportunities
Smart economy	Food supplies
Smart buildings	Remote control of smart/fully automated buildings
Smart energy	Energy savings
Smart environment	Smart metering
Smart water	Water monitoring, metering, and management
Smart waste	Waste bin monitoring
Smart economy	New businesses Innovation hubs Apps and data economic growth Employment opportunities Marketing with data analytics Digital wallets for intercity transactions Digital business development Advanced new city/district development for residents/businesses
Smart government	Open data and platforms Public consultations Participation in policy making Citizen engagement in local aspects Volunteer engagement Complaint registration
Smart education	Digital skills development Digital entrepreneurship attitudes development
Smart government	Participation in innovation Raising citizen awareness

the data culture within organizations and across ecosystems by investing in training for upskilling staff and developing data leadership capacity. Data can appear in several components of the value chain (Figure 2), while a discrete value chain can also be considered for BOLD. The literature findings show that data can be offered directly to consumers and stored and processed. Consumers and prosumers can be services, apps, and even artificial intelligence algorithms automating the processes of analyzing data. Computational algorithms can identify traffic patterns and societal problems.

RESEARCH METHODOLOGY

SC values (Table 1) can be associated with BOLD and organized according to the main categories of SC stakeholders: society, business, and public values. Societal value can be seen as the nonmonetary value created from BOLD, such as citizen engagement. Public value is created from BOLD in terms of generating good governance and promoting transparency, efficiency, and trust in the SCC ecosystem. Finally, business value is the monetary value created by BOLD, which leads to new commerce and product development, resulting in local economic growth. The role of data for circularity can be unraveled since information can be used to coordinate circular activities, enhance circular data economy, and highlight the role of sharing and reuse, which are primary circular processes.

The SCC BOLD business model canvas contains the following updates to the original version to meet the needs of the SCC value chain (Figure 3):

1. Instead of the original customer segments building

block, we propose the SC ecosystem values block (societal, business, and public), which is targeted by corresponding BOLD values.
2. The collection of capabilities building block replaces the original channels building block to describe how an SCC communicates with ecosystem values to deliver the value proposition of BOLD. These capabilities can be categorized as data resources, assets (sensors, the cloud, storage, and so on), application programming interfaces (APIs) and platforms, skills and knowledge, market size, community capacity, and data policies.
3. The customer relationship block was substituted by the engagements block. This block describes with whom an SC engages in creating and providing value from BOLD to satisfy ecosystem values. Engagement is categorized in the SC stakeholders (citizens; local, state, and national governments; businesses; and so on), researchers and academia, international organizations, standards, other cities, and third-party tools.
4. Block data are used to describe the requirements for value generation, as opposed to those in the key partnerships block.
5. The original revenue streams block is divided into new blocks: the revenue model and values due to the different types (monetary and nonmonetary) generated using BOLD in SCCs.
6. Similarly, the original cost structure building block is analyzed in the cost model block (monetary costs) and effort/investments block (nonmonetary costs).

The preceding business model canvas is grounded in literature findings and empirical knowledge from the SCs of Trikala, Greece, and Antwerp, Belgium. They make sense in corresponding SCC planning. However, the model's structure and context had to be validated, and in this respect, a survey was conducted with the participation of SC experts currently involved in SC initiatives in Europe. Several efforts in Europe (for instance, Saunders et al.[52]) examine how data and cutting-edge ICT transform the SCC ecosystem and generate new types of value, especially types based on BOLD, such as new kinds of trust and smart service tokenization.

An invitation was sent to contacts from 40 members of the European Digital Cities Challenge (https://2019.digitallytransformyourregion.eu/) who clearly understood the role of BOLD in establishing city digital transformation and sustainability. The initiative took place between 2017 and 2020, and the involved cities gained policy advisory services and mentoring and coaching opportunities, and they shared a network of collaboration, knowledge exchange, and peer learning.

