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THE "SMART CITY": A FUNCTIONAL MODEL AND DIGITAL INTELLIGENCE IN EUROPE'S DIGITAL DECADE 2030

ABSTRACT The concept of a "smart city" is an important element of progress in the economy and society, aiming to make cities not only centres of government, business and culture, but also good places to live in a sustainable way. The paper presents a proposal for a comprehensive functional model of a smart city, founded on several diverse sources, which can be used as a reference view for local government research or implementation purposes. It is complemented by a framework of "digital intelligence", which reflects key digitalisation drivers that support the development of functional areas of the smart city. The functional model and the technical framework are then evaluated against the Digital Europe programme of the European Commission to indicate the alignment of local – city development – with the country and EU agenda.

Keywords: smart city, intelligent city, digitalisation, urban development, municipal management, digital strategy, digital intelligence

INTRODUCTION

When looking up the term "city" in the Google Search service, we obtain over 18 billion entries.[1] At the same time, the term "smart city" can be found 70 million times, yielding a simple ratio of "smart-to-city" of 0.4%. Naturally, looking at the absolute value of this information, we can only assume a concept coined at the end of the previous millennium has a non-negligible but still relatively small presence. More important is to understand how it is developing. In the Google Trends service, the term "smart city" is present from the beginning of the available data set (01.01.2004), with a visible growth in presence starting at the beginning of 2014, a peak in August 2015, a slowdown until April 2016 and entering a stabilisation period we observe today.[2] The search engine documented presence of the concept in the public discussion space has, therefore, been visible for over 20 years, sparking interest in its architecture, purpose and value for the economy and society. At the same time, its growth towards stabilisation and maturity calls for formulating a view on what the current understanding of the concept is and into which form it has evolved over the many years of development. As an inspirational entry point into the research subject, the authors performed a "pulse" view of the smart city as a paradigm. This was achieved by querying a diverse pool of economic and geographical experiences available in the authors' LinkedIn network,[3] with two simple questions: *how do you understand the smart in the smart city?* and *what makes a city smart?*. The most common responses included: "smart mayors or city managers", "smart residents", "smart homes", "omnipresent technology", "data-driven decisions" or "human-centred design". Despite the miniature sample of statements, we can already perceive a high variety of comprehension and a clear lack of a single core response. The technological or "digital" views (e.g. data, technology) are mixed with the evaluation of human capabilities (e.g. local government officials and managers, citizens) as two main sources of the intelligent behaviour of the city. One may only assume that the presence of technology and the intelligence of inhabitants built into the core functional blocks of the municipal organism drive its collective smartness.

Moving into the research of the available literature shows that publications related to the definition and classification of smart cities are readily available, covering a wide range of views and models formulated by the scientific, governmental and business communities, as summarised by Anthopoulos, for example.[4] In such summaries and other literature, we observe a similar struggle between "smartness" being sourced by the

[1] Data as of 29.03.2025. Only the English term was used; 'smart city' was given as a phrase. Source: search engine Google, main page of the search results, www.google.com.

[2] Only the English term was used. Statistics are for the world. Data correction made by Google (01.01.2016) took place after the peak of 08.2015 so the growth towards the maximum was not subject to this change. Source: https://www.trends.google.com.

[3] Business networking portal: www.linkedin.com, 55 opinions collected in 2025.

[4] L. Anthopoulos, *Understanding Smart Cities: A Tool for Smart Government or an Industrial Trick?*, Cham 2017.

advancements in the technology[5] or mainly by the human side.[6] Obviously, siding with any one of these views can be immediately countered with a proposal for a balanced view, where both the technology and the human intelligence are of equal importance. Additionally, they interact with a large number of other digital "Smart" drivers in the domains of infrastructure (utilities), economy and finance, governance (administration), resource consumption and protection,[7] mobility and quality of living,[8] sustainability,[9] education, healthcare, property management and public safety.[10]

The existence of the smart city in the form of an open concept, without fixed and agreed definition boundaries, drives multidirectional discussions and the search for innovation aimed at supporting three main goals of every community: survival, growth and the consumption of jointly created benefits or comfort. This is especially important in times of dynamic digitalisation, social changes, further migration from rural areas to cities, as well as the accelerating and interconnecting of survival risks:[11] economical, environmental, geopolitical, societal and technological.[12] While this freedom of concepts and ideas is a desired element of human creativity and solution-shaping, the streamlining of thought processes provides the benefit of creating a framework for structured exchange between the worlds of government, business and academia. In this respect, although interesting attempts are made to systematise the ontology of the domain (e.g. Ramaprasad[13] proposes an ontological scheme structured around six pillars: smart structure, functions, focus, semiotics, city stakeholders and outcomes) – an established reference model to which all researchers and practitioners could link back their numerous ideas and conclusions is not clearly visible. The goal of this paper is to attempt the formulation of such a model by composing a collective view on the

5 N. Komninos, "Smart Cities," in B. Warf (ed.), *The SAGE Encyclopedia of the Internet*, 2018, pp. 783-789.

6 R. Hollands, "Will the Real Smart City Please Stand Up?," *City*, vol. 12, no. 3 (2008), pp. 303-320.

7 S. Alawadhi et al., "Building Understanding of Smart City Initiatives," in H.J. Scholl, M. Janssen, M.A. Wimmer et al. (eds), *Electronic Government*, vol. 7443, Berlin–Heidelberg 2012.

8 R. Giffinger, C. Fertner, H. Kramar, R. Kalasek, N. Milanovic, E. Meijers, "Smart Cities – Ranking of European Medium-Sized Cities," *Vienna University of Technology*, October 2007, at https://www.researchgate.net/publication/261367640_Smart_cities_-_Ranking_of_European_medium-sized_cities, 15 September 2025.

9 G. Adler, "Vorwort," in *Smart City Charta. Digitale Transformation in den Kommunen nachhaltig gestalten*, Bonn 2017, at https://www.bbsr.bund.de/BBSR/DE/veroeffentlichungen/sonderveroeffentlichungen/2017/smart-city-charta-de-eng-dl.pdf?__blob=publicationFile&v=3, 31 August 2023.

10 D. Washburn, U. Sindhu, "Helping CIOs Understand smart city Initiatives," *Forrester*, 11 February 2010, at http://www.academia.edu/download/26074613/73efa931-0fac-4e28-ae77-8e58ebf74aa6.pdf, 25 October 2023.

11 A. Collins, "The Global Risks Report 2018, 13th Edition," *World Economic Forum*, at https://www3.weforum.org/docs/WEF_GRR18_Report.pdf, 22 August 2023.

12 This reference is made to emphasise the fact that cities are subject to increasing pressure from all risks identified by the World Economic Forum.

13 A. Ramaprasad, A. Sánchez-Ortiz, T. Syn, "A Unified Definition of a Smart City," September 2017, at https://inria.hal.science/hal-01702978/document, 25 August 2025.

building blocks of the "smart city" concept in reference to the functional areas of municipal activity. Looking at the relevance of digitalisation for the development of smart cities, the model is then enhanced with a technical view on which digital capabilities are needed to support individual functional areas of municipalities. The collective view on the functions and technologies that constitute the smart city paradigm is then verified against the leading regional strategies and policies, which in our case are represented by the European Union. There are three primary research challenges and goals:

- G1: development of a functional model of a "smart city;"
- G2: framework for digital city intelligence;
- G3: positioning the smart city within Europe's Digital Decade 2030 policy programme.

The approach taken by the authors to achieve the above goals included the following: 1. study of available literature, both scientific and industrial (including the body of knowledge from the municipalities running smart city initiatives as well as vendors of smart city products and services); 2. morphological analysis of identified smart city models, frameworks and ontologies from the functional point of view (with reference to the base activities of the municipalities); 3. synthesis of the results into a functional model, including a proposed taxonomy and definitions of individual smart elements; 4. expert enhancement of the functional model with the corresponding technology capabilities to create a framework of what could be considered the technological drivers of digital intelligence; 5. analysis of how the functional model and the technical framework of the smart city align with the strategies and policies of the European Union, using the main objectives of the Digital Decade 2030 programme.

1. FUNCTIONAL MODEL OF THE SMART CITY CONCEPT

The approach taken to construct the model of the smart city concept assumed the collection and analysis of city functions associated with the term "smart" or "intelligent" in the literature or in practical municipal use cases. The high-level morphology of the model was then constructed by grouping similar functions into frequency clusters that serve as indicators of their presence in the public debate surrounding the smart city concept.

