Smart Cities: A Response to Wicked Problems

Ekene Okwechime, Peter B. Duncan, David A. Edgar, Elisabetta Magnaghi, and Eleonora Veglianti

Abstract In this paper we investigate the underlying theoretical and practical dimensions of the smart city concept. Exploring the smart city concept is necessary for understanding its meaning and usefulness. We begin by framing the problems faced in cities, i.e. urban issues, as wicked problems: complex and intractable. Then, a review of the meaning of a smart city is carried out in order to reach a holistic working definition of the concept. We also provide a description of how stakeholders are organized in providing smart-city-based solutions to urban problems in cities. A smart city case study situated in Glasgow, Scotland is developed. By doing so, we provide a new and practical perspective to comprehend the meaning and the use of the smart city concept in addressing urban problems by synthesizing important success factors.

Keywords Smart city · Urban problems · Wicked problems · Stakeholders

1 Introduction

The preference to live and work in cities has become increasingly dominant, which has led to the growth (and predicted future growth) of cities. City authorities have to grapple with complex urban problems. Cities now need to manage issues that

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E. Okwechime (✉)
Lancashire School of Business and Enterprise, University of Central Lancashire, Preston, UK
e-mail: eokwechime@uclan.ac.uk

P. B. Duncan · D. A. Edgar
Department of Business and Management, Glasgow Caledonian University, Glasgow, UK

E. Magnaghi
Department of Business and Economics, Université Catholique de Lille, Lille, France
e-mail: elisabetta.magnaghi@univ-catholille.fr

E. Veglianti
Department of Economics, University of Uninettuno, Rome, Italy
e-mail: eleonora.veglianti@uninettunouniversity.net

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arise from this population growth by creating smarter cities. The problems that have served as a precursor for the prominence of smart cities are conceptualised to be wicked problems (after Bettencourt [11]).

Therefore, to understand smart cities, it is important to begin with exploring the nature of wicked problems. The rise in population and projected growth of cities require stakeholders to find innovative ways to provide more efficient amenities through the development of smart cities ([15], [56], [68], [67]).

The rest of the article is structured as follows. Section 1.2 critically evaluates—the nature of problems that have led to the adoption of the smart city concept—wicked problems. Accordingly, to arrive at a working definition of the smart city concept (as a response to wicked problems), Sect. 1.3 critically examines the meaning of a smart city. In line with this, Sect. 1.4 critically evaluates the way organisations and stakeholders come together to work on smart city initiatives, via public-private partnerships and the Triple Helix. A smart city case study is presented in Sect. 1.5. Finally, recommendations and a conclusion are provided in Sect. 1.6.

2 Wicked Problems

The purpose of this section is to critically examine the wicked problem concept. Wicked problems are problems that are perceived to be malignant (deep rooted) or vicious (cyclical), tricky (difficult to understand) and even aggressive (leading to grave consequences) ([18], [22]). The term 'wicked' does not refer to the problems under consideration as being ethically despicable but refers rather to their intrinsic nature.

The ethical undertone of the term, however, stems from how the problem-solver deals with the problem. This raises the question on whether it is morally objectionable for planners to treat a problem as a tamed one or to ignore its viciousness, cyclicality, difficulty or its impending consequences because of the failure to solve a problem [63].

The wicked problem concept was officially described in a treatise titled 'Dilemmas in the General Theory of Planning' [63]. The concept is built on the premise that tackling problems in policy areas are likely to fail due to their intrinsic nature. This is because such problems can be wicked and untameable, unlike problems in the pure sciences that are identified and tamed [63]. Rittel and Weber ([63, pp. 161–166]) then introduced ten characteristics of a wicked problem:

1. "There is no definitive formulation of a wicked problem.
2. Wicked problems do not have any fixed or stopping rules.
3. Solutions to a wicked problem cannot be binary options such as true-or-false, but rather can be good or bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a 'one-shot operation'; because there is no opportunity to learn by trial and error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well described set of permissible operations that may be incorporated into the plan.

7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The social planner has no right to be wrong (i.e., planners are liable for the consequences of the actions they generate)".

In line with the characterisation of a wicked problem, various scholars, Bettencourt [11], Camillius [13], Conklin [20], Ferlie et al. [28], Jentoft and Chuenpagdee [42], have reformulated their own perceptions of a wicked problem into different subject areas. Bettencourt [11] has narrowed a wicked problem to be a problem of knowledge that focuses on algorithmically calculating problems in urban planning, while Camillius [13] related it to strategy creation in business. What these variations of a wicked problem illustrate is that the ten characteristics of a wicked problem (by Rittel and Webber) are not a set of tests, but rather offer insights that could help a problem-solver determine the nature of a given problem.

A recurring theme from these variations of wicked problems is the scope and scale of the problem. For instance, solving an equation in mathematics or analysing the constituents of an unknown compound or making a checkmate in five moves in a game of chess are not wicked problems ([13], [22]). In these examples, the mission is clear, even if the problem is not solved. On the contrary, urban problems like many social ones, lack clarity in terms of a stated problem.

