D.2.1 Design of Health and Smart City Ecosystem Framework

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ATHIKA

1 Concept of a Health and Smart City Ecosystem

Countries around the world are seeking to achieve economic growth that is smart (innovation-led), inclusive, and sustainable. There is a set of definitions that put emphasis just on one urban aspect (technological, ecological, etc.) leaving apart the rest of the circumstances involved in a city. This group of mono-topic descriptions are misunderstanding that the final goal of a Health and Smart City is to provide a new approach to urban development in which all aspects are treated with the interconnection that takes place in the real life of the city. Improving just one part of an urban ecosystem does not imply that the problems of the whole are being solved.

The aim of Task 2.1 reported in this document is to provide a methodological background for the development of a health and smart city ecosystem framework which will be tested during the next work packages of Erasmus+ project ATHICA and will be used as learning material of training programmes. For that, the concept of health and smart city is discussed in this section. The next section discusses health and smart city ecosystem layers, as well as its dimensions and finishes with the proposed framework for health and smart city ecosystem. Finally, this document ends with the example list of metrics which can be used for the analysis of different health and smart city challenges.

The roots of the smart city term can be found in the late nineties, however since 2005, when the main ICT global players (CISCO, Siemens, IBM, etc.) highlighted the integration of information systems with urban processes, the term has evolved to a more complex concept (Ferro at all., 2013).

"A city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." Caragliu et al. (2009)

The growing number of technological devices and the improvements in the ability to process the data gathered from these devices with minimum error attracted the attention of health and care stakeholders. Indeed, **smart health is the provision of health services using the sensing capabilities and infrastructures of smart cities.** Thus, **smart cities have to provide the necessary contextual framework for the right management and development of smart health**. For example, smart health requires the use of sensors in smart devices for proper monitoring of the health status of individuals living within a smart city (Figure 1). In this case, the smart city infrastructure is a set of networked dedicated or non-dedicated sensors, data storage, analytic centres, interventions based on the results of analysis. Smart health systems make use of devices with embedded sensors (as non-dedicated sensing components) for environmental and ambient data collection such as temperature, air quality index (AQI) and humidity. In addition, wearables and carry-on sensors (as the dedicated sensing components) are also utilized to acquire patient-generated healthcare data. Both dedicated and non-dedicated sensory data are transmitted to the data centres as the inputs for processing and further decision-making processes. To achieve this goal, the already existing smart city framework coupled with IoT networks needs to be leveraged. (Obinikpo & Kantarci, 2017)

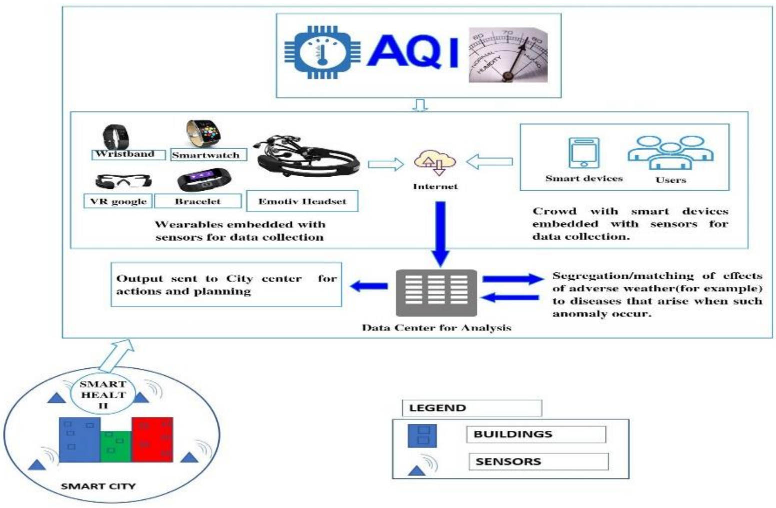

Figure 1 Smart health embedded within a smart city. (Obinikpo & Kantraci, 2017)

Smart cities need an integrated approach in order to harness the full potential of smart infrastructure. Integrated approaches are effective tools for capturing the dynamic relations between people, policies and environments. It is necessary to define the framework of health and smart city first in order to capture the healthcare domain in a smart city ecosystem. The next section is dedicated to the development of a conceptual health and smart city ecosystem framework.

2 Health and smart city ecosystem framework

For the development of the conceptual health and smart city ecosystem framework various studies and research articles were examined. As it was discussed in the previous section, a well-established smart city ecosystem is a necessary condition for the development of smart health and care services. Thus, a proposed health and smart city ecosystem framework is based on the smart city ecosystem layers and dimensions with the proposed health and care contextual perspective.