The authors selected and analysed 20 primary sources,[14] created over the period of 10 years (2014-2024), where elements of the smart city were listed. Source selection

[14] Source list as references to the bibliography: D. Washburn, U. Sindhu, "Helping CIOs Understand Smart City Initiatives...;" P. Tsarchopoulos, "Trends in Smart City Development," *URENIO*, 11 January 2017, at http://www.urenio.org/2017/01/11/trends-smart-city-development, 24 April 2023; "Surbana Jurong and Microsoft Develop Cloud-Based Smart City in a Box Solutions, Enhance App Offerings," *Microsoft*, 25 November 2016, at https://news.microsoft.com/en-sg/2016/11/25/surbana-jurong-and-microsoft-develop-cloud-based-smart-city-in-a-box-solutions-enhance-app-offerings/, 23 April 2023; A. Zanella et al., "Internet of Things for Smart Cities," *IEEE Internet Of Things Journal*, vol. 1, no. 1 (2014), pp. 22-32; B. McQueen, "Future City – Seminar Series 2017-2018, Big Data Analytics For Connected Vehicles And Smart Cities," at http://www.cece.ucf.edu/wp-content/

was aimed at providing a high diversity of inputs, including municipalities, solution vendors and consulting companies. Every occurrence of a functional element in the source was classified under either a core functional area (general descriptions) or a sub-area (higher level of detail). As a result, 294 occurrences of smart city elements were clustered into 80 sub-areas and 17 core areas. Descriptive statistics of this mapping are shown in Figure 1 below.

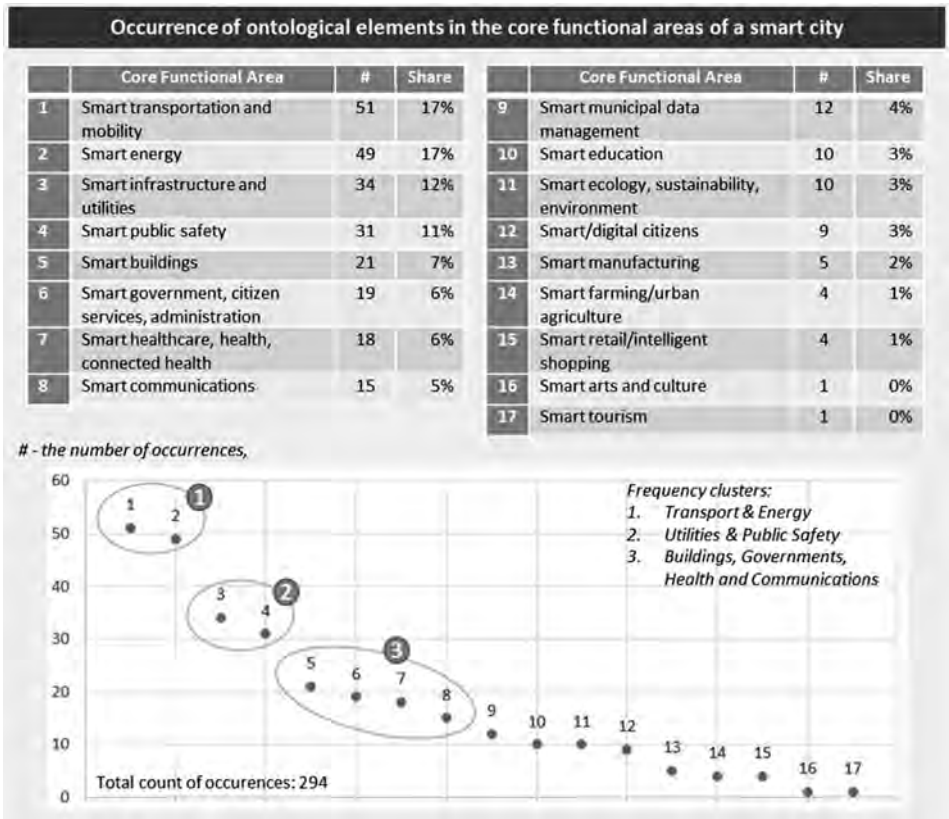
The first cluster contains two sub-groups with the highest individual share of occurrences: transportation (17%) and energy (17%), making together over one third of the total occurrences. In the second cluster, we can identify two further major sub-groups: infrastructure and utilities (12%) and public safety (11%). The third cluster contains four sub-groups: smart buildings (7%), governance (6%), healthcare (6%) and communications (5%). All three clusters make up 81% of the total occurrences, providing an indication that they constitute the core elements of the smart city concept.

The next step in the study was to describe the content of the ontological elements and identify the digital drivers that could be considered as inducing the "smart" nature of these elements. In other words, the goal was to understand what is needed to

uploads/2017/10/McQueen-UCF-big-data-analytics-for-connected-vehicles-and-Smart-cities-v100.pdf, 31 August 2023; "Urban Hub – interaktive Plattform für Personen, die die Zukunft unserer Städte und unserer Mobilität gestalten," *Smart City 3.0.*, 2018, at http://www.urban-hub.com/de/cities/barcelona-macht-seine-smart-city-noch-smarter-2/, 31 August 2025; M. Helland, "Microgrid Technology Paving the Way towards Smart Cities," *Medium Corporation*, 26 October 2015, at https://medium.com/solar-microgrid/microgrid-technology-paving-the-way-towards-smart-cities-ed9cc55e57d, 30 August 2025; K. Jäger, "Smart City: intelligent, vernetzt und effizient," *Energie Digitalisieren*, 12 June 2020, at https://energie-digitalisieren.de/knowhow/smart-city-intelligent-vernetzt-und-effizient, 25 August 2025; "White Paper: From City Theory to Smart Tech Reality," *SmartCitiesWorld*, 2017, at https://www.smartcitiesworld.net/whitepapers/white-paper-from-city-theory-to-smart-tech-reality, 30 August 2025; "Smart City – Innovationen für Stadt und Land," *Frauenhofer Institut*, 2022, at https://www.iese.fraunhofer.de/de/trend/smart-city.html, 30 August 2025; A. Gomstyn, A. Jonker, "Was ist eine Smart City," *IBM*, 22 November 2023, at https://www.ibm.com/de-de/topics/smart-city, 25 August 2025; "Lighting up Thriving, Sustainable Digital Cities. Enterprises and Cities Can Support Each Other throughout Digital Transformation," *Huawei*, 2022, at https://e.huawei.com/en/ict-insights/global/ict_insights/ict33-digital-city, 25 August 2025; "Your Community, Their Future," *Nokia*, at https://www.nokia.com/industries/smart-communities/, 25 August 2025; C. Aoun, "The Smart City Cornerstone: Urban Efficiency", *Schneider Electric*, 2013, at https://download.schneider-electric.com/files?p_Reference=998-2095-01-30-13_EN&p_EnDocType=White%20Paper&p_File_Id=309164936&p_File_Name=998-2095-01-30-13_EN.PDF, 25 August 2025; "Smart Cities," *European Commision*, 2022, at https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en, 25 August 2025; "Creating the Smart Cities of the Future. A Three-Tier Development Model for Digital Transformation of Citizen Services," *PWC*, May 2019, at https://www.pwc.com/gx/en/sustainability/assets/creating-the-smart-cities-of-the-future.pdf, 25 August 2025; S. Hajduk, "Modele smart city a zarządzanie przestrzenne miast," *Gospodarka Naukowa. The Polish Journal of Economics*, vol. 2, no. 302 (2020), pp. 123-139; H. Attaran, N. Kheibari, D. Bahrepour, "Toward Integrated Smart City: A New Model for Implementation and Design Challenges," *Geo Journal*, vol. 87, Suppl. 4 (2022), pp. 511-526; M. Gurick, S. Felger, "Organisation and Community Intelligence in Smart City Leadership and Beyond," *IET Smart Cities*, vol. 4, no. 1 (2022), pp. 47-55; "Secure, Sustainable Smart Cities and the IoT," *Thales*, at https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/inspired/smart-cities., 25 August 2025.

bring a given municipal function to a state that is regarded as "intelligent" or "most advanced" in the current paradigm of smart cities. The description is provided at the level of the 17 core functional areas.

Figure 1. Occurrence of ontological elements in the core functional areas of a smart city



	Core Functional Area	#	Share
1	Smart transportation and mobility	51	17%
2	Smart energy	49	17%
3	Smart infrastructure and utilities	34	12%
4	Smart public safety	31	11%
5	Smart buildings	21	7%
6	Smart government, citizen services, administration	19	6%
7	Smart healthcare, health, connected health	18	6%
8	Smart communications	15	5%
9	Smart municipal data management	12	4%
10	Smart education	10	3%
11	Smart ecology, sustainability, environment	10	3%
12	Smart/digital citizens	9	3%
13	Smart manufacturing	5	2%
14	Smart farming/urban agriculture	4	1%
15	Smart retail/intelligent shopping	4	1%
16	Smart arts and culture	1	0%
17	Smart tourism	1	0%

Source: authors.

