

Conference Topic: “Cluster 3: Territories and Innovation”.

**TITLE: METAMODEL FOR SMART CITIES AND VILLAGES: A CATALAN
PERSPECTIVE**

Abstract

In the urban context, the objective is generally to solve how to handle typical problems of highly populated areas, such as traffic, mobility, waste management, pollution and consumption of energy, among others; all these problems, due to their data-intensive nature, have no direct application in the rural world, where data generation is not so frequent and is much more dispersed and fragmented (Mukti et al., 2022). In the rural context, on the other hand, the effort is focused on solving how to empower citizens and develop the regional economic potential (Maja et al., 2020) to prevent depopulation. Literature is scanty to develop a metamodel, that we define as a model that considers the different dimensions of a city (rural, coastal, size, touristic, industrial, etc.) (Maja et al., 2020). Our paper aims to fill this gap. The methodology is divided into two phases. The first phase is based on a large literature review and a compilation of smart cities models proposed by different authors with their respective dimensions. The second phase takes as input the result of the first phase and is based on the result of a series of workshops held with a team made up of municipal representatives to review, analyze and propose a model of models (metamodel).

Keywords: Smart City, Municipality, Village, Metamodel

1. Introduction

According to the United Nations report (UN, 2015), most of the world’s population is living in urban areas. However, the projections for 2030 indicate that almost half of the population in developing countries is expected to live in rural zones (Mukti et al., 2022). Academics are showing their interest in the research related to the adoption of smartness to improve the quality of life and economic situation (Ramirez et al., 2021). But there is a difference in focus between the adoption of smartness between people living either in urban or in rural areas (Martinez-Gil et al., 2020).



In the urban context, the objective is generally to solve how to handle typical problems of highly populated areas, such as traffic (Grimaldi, 2020), mobility, waste management, pollution and consumption of energy, among others (Angelidou, 2015); all these problems, due to their data-intensive nature, have no direct application in the rural world, where data generation is not so frequent and is much more dispersed and fragmented (Mukti et al., 2022). In the rural context, on the other hand, the effort is focused on solving how to empower citizens and develop the regional economic potential (Maja et al., 2020) to prevent depopulation.

Various models have been proposed to evaluate smartness with an aim to improve policymakers' actions. Nevertheless, their focus was on urban and big areas, discarding the small or rural zones (Hajek et al., 2022). Moreover, despite efforts and initiatives, the results are below the expectations. The main reason is smartness is evaluated in an aggregated way, while metropolitan areas are very heterogeneous systems. Consequently, literature is scanty to develop a meta-model, that we define as a model that considers the different dimensions of a city (rural, coastal, size, touristic, industrial, etc.) (Maja et al., 2020).

The objective of this work is there for twofold, on the one hand, to provide a comprehensive metamodel that is extensive and applicable to any kind of city, it looks to help to have a comprehensive overview of all the elements to be considered in the development of a smart community and to understand how they can be linked in order to establish priorities and achieve greater synergy of the measures to be implemented. And, consistent with the above, the second objective is based on the provision of a framework to analyse the different levels of digital maturity that municipalities must walk in their development journey.



2. Theoretical background and Methodology

This study reports on an analysis conducted to start filling the knowledge gap generated around the smart and sustainable development of cities and villages and provides insights into the different dimension this ecosystem has from a holistic view, which helps to define what strategic principles cities and villages should consider when approaching the design and implementation of strategies for smart development. The methodology is divided into two phases. The first phase is based on a large literature review and a compilation of smart cities models proposed by different authors with their respective dimensions. The second phase takes as input the result of the first phase and is based on the result of validation held with a list up of experts to review, analyse and propose a model of models (metamodel).

2.1. Phase 1: Literature Review

According with the literature review, five main proposals analysing the functions in smart cities and communities were reviewed. From all this research main elements and activities that define a Smart City were included. The articles under analysis are presented below.

- Model 1: Current trends in Smart Cities initiatives.

Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., & Scorrano, F. (2014)

- Model 2: *Estudio y guía metodológica sobre Ciudades Inteligentes*

López, M., Martínez, P., & Fernández, S. (2015).