2.1 The layers of the health and smart city ecosystem

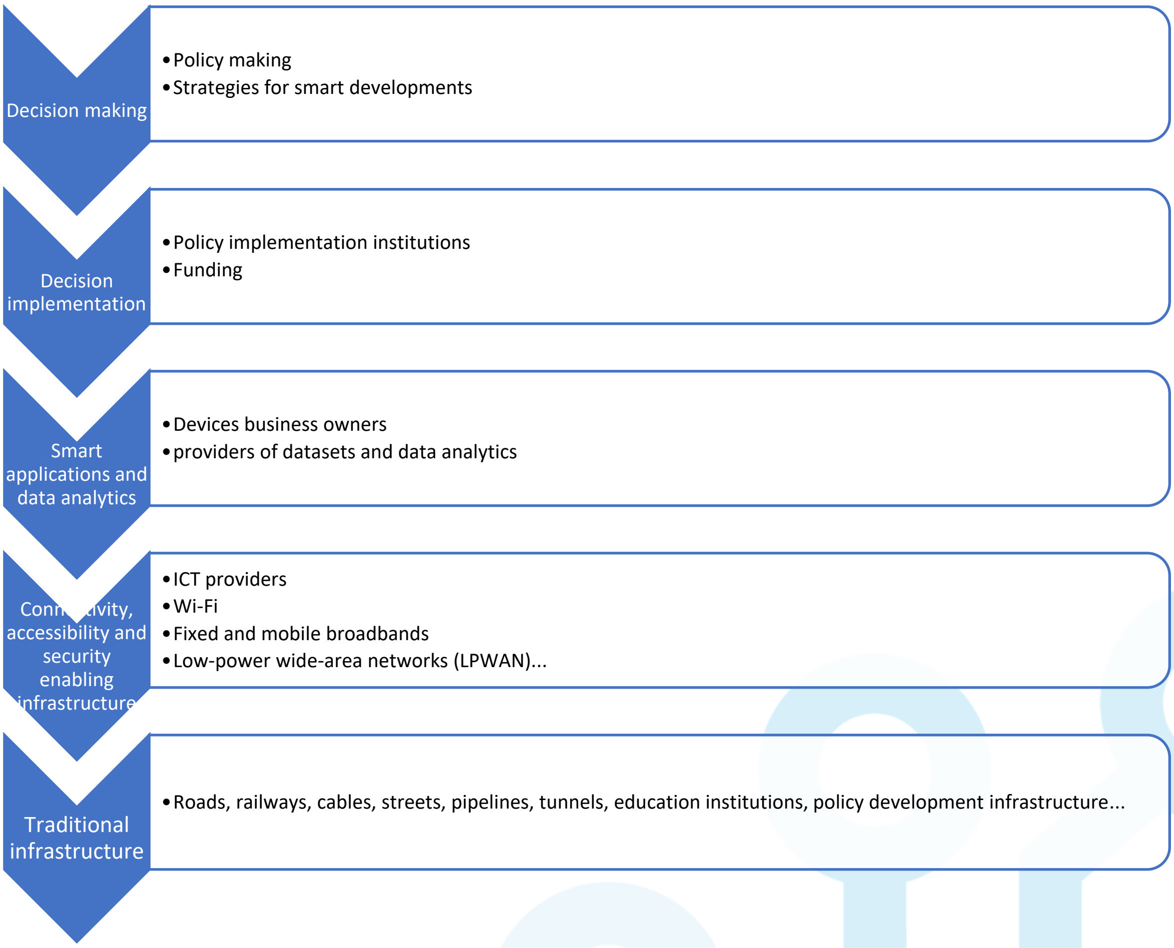

Figure 2 Smart city ecosystem layers

2.2.1 Decision making

Policies and partnerships are the catalysts of the smart city. They augment and amplify limited city resources and capabilities, scale faster, while minimizing risk. Effective smart city ecosystem architects unite the needs

of policymakers, technologists and innovators to create sensible policies that create the right outcomes. They proactively seek out public and private collaborators and build sustainable and synergistic partnerships.
Smart cities plan and execute investments in their territories on the basis of medium- to long-term integrated strategies and target sustainable development. Political components represent various political elements (city council, city government, and city major) and external pressures such as policy agendas and politics that may affect the outcomes of IT initiatives. Institutional readiness such as removing legal and regulatory barriers is important for smooth implementation of smart city initiatives.
Good smart city governance contains effective decisions and adequate incentives when all citizens act in their own self-interest and make desired outcomes. This can be achieved by having a clearly developed vision which characterises what values need to be generated. However, due to an interconnected, fast-evolving and unpredictable global environment, city governments no longer have in-house sufficient resources and information, thus Ferro at all. (2013) suggest to enable an "extended governance" form of governance, when intelligence of actors residing outside governmental boundaries is used for the management of public resources. ICT technologies allow to turn the eyes and the brains of people to oversee the intricacy of city processes and functions that would otherwise be impossible for local administrations to constantly monitor. It may significantly improve policy making cycle by making it more demand-driven and by demonstrating existing problems by multitude of perspective and cultural backgrounds, simultaneously reducing the risk of biased or oversimplified problem setting. (Ferro at all., 2013)
Challenges:

- Ensuring the quality of big sensed data acquisition (Obinikpo & Kantarci, 2017)
- The ability to leverage these data is an important aspect of smart health development (Obinikpo & Kantarci, 2017)
- Building a sustainable smart city structure (Obinikpo & Kantarci, 2017)
- Balancing three overriding concerns: achieving a high quality of life for all citizens, maintaining economic competitiveness and protecting the natural environment (Ferro at all., 2013)
- Governments no longer have in-house sufficient scope, resources, information or competencies to respond effectively to the policy needs of an interconnected, fast-evolving and unpredictable global environment (Ferro at all., 2013)
- Possibility of predictions
- Muti-disciplinary sectors involved in the decision taking

2.1.2 Decision implementation: management and operations

A white paper on European Governance introduces the concept of good governance based on five pillars: openness, participation, accountability, effectiveness and coherence (European Governance: a white paper, 2001). Citizen participation is a vital factor for a good governance of a smart city which becomes achievable with the tremendous development of ICT (Ferro at all., 2013). Ferro at all. (2013) proposed a synoptic framework (figure 3) which discusses the role of ICT in the governance of the transition process that smart cities will have to undergo. The framework provides a unifying view of ICT role as well as of the ingredients necessary to turn technological infrastructure into value for society. It demonstrates the relationship between the necessary inputs (the foundation), the expected outputs (the pillars), and the desired outcomes (the roof) of a smart and sustainable urban ecosystem. The framework can be used for the definition of smart city strategies and the design of impact assessment frameworks for the evaluation of a city performance against a number of long-term policy objectives to be operationalized in terms of value creation. (Ferro at all., 2013)

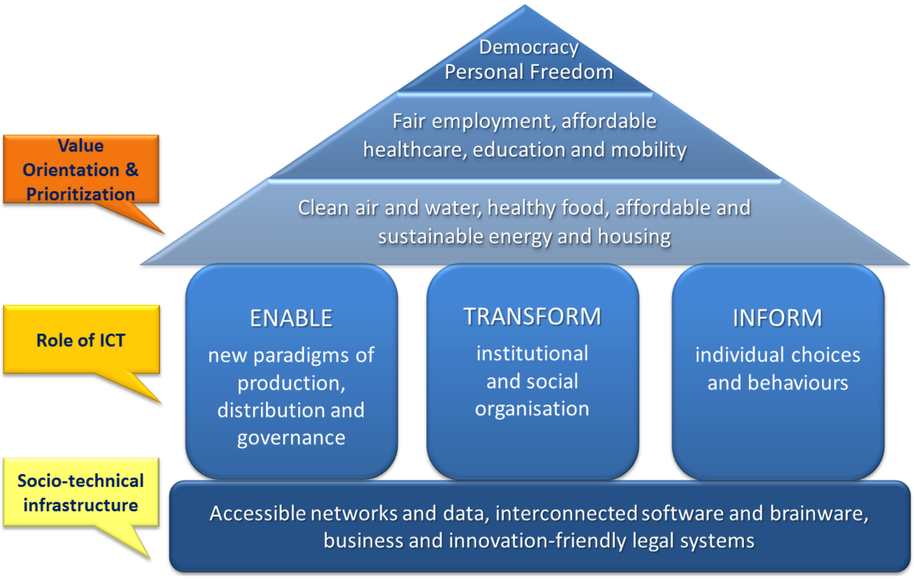

Figure 3 The Smart City House: ICT in Smart Cities Governance (Ferro at all., 2013)

Thus, governments have to change the traditional approaches to meet their responsibilities for the built environment, energy, telecommunications, transportation, water and waste management, health and human service, public safety and payments and finance. There are different ways of investing in smart cities where the majority of private investment, so far, has been concentrated in the transport and mobility sectors. This investment is usually directly in tech start-ups or through venture capital funds. Cities can influence the pace and type of smart development by creating an environment—through regulation, subsidies, etc—that supports private-sector development (The Economist, 2018). Often cities are unable to solicit private investment on their own, as the long-term instruments that institutional investors require or the cities' liabilities are connected with the national government. City governments tend to rely on the financial models they have always used for traditional infrastructure, such as public-private partnerships (PPP) and private financing initiatives (PFI), or by issuing bonds (municipal revenue bonds, which are backed by the revenue stream of a specific project, or general obligation bonds that can be repaid through a variety of tax sources). Projects where government and investors both have an ongoing shareholder role may increase the likelihood of success. Mature financial markets and well-established regulatory systems are critical to allow innovation and investment to thrive (The Economist, 2018).