(1) Transportation

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Roads	1. **Dynamic flexibility and adaptability of the road network** to the changing usage and environmental conditions and patterns, e.g. by dynamic allocation of fast/slow lanes and their direction, change of the red-light timing to alleviate congestion, lowering limits in fog 2. Ability to support the **multi-modal, bi-directional communication with road users**, e.g. via signs, radio, mobile apps 3. **Forecasting best times for service operations on the roads** running repair/construction activities, e.g. in the least traffic-disrupting times 4. **Automation and enhancement of road inspection** via drones/robots 5. **Collection of information on road issues**, e.g. new damages, debris, via reporting by users 6. **Smart road tolling** – collection of usage fees from domestic and foreign users of the roads via a multi-channel and usage and intensity-driven model 7. **Instant dispatch of road emergency services** after the identification of accidents or crisis scenarios	1. Real-time collection of: a. traffic data via sensors and mobile devices (e.g. Google Maps) b. infrastructure and device data c. environmental conditions d. event alerts 2. Mining the acquired data, including image analysis 3. Instant adaptation of road control (signals, info boards) via I/O[15] devices 4. Instant adaptation of parking control (signals, info boards) via I/O devices 5. Optimisation algorithms for traffic/parking, route planning 6. Expert system decision-making based on rules and heuristics (e.g. recognition of congestion caused by increased activity or an accident) 7. Push notifications via mobile apps 8. Collection of feedback via mobile apps 9. Applications and web services as hubs for online data access 10. Data integration between transportation services (e.g. accident information triggering the crisis procedures)
Smart Parking	1. **Management of open spaces** with driver notification, pre-booking and usage patterns 2. **Smart parking ticketing** – collection of usage fees from domestic and foreign users of the roads	
Smart Public Transportation	1. **Integrated multi-modal transportation** (e.g. train, bus, tram, underground, ferry, bike and walk trail, airport or sea/lake port connectivity, city bikes, city scooters, car-sharing) 2. **Park and ride** – integration of public parking with the public transportation options 3. **Smart public transportation ticketing** – multi-method payment system, payment applications and integration with banking 4. **On-board and instant diagnostics** of the public transportation system (e.g. monitoring of delays, technical problems, usage and issue feedback 5. **Smart timetables/schedules** – online communication of changes, delays and events (planned and unplanned), integration with the map services (e.g. Google Maps), simulation of travel times, advice on waiting times for connecting rides	

[15] I/O devices are Input/Output hardware/software controllers that enable remote setting of operational parameters of continuous or discreet processes, e.g. by reducing flow on a valve or switching the infrastructure components on/off.

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Public Transportation	6. **Self-driving cars** – both attended and unattended automated movement of vehicles with or without passengers, privately or organised (e.g. taxi corporations or Uber-type services) 7. **Smart logistics** – optimisation of routes for delivery trucks/vehicles with **fleet communication** (e.g. swarm models, failover/backup options)	11. Technical communication interfaces and protocols for interactions between the public infrastructure and private devices (e.g. an EV car reporting the completion of the battery load, notifications of technical problems or accidents) 12. 3-dimensional (3D) space planning to cover the airspace as a relevant part of the transportation options 13. Spatial objects database for stationary and movable structures and devices 14. Live processing of transponder information for movable objects in the municipal land/water and airspace
Electrical Vehicle (EV) Ecosystem	1. **Charging infrastructure** integrated with parking and optimised for maximum usage (e.g. pricing for going over the time limit after the charge is complete) 2. **Dynamically managed clean-air access zones** where only EV vehicles are allowed, promoting the entry of the municipality with a non-combustion engine vehicle, e.g. by free parking or fast lanes for e-vehicles 3. **EV value added services**, e.g. servicing during work hours or charging time 4. **EV rental, sharing** and per-minute use	
Drone Ecosystem	1. **Landing pads, waiting zones and pathways** for land/water and air drones 2. **Land/water and air-drone licensing for operation in the public space**, including the identification friend-or-foe (IFF) systems to prevent unauthorised rides or flights that might pose a risk to the municipality 3. **Land/water and air space traffic management** for authorised devices and planned flights, synchronised with non-drone traffic (e.g. helicopters, planes) 4. **Smart drone activities** to support municipal functions, e.g. automated inspection of buildings or natural habitats (fauna and flora), monitoring of human traffic, assistance in fire protection/police/ambulance service, environmental monitoring, precision farming, special or regular deliveries of goods (e.g. spare parts, medications)	

(2) Energy

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Power Grid	1. **Dynamic flexibility and adaptability of the power grid** (understood as a system of energy generation/acquisition, transport, consumption) to the changing usage and environmental conditions and patterns, with the goal of minimising consumption of non-renewable sources 2. **Sustainable local micro-grids**, based on **renewable energy** sources, (solar, wind, water, bio-energy) with the goal of energy independence, accumulation of energy (e.g. local battery storage, water reservoirs), use of cogeneration of heat and electricity, integration of small, distributed sources, municipal district heating and cooling with environmentally sound technologies and natural methods (green areas, water flow, air tunnels) 3. **Energy monitoring and management** on the city and district/building level – usage minimisation, trend optimisation, waste detection, advice on usage for the inhabitants 4. **Smart lights** – city lighting systems with needs-based adaptive activation, automated information on faulty elements (e.g. burnt-out light), use of Light Emitting Diode (LED) technology, adjustment to weather conditions. 5. **Control of electromagnetic emissions** – reduction of "electric pollution" and its negative effects on living organisms and the overall infrastructure 6. **Smart distribution of fossil fuels** – locating the stations on the outskirts of the city, planning cistern movements to avoid incidents	1. Real-time collection of: a. usage data b. infrastructure and device data 2. Mining the acquired data 3. Optimisation algorithms for power usage 4. Expert system decision-making in the power grid based on rules and heuristics, including the balancing of renewable and auxiliary energy sources 5. Instant adaptation of energy control (e.g. instant reduction on non-critical endpoints) via I/O devices 6. Extended database of the municipal grid components with their 3D location, materials composition and history (e.g. date a pipeline made of a particular steel alloy was installed)

(3) Infrastructure and utilities

The terms "infrastructure" and "utilities" are used interchangeably in the literature and in municipal discourse. It is, however, proposed to interpret their meaning from a more precise engineering perspective, where the infrastructure provides the means for utilities to be delivered to consumers. For example, an underground network of conduits allows for various pipes or tunnels (infrastructure), in which it is possible to supply fresh water and collect wastewater for treatment (utility/service for the end consumers).

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Infrastructure Smart Utilities	1. **Smart waterworks** – a highly digitised system of water acquisition, purification and delivery which is running continuously under the control of the Supervisory Control and Data Acquisition (SCADA) systems 2. **Smart wastewater plant** – a broadly digitised system of sewage collection and treatment, supported by SCADA systems 3. **Smart natural gas distribution (pipeline or individual tanks)** – a highly digitised system for transporting the natural gas from the storage or a direct pipeline to end consumers, supported by SCADA systems 4. **Remote metering** – obtaining usage information via devices that report the needed data without human intervention and can run diagnostics on the customer entry point 5. **Detection of leaks** – transformation of available usage data into hypotheses on potential uncontrolled/non-visible loss of a given utility 6. **Detection of undesired changes in the infrastructure** – use of data on process flows, their stability and the product quality to identify potential issues, e.g. dangerous organisms building up on pumps, valves or in the pipelines 7. **Smart waste/garbage management and recycling** – an integrated system of collecting the waste and processing its utilisation or storage, using: a. smart bins/containers with waste sensors that report the level of receptacle load or its condition (e.g. smell, fire, moisture) b. access control to the bins, linked to the metering/fees c. underground waste transportation routes d. waste truck run optimisations e. properly sorted as a source of energy (e.g. from burning)	1. Real-time collection of usage, infrastructure and device data 2. Mining the acquired data 3. Optimisation algorithms 4. Expert system decision-making 5. Instant adaptation of processes via I/O devices 6. Integration of data and real-time processing in the SCADA systems 7. Extended database of municipal infrastructure components with their 3D location 8. Omnipresent usage of the Global Positioning System (GPS) 9. Usage of the Geographical Information Systems (GIS) to perform analysis of existing network layouts (e.g. to run excavations without damage and in the most suitable place for short pavement/street unavailability periods) 10. Universal tagging of infrastructure points and devices, including Remote Frequency Identification (RFID) 11. Application(s) and websites as hubs for digital services

(4) Smart public safety

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Public Safety (police, urgent care, fire protection and fighting, city code enforcement)	1. **Emergency identification** – use of environmental sensors to detect smoke/fire, flooding, fog or any other adverse conditions that could impact the living population of the municipality (people, animals, plants), automated video analysis 2. **Emergency notification** – instant communication of danger posing abnormalities such as unconscious/hurt/homeless people/animals in public spaces, identification of caller's location and personal features (linked to the demand for services – e.g. the number of ambulances or a special service for small children to be dispatched) 3. **Integrated mobilisation of all emergency services** to ensure full coverage of potential issues 4. **Security surveillance** – collection and processing of images from video devices located on assets or personnel (movable and wearable) with face recognition, population counting and behavioural analytics such as predicting unwanted/forbidden behaviour, illegal intrusion/zone violation or objects left unattended 5. **Smart access and security** – intelligent authentication and authorisation systems, badges and perimeter control used in permanent zones (e.g. public buildings) and temporary spaces (e.g. during municipal events)	1. Real-time collection of usage, infrastructure and device data 2. Mining the acquired data, especially with anti-crime and anti-terrorism measures 3. Optimisation algorithms 4. Expert system decision-making in crisis management 5. Instant adaptation of processes via security I/O devices (e.g. cameras, card readers, locks, gates) 6. Extended database of municipal inhabitants and guests (humans and animals) 7. Application(s) and websites as hubs for digital services