Of the 40 invited experts, 11 (27.5%) agreed to participate in the two-fold survey. They were from different European Union countries that represented a sample diverse enough

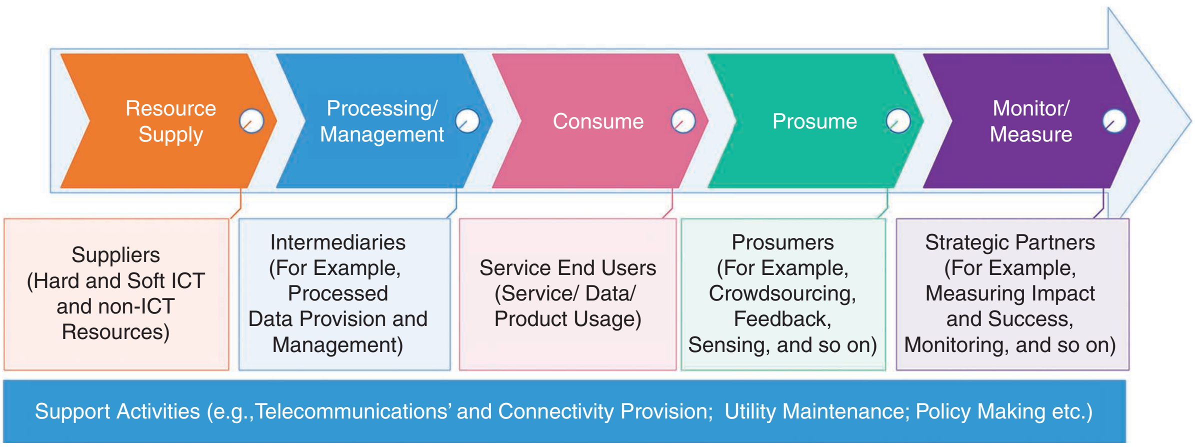

FIGURE 2. A generic value chain for BOLD in SCCs.