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- Model 3: New forms of entrepreneurship and innovation for developing Smart Cities
Grimaldi, D. (2016).
- Model 4: Smart cities as a source for entrepreneurial opportunities: Evidence for Spain
Barba-Sánchez, V., Arias-Antúnez, E., & Orozco-Barbosa, L. (2019).
- Model 5: Smart Cities: Definitions, Dimensions, Performance, and Initiatives
Albino, V., Berardi, U., & Dangelico, R. M. (2015).

2.2. Phase 2: Panel of expert validation

The dimension and functions observed in the previous phase, of literature review, were share with a panel of experts to validate the relevance of the structure proposed. This was developed with five rounds of workshops, refining in each iteration the content of the meta model resulting of this work.

The panel of experts was compound by six experts with more than ten years of experience in the fields of: information and communication technologies, innovation, open government and digital technologies, organization and digital policies.

3. Results

This research was built to stablish a comprehensive metamodel of smart cities and village that was able to increase the current understanding of the development of these areas.

3.1. Literature review



The literature review allowed to see the main areas that science propose as fundamentals to the evolution of smart cities and village.

The results will be presented below.

- **Model 1: Current trends in Smart Cities**

Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., & Scorrano, F. (2014). Current trends in Smart City initiatives: Some stylised facts. *Cities*, 38, 25-36

The work team of the aforementioned in Model 1 proposes, as can be seen in the figure below (Figure 1), that the domains in which urban development policies are applicable and can be classified into two predominant groups, as to 'hard' or 'soft', in relation to the importance of ICT systems as key enabling technologies. Specifically, the hard domains refer to office and residential buildings, energy networks, natural resources, energy and water management, waste management, environment, transportation, mobility and logistics. In these environments, an improvement in sustainability is based on the deployment of ICT systems, together with the introduction of appropriate policy interventions and urban planning. From the perspective of Model 1, hard domains are the scenarios where the vision of a city that senses and acts can be most applicable, thanks to the use of sensors, wireless technologies and software solutions for manage "big data".

Conversely, soft domains include areas such as education, culture, policies that encourage entrepreneurship, innovation and social inclusion, as well as communication between local public administrations and citizens (e-government). In these areas, ICTs play a more limited role and do not necessarily aim to process and integrate information in real time.



It is also mentioned in this model that, in the cases of innovation and social inclusion policies, Smart Cities initiatives are not characterized by the deployment of new technologies but by public interventions aimed at creating the appropriate social and institutional conditions (for example, incentives, ad hoc organizational bodies, etc.). In the case of culture, it is expressed that public participation could aim to improve the exploitation and attractiveness of a city's cultural heritage. In the case of policies that foster human capital and innovation capabilities, the role of local policies in creating the appropriate institutional condition could mean, for example, the establishment and support of local incubators for new high-tech companies and their connection to the global world (innovation systems at scale). Areas such as health and public safety can fall somewhere between the hard and soft domains, as Smart Cities interventions in these environments can be characterized by the deployment of sensors and wireless technologies or by the deployment of practices and campaigns aimed at creating social values.

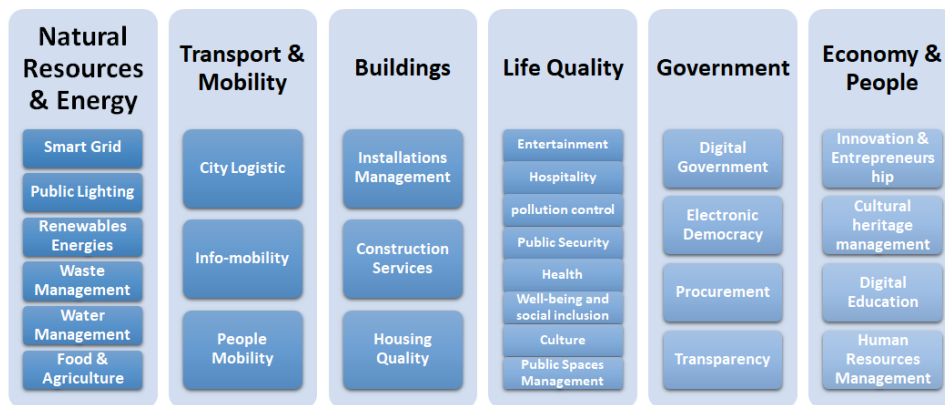


Figure 1: Model 1: Currents trends in Smart Cities – Neirotti, Marco, Cagliano, Mangano & Scorrano. (2014).