(5) Smart buildings

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Buildings (all sizes and types of residential, business or public architecture) Integration of the **private** ownership of property with the **public** spaces	1. **Smart devices** and **appliances** in a single room of an apartment (**smart home**), through **smart houses** and building complexes to self-contained **smart residential areas or communities** ("smart city within a smart city") 2. **Intelligent municipal service points**, e.g. **transportation stops** (e.g. reporting on the upcoming traffic, weather advice) or **toilets** that report their state (e.g. abnormally long usage by a single individual, overall statistics of use) and dynamically shape the demand for resources such as bathroom supplies or cleaning 3. **Energy management** – optimisation of usage, self-generation, energy-efficient design 4. **Flexible usage of space** – sharing, reshaping, customising to changes in demand 5. **Green management** – rooftop and wall vegetation, rainwater collection for watering, water and air recirculation 6. **Advanced preventive maintenance** – automated drone or robotic inspections and service work, sensor-based structural health checks of the buildings	1. Real-time collection of usage, infrastructure and device data, especially in the Internet of Things (IoT) interconnectivity mode 2. Mining the acquired data 3. Optimisation algorithms 4. Expert system decision-making 5. Instant adaptation of processes via I/O devices 6. Extended database of municipal buildings and structures 7. Application(s) and websites as hubs for digital services

(6) Smart government, citizen services, administration

In this functional area, we are already accustomed to the widespread application of the term "e-Government", formulated before the year 2000 during the first period of intensive development of "e" (electronic and internet-based) services. The idea of having digital public administration services is based on two key principles. First, government services are mainly based on well-defined legal documents and procedures (city ordinances and codes, local and regional laws) that are a good target for automation – either via conventional information systems or by digital workers (bots, robots, artificial intelligence) executing human tasks. Second, official government matters are high-scale processes, frequently requiring a personal visit to the office during standard working hours (necessitating some time off work) and with the risk of having to wait in a queue. High scale and challenging conditions provide a strong impetus for developing a solution where processes can be run in a client self-service and 24/7 mode.

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Government Smart Citizen Services Smart Administration	1. **Smart identification/authentication** of inhabitants and guests and **authorisation** of their requests/operations, undeniable identity, fit for non-repudiation purposes, linked to countrywide identification schemes, but optionally enhanced with additional local solutions, e.g. based on biometrics. 2. **City card** – a platform for controlling access, usage and monitoring of citizen activity; it combines the identity features with access to services (e.g. transportation, recreational facilities or library services) 3. **Smart economic development** – strategic planning of investment in either business or residential projects, respecting the protection of natural environment, providing equal opportunities and harmonising the development with the overall goals of the municipality 4. **Smart permitting and licensing**, including smart land use – in line with the planned economic development, based on data analysis and citizen dialogue 5. **Crowdsourcing of ideas and problem-solving** – set-up of a participative community where issues and ideas are openly discussed and votes are taken (e.g. a portion of the city's investment budget is spent on citizen inspired topics) 6. **Smart social services** – data-based identification of places of need for social support, monitoring of aid provided and convergence of public and private support 7. **Regional control centre for coordination of municipal activity with other communities in the area**, with the provinces and relevant public and private entities, e.g. to support crime prevention, natural disaster management, health risks and citizen support 8. **Smart voting** – digitally organised election processes that serve not only the formal selection of municipal officials (local elections), but can also be used to invoke public opinion on any other topic, in a referendum or a common vote formula	1. Real-time collection of usage/behavioural and device data 2. Mining the acquired data 3. Optimisation algorithms, especially in workflow and queue management 4. Instant adaptation of processes via I/O devices, especially related to the usage of a city card 5. Extended database of inhabitants and guests with their usage of city services 6. Extended database of permits and licenses 7. Application(s) and websites as hubs for digital services

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart City Financials	1. **Design of the business case** – inclusion of high expectations from inhabitants and guests that new smart services are provided free of charge, so the financing must be assured elsewhere (e.g. cross-financed from other revenue-generating city functions, central subsidies or private-public partnerships) 2. **Alignment with** the Environmental, Societal and Governance **(ESG) guidelines** for high sustainability 3. **Smart city budgeting** – ensuring a long-term view on infrastructure and technology investments (e.g. building a fibre optics network) combined with a dynamic situation development (demand for a service can grow/fall drastically in much shorter timeframes than before) 4. **Personalised pricing of municipal services** – tuning to current trends (e.g. payment solely for the usage of a service), data-driven transparency of calculated amounts, dynamic pricing (promotional, discounting, waiving fees) 5. **Advanced consumer billing features** – digital and userless measurement of usage required for billing; forecasting based on usage for optimisation of down payments 6. **Invoicing consumers** – digitalised and paperless, preferably in apps, transparency of billing information used for invoicing, notifications and bi-directional communication between the city hall and the consumers 7. **Payment processing** – digitalised and paperless, preferably in apps, integration with multiple payment schemes and financial institutions, processing and settlement of small amount payments (e.g. for the usage of a restroom, transportation ticket) 8. **Collection and recovery of receivables** – digitalised and paperless, preferably in apps, dynamic notifications for debtors 9. **Reporting of the financial flows and results** – real-time data and transparency provided to internal and external stakeholders 10. **Financial records management** – digitalised and paperless, preferably in apps, availability of full history of financial flows, including the continuity of information despite ownership changes (e.g. for property) 11. **Financial optimisation** – processing of big data for efficient business case reviews, analysis of trends or "the new normal" in smart service consumption, change management of new services	1. Linking financial data to the functions of the city and usage patterns 2. Big data financials – at the lowest possible analytical level across the municipal data model 3. Mining the financial data to understand development trends, as well as new financial risks that require mitigation 4. Optimisation algorithms, especially regarding fees and pricing 5. Extended database of inhabitants and guests with their financial history, linked to the individual or to the property for continuity of monitoring 6. Application(s) and websites as hubs for digital services

(7) Smart healthcare, smart health, connected health

The health domain covers a range of topics related to providing continuous and integrated medical care for the members and visitors of the municipality with different medical insurance options.

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Healthcare Smart Health Smart Connected Health	1. **Comprehensive prevention** – controlled and data-driven vaccinations, education (e.g. dental care programmes, first aid courses in schools and companies), common disease diagnostics (e.g. breast cancer mammography), regular medical checks for employed individuals (with additional controls for people at risk of transmitting the disease e.g. via the food chain), "all-weather" programmes in pre-schools and schools (e.g. outdoor activity in all non-critical weather conditions) 2. **Highly available urgent care** – ambulance services and in-house visits arranged with priority road and infrastructure usage, medical points with the availability of Automated External Defibrillators (AED) integrated into city maps and communications, cab/taxi drivers with paramedic training, drone delivery of medication (e.g. anti-venom serum for bites of venomous animals, anti-allergic substances for severe allergic reactions), use of drones and helicopters for fast transportation of people with serious medical conditions 3. **Epidemic control and containment based on data** analysis – rapid reaction to infection outbreaks, collection and processing of infection information, tracking relationships of infected patients and communication with people at risk of getting infected 4. **Data-driven hospital services** – ensuring the entire scope of medical procedures is available to patients despite the volatility of the population, ongoing analysis of supply and demand, especially in view of human migration (in/out) and the emergence of new bacteria/viruses related to the movement of people from various geographies and their respective medical care levels 5. **Managed facility control** (e.g. availability of first aid kits) and "human-touch" business control (e.g. the level of hygiene in barbershops, restaurants, swimming pools or gyms) 6. **Smart monitoring of private non-licensed health facilities** (e.g. alternative/natural medicine, paramedics) to prevent misuse affecting city inhabitants 7. **Homeless shelters** – data-driven management of cases of homeless people to allocate them to appropriate resolution facilities (e.g. return to home, place of origin, hospital treatment, resocialisation centres, hospices)	1. Real-time collection of health-relevant data about the people, animals, plants and places (e.g. public fountains) 2. Mining the acquired data 3. Optimisation algorithms 4. Expert system decision-making, especially regarding the topics of epidemics 5. Instant adaptation of processes via I/O devices (e.g. blocking public spaces upon the discovery of a health hazard) 6. Extended database of health/sickness cases in people, animals and plants 7. Application(s) and websites as hubs for digital services

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Healthcare Smart Health Smart Connected Health	8. **Animal control** – data-driven management of stray animals, animal stores and private collections (permit-based control of wild and dangerous animals), use of digital animal signage ("chips" and ID tags), animal vaccinations; management of protected animals (e.g. birds of prey nesting in cities) and borderline areas (e.g. sections of the city near forests, lakes, rivers, swamps); digitised notifications about animals in need or endangered	

(8) Smart communications (two dimensions: infrastructure and processes)