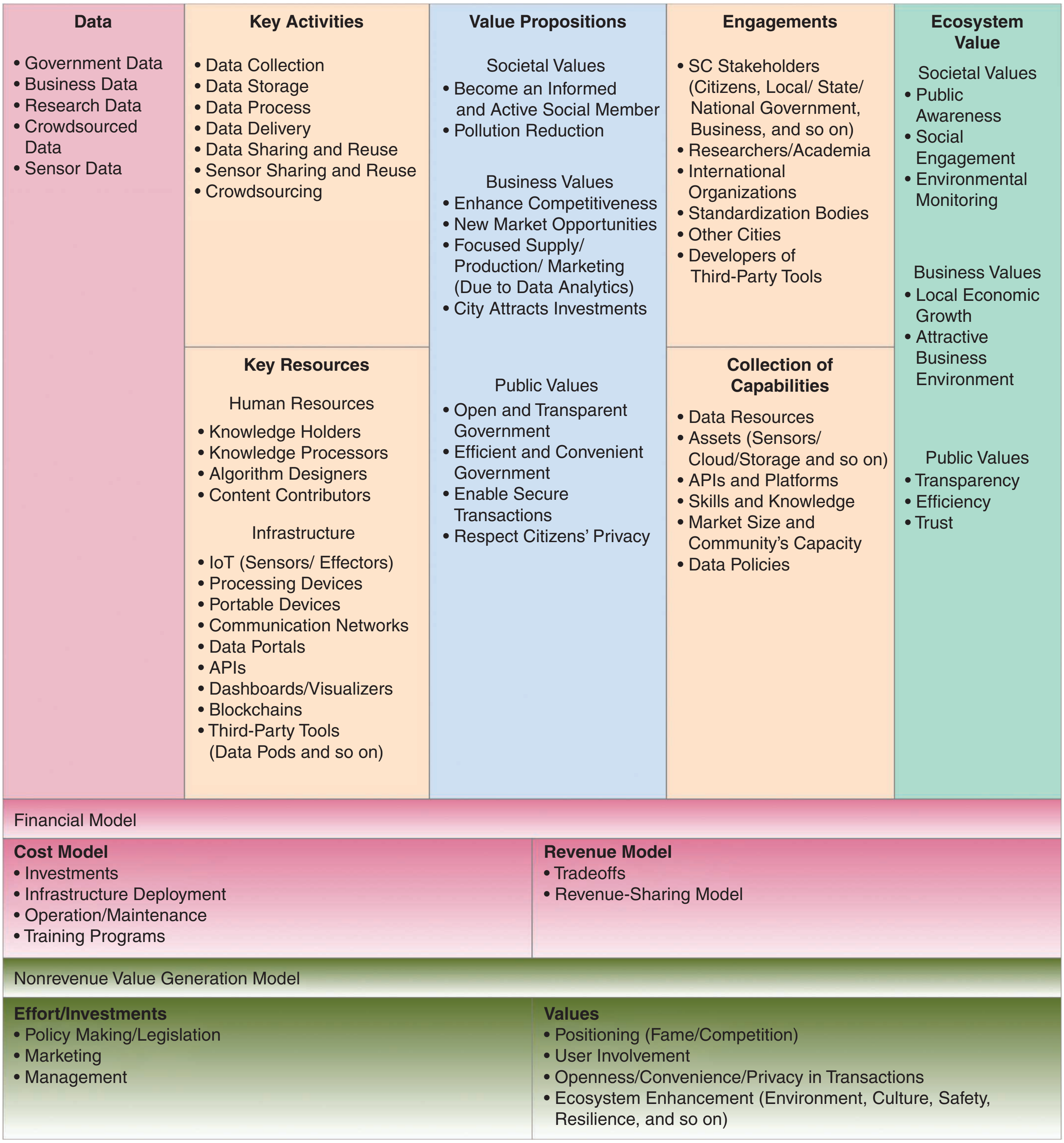

FIGURE 3. The proposed business model canvas for BOLD in SCCs.

to generate some useful outcomes. During the first phase, the participants were asked to fill out an online questionnaire, where the proposed canvas and each building block were explained. The respondents had to express their agreement with the canvas and each of its building blocks, following a Likert scale ranging from one (complete disagreement) to five (complete agreement). Moreover, they could comment on their answers. Then, the collected answers were processed, and the overall agreement with the canvas and its context was calculated.

During the second phase, interviews took place in March 2021, with the same participants, aiming to realize the reasons for the expressed disagreements. The interviews were conducted remotely with each participant, and their objectivity was ensured through the use of a common semistructured questionnaire and the participation of two surveyors. Each interview lasted approximately 1 h. Each participant was asked to comment on the findings from the first phase.

Results: Reliability analysis

The results of the first round are presented in (Table 3), depicting the mean and standard deviation values of the collected Likert (one to five) scores. To validate the reliability of the results, Cronbach's alpha test[52] was performed. The test measured the internal consistency of the results and provided useful insight into their acceptance. Since all the questions measured the same parameter (the agreement level about whether each block and element should be included in the business model canvas), the test was initially performed for the whole canvas, returning a strong internal consistency (alpha = 0.901), and then it was repeated for each block (Table 4).

Discussion

The preceding outcomes show that the canvas structure was found to be useful by the experts. Still, agreement about its context varied, resulting in unaccepted items in the value proposition and collection of capabilities blocks and a questioned key activities context. This disagreement was investigated via interviews with the experts. SC goals and context might be completely different, and therefore, their value propositions, capabilities, and activities vary.

THE PUBLIC VALUES OF TRANSPARENCY AND TRUST ARE HIGHLY IMPROVED USING BOLD, REGARDLESS OF THE APPROACH'S CURRENT LIMITED SCALE.