• **Model 2: Study and methodological guide on Smart Cities**



López, M., Martínez, P., & Fernández, S. (2015). Estudio y Guía metodológica sobre Ciudades Inteligentes. Deloitte Consulting para el ONTSI - Observatorio Nacional de las Telecomunicaciones y de la Sociedad de la Información.

The model proposed in the second place is the one that Deloitte has made based on a selection and analysis of various reports, works and perspectives of different entities and public bodies, local administrations, private entities and public-private organizations involved in the development of Smart Cities, with the purpose of conceptualizing the Smart City and defining the functional areas that make it up. Based on this, the areas shown in Figure 2 emerge as a summary, where six large blocks are identified, made up of the following areas and sub-areas.

- Smart Environment, focused on the efficient and sustainable management of the city's resources, and which includes the sub-areas of: Energy, Water, Urban Environment and Waste Management.
- Smart Mobility, focused on improving mobility and transport, and accessibility in the city, and which includes the sub-areas of: Road Infrastructure, Transport and Traffic, Parking, ICT Connectivity and Accessibility.
- Smart Governance, focused on guiding an open and transparent government, and which relies on technology to achieve quality and efficiency in its services and activities, and which includes the sub-areas of: Strategic Planning, Geographic Information of the City, Digital Administration, Transparency and Participation.
- Smart Economy, focused on the economic and competitive development of the city based on innovation, and which frames the sub-fields of: Tourism, Consumption, Commerce and Business, Digital Enterprise, Innovation Ecosystem and Employment and Entrepreneurship.



- Smart People, focused on enhancing the social and human capital of the city, and which takes into account the sub-areas of: Citizen Collaboration and Digital Inclusion.
- Smart Living, focused on increasing the quality of life of the people who are part of the City, and which includes the following sub-areas: Health, Education, Culture and Leisure, Social Affairs, Security and Emergencies, Urbanism and Housing and Infrastructure Public and urban equipment.

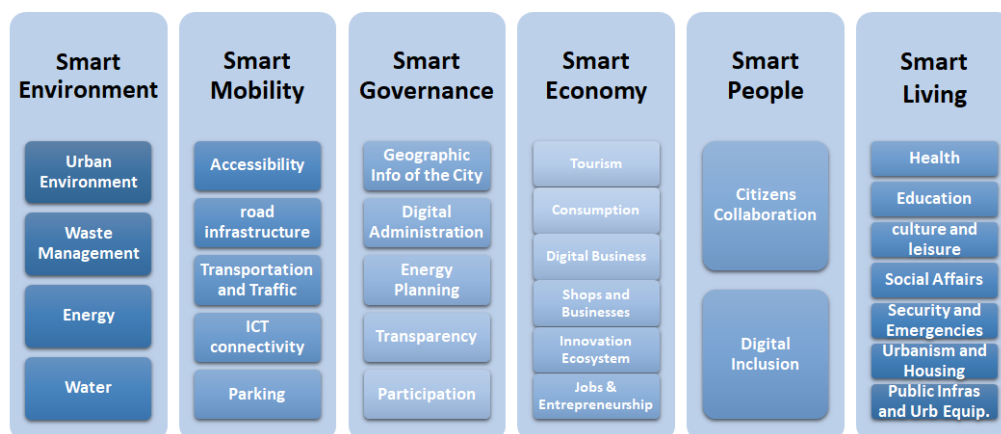


Figure 2: Model 2: Study and methodological guide on Smart Cities - López, M., Martínez, P., & Fernández, S.. - Deloitte Consulting para el ONTSI (2015).