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Communications Infrastructure	1. This function can potentially be considered as part of functional area 3 (infrastructure and utilities); however, in the literature, it is treated separately. This could be because the predecessors (phone/copper networks) were largely managed by commercial organisations, whereas with internet access, cities are more inclined to create their own wide area networks, independent of commercial providers. 2. **Fibre optics as core infrastructure** – planning of city networks and public works including the installation of fibre optic cabling capable of servicing private and commercial inhabitants/guests 3. **Internet connectivity in public spaces** – assuring wireless access to the internet in either fully open, pre-registered or paid mode, with and without bandwidth and time limitation 4. **Max available cellular network coverage** – availability of cellular mobile data in the entire municipal area, using the highest technical standards (e.g. at present, 5G)	1. Real-time collection of usage, infrastructure and device data in the communications network 2. Mining the acquired data 3. Optimisation algorithms 4. Expert system decision-making 5. Application(s) and websites as hubs for digital services
Smart Communications Processes	1. **Asynchronous two-way omnichannel** for interaction between the municipality and its inhabitants/guests via a broad range of technical methods (e.g. app, phone, chat), retaining the continuity of the service at the Client Relationship Management level (as in commercial CRM systems, but directed towards inhabitants and guests as clients) 2. **Crisis communication** – use of physical media (e.g. sirens, announcement speakers) and digital applications (e.g. NINA in Germany or the RCB Alerting in Poland) to mass notify people in each area about risks and mitigation procedures	1. Real-time push notifications 2. Real-time feedback collection via apps and physical devices (e.g. intercoms at train stations or inside the trains) 3. Application(s) and websites as hubs for digital services

(9) Smart municipal data management

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Municipal Data Management	1. **Open municipal data** – providing access to municipal data (raw data sets) which is not limited by any legal conditions, such as the protection of personal information, but can be beneficial to the community and individuals (e.g. detailed maps of city infrastructure, data on traffic, weather, air quality, prices of services); this sort of data is in direct competition with commercially available alternatives (e.g. Google) that create data from global (e.g. satellites) and local (e.g. individual mobile devices) sources 2. **Municipal business intelligence** – reports and analytical data sets that provide additional insights for companies and individuals (e.g. on the movement of cars/people, development of the population, diversity of inhabitants) 3. **Data democratisation** – both items above are delivered within the democratisation concept, defined as non-biased and user-friendly access to data, including the ability to download for further processing on local systems 4. **City data cloud** – provision of a municipal data and application store for use by the community; it includes access rights management, storage of data sets, availability of municipal application programming interfaces (APIs) and software development containers allowing the building of systems and solutions; these services again compete with commercial or national cloud solutions; however, their municipally managed version allows for the streamlining of efforts in building a city-wide information system that would serve the community in a focused way, with the comfort of local control 5. **Social media data integration** – processing/mining of data collected via social media channels – e.g. opinions, evaluations, descriptions, requests; ongoing monitoring of social media traffic in self-managed and open channels, including vendors of city services	1. Real-time collection and integration of municipally relevant data 2. Mining the acquired data to support decision processes 3. Use of cloud solutions 4. Availability of APIs to enable the API City

(10) Smart education

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Education	1. **Inclusive education** – provision of public education infrastructure and programmes for all age and background groups (day care facilities, schools, universities, education of pensioners via "3rd-age universities", promotion of inclusive teaching, diversity programmes, integration courses) 2. **Smart education projects** – organised around the digitalisation of the learning and development process; together with the primary activity of creating computer-based learning, cities invest in virtual classrooms, allowing them to deliver educational services to a mass audience, offering multi-mode options (e.g. assisted or self-study, synchronous or asynchronous, self-paced, grade or completion based, with official certifications) 3. **Educational campaigns** – related to various aspects of city life, from basic ecology and well-being to the introduction of new technologies (e.g. for public transport ticketing, personal identification or usage of city mobility services) 4. **Neo-libraries** – the once forecasted "decommissioning of traditional, physical library services" was prevented by the dynamic adoption of new technologies and conversion to a hybrid model where, regardless of the form of interaction, libraries remain local centres for information, research, human interactions and development	1. Push notifications to inform citizens about the educational offer 2. Accessibility tools and software to make the technology understandable and non-limiting for all citizen groups 3. Integration services that enable cross-party cooperation (e.g. joint content store, virtual working rooms) 4. Application(s) and websites as hubs for digital educational services

(11) Smart ecology, sustainability and environment

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Ecology Smart Sustainability Smart Environment	1. **Data-driven ecology** – various elements of the biosphere are monitored (e.g. geological conditions, water circulation, biome activity, drought) to make informed decisions on the protection and development of the environment 2. **Real-time climate monitoring** – local and integrated with the global services: measurement, forecasting, planning; detection of abnormal activity – avalanche/earthquake/tsunami/volcano eruption, smog control, rain/stormwater monitoring via sensors and applying retention policies/flood control 3. **Smart landscaping** – exposing vital elements of the environment (e.g. rivers, ponds) or masking undesirable constructions (e.g. industrial installations covered with green areas).	1. Real-time collection of environment relevant data 2. Mining the acquired data 3. Optimisation algorithms for city behaviours in the presence of detected threats 4. Expert system decision-making, especially around the topics of sustaining all forms of life 5. Instant adaptation of processes via I/O devices (e.g. flood gates) 6. Extended database of environmental measurement 7. Application(s) and websites as hubs for digital services and communication with the community

(12) Smart/digital citizens

The presence of the term "smart/digital or e-" citizen in the discourse on the development of smart cities is surprisingly low, especially in the "client-centric" ontologies of today's economic thought. If we go back to the basics, citizens are the true core and reason for the existence of cities. We might then expect that smart cities are occupied by smart citizens who embrace digitalisation as one of the key sources of "smartness".

City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
Smart Citizens	**Digitally enabled citizens** – capable and willing to utilise the newest technologies to achieve higher performance in execution of city-related matters **Citizen as a core source of feedback about the municipality** – real-time and continuous measurement of the net promoter score (NPS) and other types of evaluations **Publicly assured morality** – neighbourhood watches and open (anonymous or not) means of notifying the authorities about the observance of illegal behaviour (e.g. dumping litter, graffiti, acts of vandalism, theft) **Support for the special care citizens** – e.g. elderly persons living alone, people with disabilities or special needs; supported by the use of sensors detecting health condition issues, tracking movement of people (upon consent); joint living communities to avoid the exclusion effect	Real-time collection of citizen-relevant data Mining the acquired data Optimisation algorithms for processing citizen data Expert system decision-making, especially around citizens' opinions Extended database of opinions linked to services Application(s) and websites as hubs for digital services and communication with the community

The remaining ontology elements are not commonly found in discussions and seem to reflect a non-mainstream line of smart city thinking. In this tail group, we identify five functional areas:

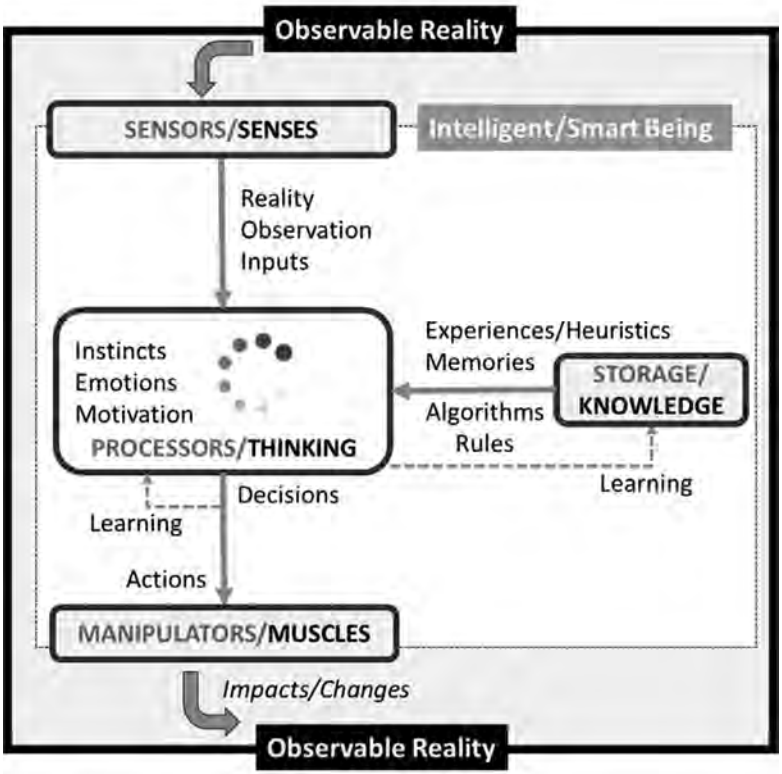
City Function (provision of)	Description and Use Cases	Digital "Smart" Drivers
(13) Smart Manufacturing	Operation of production facilities in line with the municipal code, care for the environment and full cooperation with the city for issue resolution (e.g. in the event of leakage of harmful substances)	1. Real-time collection of usage/behavioural and device data 2. Mining the acquired data 3. Optimisation algorithms 4. Instant adaptation of processes via I/O devices 5. Expert system decision-making, especially around citizens' opinions 6. Application(s) and websites as hubs for digital services and communication with the community, especially reaching out to industrial, agricultural and commercial entities operating in the municipality
(14) Smart Farming/ Urban Agriculture	Integration of farming into the municipal organism, ranging from growing crops to community gardens or beehives located on corporate property. What can be observed is the return of agricultural elements into the city limits, offsetting the negative effects of overurbanisation and the collapse of complete biomes	
(15) Smart Retail/ Intelligent Shopping	As one of the core human activities, obtaining supplies necessary for daily living consumes a large amount of time and resources. Enabling new ways of ordering (e.g. online) and delivery (e.g. via trucks or to pick-up stations, using external warehouses to bypass the necessity to stock shelves, drone or robotic delivery), therefore, has strong impacts on the shopping experience and its overall cost and environmental effects (e.g. traffic-driven pollution and noise, fuel consumption)	
(16) Smart Art and Culture	Mentioned only once, it refers to weaving the cultural offer into everyday city life, with a defined programme of events in municipal facilities or online	
(17) Smart Tourism	Using digitalisation to manage the flow of visitors to a municipal area, for example by providing a mobile application that guides tourists through points of interest via a pre-defined route – in order to minimise traffic (e.g. by encouraging the use of public transport during specific time slots), offering discount coupons to attractions with lower visitor rates or to high-capacity accommodations to avoid queuing or providing direct contact emergency numbers to ensure quick resolution of health and safety incidents. The applications are usually combined with basic registration statistics, linked to participation monitoring (e.g. usage of coupons), allowing city management to analyse visitor demographics and flow across the map of points of interest	

