# Human Smart Towns: a viable strategy for disaster response

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**Abstract**

L'Aquila's 2009 6.3-magnitude earthquake devastated the city and surrounding areas, causing widespread destruction and loss of life. However, disasters may offer an opportunity to apply innovative, smart-oriented reconstruction approaches to revitalize towns, aligning with citizens' needs. A smart town functions as an interconnected, multidimensional ecosystem of parties that work together effectively. GIS (Geographic Information System), 5G, cloud-edge computing, and other modern technologies are being incorporated into reconstruction efforts not only to repair damage but also to enhance the efficiency, safety, and livability of towns. The performance of on-site ICT (Information and Communication Technologies) is often insufficient to implement smart solutions, and some bottlenecks appear that next-generation networks can address. Using a socio-technical perspective and a real-world case study, this work-in-progress presents preliminary insights into radio network planning for broad connectivity, vital for building smart services and promoting land regeneration after natural disasters.

**Keywords**

Smart Towns, Digitalization and Digital Transformation, Digital Services, Tech Enablers, Radio Network Planning

## 1. Introduction

The "smartification" of small and medium-sized settlements as a policy idea, along with the perception of citizens as users and consumers, has gained prominence in recent years [1]. In addition, the vision of urban/rural agglomerations is changing from static to dynamic: previously seen as a set of immovable buildings and infrastructure, they are now being transformed into smart ecosystems [2].

Disaster recovery is one of the processes that governments in the Global North address using technology to achieve some goals, such as green and sustainable reconstruction, resilience, future economic growth, and better quality of life for the local population, attracting new residents and improving the place branding [3, 4, 5, 6, 7]. These cannot be built on purely technological solutions (hard infrastructure), but must be holistic and comprehensive, including the human side (soft infrastructure) [8]. The citizens must then be involved and empowered in policy-making processes; otherwise, they will simply access a range of services as users/consumers whose data are continuously collected [9, 10].

The Abruzzo region and its capital L'Aquila (which has suffered a population decline in recent years [11]), located close to the Apennine mountains and hit hard by two of the deadliest earthquakes in Italy's recent history (in 2009 and 2016), have been at the center of State- and technology-led reconstruction initiatives, also encouraging investments in entrepreneurial tech-driven hubs [12, 13]. By Law [14], two special public administrations (PA)-the "*Ufficio Speciale per la Ricostruzione della città dell'Aquila (USRA)*" and the "*Ufficio Speciale per la Ricostruzione dei Comuni del Cratere (USRC)*"-were established to monitor and manage the post-earthquake reconstruction process. The focus here is on the USRC, which is responsible for 56 municipalities (the so-called *seismic crater*), small towns where ICT solutions have to deal with the cultural heritage to be preserved and the particular morphology of the territory.

In [10], Oliveira and Campolargo argue that people, rather than technology, are the real actors in territorial smartness; therefore, they introduced the phrase "*Human Smart City*". According to them, the creation of a participatory innovation ecosystem is crucial, as also recently reaffirmed by Marchesani and Ceci [15]: the authors' findings show how the integration of different actors within the Quadruple Helix

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approach (government, business, academia, and civil society) fosters co-creation and responsiveness to digital challenges; and how public-private partnership (PPP) through open innovation creates value by accelerating digital transformation (implementation of digital services) and strengthens public service delivery. The USRC and the municipalities under its competence have realized that the post-earthquake physical reconstruction must be complemented by socio-economic revitalization actions, as the case study in the Appendix A demonstrates.

Drawing on socio-technical traditions [16, 17, 18], technological implementations cannot be separated from the human context in which they are embedded, emphasizing the importance of mediating social and technical elements in effective ICT systems design for smart settings [19, 20]. Coe et al. [21] recognize the potential for citizen participation through the use of technology. For example, a digital platform helps an organization both internally (information sharing and employee work) and externally (user interaction and transparent communication), such as the new USRC GIS platform released in November 2024 [22, 23, 24]. GIS data (such as building structures, terrain, population density) can be used to tune and plan radio wave propagation, monitored in real-time [25]. In addition, technology-driven reconstruction also promotes the digital economy [26]. For example, the use of 5G or solar-powered mesh networks can ensure that towns maintain Internet and communication capabilities even when power grids are disrupted, making them more self-sufficient.