- **Model 3: New forms of entrepreneurship and innovation for developing Smart Cities**

Grimaldi, D. (2016). "New forms of entrepreneurship and innovation for developing Smart Cities", 121 p. Retrieved from <http://hdl.handle.net/2117/105833>

The analysis proposal number three, is based on what was presented by Didier Grimaldi in 2016, in his work entitled "New forms of entrepreneurship and innovation for developing Smart Cities" which postulates, based on different classifications compiled after studies comprehensive of cities



around the world, which domains mainly listed include Energy, Transport, Life, Open Government and Economy.

And at the same time, it shows the tendency to fix the domains and characteristics of a Smart City based on two opposing approaches:

A. TOP-DOWN initiatives, where:

- Urban infrastructure is prioritized, and management is established by the City Council with a unidirectional (top-down) and ICT-oriented approach.
- The high-level domains here are (See Figure 3):
 - Energy networks, where ICTs allow multiple energy sources to be managed and integrated into the common network.
 - Environment, where ICTs make it possible to better protect environmental resources and control pollution.
 - Transport, where ICT provides users with information about traffic and public transport.
 - Healthcare, where ICTs help prevent and diagnose diseases and reduce healthcare costs.
 - Public security, where ICTs help protect the integrity of citizens and their belongings by feeding information in real time.
 - Electronic government and administration where ICTs promote digitized public administration.

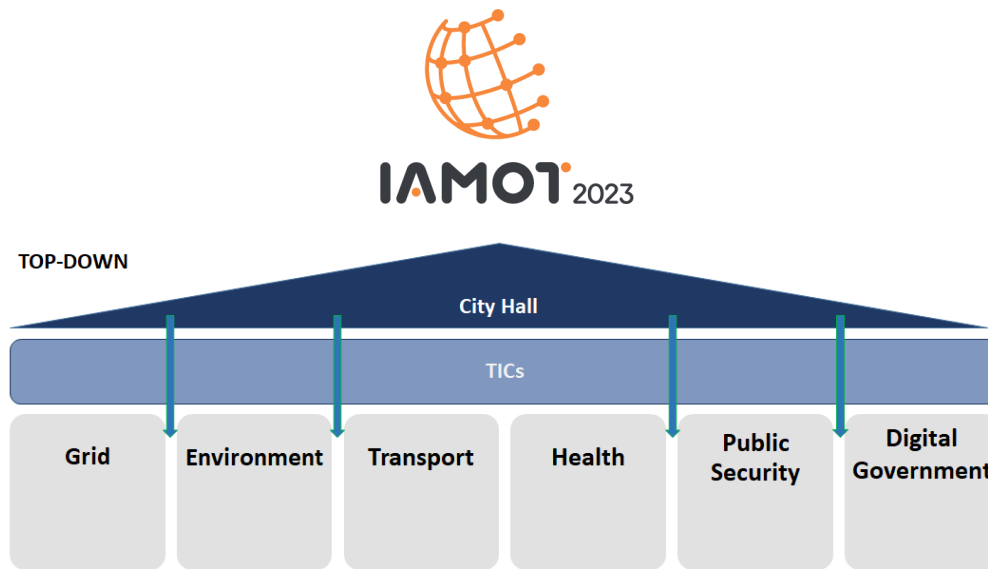


Figure 3: Main Domains of the city according to the Top-Down approach

A. BOTTOM-UP initiatives, one:

- Access to data is encouraged and citizens are allowed to develop their own initiatives.
- The deployment of new technologies is not the main objective, but the cooperation of citizens to eliminate injustice, "return" social rights, mitigate inequalities and help the integration of excluded people, provide assistance to citizens with functional diversity, older or younger people or providing access to culture and education for disadvantaged people.
- Considers that cities are not just a grid of smart sensors and a list of services, but have a unique character that is reflected in the everyday life and culture of citizens.
- Domains are related to education, culture and healthcare.
- Intelligence is people-oriented and ICT plays a limited role.
- Cooperation between citizens can be organized in a place that is usually called Living Laboratories (Living Labs), a shared physical space with the aim of involving users in a creative and collective perspective. (See figure 4):