The functional areas presented above, with examples of use cases, form a practical model of the smart city concept, founded on the knowledge base of sources analysed by the authors. The model can be used in ongoing research to identify further functional areas or changes and innovations taking place in the existing ones. From the point of view of municipal management, the model can be used as a checklist for the verification or formulation of smart city strategies and development plans. As such, the model completes the first goal (G1) of the paper.

2. FRAMEWORK OF DIGITAL CITY INTELLIGENCE

While completing the model, the authors included an expert indicative self-evaluation of digital drivers that contribute to the "smartness" or "intelligence" of each of the functional areas. The digital drivers are understood as information technologies, both hardware and software, that enable, improve or facilitate the advanced execution of city functions, thus increasing the collective "intelligence" of a municipality. In this paper, it is proposed to model intelligence in a simplified way – as the ability to understand observable reality via the senses, process the inputs using knowledge, react to them (make decisions) and modify reality through actions (or lack thereof). A schematic of this understanding is shown in Figure 2, with four intelligence areas:

Figure 2. Simplified representation of municipal intelligence/smartness



Source: authors.

The efficiency and effectiveness of intelligence in the presented model is driven by maximising the performance of all intelligence areas that jointly allow us to understand and change reality: **sensors, processing, storage and manipulators** (physical means of action). In a basic view of any process or function, we commonly optimise them

continuously along three core dimensions: time, quality and cost. The optimisation of time is no longer associated solely with the duration of an activity; it also means getting things done "in real time", "just in time" or "agile" (dynamic, non-sequential, prototype-driven). The paradigm of cost has also evolved from the pure monetary value of resources needed multiplied by the duration of their use. It is now common to view costs in a broader sense, analysing also the indirect cost elements as well as social and environmental impacts. The improvement of quality is focused on delivering products and services that meet customer needs and expectations. In summary – municipal intelligence has the potential to grow when its **senses, thinking, knowledge and "muscles"** are continually improved. Converting this to a digitalisation or technology taxonomy view – the functional areas of the city need to improve their sensors, processors, storage and manipulators accordingly. Using the already listed indicative digital smart drivers, it is possible to map them onto the four areas of the digital taxonomy of city intelligence (see Figure 3).

Figure 3. Digital "Smart" Drivers and their assignment to the municipal intelligence areas

Digital „Smart" Drivers	Count
Applications and WWW Sites	13
Data Analysis/Mining	13
Real Time Data	13
Advanced Databases/Big Data	12
Algorithm Optimization	12
Expert/Decision System	10
Instant I/O Operations	10
Push/Pull Communications	5
Data Exchange/Integration	5
Spatial Planning/GIS/GPS	4
Accessibility	1
Cloud Computing	1
Physical Asset Tagging	1
Total:	100

Digital „Smart" Drivers	Count
Sensors	**18**
Real Time Data	13
Physical Asset Tagging	1
Spatial Planning/GIS/GPS	4
Processors	**23**
Algorithm Optimization	12
Expert/Decision System	10
Cloud Computing	1
Storage	**30**
Advanced Databases/Big Data	12
Data Analysis/Mining	13
Data Exchange/Integration	5
Manipulators	**28**
Applications and WWW Sites	13
Push/Pull Communications	5
Instant I/O Operations	10
Accessibility	1
Total:	100

Source: authors.

Despite operating on a relatively high level of abstraction, we observe that all elements of the digital municipal intelligence taxonomy are driven or supported by technological development. This indicates that proper attention needs to be given to

understanding new technologies and how they can and should be used to increase the smartness of a municipality. Knowledge/storage, with 30% of driver occurrences across the functional areas, holds the most prominent position, suggesting that knowledge management and the optimal usage of data are key to growing municipal intelligence. Almost equally important (28% of driver presence) for smart cities are the manipulators/muscles, which help to actively manage the physical complexity of the municipal architecture and the behaviour of its users. It is important to note that almost half of the occurrences in this element (13% of total) are attributed to Applications and WWW Sites, through which the actions of the population can be invoked, without operating physical devices controlled by the city. The processors/thinking, with a driver occurrence of 23%, and sensors/senses scoring 18% also represent a strong share of the total. This balance of drivers supporting the intelligence areas encourages their widespread adoption, backed by the notion that technology implementation can improve the performance of the entire city intelligence.

The above discourse on the technological factors as digital "smart" city drivers allows for the formulation of the framework of digital city intelligence and concludes the goal (G2) of the paper. This enables us to move to the final goal (G3) of positioning digital city intelligence, as defined by the authors, within Europe's Digital Decade 2030 policy programme.

3. POSITIONING THE SMART CITY IN EUROPE'S DIGITAL DECADE 2030 POLICY PROGRAMME

Both the functional model of the smart city and the digital intelligence framework are of universal nature and can be used globally. At the same time, the practical application of these theoretical concepts needs to be linked to local specifics and policies. In the European Union, the vision, goals and executive practices on the digitalisation of the economy and society are formulated in the Digital Europe Programme (DIGITAL), focused on bringing digital technology to businesses, citizens and public administrations.[16] DIGITAL operates in line with the EU's goals defined in the European Commission's Communication – 2030 Digital Compass: The European Way for the Digital Decade and in the Policy Programme – Path to the Digital Decade.[17] The Digital Decade Programme formulates four cardinal points under which the Digital Decade targets are defined (Figure 4).

[16] "The Digital Europe Programme," *European Commission*, at https://digital-strategy.ec.europa.eu/en/activities/digital-programme, 25 August 2025.

[17] "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 2030 Digital Compass: the European Way for the Digital Decade," Document 52021DC0118, COM/2021/118 final, *European Commission* Brussels, 09.03.2021, at https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52021DC0118, 25 Agust 2025.

Figure 4. Digital "Smart" Drivers and their assignment to the municipal intelligence areas

Cardinal Point of the EU Digital Decade	EU Digital Decade Goals
1. A digitally skilled population and highly skilled digital professionals	1. Information and communications technology (ICT) specialists: 20 million employed, more graduates and gender convergence 2. Basic digital skills: min 80% of population can use tech for everyday tasks
2. Secure and sustainable digital infrastructures	1. Connectivity: gigabit for everyone 2. Cutting-edge semiconductors: double EU share in global production 3. Data – edge & cloud: 10,000 climate-neutral highly secure edge nodes 4. Computing: first computer with quantum acceleration
3. Digital transformation of businesses	1. Tech uptake: 75% of EU companies using cloud, ai or big data 2. Innovators: grow scale-ups & finance to double EU unicorns 3. Late adopters: more than 90% of SMEs taking up tech
4. Digitalisation of public services	1. Key public services: 100% online 2. E-health: 100% of citizens have access to medical records online 3. Digital identity: 100% of citizens have access to digital id

Source: authors based on the EU Digital Decade Policy Programme.[18]

The first cardinal point contains a very important notion that the digitalisation of the EU needs to develop human capital on both the technology supply and demand sides. In this respect, the objective is not only to shape a diverse workforce capable of building and operating the digitalisation services, but also to educate and engage, in an inclusive manner, the community of digitalisation users. The human capital dimension was not explicitly mentioned in the proposed framework of digital city intelligence, but its importance is foundational and can be considered a critical prerequisite for the digitalisation of any type of human activity. Referring this EU goal to the functional model of the smart city, we observe a close alignment with the idea of "smart education" (functional area 10) serving smart citizens (12) supported by a "smart government" (6).