The interviews show that the pollution reduction element was considered too specialized for the value proposition building block. Moreover, there was disagreement about securing transactions and respecting citizens' privacy. In some cases, all data can be open, whereas, in other situations, interviewees suggested a city blockchain system for secure transactions and privacy enhancement technologies for ensuring confidentiality, including multiparty computation. For the societal value proposition, agreement was expressed about creating informed and active social citizens, although appropriate tools must be provided to empower them. Additionally, the participants agreed about the need for an open and transparent government and efficient and convenient government public value propositions, commenting that BOLD must be analyzed and monitored, not simply produced.

For the collection of capabilities block, respondents expressed disagreement about assets, APIs, and platforms, commenting that those elements are not essential for the production and distribution of BOLD. Participants agreed about data resources, skills and knowledge, and data policies. Market size and community capacity play a vital role in using BOLD, regardless of a community's size. Concerning the key activities block, respondents commented that sensor sharing, reuse, and crowdsourcing are not essential for BOLD value generation.

The participants agreed with the societal, business, and public values classification in the ecosystem value building block. To achieve societal value, some participants commented that increasing public awareness and social engagements require appropriate data tools (for instance, data pods). Disagreement was expressed about the environmental monitoring value, with comments that it was too specialized and appropriate only for certain specific applications. The participants agreed about business values, declaring that the value created using BOLD

TABLE 3. The survey results.

Ecosystem values	**Mean**	**Standard deviation**
Societal values (public awareness)	4.5	1.12
Societal values (social engagement)	4.67	0.75
Societal values (environmental monitoring)	3.67	0.94
Business values (local economic growth)	4.83	0.37
Business values (attractive business environment)	4.33	0.94
Public values (transparency)	4.83	0.37
Public values (efficiency)	3.83	1.07
Public values (trust)	5	0
Value proposition		
Societal values (become an informed and active social member)	4	1.15
Societal values (pollution reduction)	3.5	0.96
Business values (enhance competitiveness)	4.17	0.9
Business values (new market opportunities)	4.33	0.75
Business values (focused supply, production, and marketing, due to data analytics)	3.83	1.07
Business values (city attracts investments)	3.83	0.69
Public values (open and transparent government)	4.83	0.37
Public values (efficient and convenient government)	4.17	1.21
Public values (enable secure transactions)	3.5	1.12
Public values (respect citizens' privacy)	3.83	1.07
Collection of capabilities		
Collection of capabilities (data resources)	4.67	0.75
Collection of capabilities (assets, including sensors, cloud storage, and so on)	3.83	0.9
Collection of capabilities (APIs and platforms)	3.83	1.21
Collection of capabilities (skills and knowledge)	4.17	0.69
Collection of capabilities (market size and community's capacity)	3.67	0.75
Collection of capabilities (data policies)	4.83	0.37

(*Continued*)

TABLE 3. (*Continued.*) The survey results.

Engagements	Mean	Standard deviation
Engagements (SC stakeholders, including citizens; local, state, and national governments; businesses; and so on)	4.83	0.37
Engagements (researchers and academia)	4.33	0.75
Engagements (international organizations)	4.33	0.75
Engagements (standards)	4	0.58
Engagements (other cities)	4.17	0.69
Engagements (third-party tools)	4.50	0.76
Key resources		
Human resources (knowledge holders)	4.83	0.37
Human resources (knowledge processors)	4.83	0.37
Human resources (algorithm designers)	3.83	1.07
Human resources (content contributors)	4.17	0.69
Infrastructure (Internet of Things, including sensors/effectors)	4.33	0.94
Infrastructure (processing devices)	4.33	0.94
Infrastructure (portable devices)	3.83	0.9
Infrastructure (communication networks)	4.17	0.9
Infrastructure (data portals)	4.17	0.9
Infrastructure (APIs)	4.67	0.75
Infrastructure (dashboards/visualizers)	4	0.82
Infrastructure (block chains)	3.67	0.75
Infrastructure (third-party tools, including data pods and so on)	4	0.82
Key activities		
Key activities (data collection)	4.83	0.37
Key activities (data storage)	4.5	0.76
Key activities (data process)	4.83	0.37
Key activities (data delivery)	4.5	0.5

(*Continued*)

TABLE 3. (*Continued.*) The survey results.