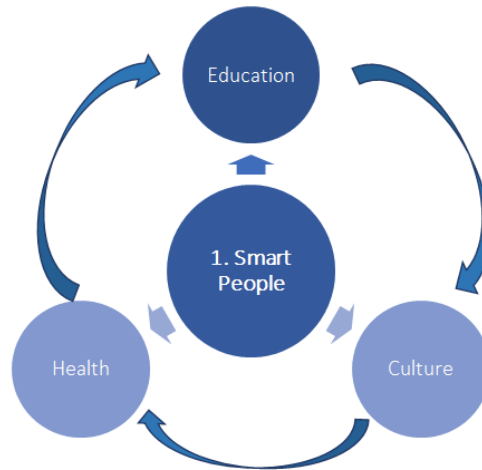


Figure 4: Main Domains of the city according to the Bottom-up approach

- **Model 4: Smart cities as a source for entrepreneurial opportunities: Evidence for Spain**

Barba-Sánchez, V., Arias-Antúnez, E., & Orozco-Barbosa, L. (2019). Smart cities as a source for entrepreneurial opportunities: Evidence for Spain. *Technological Forecasting and Social Change*, 148

The proposal made by the researchers of model four, is based on the fact that the intended goals of a Smart City include ensuring security, providing information services and facilitating an environment conducive to the spirit business

It further postulates that the main objective of the Smart City can be approached from two perspectives: as the objective of urban development projects, or as support for specific development policies (as a vehicle to attract investments and attract entrepreneurs and highly skilled labour).



He adds that all definitions of Smart City have one element in common and that element is the use of ICT in the implementation and development of the smart city and in all the dimensions involved. However, the concept contains other dimensions such as social or ecological ones that modify this technological scenario, adding social value through innovation and creativity.

He concludes his introduction by explaining that the (smart) city is based on three main pillars: planning and management services; infrastructure services; and human services. And that different innovations or emerging technologies of information and communication are called to play a fundamental role in the implementation of the smart city. These technologies include: Internet of Things, Communication Networks, Cloud and Edge Computing, Big Data. Other disruptive technologies that will play an important role in smart cities are robotics (Salvini, 2018), drones (Menouar et al., 2017), autonomous vehicles (Meyer and Shaheen, 2017), blockchain (Marsal-Llacuna, 2018), cognitive computing (Williamson, 2017), among others (López, Martínez & Fernández, 2015).

Regarding the environment, waste collection is monitored by sensors not only to improve the cleaning and selective collection services of the cities, but also to comply with the recycling rates imposed by the European Union for 2020. Solutions for energy savings in public lighting, air conditioning and lighting systems in public spaces, smart meters, etc. it raises them as already considerably extended. On the other hand, mobility explains that it benefits from the use of ICT services such as the calculation of optimal routes, traffic consultancy and parking management. Finally, many other applications claim citizen participation as a key element in the smart city concept. (Figure 5)