Bettencourt [11] argues that solving a wicked problem could require the problem-solver to produce an inventory of possible solutions ahead of time. This implies that the problem solver would not seek out the root causes of the problem but will satisfice on solutions. Von Hippel and Krogh [38] also note that with listing an inventory of solutions, satisficing a search alternative can be deployed to justify solutions that can be deemed satisfactory. However, Bettencourt [11] and Von Hippel and Krogh [38] do not specify if an inventory of more problems arising from satisficing would also need to be produced at any point of the problem-solving process.

The 'wickedness' of a problem does not mean that the latter is difficult; it otherwise means that it cannot be completely solved ([20], [28]). The inability to address it can also be due to various underlying intertwined complex causes. In effect, if one aspect can be solved, there will be currents of other issues coming from the interconnected problems emanating from the one the planner had attempted to solve [42].

The complexity of urban problems would have an impact on how planners attempt to solve problems. This problem is symptomatic in different spheres of socio-economic, organisational and political planning. For example, when top managers in organisations deal with the issue of creating strategy, whereas ecologists try to deal with fishing and coastal governance ([20], [42]).

The ten characteristics of a wicked problem are in line with the nature of urban problems; because such problems have no defining mechanism or formula and are ill structured and complex. The issues in a city are often nebulous and cannot be entirely solved and emerge from an organised and functioning social complex system. For

instance, if a city faces unprecedented challenges like high crime rates and poverty; completely solving the problem could prove intractable.

This is because planners cannot possibly know how city dwellers will want to develop their city, even down to the elementary basics of planning, such as shapes of streets, houses, use of spaces and zoning. Solving problems like this makes it 'wicked' because each problem is intertwined with another and solving one exposes the planners to others (Goodspeed 2015). Given that wicked problems defy traditional problem-solving techniques, what the above demonstrates are the challenges organisational stakeholders in the public sector currently encounter. Therefore, a wicked problem can be described as problems bridled with deep complexity with unknown consequences.

This section has critically examined the nature and characteristics of a wicked problem. It has been argued that a wicked problem cannot be reduced to an equation: a low and accurate understanding of a problem. Having done so, this then raises a fundamental question of how a wicked problem can be addressed in a city. To this end, the following section critically examines the smart city concept, a proposed solution to urban problems.

3 The Smart City Concept

The purpose of this section is to critically examine the meaning of the smart city concept and its characteristics. To understand the smart city concept, a definition is pertinent. As noted in Sect. 1.2, the smart city concept has partly been adopted as a response to wicked problems. The definition of a smart city itself poses one of the most fundamental challenges to adopting the concept (Hollands 2008, [56]).

Furthermore, the issue with a definition arises partly because there are terms analogous to the smart city concept that have the same goal ([15], [73]). Albino et al. [1], in their review of definitions and characteristics of smart cities, identified the shared constituents of the various smart city labels.

There are analogous terms such as the 'creative city' by Bayliss [10]; the 'entrepreneurial city' (Hollands 2008) and 'intelligent city' by Komninos et al. [44]. Albino et al. [1] argue that underneath the quest for urban smartness—and the various smart city labels—lies a shared aim to make cities perform better in comparison to traditional ones.

Table 1 provides various definitions of a smart city; drawn from Albino et al.'s [1] review of the definition of the concept. In general, the table reveals that the smart city concept entails the diffusion and integration of ICT, the inclusion of citizens in the decision-making and creative process of the city to provide cost efficient and effective services. The first column in Table 1 contains an outline of definitions, while the second column contains the sources of those definitions.

The term 'smart city' is treated as a conceptual dimension by which being smarter involves strategic directions; because cities are the centre of economic activity and administrative control in society [32]. Governments and public agencies are rapidly

Table 1 Definitions of Smart City

Definition	Source
Smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality.	Bakıcı et al. [6]
Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centres that are at once integrated, habitable, and sustainable.	Barrionuevo et al. [8]
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. [15]
Smart cities will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone.	Chen [17]
Two main streams of research ideas: (1) smart cities should do everything related to governance and economy using new thinking paradigms and (2) smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life.	Cretu [23]
Smart community—a community which makes a conscious decision to aggressively deploy technology as a catalyst to solving its social and business needs—will undoubtedly focus on building its high-speed broadband infrastructures, but the real opportunity is in rebuilding and renewing a sense of place, and in the process a sense of civic pride. Smart communities are not, at their core, exercises in the deployment and use of technology, but in the promotion of economic development, job growth, and an increased quality of life. In other words, technological propagation of smart communities isn't an end in itself, but only a means to reinventing cities for a new economy and society with clear and compelling community benefit.	Eger [26]
A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. Smart city generally refers to the search and identification of intelligent solutions, which allow modern cities to enhance the quality of the services provided to citizens.	Giffinger et al. [31]

(continued)

Table 1 (continued)