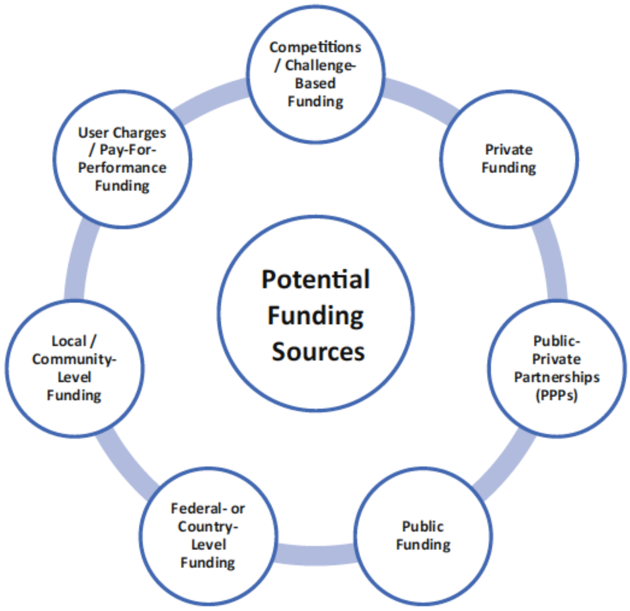

Figure 4 The potential funding options for Smart City projects (Galati, 2018)

As citizen participation is a vital factor for a good governance of the health and smart city, assurance of ethical decisions and management becomes inevitable. A number of research projects have analysed the ethical implication of Smart Health (e.g. EU FP7 PHM-Ethics project). For instance, eight themes describing the ethical implications of PHM (PHM refers to any electronic device or system that monitors and records data about a health-related aspect of a person's life outside a hospital setting) were identified through a review of 68 academic articles concerning PHM by the proceedings of ETHICOMP 2011. (Mittelstadt, Fairweather, McBride & Shaw, 2011). The eight identified ethical themes include **privacy, autonomy, obtrusiveness and visibility, stigma and identity, medicalisation, social isolation, delivery of care, and safety and technological need**.

Large amounts of medical data may be transferred from the home to the hospital or clinician. This may result in what Habermas (1992) terms the **'colonisation of the lifeworld'** in which the private concerns and activities of the patient become the concerns of the public institution which draws information from the patient's private world and seeks to influence and change activities within the patient's home environment. The ethical dilemmas are always embedded into fundamental questions such as identity and privacy –or human dignity (human beings recognised "ends" in themselves), free will and autonomy, as well as responsibility with others and solidarity (expanding compassion to larger communities).

Before going deeper on the more specific ethical issues related to Smart Health, it is convenient to provide an overall framework to present ethics in relation to technological change (a core of innovations linking Internet of Things, BigData and Artificial Intelligent Systems), and adopt a "vocabulary" rich enough to allow us to produce meaningful "narratives".

Ethics can be considered from different philosophical perspectives –from "teologist" as first conceptualised by Aristotle; "utilitarian" by liberal thinkers such as Bentham and Mill, or more recently by Rorty and neopragmatists; "deontologist" by Kant, or more recently Rawls, and Habermas; or "emotivist" by Hume, or Nietzsche. Different ethical approaches influence differently our views in relation to how to apply smart health and how it should be regulated (understanding laws as "minimum ethics"). Smart Health Ethical framework see Annex No. 1

Challenges:

- Best outcomes to develop and finance smart cities come from partnerships and co-ordination with mayors, national planning agencies, private-sector developers, investors (whether institutional or venture capital) and citizens. But what constitutes success for a smart city project will vary, as what is "smart" will be different for different cities.

- The return on investment and the definition of success may differ based on perspective: societal versus financial.
- Many cities' inability to solicit private investment holds back smart city projects. Most cities do not have the technical or physical capacity to prepare projects for investment.
- Barriers to smart city creation and success will vary by market type; corruption may be an obstacle in emerging markets, whereas privacy may pose more of a problem in developed markets.
- Ethical privacy assurance

2.1.3 Smart applications and data analytics

Technology alone is not enough for the development of smart city. There is a need for diverse complementary investments to new policy frameworks and organizational change or training, because ICT itself is only an instrument which could be considered as valuable only when it allows to attain a set of objectives for a specific target group of stakeholders. Thus, essential value for smart city is created by innovative solutions developed, with the help of ICT, by public and private organizations (Ferro at all., 2013).

Cities have become actual "data engines" which constantly produce and consume data. A huge variety of devices (sensors and mobile equipment) and applications act as data sources, which record multiple everyday activities, from everywhere and produce large scale of heterogeneous datasets (Moustaka et al., 2018). Data produced in the city's operation context is considered as a significant asset for the deployment of Smart Cities (SC) (Kitchin, 2014). It impacts the emergence of a novel sector: the so– called "data economy". In SC data economy, new business models, which utilise and correlate data to reveal their analytics, will drive the cities future. More specifically, urban data collected from the Internet–of–Things (IoT) infrastructures and analysed with different methods can largely improve several monitoring and response tasks and services (Chun et al. 2014). SC data impact multiple services in various inter–disciplinary domains such as smart transportation, resource efficiency, crowd–source-based services, etc. (Djahel et al. 2015). For example, Transport Management Systems (TMS) operation is based on the use of real–time data (e.g., social media data for the detection of traffic congestions, road accidents, etc.) and on new technologies (e.g., smart cars, smartphones, etc.), aiming to save time and ensure the citizens' road safety (Djahel et al. 2015). Marr (2017) found that there are 4.9 billion connected objects, which are expected to reach or exceed 50 billion in 2020 and over 1.4 billion smartphones. Generally, the construction of smart city applications and data analytics can be divided into three levels, including the construction of public infrastructure, construction of public platform for smart city, the construction of application systems.

ICT can practically contribute to the improvement of the governance of the life of city through such domains as budgeting (through easer and veracious identification of priorities), emergency management, urban planning and management, environment and energy management, Healthcare (e.g. possible alternative policies aimed at reducing the impact of aging populations on the healthcare systems, diffusion of contagious illnesses on robust estimations and real-time data rather than on more emotional approaches) (Ferro at all., 2013).