To realize smart towns, the ICT infrastructure, e.g., broadband networks, needs to be improved, as the installation of fiber optic cables and wireless networks is still in the early stage [27]. Widespread network coverage is essential to build intelligent utility management networks (e.g., electricity, water, sewage, telephone) that make a location (in this case, a town) definable as "smart". In this way, we will hear about smart towns and not just smart cities, especially considering towns as hubs of investment, resources, specialization, and innovation, from whose digitization passes that of the whole of Italy (which, despite being among the G7 countries, lags behind in the ICT area according to the Digital Economy and Society Index (DESI) [28], unfortunately).

Thus, a collaboration has been established between the USRC and the Telecommunications Engineering Research Group at the University of L'Aquila: the PA involves the academia, which, being knowledge-based, supports investigating the scenario and choosing the best solution [29]. Rethinking telecommunication network covers four key areas (radio network design, measurement, analysis, management). Radio access optimization can be achieved through protocol analyzer and simulation of radio wave behavior, frequency, traffic planning, and market opportunities. Hardware/software integration, such as GIS and Altair WinProp[1] or CE RCP (Cellular Expert | Radio Coverage Planner) within ArcGIS Pro[2] tools, helps to propose locations, configurations, and settings of network nodes, mapping radio signal distribution, modeling terrain effects, and calculating coverage area forecasts. The expected result is the definition of guidelines and a flexible wireless network architecture for the USRC to achieve sufficient coverage in the target area, ensuring satisfactory quality of service (QoS) and low bit error rate, determining the optimal placement of new radio towers, antennas, databases, and existing base stations, maximizing radio signal strength and distribution, reducing interference; to provide the required network capacity with a low service drop rate/blocking and satisfactory throughput for users; and to implement a cost-effective network infrastructure (i.e., the minimum number of sites and transmitters needed to meet coverage, quality, and capacity requirements).

## 2. Background

Most projects to improve services offered at the local and regional levels rely on the use of ICT to encourage the development of so-called smart communities, taking a holistic view [30]. A smart community can have various dimensions (cities, towns, etc.) and aims to involve as many stakeholders as possible in "public life" (e.g., PPP) by facilitating its transformation in a positive way [31]. Through unified efforts and synergistic work, a community can benefit from the potential of ICT (thereby

[1] https://web.altair.com/winprop-telecom

[2] https://www.esri.com/partners/cellular-expert-a2T70000000TRiuEAG/ce-rcp-radio-coverag-a2d5x000006jOXvAAM

connectivity and digital as an enabler for smart services) much sooner than it otherwise would. Moreover, with the telecommunications infrastructure, smart communities are also economically more competitive and attractive. The same was done by the Agency for Digital Italy (AgID) with Decree Law No. 179/2012[3].

From the foregoing, it is evident that the smart model is not exclusive to cities, but also to towns (the reference scenario). Despite the smaller size, the underlying concept is the same. Therefore, the application of the definition of smart city as smart town.

## 2.1. Definition of Smart City

Smart cities first appeared in the literature in 1997 and have since attracted considerable scientific and industrial attention [32, 33, 34]. Many scholars have contributed to the definition of what a smart city is. Washburn et al. [35] stress that the computerization of services is crucial to improving the current condition of cities, which often have to live with inadequate infrastructure and poor services for citizens. Rios [36] defines a smart city as a city that inspires, shares culture and knowledge, and encourages its inhabitants to improve aspects of their lives. Partridge [37] defines the smart city as a city where ICT can play a fundamental role in the implementation of information and services that are provided to the public.

Several scholars illustrate the technological, human, and institutional factors that make up the smart city [38], as shown in Figure 1. Albino et al. [39] link the general model of the six key dimensions of a smart city to related aspects of people's lives (see Figure 2), while Dameri and Rosenthal-Sabroux [40] identify four basic components of a smart city (land, infrastructures, people, government) and three main characteristics by which a city's smartness is measured:

- *effectiveness* is the ability to supply effective services to citizens;
- *environment consideration* is how to seek to prevent further environmental degradation;
- *innovation* is how the city uses available new technologies to improve the quality of core components.