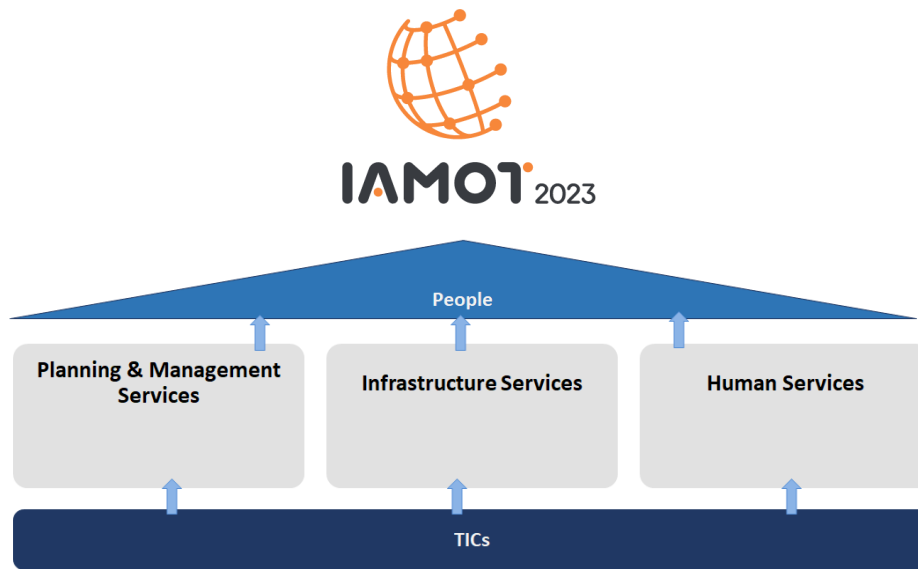


Figure 2: Model 4: Smart cities as a source for entrepreneurial opportunities: Evidence for Spain

• Model 5: Smart Cities: Definitions, Dimensions, Performance, and Initiatives

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of urban technology*, 22(1), 3-21.

Model 5 seeks, among other aspects, to identify the main dimensions and elements that characterize a smart city, through an approach based on an in-depth bibliographic review of relevant studies, as well as official documents of international institutions. In this sense, it provides that the most common characteristics of smart cities can be summarized in:

- The network infrastructure of a city that allows political efficiency and social and cultural development.
- An emphasis on urban development driven by businesses and creative activities.
- The promotion of urban growth, the social inclusion of various urban residents and social capital in urban development.
- The natural environment as a strategic component of the future.

Based on what has been explained above, a group of elements is listed without order, which are summarized below:



- Education.
- Infrastructure.
- Economy.
- Life quality.
- Mobility.
- Natural environment.
- People.
- Government.
- Technology.
- Economic Development.
- Labour Growth.
- Interconnection.
- Integration.
- Innovation.
- Human Talent.
- Energy.
- Waste.
- Water.

3.2. Panel of Expert Validation

Having exposed the different dimensions proposed by the experts as fundamental in the conception of a smart city, a metamodel of the transformation of municipalities adjusted to the reality of Catalan municipalities has been drawn up, designating key dimensions and components, which are shown and describe below (Figure 6). The aim here is to review all the fundamental aspects that make up a municipality, allowing to present the elements that must be worked on to achieve municipal development and growth from a comprehensive vision.

This final metamodel proposal is the result of five iterations of sessions, with each iteration improving the metamodel's content. Six professionals with more than ten years of experience in the following domains comprised the panel of experts: information and communication technologies, innovation, open government and digital technologies, organisation, and digital policy. The main conclusions of these sessions justify this final structure.



The most relevant outcome for practitioners is to provide a metamodel that allows to have a comprehensive view of all the links necessary for the digital transformation of a municipality, and with this facilitate the municipal task in the change pursued. A proposal was made to present this in aggregate form with all of the possible challenges or fields in which action is required, so that municipalities can choose which areas of action to focus their development strategy. For this, five main dimensions or "boxes" have been defined, based on the two in which the municipality has the greatest influence: (1) Digital Administration of the City Hall itself and aspects related to (2) Urban Public services and physical infrastructure of the Municipality. In the upper boxes the services offered to citizens to improve their quality of life (3) Live, (4) People and (5) Economy, which although in some cases are not the direct responsibility of the municipality, can still work together with the other members of the business and social ecosystem, to generate the most favourable context for its development. Also, in line with the conclusions reached in the workshops held, (6) Transversal elements were defined in all dimensions to facilitate their operation and interaction, such as transversal elements of interoperability, connectivity, data governance, knowledge management, cyber security, etc.