Quality healthcare is among the fundamental requirements of smart cities. Appearance of the IoT fostered development of smart connected health systems which became an integral component of smart city services. Figure 5 shows that data acquisition and processing are essential for the effective healthcare delivery. The data can be acquired through wearables and carry-ons which are in various forms. Also, data for the delivery of effective healthcare services are acquired through probes and mobile crowd-sensing (see figure 5) (Obinikpo & Kantarci, 2017).

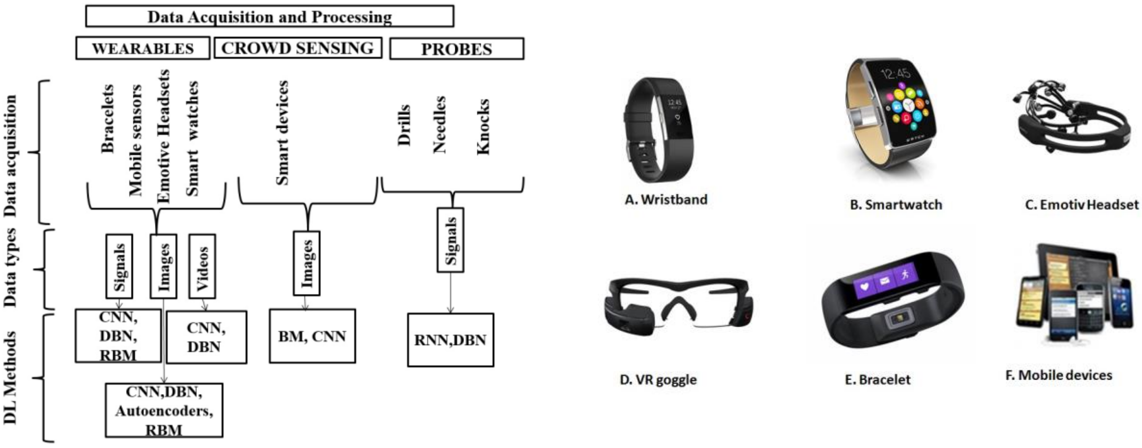

Figure 5 Examples of sensory data acquisition and processing techniques and examples of wearables/carry-ons. (Obinikpo & Kantarci, 2017)

Challenges:

- \- Data sources and types
  - \- sources ranging from power grids to traffic light
  - \- different sources generating different type of data
  - \- ensuring the accuracy of the acquired data
- \- Data and information sharing
  - \- raw data is huge to share
  - \- difficulty in knowing what to share
  - \- ownership, governance, access, and legitimate use of data
- \- Security and privacy
  - \- crucial information which need to be secured.
  - \- security and adversarial vulnerability of infrastructure and predictive models/algorithms
- Data bias may discriminate against genders, ethnicities, health backgrounds.
- \- Cost
  - \- expensive data handling
  - \- new technological requirements
- \- City Population - increase in big data volume.
- In healthcare:
  - interoperability of electronic health systems and digital health solutions
  - analytic and clinical validity of enabled predictions in the real-world setting
  - availability of timely, safe, efficacious, and cost-effective smart interventions
  - more successfully implemented case studies are needed
  - data bias may reduce patient safety and the effectiveness of interventions and destroy public trust.

2.1.4 Connectivity, accessibility and security enabling infrastructure

Only a connected city can become a smart city. Consequently, network of data-collecting sensors and devices, comprehensive broadband and wireless networks, and platforms on which data can be stored and shared have to be developed. Fixed and mobile broadband, low-power wide-area networks (LPWAN) and free Wi-Fi throughout a city are needed to support the ever-growing data usage. Smart technologies generate huge volumes of data; however this data only becomes useful once it is made available to actors who can build smart applications. It can be achieved through the existence of open data platforms (Smart cities..., 2018).
While connectivity is mission-critical, today's smart city ecosystem architects are faced with several challenges. In the smart city, connectivity is not an option nor is it someone else's problem to solve. Smart

city architects must lead with new policies and public-private partnerships. They must develop new innovative investment strategies, and create new connectivity ecosystems with city-owned, service provider owned, and community-owned infrastructure. The availability and quality of the ICT infrastructure are important for smart cities. Indeed, smart object networks play a crucial role in making smart cities a reality. ICT infrastructure includes wireless infrastructure (fiber optic channels, Wi-Fi networks, wireless hotspots, kiosks), service-oriented information systems.

Challenges:

- Unequal access to basic connectivity
- Inadequacy of existing services
- A confusing array of emerging LPWAN options.
- power consumption
- data security.

2.1.5 Traditional infrastructure

City infrastructure consists of structures and services that act as a basis for the economy and quality of life of a city. This includes both hard infrastructure such as bridges and soft infrastructure such as IT services.[1] The most common infrastructure is the system for transportation of water (pipes, canals, tunnels, ditches, water bridges and pipelines), heating system, railways, streets, lighting, IT infrastructure, telecommunications infrastructure, security infrastructure, hospitals, education institutions, policy infrastructure and etc. Developed traditional infrastructure is a precondition for the smart city development.

Challenges:

- Outdated traditional infrastructure which is hard to combine with high-tech tools
- In healthcare:
    - heterogeneity of locally implemented digital health/ EHR systems that may not integrate with smart healthcare interventions-

2.2 Dimensions of the health and smart city ecosystem and its operationalization[2]

2.2.1 Mobility

- Congestion pricing: Fees for private car usage in certain areas, during times of peak demand, or both.
- Intelligent traffic signals: Improvement of overall traffic flow through dynamic optimization of traffic lights and speed limits, leading to higher average speeds on roads and less frequent stop-and-go conditions. Includes traffic light pre-emption technology, which gives priority to emergency vehicles, public buses, or both.
- Real-time public transit information: Real-time information about arrival and departure times for public transportation modes, including informal bus systems.
- Real-time road navigation: Real-time navigation tools for choosing driving routes, with alerts for construction, detours, congestion, and accidents. Largely applies to those driving alone or in a car pool.
- Predictive maintenance of transportation infrastructure: Sensor-based monitoring of the condition of public transit and related infrastructure (such as rails, roads, and bridges) so that predictive maintenance can be performed before breakdowns and disruptions occur.
- Digital public transit payment: Digital and touchless payment systems in public transportation that allow for prepayment and faster boarding. Includes smart cards and mobile payments.