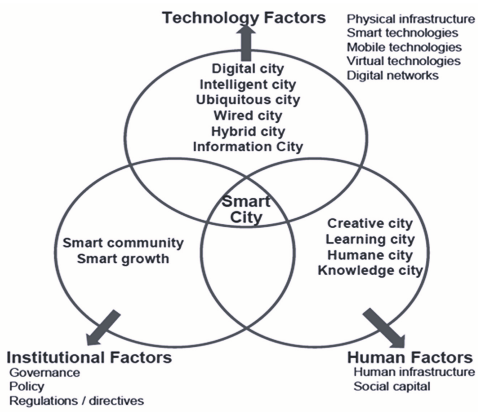


**Figure 1:** Three main Components of Smart City [29].

## 2.2. Smart City as Ecosystem

Smart cities are often seen as an ecosystem rather than a marketplace, where the key element is different actors working together to create a value proposition [41, 42]. Couzineau-Zegwaard et al. [43] point out the possibility of comparing the concept of a smart city with that of an ecosystem, illustrating a smart city ecosystem starting with the fact that a smart city "cannot be viewed as a sum of parts but holistically as a network of interconnected infrastructures dependent on each other" [44]. To this

[3]https://www.gazzettaufficiale.it/eli/id/2012/12/18/12A13277/sg

| Components of a smart city | Related aspect of urban life |
|---|---|
| smart economy | Industry |
| smart people | education |
| smart governance | e-democracy |
| smart mobility | logistics & infrastructures |
| smart environment | efficiency & sustainability |
| smart living | security & quality |

**Figure 2:** Six Dimensions of Smart City [39].

end, they consider the PlanIT valley project in Portugal, which aims to create services for sustainable urbanization [41]. In the same vein, Díaz-Díaz et al. [45] with the case study of Santander (Spain) emphasize that for a city to call itself smart, it must consist of an ecosystem composed of different stakeholders from the public and private sectors.

Similarly, in an ecosystem, different actors cooperate and compete to develop services to meet customers' needs [46]. The definition of ecosystem has different facets, and many scholars have contributed to defining what it is [47, 48]. According to Adner [49], an ecosystem is “the alignment structure of the multilateral set of partners that need to interact for a focal value proposition to materialize,” emphasizing the contribution of anyone to the realization of a service. The elements characterizing an ecosystem are [47]:

- *activities* to carry out to deliver the value proposition;
- *actors* are the entities that perform the activities;
- *strategy* looks at the risks, the relationships among actors, and the characteristics of input-output flows between them.

Consequently, a smart city turns out to be an ecosystem in which there is the presence of interconnected technologies in such a way as to ensure improved service delivery and the presence of different stakeholders cooperating with each other [50]. This recalls the concepts of “learning-by-combining” and “learning-by-interacting” introduced by Lundvall [51], where electronic apparatuses and digital move together with people [52].

## 2.3. Emerging Technologies as Enablers of Smart City

The smart city phenomenon is closely related to the development of 5G & beyond technology and Internet of Things (IoT) [53].

In Italy, 5G trials have been launched in cities such as Prato and L'Aquila [54]. In 2017, the Italian government announced that L'Aquila would become a pilot area to test 5G technology with the INCIPIT project[4] involving the national investment fund Cassa Depositi e Prestiti, the energy company Enel, the Italian telecom company Wind Tre, and the Chinese telecom giant ZTE. In 2019, the Smarter Italy program (SIp) was launched, and among the program's testbed was L'Aquila, classified as a “smart city” SIp along with 10 other major Italian cities such as Bari, Genoa, Turin, Milan, Rome [55]. In the early 2020s, L'Aquila renewed the plan to become a smart city, describing the smart factor as the key to rebuild links between the city and its surroundings, serving as a bridge between large, densely populated urban areas (such as Rome, which is 150 km from it) and rural, depopulated ones (such as towns)[5]. Adding to the evolution of telecommunications to make Italy smarter is the RESTART program - NextGenerationEU, funded by the EU as part of the Italian NRRP (National Recovery and Resilience Plan), which kicked off in January 2023 [56]. In other countries, examples of 5G testing include the city of Alba Iulia in Romania [57] and the LuxTurrim5G project led by Nokia Bell Labs in Espoo (Finland) [58]: in both, the technology was used to implement smart lighting.

[4]http://incipict.univaq.it/
[5]https://trasparenza.comune.laquila.it/archivio28$_{p}rovvedimenti - amministrativi_{04}45805_{7}25_{1}.html$

Zhang et al. [59] state “5G systems are expected to provide society with comprehensive connection that can break through the limitations of time and space to create all-dimensional user- or service-centered interconnections between people and things.” In wide-area coverage, network slicing allows varying requirements (e.g., QoS) of different applications to be met by dividing the same physical network into multiple logical networks. Instead, ultra-low latency and high reliability find fertile ground in hybrid networks that connect machines to humans by generating data traffic, such as smart cities [60]. Such features will certainly be useful for the measurement, control, and monitoring of smart objects [61], and will also enable increased data traffic and the deployment of machine-to-machine systems with coverage and hotspot capabilities [62]. However, 5G networks must provide connectivity with low impact in terms of cost, energy consumption, effects of human exposure to electromagnetic field, and visual impact.