Key activities	**Mean**	**Standard deviation**
Key activities (data sharing and reuse)	4.67	0.47
Key activities (sensor sharing and reuse)	4	0.82
Key activities (crowdsourcing)	4.17	0.69
Data		
Data (government data)	5	0
Data (business data)	4.67	0.75
Data (research data)	4.5	0.76
Data (crowdsourced data)	4.5	0.76
Data (sensor data)	4.83	0.37
Revenue model: Values		
Revenue model (tradeoffs)	4.17	0.37
Revenue model (revenue sharing model)	4	0.58
Values (positioning, including fame/competition)	4.33	0.75
Values (user involvement)	4.33	1.11
Values (openness, convenience, and privacy in transactions)	4.17	0.69
Values (ecosystem enhancement, including environment, culture, safety, resilience, and so on)	4.33	0.75
Cost model: Effort/investments		
Cost model (investments)	4.33	0.94
Cost model (infrastructure deployment)	4.33	0.94
Cost model (operation and maintenance)	4.67	0.75
Cost model (training programs)	4.83	0.37
Effort/investments (policy making and legislation)	4.83	0.37
Effort/investments (marketing)	4.5	0.76
Effort/investments (management)	4.67	0.47
Effort/investments (data cocreation)	4.67	0.47

TABLE 4. The reliability tests.

Tested part	Cronbach's alpha	Internal consistency
Total test analysis	0.901	Excellent
Ecosystem value	0.676	Questionable
Value proposition	−0.119	Unacceptable
Engagements	0.84	Good
Collection of capabilities	0.24	Unacceptable
Key activities	0.537	Poor
Key resources	0.929	Excellent
Data	0.956	Excellent
Revenue model: values	0.827	Good
Cost model: effort/investments	0.758	Acceptable

can lead to local economic growth, requiring business to undertake initiatives that capture this value. About the creation of an attractive business environment, BOLD can lead to a collaborative ecosystem, though this is not the only direct result. Finally, the participants agreed that the public values of transparency and trust are highly improved using BOLD, regardless of the approach's current limited scale. Moreover, the participants claimed that BOLD alone is insufficient to enhance government efficiency.

Strong agreement was expressed about the engagement building block. Researchers and academia act as actuators for transforming BOLD into a key SC asset. Other cities provide best practices and improve competition. Standards and international organizations provide guidelines and best practices. Third-party tools (for instance, data pods) are not a prerequisite, but they can enhance BOLD exploitation. Moreover, agreement about the key resources block was expressed, excluding algorithm designers and blockchains. Blockchains are not a prerequisite but can ensure security and trust. The Internet of Things, processing, and portable devices are not a prerequisite but an enabler.

The participants agreed on the revenue model and values blocks, commenting on the essential role of appropriate tools to help citizens engage and generate data-oriented thinking. Furthermore, the participants expressed strong agreement about the rest of the building blocks and their context, without leaving any further comments, while the collected inputs provide useful directives about how each of the building block's elements can be utilized for value generation. The participants' disagreements and comments resulted in an updated canvas (Figure 4).

This article addressed value generation from BOLD in SCs and three RQs, which were answered via a multimethod approach: a literature review, a survey with a structured questionnaire, and interviews with experts. In response to RQ1, three types of value were determined for BOLD: societal, business, and public. A community raises its awareness and engages in local initiatives; business opportunities from the data key asset grow, together city competitiveness; and government transparency, efficiency, and trust are supported.

Regarding RQ2, the literature findings resulted in a generic value chain (Figure 2), where several actors collaborate within the SC ecosystem to create and deliver value via emerging services and products. Finally, about RQ3, the business model canvas was adopted, calibrated, tested, and revised with the inputs from SC experts to become suitable for BOLD value generation and flow (Figure 4). The value chain and business model canvas can be considered useful tools for sustainable city planning for local government consistency (transparency and accountability), community social cohesion (via engagement), and city economic prosperity (business growth based on data economy). Even recent studies[53] follow the typical business model canvas to depict data value flows in digital ecosystems, and in this respect, the extended canvas concerns something novel about BOLD value flows in SCCs.