[1] https://simplicable.com/new/city-infrastructure

- Autonomous vehicles: Vehicles outfitted with sensors and software to operate themselves; full self-driving capability is achieved when human intervention is not expected to take control at any point.
- Bike sharing: Public-use bicycles, either in docking hubs or free-floating, to provide an alternative to driving, public transit, and private bike ownerships. This option can bridge the first-mile / last-mile segment when public transit does not take a commuter from door to door.
- Car sharing: Access to short-term car use without full ownership; can be round-trip (station-based), one-way (free-floating), peer-to-peer, or fractional.
- Demand-based microtransit: Ride-sharing services with fixed routes, fixed stops, or both, often supplementing existing public transit routes. Algorithms use historical demand to determine routes, vehicle size, and trip frequency. May include options to reserve seats.
- E-hailing (private and pooled): Real-time ordering of point-to-point transportation through a mobile device. Pooled e-hailing involves matching separately called rides with compatible routes dynamically to increase vehicle utilization (that is, local optimization of real-time demand).
- Integrated multimodal information: Real-time information about price, time, and availability of transportation options across many modes.
- Parcel load pooling: Online matching of demand for deliveries with the available supply of trucking capacity. By maximizing vehicle utilization, fewer trucks make a greater number of deliveries.
- Smart parcel lockers: On-site drop boxes at locations where people can pick up packages using individual access codes sent to their mobile devices.
- Smart parking: Systems that guide drivers directly to available spaces; can also influence demand through variable fees.

2.2.2 Security

- Predictive policing: The use of big data and analytics (including social media monitoring) to predict where and when crimes are likely to happen with greater precision. These systems are used to deploy police patrols and target prevention efforts.
- Smart surveillance: Intelligent monitoring to detect anomalies based on visual feeds including facial recognition, smart closed-circuit TVs, and license plate recognition.
- Real-time crime mapping: Technology used by law enforcement agencies to map, visualize, and analyze crime incident patterns. Information and intelligence gathering serves as a management tool for allocating resources effectively and creating accountability among officers.
- Personal alert applications: Applications that respond to emergencies by alerting emergency response services, loved ones, or both. Devices (such as personal safety wearables, car crash detectors, and fall alert systems) may transmit location and voice data.
- Gunshot detection: Acoustic surveillance technology that incorporates audio sensors to detect, locate, and alert police agencies to gunfire incidents in real time.
- Data-driven building inspections: The use of data and analytics to focus inspections on buildings with the greatest potential risks (for example, prioritizing commercial buildings for fire code inspections and homes for lead inspections).
- Disaster early-warning systems: Technology designed to predict and mitigate the effects of natural disasters such as hurricanes, earthquakes, floods, and wildfires.
- Emergency response optimization: The use of analytics and technology to optimize emergency response call processing and field operations, such as the strategic deployment of emergency vehicles.
- Home security systems: Security systems that monitor homes and alert users, emergency response services, or both to unusual activity.
- Body-worn cameras: Wearable audio, video, or photographic recording systems, typically used by police officers to record incidents and police operations.
- Crowd management: Technology to monitor and, where necessary, direct crowds to ensure safety.
- Number of web-based attacks
- Number of online theft money

- Online theft of information
- Number of computer viruses

2.2.3 Health & Wellness

- Data-based public health interventions for maternal and child health: The use of analytics to direct highly targeted health interventions for at-risk populations (in this case, identifying expectant and new mothers to drive educational campaigns about pre- and post-natal care).
- Data-based public health interventions for sanitation and hygiene: The use of analytics to direct highly targeted interventions, such as understanding where to increase rainfall absorption capacity or collecting crowdsourced data on gaps in sanitation systems.
- First aid alerts: Technologies that alert bystanders trained in CPR so that cardiac arrest victims receive prompt and critical care.
- Infectious disease surveillance: Data collection, analysis, and response to prevent spread of infectious and epidemic diseases. Includes awareness and vaccine campaigns (for example, for HIV / AIDS).
- Integrated patient flow management systems: Real-time hardware and software solutions that provide visibility into where patients are in the system to improve hospital operations and coordinate utilization on a city or multiple-facility level.
- Lifestyle wearables: Wearable devices that collect data on lifestyle and activity metrics and inform the wearer; may promote exercise or other aspects of a healthy lifestyle.
- Online care search and scheduling: Tools that assist in selecting payors and providers with financial and clinical transparency.
- Real-time air quality information: Sensors to detect and monitor the presence of air pollution (outdoor, indoor, or both) in real-time. Individuals can view the information online or on a personal device and choose to modify their behavior accordingly.
- Remote patient monitoring: The collection and transmission of patient data for analysis and intervention by a health-care provider in another location (for example, monitoring vitals or blood glucose readings). Includes medication adherence technologies that assist patients in taking medications as recommended by their healthcare provider.
- Telemedicine: Virtual patient and physician interaction through audio-visual technology.

2.2.4 Education

- Smart and innovative population. New skills for working with the big urban data sets that drive these innovations must be taught to upcoming generations to ensure that they can be active smart city citizens. Citizens must have a good understanding of sustainability issues and possess the essential skills for using large complex datasets (Wolff at all. 2015).
- Strong entrepreneurial ecosystem
- Universities work in close collaboration with businesses and local government to ensure development and test of new technologies, turn ideas into prototypes and unlock and analyse urban data for the good of a city's citizens whilst delivering digitally savvy graduates to the workplace.[2]
- Personalized learning. Which adjusts the style, content, sequencing, and pace of instruction to meet the needs and goals of each student.
- Online retraining programs to help millions of midcareer workers gain marketable new skills and find their way into new occupations.
- Digital hiring platforms (as mentioned above) to ensure that labour markets are as efficient and fluid as possible.

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[2] https://edtechnology.co.uk/Blog/how-will-higher-education-help-to-make-our-cities-smart/

2.2.5 Sustainability (Energy, water, waste)

- Dynamic electricity pricing: Dynamic adjustment of electricity prices to shave peaktime demand and reduce electricity generation cost. By reducing peak demand, cities can reduce the number of power plants that operate during peak hours.
- Smart streetlights: Connected and sensor-equipped energy-efficient streetlights (including LED) that optimize brightness and reduce maintenance needs. Smart streetlights can be equipped with speakers, gunshot detection sensors, and other features to enhance functionality.
- Leakage detection and control: Remote monitoring of pipe conditions using sensors, and control of pump pressure to reduce or prevent water leakage. The early identification of leaks can prompt follow-up actions from relevant city departments and utility companies.
- Smart irrigation: Optimization of irrigation using analysis of information such as local weather, soil conditions, plant type, and so forth to eliminate unnecessary watering.
- Water consumption tracking: Feedback (via mobile app, email, text, and so forth) on a resident's water consumption to increase awareness and reduce consumption. Smart water meters allow utility companies to measure consumption remotely, reducing labor costs for manual meter reading. It also enables the potential for dynamic pricing.
- Water quality monitoring: Real-time monitoring of water quality (in mains, rivers, oceans, and so forth) with alerts delivered to the public via channels such as mobile app, email, text, or website. This warns the public against consuming or coming into contact with contaminated water and prompts cities and utilities to follow up promptly.
- Digital tracking and payment for waste disposal: Digitally enabled pay-as-you-throw systems; includes feedback (via mobile app, email, text, and so forth) delivered to users to increase awareness and reduce waste.