The second point is oriented towards the creation of an infrastructural base for the widespread availability of high-performing technologies. In the smart city model, this corresponds to several functional areas, mainly "infrastructure and utilities" (3), "communications" (8), "transportation" (1), "energy" (2), "buildings" (5) and "smart municipal data management" (9). The secure and sustainable digital infrastructure has a strong presence in all digital city intelligence areas. It is simply a base on which all digitalisation is built and, therefore, needs to be strategically managed for high performance and availability. The Digital Decade anticipates further cloudification of digital services, but also specifically mentions the use of edge computing, which shows a very important balance between moving towards centralised solutions while keeping

[18] "Digital Decade – Policy Programme," at https://digital-strategy.ec.europa.eu/en/policies/digital-decade-policy-programme, 25 August 2025.

in mind that a large amount of data can and should be processed close to the actual users and usage areas. This brings us to the concept of a smart city cloud, which takes the benefits of cloud technology to be used mainly by a geographically well-defined municipal area of use. Smart city services generate and consume very high volumes of data and computing power. Current research and work of central and local government point to numerous advantages of the cloud, but also to many hurdles that need to be addressed, among others:

Figure 5. Advantages and hurdles of using the cloud for smart city development

Advantages	Hurdles	Source
Intelligent planning using available data, a data marketplace for seamless exchange of information, new citizen services	An incomplete regulatory environment regarding the usage of technology, a lack of clear cloud business architecture in a city	BMWK[19]
Better handling of mobility, social policy and crisis management, improved city services and internal processes, better choices in city elections, data/statistics-based decisions	High investments in technology, operating teams and analytics of city data, a complex regulatory environment and data governance, low awareness of the importance of data management, poor data quality and a lack of public trust in the cloud	Deutscher Städtetag[20]
Satisfying the online/digital service expectations of citizens, customer self-service, automated processes, flexibility and safety in the technical blueprint of a municipality	Necessity to implement professional/commercial methods of software development (high cost). Cloud as a disruption that requires strong change management.	BMI, Frauenhofer[21]

Source: indicated in the table.

The initial fear of the cloud being either a place where unknown individuals or organisations have uncontrolled access to the data or existing as an IT solution fully dependent on the availability of global internet connectivity seems to be diminishing as cloud providers prove their ability to deliver continuous, seamless and secure services. With the adoption of the cloud, smart cities increase their level of technical competence and create stronger IT capabilities. There is a strong resemblance between

[19] "Cloudbasierte Datenplattform für smarte Kommunen," *Bundesministerium für Wirtschaft und Energie*, at https://www.bmwk.de/Redaktion/DE/Artikel/Digitale-Welt/GAIA-X-Use-Cases/smart-city-datenplattform.html, 6 August 2023.

[20] *Die Stadt der Zukunft mit Daten gestalten. Souveräne Städte – nachhaltige Investitionen in Dateninfrastrukturen*, Berlin–Köln 2021, at https://www.staedtetag.de/files/dst/docs/Publikationen/Weitere-Publikationen/2021/stadt-der-Zukunft-mit-daten-gestalten-studie-2021.pdf, 6 April 2023.

[21] J. Gottschick, U. Holzmann-Kaiser, H. Kurrek, "Cloud-Betrieb Im Öffentlichen Sektor: Selbstbedienung, Automatisiert," *Kompetenzzentrum Öffentliche IT*, Februar 2021, at https://www.oeffentliche-it.de/publikationen/cloud-betrieb-im-oeffentlichen-sektor-selbstbedienung-automatisiert/Cloud-Betrieb%20im%20%c3%b6ffentlichen%20Sektor%20-%20Selbstbedienung,%20Automatisiert.pdf, 6 August 2023.

financial institutions[22] declaring their future as becoming "fintech ventures" and cities becoming smart through technology. In both domains of financial and municipal services, the significance of cloud usage is becoming the new paradigm or at least a development path that cannot be ignored.

The third cardinal point (digital transformation of businesses) can be linked to the companies being instances of "smart citizens" (12), but also to "smart manufacturing" (13), "smart farming and urban agriculture" (14), "smart retail and intelligent shopping" (15), "smart arts and culture" (16) and "smart tourism" (17). Apart from the smart citizens, all functional areas listed in the previous statement have a very low number (< 2%) of occurrences in the analysed sources. This could suggest that the focus of EU policy is shifting towards areas that until now did not attract sufficient attention in the overall digitalisation activities. This could definitely provide the benefit in the form of increasing the intelligence of businesses as members of smart municipalities. In this context, the use of Artificial Intelligence (AI) is also mentioned in relation to businesses. It is important to note that the usage of AI is assumed to be applicable to all entities functioning in the EU, including central and local governments, as stipulated in the "Artificial Intelligence for Europe"[23] strategies already present in 2018 and subject to dynamic development and regulation.[24] As the data of smart cities moves towards an accessible and broad pool of highly usable facts, these can be plugged into smart solutions based on the use of artificial intelligence or at least complex rule systems that allow for the formulation of decision proposals. Over the past few years, city dwellers have become invisibly acquainted with various AI-based solutions, such as traffic management (based on the analysis of vehicle movements), recognition of public hazards (scanning of faces or behaviours, using city-wide visual infrastructure to track crime) or communicating with city departments via sophisticated and user-friendly chatbots. The dawn of ultra-efficient AI solutions, as powerfully displayed by tools such as ChatGPT, provides a strong indication of significant potential to combine AI with the city cloud and the network of sensors/IOT infrastructure. This seems to be a natural way to further increase the smartness of a municipality – simply by enhancing its intelligence via machine learning and decision support systems taken to the next, AI-driven level.

The fourth cardinal point (digitalisation of public services) is directly linked to the smart city concept in both the functional and technological senses. The goal of

[22] Famous sample from ING CEO who stated the bank would turn into a tech company with a banking license. "'We want to be a tech company with a banking license' – Ralph Hamers," *ING*, 8 August 2017, at https://www.ing.com/Newsroom/News/We-want-to-be-a-tech-company-with-a-banking-license-Ralph-Hamers.htm, 25 August 2025.

[23] "Communication from the Commission, Artificial Intelligence for Europe," *European Commission*, Brussels, 25.4.2018, COM(2018) 237 final, at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:237:FIN, 26 August 2025.

[24] An important milestone was the "EU AI Act: First Regulation on Artificial Intelligence," *European Parliament*, 8.06.2023, at https://www.europarl.europa.eu/topics/en/article/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence, 26 August 2025.

having 100% of the key public services online in the EU community perfectly translates into working towards the increasing intelligence of municipalities as building blocks of local governance. The authors confirmed a very high position of applications and online services in the concept of the smart city. The existence of such solutions for cities is a natural part of common digitalisation. Within a municipal area, numerous services can be offered to inhabitants and visitors. One way to understand the diversity of areas covered by municipal applications is to look at the popular rankings or recommendations of city applications. Based on the sample 10 rankings found in the first two pages of the Google Search Engine results,[25] the following table of features can be composed.

Altogether, 33 features are mentioned in the sample sources, of which 51% (17 features) are cited only once. The maximum number of occurrences in various rankings and recommendations can be attributed to the functionality of maps (present in all sources), followed by transportation (7 occurrences), tours/trips (6), events and meetups/social media (both 5) and attractions, recommendations from locals and lifestyle/nightlife (all 4). These features can be considered mainstream, forming the core of the city application architecture. The remaining items demonstrate a high degree of specialisation by delving into selected topics (e.g. biking/running, parking, rentals, sharing or public safety). There are also innovative areas such as finding wireless networks, walking the city by following landmarks or special points (instead of classical street views), carbon footprint and pollution monitoring or much-needed guides on the accessibility of city areas for the handicapped. In terms of features that facilitate city cash flows, we identify three visible areas: 1. ticketing (transportation, events, tours); 2. currency exchange; 3. discount shopping/living.

[25] "The 10 Apps You Need to Survive in a New City," at 10 Travel Apps to Help you in a New City – Patterson Travel, 10 October 2024; S. Parker, "10 Best Apps for City Tourists," *Big World. Small Pockets*, 27 October 2021, at https://www.bigworldsmallpockets.com/10-best-apps-for-city-tourists-awesome-app-giveaway-2, 10 October 2024; S. Tanzeem, "The 8 Best Apps to Use When Moving to a New City," *Make use of*, 19 March 2022, at https://www.makeuseof.com/moving-to-new-city-apps/, 10 October 2024; M. Barber, "The 9 Best Apps for Exploring Cities. How to Get Around – and See – the City with Fresh Eyes," *Curbed*, 27 June 2017, at https://archive.curbed.com/2017/6/27/15876950/best-apps-cities-travel, 10 October 2024; "Windows Apps," *Softonic*, at https://en.softonic.com/top/iphone-apps-for-exploring-cities, 10 October 2024; M. Herd, "Crime to Clubs, Tourism to Toilets as Best City App Contest Enters Next Stage," *Support the Guardian*, 25 April 2014, at https://www.theguardian.com/cities/2014/apr/25/crime-clubs-tourism-toilets-best-city-app-contest, 10 October 2024; A. Craddock, "The Best Free Apps to Explore Your New City," *Insider Guides. International Student Resources*, 18 March 2019, at https://insiderguides.com.au/best-apps-explore-city, 10 October 2024; "Experience like a Local Apps and Websites," at https://www.bonappetour.com/labs/experience-like-a-local-apps-and-websites/, 10 October 2024; S.C. Stuart, "Tourism Tech: Can These Apps Help You Explore Your City?," *PCMag*, 28 January 2023, at https://uk.pcmag.com/travel-how-to/145161/tourism-tech-can-these-apps-help-you-explore-your-city, 10 October 2024; "Best Smart City Apps for Android," *Source Forge*, at https://sourceforge.net/software/smart-city/android, 10 October 2024.