Despite the useful results from this article, some limitations must be recognized and can be addressed in future research. The sample of experts that contributed to this work was quite small (11 experts, representing 27.5% of the invited ones). Another limitation concerns the origins of the sample: medium-size European cities, which face similar challenges and follow common policies

Data
- Government Data
- Business Data
- Research Data
- Crowdsourced Data
- Sensor Data

Key Activities
- Data Collection
- Data Storage
- Data Process
- Data Delivery
- Data Sharing and Reuse

Key Resources

Human Resources
- Knowledge Holders
- Knowledge Processors
- Algorithm Designers
- Content Contributors

Infrastructure
- IoT (Sensors/Effectors)
- Processing Devices
- Portable Devices
- Communication Networks
- Data Portals
- APIs
- Dashboards/Visualizers
- Blockchains
- Third-Party Tools (Data Pods and so on)

Value Propositions

Societal Values
- Become an Informed and Active Social Member (With Data Tools)

Business Values
- Enhance Competitiveness
- New Market Opportunities
- Focused Supply/ Production/Marketing (Due to Data Analytics)
- City Attractiveness for Investments

Public Values
- Open and Transparent Government
- Efficient and Convenient Government
- Enable Secure Transactions (With City Blockchain)
- Respect Citizens' Privacy (With Data Anonymization)

Engagements
- SC Stakeholders (Citizens, Local/ State/ National Government, Business, and so on)
- Researchers/Academia
- International Organizations
- Standardization Bodies
- Other Cities
- Developers of Third-Party Tools

Collection of Capabilities
- Data Resources
- Skills and Knowledge
- Market Size and Community's Capacity
- Data Policies

Ecosystem Value

Societal Values
- Public Awareness (With Data Tools)
- Social Engagements (With Data Tools)

Business Values
- Local Economic Growth
- Attractive Business Environment

Public Values
- Transparency
- Efficiency
- Trust

Financial Model

Cost Model
- Investments
- Infrastructure Deployment
- Operation/Maintenance
- Training Programs

Revenue Model
- Tradeoffs
- Revenue Sharing Model

Nonrevenue Value Generation Model

Effort/Investments
- Policy Making/Legislation
- Marketing
- Management
- Data Cocreation

Values
- Positioning (Fame/Competition)
- User Involvement
- Openness/Convenience/Privacy in Transactions
- Ecosystem Enhancement (Environment, Culture, Safety, Resilience, and so on)

FIGURE 4. The updated business model canvas for BOLD in SCCs.

and opportunities. For the generated canvas to be broadly accepted, the survey must be extended with the engagement of a bigger expert sample, including cities from other continents that can also benefit from BOLD. In this regard, some future thoughts for this study concern conducting a survey with the participation of a broader sample of SC experts during the Intelligent Cities Challenge (https://www.intelligentcitieschallenge.eu/), drawn from cities beyond Europe (Asia, the United States, Canada, and Latin America). Moreover, the generated outcomes will be tested in real SC cases during a research project that is under implementation.

ACKNOWLEDGMENT

Some of this article's context was based on empirical knowledge from the cities of Trikala and Antwerp. The survey performed in this study took place with the engagement of experts from cities that participated in the Digital Cities Challenge European initiative. The upcoming survey is to be performed under the Intelligent Cities Challenge European initiative, while further testing will be performed under the research project Smart Cities as Hubs: Defining a System for City Flows' Management (project 2652/2021), which was granted for development in December 2021 by the Hellenic Foundation for Research and Innovation. Moreover, parts of this study were generated as part of a master's of science thesis in the Postgraduate Program in Project and Program Management, University of Thessaly, Greece.

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