- Waste collection route optimization: The use of sensors inside trash bins to measure trash volume and direct the routes of garbage trucks. This application keeps garbage trucks from traveling to trash bins with little waste volume.
- Building automation systems: Systems that optimize energy and water use in commercial and public buildings by leveraging sensors and analytics to manually or automatically eliminate inefficiencies. Includes optimized lighting and HVAC as well as features such as access / security control and parking information.
- Distribution automation systems: Different types of smart grid technologies, including FDIR, M&D, Volt/Var, and substation automation, to optimize energy efficiency and the stability of the power grid.
- Home energy automation systems: Optimization of home energy consumption using smart thermostats, programmable and remote controllable electronic devices (smart home), and standby electricity control.
- Home energy consumption tracking: Tracking of residential electricity consumption with feedback delivered to the user via mobile app, email, or text to increase user awareness and encourage conservation. Also allows utility companies to measure electricity use remotely.

2.2.6 Economic development and housing

- Digital business licensing and permitting: Digitized process (such as an online portal) for businesses to obtain operating licenses and permits.
- Digital business tax filing: Channel for businesses to complete tax filing online.
- Digital land-use and building permitting: Digitization and automation of the application process for land-use and construction permitting, reducing approval time and increasing transparency.
- Local e-career centers: Online platforms for posting jobs openings and candidate profiles; may use algorithms to match compatible candidates with available jobs. Reduces job-hunting time and increases net new employment.
- Online retraining programs: Lifelong learning opportunities delivered in digital format, especially to help individuals who are unemployed or at risk of becoming unemployed gain new skills.

- Open cadastral database: Complete database of land parcels in the city, open to the public; enables a more efficient land market by creating transparency of available land and lowering the cost of land parcel registration.
- Peer-to-peer accommodation platforms: Digital marketplaces where individual hosts can list and rent out short-term accommodations.
- Personalized education: The use of student data to identify individuals who need additional attention or resources; potential to tailor learning environments for individual students.

2.2.7 Engagement & Community

- Digital citizen services: Digitization of citizen-facing government administrative services such as income tax filing, car registration, or applying for unemployment benefits. Includes digitization of the user journey as well as back-end support functions as needed.
- Local civic engagement applications: Public engagement in city affairs through digital apps. May include reporting nonemergency nuisances and maintenance needs (for instance, reporting broken streetlights via a 311 app), giving input on policy decisions, participating in digital city initiatives (such as open data hackathons), and interaction with city officials and departments on social networks.
- Local connection platforms: Websites or mobile apps that help people connect with and potentially meet others in their community. May be used to find people with similar interests and hobbies, to connect with neighbours, and so on.

Table 1 Framework of health and smart city ecosystem (developed by the authors according to literature review and Chan Benson, 2018; McKinsey, 2018).

Dimension Layer	Mobility	Security	Health & Wellness	Education	Sustainability (Energy, water, waste)	Economic development and housing	Engagement & Community
Decision making	Is there a smart mobility strategy/vision which cares about effectiveness and efficiency of Health and Wellness services? Is big data and analytics used for predictive policing?	Is there a smart security strategy/vision which cares about effectiveness and efficiency of Health and Wellness services? Is big data and analytics used for predictive policing?	Is there a smart Health and Wellness strategy/vision? Is big data and analytics used for predictive policing?	Is there a smart education strategy/vision which cares about effectiveness and efficiency of Health and Wellness services? Is big data and analytics used for predictive policing?	Is there a smart sustainability strategy/vision which cares about effectiveness and efficiency of Health and Wellness services? Is big data and analytics used for predictive policing?	Is there a smart economic development and housing strategy/vision which cares about effectiveness and efficiency of Health and Wellness services? Is big data and analytics used for predictive policing?	Is there a smart engagement and community strategy/vision which cares about effectiveness and efficiency of Health and Wellness services? Is big data and analytics used for predictive policing?
Decision implementation: management and operations	Are there PPP which develop smart mobility to make Health and Wellness services effective and efficient?	Are there PPP which develop smart security to make Health and Wellness services effective and efficient?	Are there PPP which develop smart Health and Wellness services?	Are there PPP which develop smart education to make Health and Wellness services effective and efficient? Do education institutions care about development of smart city citizens?	Are there PPP which develop smart sustainability projects to care about Health and Wellness of City Citizens?	Are there PPP which develop smart economic development and housing projects to make Health and Wellness services effective and efficient? Are there smart services which serve for the effectiveness and efficiency of Health and	Are there retraining and education programs for city citizens to develop smart citizenship?

						Wellness sector?	
Smart applications and data analytics	Are there innovative mobility solutions developed, with the help of ICT, by public and private organizations to make Health and Wellness services effective and efficient? Is there urban mobility data collected and used to make Health and Wellness services effective and efficient?	Are there innovative security solutions developed, with the help of ICT, by public and private organizations to make Health and Wellness services effective and efficient? Is there urban security data collected and used to make Health and Wellness services effective and efficient?	Are there innovative Health and Wellness sector development solutions developed, with the help of ICT, by public and private organizations? Is there urban Health and Wellness data collected and used to make services effective and efficient?	Are there innovative education solutions developed, with the help of ICT, by public and private organization to make Health and Wellness services effective and efficient? Is there urban education data collected and used to make Health and Wellness services effective and efficient?	Are there innovative sustainability ensuring solutions developed, with the help of ICT, by public and private organization to make Health and Wellness services effective and efficient? Is there urban sustainability data collected and used to make Health and Wellness services effective and efficient?	Are there innovative solutions developed for economic development and housing, with the help of ICT, by public and private organizations to make Health and Wellness services effective and efficient? Is there urban economic development and housing data collected and used to make Health and Wellness services effective and efficient?	Are there innovative engagement solutions developed, with the help of ICT, by public and private organization to make Health and Wellness services effective and efficient? Is there urban engagement and community data collected and used to make Health and Wellness services effective and efficient?
Connectivity, accessibility and security enabling infrastructure	Are there connectivity technologies and platforms developed which support smart technologies, which generate city mobility data?	Are there connectivity technologies and platforms developed which support smart technologies, which generate city security data?	Are there connectivity technologies and platforms developed which support smart technologies, which generate city health and wellness data?	Are there connectivity technologies and platforms developed which support smart technologies, which generate city education data?	Are there connectivity technologies and platforms developed which support smart technologies, which generate city sustainability data?	Are there connectivity technologies and platforms developed which support smart technologies, which generate city economic development and housing data?	Are there connectivity technologies and platforms developed which support smart technologies, which generate city engagement and community data?
Traditional infrastructure	Is there traditional mobility infrastructure developed to make Health and Wellness services effective and efficient?	Is there traditional security infrastructure developed to make Health and Wellness services effective and efficient?	Is there traditional Health and Wellness infrastructure developed?	Is there traditional education infrastructure developed to make Health and Wellness services effective and efficient?	Is there traditional sustainable infrastructure developed to make Health and Wellness services effective and efficient?	Is there traditional economic development and housing infrastructure developed to make Health and Wellness services effective and efficient?	Is there traditional engagement and community infrastructure developed to make Health and Wellness services effective and efficient?