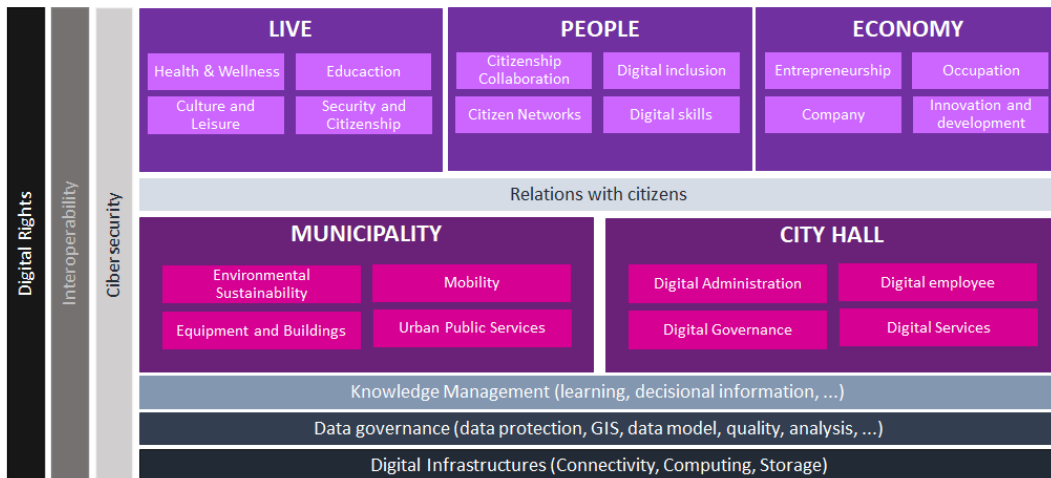


Figure 6: Digital Municipality Transformation Metamodel (Own Development)

The dimensions and sub-elements that make up the Transformation Metamodel are described in this section.

a) DIMENSIONS

- MUNICIPALITY
- CITY HALL
- LIVE
- PEOPLE
- ECONOMY

b) TRANSVERSAL ELEMENTS

- Knowledge Management
- Data Governance
- Digital infrastructures
- Interoperability
- Cybersecurity
- Digital rights
- Relations with Citizens



a) DIMENSIONS

MUNICIPALITIES

The Municipality block mainly brings together the components of an intelligent city of a more structural nature, which due to their condition fall directly under the municipal field of action.

This dimension covers the following sub-areas:

- Environmental Sustainability
- Mobility
- Equipment and Buildings
- Urban Public Services

CITY HALL

The City Hall block involves the incorporation of technology to optimize the benefits and services that the municipality has both for its internal management and for the attention to the needs of citizens. This dimension encompasses the following sub-areas:

- Digital Administration
- Digital Governance
- Digital Workers
- Digital Services

LIVE



This blog aims to work on elements that improve the quality of life of the people who are part of the municipality and contemplate the following sub-areas:

- Health and Well-being
- Education
- Culture and leisure
- Security and Citizenship

PEOPLE

This is a higher level that seeks to enhance the social and human capital of the municipality.

This dimension supplies the following sub-areas:

- Digital inclusion
- Citizen Networks
- Digital skills
- Citizen Collaboration

ECONOMY

This blog seeks to contemplate and give visibility to the elements that are oriented towards the economic and competitive development of the municipality, and involves the following sub-areas:

- Entrepreneurship



- Employment
- Company
- Innovation and Development

b) TRANSVERSAL ELEMENTS

The category of "Transversal Elements" has been defined to concentrate those functions which, due to their characteristics, affect all the previous elements, that is to say, they are common to all of them, and a global vision and management is necessary.

They are described below:

- **KNOWLEDGE MANAGEMENT**

Work intended to acquire, increase, organize, distribute and share knowledge among all the workers and citizens of the Municipality, includes learning, decision-making information, etc.

- **DATA GOVERNANCE**

Set of processes, functions, policies, rules and measures that guarantee the effective and efficient use of information in order to help the municipality meet its objectives. It allows setting a series of processes and responsibilities that ensure the quality and security of the data used in the society or municipality. Data governance defines who can take action, on what data, in what situations and through what methods. Includes data protection, GIS, data model, quality, analytics, etc.



- **DIGITAL INFRASTRUCTURES**

Basic elements necessary for the development and support of all these technological services. These elements can be servers, fiber optic networks, towers for wireless communications, cloud storage farms, etc. and also other household items such as routers or network connectors. In short, the digital infrastructure is everything that supports these technological services and the information transfers associated with them: connectivity, computing, storage, etc.