Figure 6. Features of city-oriented mobile applications

	Count of features in the source	6	8	7	8	7	17	6	7	6	4	
ID	Source → Feature ↓	1	2	3	4	5	6	7	8	9	10	Count of features in all sources
1	City maps with locators (food, shopping, art etc.)	x	x	x	x	x	x	x	x	x	x	10
2	Transportation/Public/Commercial/Mixed	x	x	x	x	x	x			x		7
3	Tours/Trips		x			x	x	x	x	x		6
4	Events	x			x	x	x			x		5
5	Meetups/Social Network			x			x	x	x		x	5
6	Attractions		x				x	x		x		4
7	Recommendations from the locals (spotted)	x			x	x			x			4
8	Lifestyle/Nightlife	x						x	x	x		4
9	Public safety	x					x				x	3
10	City guides			x		x	x					3
11	Currency exchange		x					x				2
12	Rentals/Couch Surfing			x					x			2
13	Bike maps/Biker portal				x		x					2
14	Civic empowerment, government communication						x				x	2
15	Commercial offers/catalogs/facility location					x	x					2
16	Urban Game/Adventure						x		x			2
17	Measurements		x									1
18	Translation		x									1
19	Wifi Finder		x									1
20	Local news			x								1
21	Nextdoor/neighborhood			x								1
22	Run apps				x							1
23	Sightseeing walks				x							1
24	Walc – walking by landmarks				x							1
25	Accessiblity						x					1
26	Health						x					1
27	Parking						x					1
28	Sharing, borrowing						x					1
29	Carbon footprint/Pollution metering						x					1
30	Discount shopping/living							x				1
31	Integrated smart city package										x	1
32	Smart building monitoring										x	1
33	Big data on customer behavior										x	1

Source: authors.

A key question that can be raised immediately is whether there are any integrated city apps that encompass many of the features currently dispersed across several providers. The integration of features in a "super app" could provide additional value for users through the "one-stop shop" experience, as well as for the city itself, by gathering a larger community of users with various needs that are presently covered in single apps. Large communities can then be managed more efficiently with respect to any form of municipal communication, service provisioning and commercialisation. Examples of attempts at providing holistic city applications include:

Figure 7. Examples and Functional Scope of Holistic City Applications

Application Class	Sample	Functional Scope
1. **Dedicated city applications** – meant to be offered and operated by the municipalities	stadtsindwir.de appsforcities.de heimat-digital.com smart-village.app cosmema.de alto.de varaamo.hel.fi sentilo.io gisa.de	events calendar, news portal, job market, transportation, booking meetings for public services, digital inhabitant services, digital engaging of the inhabitants and reporting issues, maps, lodging, tourist attractions, places of interest, shopping guide, societies, bike and trekking tours, information on environmental protection, services for special groups (elderly, disabled, children), property advisory and management, city council governance, best school routes, immigration services, management of cemeteries, waste and recycling management, social media integration, emergency notification via push
2. **Commercial city applications** run be companies, especially payment processors	skycash.com flowbird.group smartappcity.com foursquare.com cashfinder.com	public transportation, parking booking and payment, highway/road fees, tickets for public events, insurance, ratings of public places and services

Source: authors.

A key observation that can be made based on the above samples is that several technology providers actively explore a holistic approach to city applications, already providing a broad range of services. At the same time, there is not a single provider that covers all functional areas of the applications, possibly due to a lack of interest or investment priorities. Commercial applications remain largely in the space associated with financial flows, thriving on payment-based business models. The potential for growth of both groups of applications can be seen as very high – both in terms of functional scope and integration of public and commercial domains towards an ever-increasing customer experience, especially with respect to financial flows that are linked to city services.

The next goal of "100% of citizens have access to medical records online" maps well to the "smart healthcare, health, connected health" functional group of the smart city. Although the EU idea is linked to the countrywide healthcare systems, the units of its architecture (e.g. hospitals, doctors, nursing homes) are hosted in municipalities; therefore, strong alignment of the global and local policy is mandatory. On the technical level, management of the medical records is largely driven by advances in big data processing combined with online services, all secured for the protection of citizens' privacy rights.

The third goal of the cardinal point on the digitalisation of public services is related to the assurance of digital identity, with the digital ID to be used by 100% of citizens. While this is understood as a country/EU ID, equipped with digital authentication and authorisation (via secure digital identity proofing and signature) – the concept of the digital ID can also be extended to municipally relevant identification functions. Further increases in the usage of the apps lead us towards a world where digital literacy

might be a must-have for living or staying in a city. This could possibly include the mandatory registration and usage of a city ID, which could mimic the nationwide system of citizen registration and identification, however with a legal construct to support city-related services, as it would not replace the national ID, but rather function in parallel to it. Various schemes of privileges for confirmed citizens are already present – e.g. citizens who pay local taxes are allowed to visit city attractions such as museums or swimming pools either for free or at a discounted price. The use of a simple city ID at the point of consumption of services would also facilitate extensive abilities for data mining on that usage, allowing not only for the optimisation of the city's offer, but also to make it more accessible and safer.

Another step in a city where citizens are subject to registration could be made by introducing a "city account", where the activity of the citizen would be recorded for future use, including information on the consumption of services, taxation or communication with the organisational units of the city. In the concept of a "city account", the financial aspect could be integrated to create a single place of interaction between municipal management and the inhabitants. One can easily imagine a model where citizens consume services (such as transportation, use of sports facilities, car/bike sharing or waste disposal) and are billed jointly at the end of a settlement period or instantly, based on pre-paid wallets. Naturally, such solutions would compete directly with standard commercial payment processors, but in the long run could bring savings to both municipalities and their inhabitants.

Based on the behavioural patterns of citizens, visible on their accounts, municipalities could consider developing scores that would be used, for example, in risk pricing of municipal (such as rent on communal housing, rental of city property for events) or third party services[26] (such as insurance or loans) or providing selected services with discounts or free of charge (e.g. frequent usage of city bikes could be rewarded with additional free time). Correspondingly, inhabitants with frequent offences (e.g. parking tickets, late payments, disturbances) could be handled in a "sheriff" way that would foster improvement in their behaviours (e.g. higher parking tickets, no access to selected services). Obviously, such ideas would have to be implemented with respect for human rights and freedoms or in environments that assume the application of a rule system subject to mandatory approval before entering or inhabiting a city. We must also be aware that any non-anonymous tracking must be subject to the highest standards of data protection and cyber security to prevent any abuse.

In summary of the chapter, we can conclude that the proposed functional model of the smart city and the framework of digital city intelligence are well integrated with the overall EU digitalisation strategy, as outlined in the Digital Europe programme. This provides a strong motivation for the implementation of digital solutions and the development of smart cities that contribute to the smart European Community.

[26] Selected municipal information is used for scoring purposes by financial institutions; for example, a family that inhabits a prestigious part of a city may be seen as a target for selected financial products or considered a less risky credit-taker due to the expected high value of the assets held.

CONCLUSIONS

Based on the analysis undertaken in this article, one may conclude that the Smart City concept is not just a vivid vision of the future, but a tangible set of changes and trends that alter the way cities operate. The role of digitalisation is key in delivering improvements in the comfort of life and overall municipal efficiency. As cities migrate to a new digital form, we observe the digitalisation of every functional area of municipal life, which, equipped with more precise information, increases their agility and precision, making them "smarter" or more intelligent.

The functional model of a smart city and the framework of digital city intelligence can be used in further research and practical work, especially in relation to the presented EU digitalisation goals and expectations of further waves of changes that will affect municipalities. It can also serve as a basis for other studies of public services, for example at the national level.

The concept of a smart city holds strong potential for further development, especially regarding the integration of various data sources and using data insights to better serve the inhabitants and society. Increasing the "smartness" is a mandatory condition for enabling innovation and optimisation of life in cities. To support this development, cities will need to create a recruitment pipeline of digital engineers and continue to educate their inhabitants and visitors. This effort can be fuelled by investing in educational programmes to develop local talent or by creating an attractive living offer to bring in external skills.

The infrastructure of a standard city is permanently extended with digital platforms. Traditional networks of water pipes or electrical wires are followed by strands of fibre optics, linking the city into an enormous network of devices and their users. This tight and geographically limited network offers many opportunities for collaboration and joint problem-solving aimed at improving the quality of life for all who are permanently or partially spending their time in the city. For many, both individuals and organisations or companies, a city may be the place where they spend most of their lives, so making this experience worthwhile is an important goal.

There is a saying attributed to the emperor Augustus, who reigned at the time of a massive societal change sparked by the birth of Jesus Christ (27 BC to 14 AD): "Urbem lateritiam invenit, marmoream reliquit" (translated from Latin: he found a city of bricks and left a city of marble). The city managers of today have a chance to deliver similar greatness to the municipalities they manage, but this time not with marble, but with digitalisation and "smart" practices across all municipal activities. An important assumption is, however, that the intelligence cannot be built only once – it needs to be continuously improved and kept alive, building resilience and readiness for the next waves of changes within economic and social progress.

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