- This conceptual health and smart city ecosystem framework ensures a holistic and integrated way while enabling innovative collaborations to improve quality of life through Healthcare. It should serve as a background for the experts to aggregate the different city data streams in the context of Health and Smart cities framework. In the last section of this document some example metrics for smart city evaluation are presented.

2.3 Example Metrics for Smart City Evaluation

This section provides some example metrics for the evaluation of a smart city which was developed by McKinsey. However, it is worth noting that an example list of metrics can be endless and depends very much on the city's "smartness" development level as well as on the context of analysed challenge in the city. For example, when a challenge of ageing residents in the city is analysed, it is worth analysing such metrics as *Emergency response time (minutes per emergency call)*, *crime numbers directed towards older people*, *average mortality age in the city*, *the availability of doctors, local older people communities and etc.*

2.3.1 Safety

Three metrics were selected to measure safety:

- Fatalities (number per 100,000 residents): This metric does not consider all deaths. It focuses exclusively on three specific types of fatalities: intentional homicides, road traffic deaths, and fire deaths.
- Crime incidents (number per 100,000 residents): Incidents included are assaults (including sexual assaults), robberies, burglaries, and auto thefts. Burglaries involve unlawful entry into a building or residence, while robberies do not.
- Emergency response time (minutes per emergency call): This is the time that elapses from the moment an emergency call is received to the moment first responders arrive on the scene. This accounts for time spent in the call center as well as in the field and includes calls to the police, fire department, and paramedics.
- Geographic concentration of crime
- Share of homicides by firearm
- Share of road traffic deaths related to alcohol use
- Percentage of assaults by strangers
- Road congestion levels

2.3.2 Time and convenience

- Time spent commuting (minutes per person per workday)
  - Current congestion levels
  - Percent of congestion contributable to commercial vehicles (B2B and B2C)
  - Average public transportation waiting time
  - Average bus occupancy
  - Existing parking and traffic signal infrastructure
- Time spent interacting with government (hours per person per year).
  - Collecting necessary paperwork
  - Traveling to and from government agencies
  - Physically waiting in government facilities
  - Filling out and submitting forms
- Time spent interacting the healthcare system (hours per person per year).
  - Finding a physician and scheduling appointments
  - Traveling to and from healthcare facilities
  - Filling out forms
  - Sitting in waiting rooms

2.3.3 Health

The DALY (disability-adjusted life year) is the metric used to measure health. It is a single number that combines the burden of mortality and morbidity (nonfatal health problems) of a disease. It is the primary metric used by the World Health Organization to assess the global burden of disease[3]. It is the sum of years of life lost due to premature mortality (YLL) and years lost due to disability (YLD), which includes a weighting factor that reflects the severity of the disease. There is a wide variation in causes of mortality and morbidity, which differs across different cities.

The impact for each application is estimated by evaluating the individual drivers of health improvements. For example, remote patient monitoring may be broken down into four components:

- Increased quality of life from improved care management
- Reduced years of life lost from chronic disease
- Reduced years of life lost from deaths in intensive care units
- Increased quality of life for the elderly due to fewer falls

Each driver is then applied to the affected DALY's category and population. Finally, impact estimates are determined by drawing on several sources of data:

- Medical studies (used directly whenever available)
- Case studies from health institutions or manufacturers: Documented evidence from
- Hospitals, device manufacturers, or WHO on the impact of technology
- Interviews with doctors and health experts

In addition to the baseline differences in disease burden, other city characteristics drive differences in impact, including:

- The availability of doctors
- Daily average and peak PM2.5 levels (measures of air quality and pollution)
- Infant mortality rate
- Levels of physical activity

2.3.4 Environmental quality

Three metrics represent environmental quality:

- GHG emissions (kg CO2e per capita per year)
- water consumption (liters per capita per day)
- unrecycled waste (kg per capita per day).

Impact on the GHG emissions baseline was calculated for applications in several domains:

- Energy: The stationary emissions baseline is further categorized into sub-baselines by energy type (fuel or electricity) and use case (residential, commercial, industrial, street lighting, water utilities, and other). For each application, changes in both energy demand and emissions factor is considered for the affected sub-baselines. The impact of energy applications on non-stationary emissions is assumed to be negligible.
- Water: Water contributes to GHG emissions in two ways. The first is by producing wastewater, which generates greenhouse gases. The second is by consuming electricity for the operation of the water system, which produces GHG emissions when generated. It is assumed a percentage decrease in water consumption would translate to an equal percentage decrease in GHG emissions from wastewater and, in case of leakage, an equal percentage decrease in GHG emissions from electricity consumption.
- Waste: Waste contributes to GHG emissions in two ways. The first is through landfill and incineration. The second is through the emissions produced by waste collection vehicles. It is assumed a percentage decrease in waste would translate to an equal percentage decrease in GHG emissions from landfill and incineration and, in case of collection vehicles, an equal percentage decrease in GHG emissions from collection vehicles.
- Mobility: The primary way in which vehicles contribute to GHG emissions is through traveling distances. For each application that affect vehicle-kilometers traveled, it is calculated the change in emissions by considering changes in passenger-kilometers traveled by mode, average vehicle occupancy and utilization, and average emission factor by mode. Applications that affected commercial vehicle-kilometers were treated similarly, but calculated at a parcel level rather than passenger level. We assumed each city's current public transportation infrastructure was capable of accommodating additional passengers switching from other modes, without having to run additional vehicles.

- Vehicles also contribute to GHG emissions through stalling. Applications that reduced stalling time are also attributed to reduction in GHG emissions, as observed in case studies.

2.3.5 Social connectedness and participation

Survey of people in cities. It included questions to understand the following:

- Demographic information, including age, sex, and city of residence
- How connected respondents feel to their local community (on a six-point scale from "very disconnected" to "very connected")
- How connected respondents feel to their local government (on a six-point scale from "very disconnected" to "very connected")
- How important these two aspects of connection are to respondents
- Which local connection platforms respondents currently use or have used in the past, if any
- Which citizen engagement applications respondents currently use or have used in the past, if any

Local connection platforms include those used for the following purposes:

- To connect with/meet neighbors
- To connect with/meet people with similar interests or hobbies
- To date new people
- To facilitate volunteering or build engagement with a religious community

Citizen engagement applications include those used for the following purposes:

- Reporting nonemergency incidents
- Following political processes online
- Participating in digital city initiatives
- Using digital channels to express opinions to local decision-makers

2.3.6 Jobs/Education

The metric used to measure jobs is formal employment per 100,000 working-age residents. This allows to capture the effects of both decreasing unemployment and increasing labour force participation.