- **INTEROPERABILITY**

Possibility to exchange information and use the information exchanged.

- **CYBERSECURITY**

Training and technology in cyber security.

- **RELATIONS WITH CITIZENS**

A bridge between the administration and citizens.

- **DIGITAL RIGHTS**

The extension to the digital environment of already existing human rights



4. Discussion

When comparing the models presented by the main researchers in the area of Smart Cities (Barba-Sánchez et al. 2019; Grimaldi, 2020; Neirotti et al., 2014), it can be seen that they all include, in one way or another, elements that are increasing their level of sophistication to reach a comprehensive satisfaction of the needs of the citizen. Although there may be variations in the way in which the individual elements proposed are grouped together (Grimaldi, 2016), it can be distinguished that they all include elements of infrastructure, such as connectivity, electricity networks, water, waste, transport and mobility, buildings, etc; that generate the technical and digital base on which the fundamental services are supported (health, education, culture, security, economy, business, employment) that make use of this base to be able to put their functions and solutions into operation in each of their areas, to conclude that the fundamental and central element of all models is the person and their training and training to be able to use these tools and for their personal fulfilment: digital inclusion, digital training, citizen collaboration (Albino, 2015).

The results emphasized that an smart and digital administration is conceived as a fundamental pillar for the impetus of the planned transformation, which takes more weight in small-sized administrations. So, its transformation to digitization as a means to guarantee the full development of citizens becomes the driving force for the rest of the components of the ecosystem at the beginning of the process. Then, once solid bases have already been generated,



these same foundations serve as support and empowerment for the remaining (TOP DOWN and BOTTOM-UP strategies applied in a complementary way).

The analysed models in the results present a complete and comprehensive view of all the dimensions to be considered in the development of a digital municipality. It is an complete starting point to have a comprehensive vision that contemplates all the aspects to be analysed and allows their prioritization and planning. Although each municipality sets its own strategy and objectives, the reality of the Catalan territory today is that it is made up of a high percentage of municipalities with less than 2,000 inhabitants and with a digital maturity in an initial instance in the majority of the cases (Ramirez et al., 2021). The proposed metamodel is an important step necessary to establish a prioritization regarding which of the elements in the digital transformation will be the ones that will be developed in the first instance and with what level of depth, taking as the main premise the main areas of municipal competence. Once the areas of basic competences are integrated into the digital model, the city can aspire to work on the other dimensions to achieve the efficiency and comprehensive functionality of the municipality for a better quality of life for its inhabitants.

5. Conclusions

Life in today's society demands constant action and evolution on the part of governments and society as a whole to adapt to the changes that are developing and to provide solutions to the needs that arise.

The digital transformation of municipalities is conceived as a way to respond to the goals pursued by the public administrations. It represents a profound change that modifies the way



in which all processes are carried out, but which will also allow innovation and guarantee a good service to the population, and above all, improve more and more efficiency, proximity and active listening, based on intelligent management, providing solutions to the new scenarios that arise, balancing for balance and territorial equality, providing opportunities for personal and professional development to all citizens, and working to reduce inequality.

Establishing the road map for this development is a fundamental step to get through the entire growth process by having a clear vision of the elements necessary to guarantee the scope of the objectives and make efficient use of all available resources (economic, technological and humans).

Establishing a metamodel that shows the key elements allows you to have this comprehensive view of the ecosystem, allowing prioritization and planning in accordance with the reality and ambition of each municipality.

With this metamodel, practitioners are able to make a step forward for the digital transformation of the local municipalities, regardless of their size and stage of development. To this end, each municipality will need to develop a road map to be able to respond to urban, economic, social and governance challenges to ensure that its citizens have a fuller life in their personal and professional dimension, where companies and organizations find an optimal ecosystem to develop, where the municipalities have the necessary optimal infrastructures and where the public administration has the satisfaction of promoting a digitally advanced society.



Acknowledgments

This study is a collaborative work with Localret, the local consortium formed by the local administrations of Catalonia. The mission of Localret is to accompany city councils in the process of transforming their town or city into a digital municipality so that their citizens can fully develop there.



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