In addition, with the growing need for real-time data processing, edge computing minimizes latency by bringing computation closer to where data are generated (i.e., at the edge of the network), reducing dependence on central infrastructure and promoting decentralized intelligence [63, 64].

## 3. 2009 Seismic Crater as testbed for Smart-oriented Reconstruction

The devastating earthquake of April 6, 2009, killed 309 people and forced tens of thousands to flee their homes [65]. In the aftermath of the event, the inhabitants were relocated to surrounding areas in temporary shelters, hotels, and rented houses [66]. Sixteen years later, public-private reconstruction is advancing, with the latter proceeding faster than the former.

In the EU-backed NRRP, the relationship between the smart initiative and the revitalization of towns (“*borghi*” in Italian) through investments in digital, tourism, and connectivity is clear. Some authors advocate investing in ICT infrastructure, with wise management of resources and participatory governance, adding that much depends on the area’s ability to learn and innovate [67]. In adopting the smart city model, the USRC faces barriers. Bottlenecks (performance, capacity, scarcity) belong to two different domains: mobile technology and smart solutions. Specifically, for mobile technology, they focus on data throughput, radio coverage, and sensors, while for smart solutions, they concern data generation and processing, low latency and responsiveness, high security levels, and bandwidth utilization [68]. By its characteristics, 5G appears to solve these bottlenecks. But this will only happen if certain limitations are overcome, such as network infrastructure gaps, insufficient equipment, high costs, and a historical moment ripe for embracing new technology. If this does not happen, the bottlenecks are unlikely to be resolved. Therefore, it will take time before the smart solutions are fully implemented.

Information systems, including GIS, integrate data from multiple sources and formats, and serve as a decision support tool for PAs, urban planners, and others, allowing them to discover patterns and take actions [69]. For example, the USRC WebGIS app[6] acts as a support for this research-in-progress, starting from the analysis of problems (e.g., mountain/rural area constraints, including location and height of natural/man-made objects) and the state-of-the-art of secure and sustainable technological solutions. Wireless propagation tools will be used to assess the connectivity of towns and develop an appropriate model.

### 3.1. Radio Network Planning: a preliminary insight

In the age of “one person, many computers,” where we have a variety of devices for different purposes merging with our lives, Weiser [70] coined the term “ubiquitous computing” and Elia [71] argues that “technological innovations affect society, and as a result new urban models emerge and thus new ways of working and living together within them.” Essential to enable digital services is reliable and widespread connectivity. Despite advances in fiber optics, mobile networks, and ultra-broadband, large areas of Italy, particularly small towns, rural and mountainous regions, lack stable, fast connections (e.g., the reference scenario). As per the 2030 European Digital Agenda, the USRC promotes *borghi connessi* for

[6]https://datigis.usrc.it/webgis

greater inclusion in network access and to help reduce the territorial digital divide. After all, the quality of connectivity has a direct impact on the provision of public services and supports competitiveness. Data analytics and automation drive planning to upgrade the municipality services offered [72].

Geography is an integral element of the digital environment. A GIS is a computer system that collects, stores, analyzes, monitors, and displays data about spatial locations on the Earth's surface. Commercial or open-source, it functions as a database with geographic information (shape files) associated with the graphic objects of digital maps: when you point to an object, you can know its related attributes (population, roads, income, etc.) and, conversely, by querying a database record, you can know its location in the map. Thus, many services that include location take advantage of GIS. In radio network planning, empirical methods have proven effective, especially if they use data directly collected from the context instead of using those from a similar scenario. As input to simulations, the tools use GIS data, physical infrastructure, and computer networks; hence, the quality of the calculations and coverage prediction models depends on their completeness and accuracy [73]. Of course, they also take into account the priorities of local stakeholders and the will of the USRC.

Attour et al. [74] look at towns such as "*living labs*" that can generate eco-innovation, where sensors and IoT devices connected through 5G or Wi-Fi networks exchange data that enable systems to learn, adapt, and respond to changing conditions, enhancing performance.