The four main avenues for affecting employment:

- Skilled labour supply: Increasing the skill and employability of individuals to fill open jobs in the city
- Labour market efficiency: Increasing transparency of available jobs to facilitate faster and/ or new job matches
- New job demand: Creating or destroying specific positions as a result of implementing applications
- Local business growth: Reducing red tape for local businesses to encourage formalization of jobs and increased profitability

Impact across cities can vary depending on many factors, including:

- Unemployment rate
- Average job search times
- Educational attainment of population
- Employment by occupation, such as taxi drivers, bus drivers, cybersecurity analysts, and local government employees
- Percent of employment from small and medium-size enterprises
- Time required to start a business and to prepare/pay business taxes
- Number of physical assets such as hospitals, schools, subway stations, and commercial buildings

2.3.7 Cost of living

Average annual expenditures per capita (in US dollars) is the metric used to measure cost of living. This does not represent average income; rather, it represents the ongoing costs required to live in the city.

The baseline expenditure in each city varies in terms of overall magnitude, as well as the distribution of spending across categories. The primary expenditures affected by smart city applications include:

- Utilities
- Housing (shelter)
- Security (including home equipment, personal products)
- Transportation (including vehicle purchases, fuel, public transportation)
- Healthcare

Other costs may not be directly affected by these technologies, including food, apparel, and entertainment.

The impact varies across cities due to differing characteristics, including:

- Distribution of spending across categories
- Time required to register property
- Interest rates for land developers
- Amount of vacant land zoned for residential developments
- Vehicle ownership rates
- Out-of-pocket expenditure as a percentage of total healthcare costs
- Share of population with chronic conditions

2.3.8 Technology base and applications

Cities are assessed in three areas: the strength of their technology base; the number and extent of applications implemented; and public awareness, usage, and satisfaction with the applications. When evaluating the technology base and applications, figures can be obtained from local government sources, published case studies, academic research, media accounts, expert interviews, interviews with service providers, and central databases.

To measure each city's technology base, indicators for the sensor network in place, the speed and extent of a city's communication networks, and the availability of open data portals are considered.

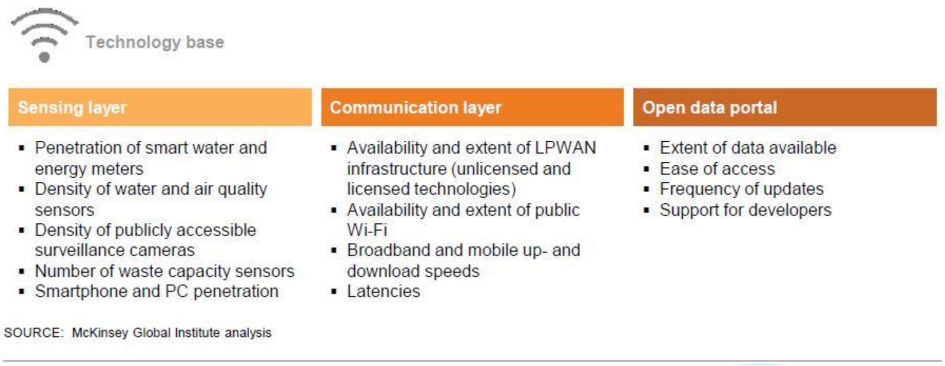

Figure 6 Technology base

In the city it should be assessed whether the following applications are piloted, available at scale, or not available.

Applications assessed

Economic development, housing, engagement

- Digital administrative citizen services
- Local citizen engagement applications
- Local connection platforms
- Local e-career centers
- Online retraining programs
- Peer-to-peer accommodation platforms
- Personalized education

Healthcare

- Data-based population health interventions
- First aid alerts
- Infectious disease surveillance
- Integrated patient flow management systems
- Lifestyle wearables
- Online care search and scheduling
- Real-time air quality monitoring
- Real-time telemedicine
- Remote monitoring applications and medication adherence tools

Mobility

- Autonomous vehicles
- Bike sharing
- Car sharing
- Congestion pricing
- Demand-based microtransit
- Digital payment in public transit
- Integrated multimodal info
- Intelligent traffic signals and vehicle preemption
- Parcel load pooling and urban consolidation centers
- Pooled e-hailing
- Predictive maintenance of transport infrastructure
- Private e-hailing
- Real-time road navigation
- Real-time public transit info
- Smart parcel lockers
- Smart parking

Security

- Body-worn cameras
- Crowd management
- Data-driven building inspections
- Disaster early-warning systems
- Emergency response optimization
- Gunshot detection
- Home security systems
- Personal alert applications
- Predictive policing
- Real-time crime mapping
- Smart surveillance

Utilities

- Behavior-based water consumption tracking
- Building automation systems
- Digital tracking and payment for waste disposal
- Distribution automation systems
- Dynamic electricity pricing
- Home energy consumption tracking
- Home energy automation systems
- Leakage detection and control
- Smart streetlights
- Smart irrigation
- Water quality monitoring
- Waste collection route optimization

SOURCE: McKinsey Global Institute analysis

Figure 7 Applications assessed

The survey is conducted to ask residents about their experience with the smart city applications available in their city.

Public adoption				
Respondents were asked: Do you know if the application is available in your city? (Awareness) Have you used this application? (Usage) If yes, how satisfied are you? (Satisfaction)				
Economic development, housing engagement	**Healthcare**	**Mobility**	**Security**	**Utilities**
Lifestyle wearables Online care search and scheduling Real-time air quality information Telemedicine	Behaviour-based water consumption tracking Home energy automation systems Home energy consumption tracking	Bike sharing Car sharing Digital payment in public stransit Integrated multimodal information Real-time road navigation Smart parcel lockers Smart parking	Home security Personal alert applications	Digital administrative citizen services Online retraining programs Peer-to-peer accommodation platforms

Figure 8 Public adoption.
Source: McKinsey Global Institute Analysis

[1] Smart cities: digital solutions for a more livable future (2018) McKinsey Global Institute
[2] Smart cities: digital solutions for a more livable future (2018) McKinsey Global Institute
[3] https://www.who.int/healthinfo/global_burden_disease/estimates/en/index2.html

3 Concluding remarks

A conceptual Health and smart City Ecosystem Framework will be used as an orientation through the possibilities of development of health and smart city health solutions in the different WPs. It serves as a tool for researchers who want to take advantage of the ICTs and solve their challenges through health and smart city initiatives.

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Annex 1 Smart Health Ethical Framework