Among the available tools, the Altair WinProp suite, which has empirical wave propagation models and network planning modules (coverage and capacity), combining accuracy and reduced computation time, will be used for air interface simulations (including 5G's mmWave). It works for a wide range of scenarios, such as rural, residential, and suburban (i.e., the reference context). It integrates with other systems: in fact, it uses different types of databases, including GIS, for forecasting and edge computing for wide coverage. In traffic assumptions, it also takes into account overhead interference that impacts the radio channel, supports the loss of power cables, and makes antenna configurations possible. Coverage prediction and analysis tools help generate detailed coverage maps and the number of tower sites needed to support them. In radio analysis, the tool calculates parameters for various transmission modes and cells because the goal is to arrive at the solution that provides the best service in terms of received power, data rate, throughput, QoS, bandwidth, delays, etc., for each location in the coverage area. Network simulations with different parameter tunings can be used to evaluate performance, taking into account the context requirements, and arrive at the optimal solution for it. A first application could be fiber sensing for seismic monitoring.

In conclusion, community interaction can stimulate the knowledge economy, which mainly favors platforms. In this regard, Alaimo and Kallinikos [75] argue the need to separate data from facts, because data live in a socio-technical dimension, are agnostic to the context that generates them, but are not neutral, that is, the choices that produce them are relative to the value systems of those who designed the ways to collect/use them, and are vital to computer science.

## 4. Conclusions

Rebuilding a territory after a natural disaster requires thoughtful and strategic planning. The 2009 earthquake-hit area is applying a smart-oriented approach, using the power of technology to improve the reconstruction process, digitize services, build smart towns, increasing territorial capital. From literature and practice, digital services are efficient but increasingly citizen-centered, confirming their cross-sectoral and multidimensional nature, as they focus as much on technology as on the people who are part of them. Although the creation of Human Smart Towns presents significant challenges, especially in terms of initial investment, training, and technological integration, it offers a long-term, sustainable, and forward-looking perspective. Thus, seismic crater municipalities play a role in creating a smarter society, serving as a case study for recovery efforts in similar disasters through experience and sharing of best practices[7]. The development of a smart reconstruction paradigm is a boost to the digital transformation of public action, and PA is modernized.

[7] https://www.eipa.eu/epsa/digital-for-reconstruction-grants/

The integration of GIS, AI, sensors, distributed computing, and advanced communication networks has the potential to innovate a reconstruction process. The demand for adequate availability and reliability of connectivity underlies smart services. This work-in-progress concerns preliminary insights on optimized use of radio resources for broad network access and signal reception in the area. The idea is to combine empirical computational methods with geographical information, as is customary among geospatial professionals. The outcome will be a technological framework accompanied by recommendations for the USRC to upgrade ICT networks and open spaces. The Special Office is implementing an exemplary model recognized worldwide for its innovative use of emerging technologies for the common good, serving as a benchmark in research on territorial resilience and technology transfer.

Finally, since communication and services are highly dependent on data, it is critical to ensure that data and infrastructure, such as telecommunications, are protected from cyber threats. The challenges of interoperability, (cyber-)security, and privacy must be addressed for successful implementation.

## Declaration on Generative AI

The author has not used any generative AI tools in the writing process.

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# A. Community-driven Approach for the Regeneration of Santo Stefano di Sessanio (Italy)

The co-design process of the territory with the communities that inhabit it is understood as a system of socio-economic relations. The Organization for Economic Cooperation and Development (OECD) recognizes the importance of public service innovation as a means by which government can ensure that public services keep pace with the changes taking place in societies, including the evolving needs, behaviors, and expectations of people.

As a result of participation in the OECD 2023 call for innovations in public services, the *community-driven approach for the regeneration of Santo Stefano di Sessanio (L'Aquila)* has been included among OECD-OPSI (Observatory of Public Sector Innovation) case studies[8]. The 2009 earthquake and the Covid-19 pandemic have amplified negative trends that were already underway (e.g., depopulation and marginalization) due to a lack of connectivity, critical infrastructures, productivity issues, and limited access to public services have over time diminished the attractiveness as a place to live/work. To address this urgency, an experimental project "*Ascolto Partecipato*" was launched in February 2023, jointly promoted by the Municipality of Santo Stefano di Sessanio and the USRC[9]. A pilot project to foster new bottom-up approaches for the revitalization of other seismic crater municipalities or rural areas. The result was the identification of action lines for town regeneration, resulting from a mutual understanding of local strengths, issues, and needs, with active involvement (as a *driver of change*) of citizens, visitors, economic operators and trade associations active in the area, public authorities, and mayors of neighboring municipalities. Their empowerment ensures that the territory's major challenges can be addressed.

[8] https://oecd-opsi.org/innovations/community-driven-approach-for-the-regeneration-of-santo-stefano-di-sessanio-italy/
[9] https://www.usrc.it/attivita/sviluppo-del-territorio/progetto-ascolto-partecipato/