Definition	Source
A smart city, according to ICLEI, is a city that is prepared to provide conditions for a healthy and happy community under the challenging conditions that global, environmental, economic and social trends may bring.	Guan [33]
A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and) monitor security aspects while maximizing services to its citizens.	Hall [35]
A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city.	Harrison et al. [36]
(Smart) cities as territories with high capacity for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management.	Komninos [44]
Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (e.g. skilled labour force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities).	Kourtit and Nijkamp [46]
Smart cities have high productivity as they have a relatively high share of highly educated people, knowledge-intensive jobs, output-oriented planning systems, creative activities and sustainability-oriented initiatives.	Kourtit et al. [47]
Smart city [refers to] a local entity—a district, city, region or small country which takes a holistic approach to employ[ing] information technologies with real-time analysis that encourages sustainable economic development.	IDA [41]
A community of average technology size, interconnected and sustainable, comfortable, attractive and secure.	Lazaroiu and Roscia [48]
The application of information and communications technology (ICT) with their effects on human capital/education, social and relational capital, and environmental issues is often indicated by the notion of smart city	Lombardi et al. [50]

(continued)

Table 1 (continued)

Definition	Source
A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains.	Nam and Pardo [57]
Creative or smart city experiments […] aimed at nurturing a creative economy through investment in quality of life which in turn attracts knowledge workers to live and work in smart cities. The nexus of competitive advantage has […] shifted to those regions that can generate, retain, and attract the best talent.	Thite [71]
Smart cities of the future will need sustainable urban development policies where all residents, including the poor, can live well and the attraction of the towns and cities is preserved. […] Smart cities are cities that have a high quality of life; those that pursue sustainable economic development through investments in human and social capital, and traditional and modern communications infrastructure (transport and information communication technology); and manage natural resources through participatory policies. Smart cities should also be sustainable, converging economic, social, and environmental goals.	Thuzar [72]
A smart city is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth. These aspects lead to smart city conceptions as "green" referring to urban infrastructure for environment protection and reduction of CO^2 emission, "interconnected" related to revolution of broadband economy, "intelligent" declaring the capacity to produce added value information from the processing of city's real-time data from sensors and activators, whereas the terms "innovating", "knowledge" cities interchangeably refer to the city's ability to raise innovation based on knowledgeable and creative human capital.	Zygiaris [76]
The use of Smart Computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient.	Washburn et al. [75]
Smart cities initiatives try to improve urban performance by using data, information and information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors, and to encourage innovative business models in both the private and public sectors.	Marsal-Llacuna et al. [53]

Source Albino et al. ([1], pp. 6–8)

embracing the notion of smartness for targeting sustainable development goals, economic growth and a better quality of life for their citizens [7].

Given the fastmoving nature of the concept and its underlying link to information communication technology (ICT) and big data, a working definition is pertinent. Based on the review of the literature, considering the various facets of a smart city, a working definition of a smart city is one where attempts are made:

> … to improve urban performance by using data and [ICT] to provide more efficient services to citizens; to monitor and optimize existing infrastructure; to increase collaboration among different economic actors and to encourage innovative business models in both the private and public sectors (Marsal-Llacuna et al. [53], p. 618).

The above working definition was adopted because of its emphasis on the use of (big) data and ICT in looking for ways to provide cost effective and efficient services for citizens and the means in which to achieve this. Even though this contribution focuses on smart cities as a response to wicked problems, it is pertinent to note that the concept could be adopted as a response to the impact of climate change, which makes cities focus on resilience and sustainability ([43], [64]). What this implies is that the impact of population growth goes beyond the physical characteristics of a city because it affects ecology. However, due to the evolution of the concept, it is difficult to identify an existing smart city [67]. This, in turn, makes cities who attempt to adopt a smart city approach become 'living laboratories' that host smart city initiatives [5].

3.1 Smart Cities as Living Laboratories

Table 1 provides an inference of smart cities being an experimental and developmental project, which make cities a 'living laboratory'. The vision of the cities is executed in smart city initiatives to test and demonstrate the workings of the smart city technology [2]. For example, some cities in the UK (and around the world) are testing out the use of driverless cars [34]. Living laboratories or 'living labs' "are eco-systems in which end-users and other relevant stakeholders are involved in the development of an innovation over a longer period of time" ([66] in Baccarne et al. [5], p. 161).

Cosgrave et al. [21] argue that the living lab approach is one adopted by most cities given that the smart city concept is introduced and developed in initiatives. Living labs are central to how cities test out the smart city concept by aiming to nurture a creative economy through the investment in quality of life, which could in turn attract and retain people [1].

Living labs also give stakeholders the opportunity to assess the immediate impact of the smart city initiative. These labs are also in line with the working definition of a smart city adopted for this research, which lays emphasis on attempting to optimise already existing infrastructure to provide effective services for the citizens.

Table 2 Characteristics of Smart Cities

Smart Economy Entrepreneurship Flexibility Internationally Embedded Productivity Transformative	Smart People Affinity towards lifelong learning Creativity Levels of educational attainment Participation in public life Social and ethnic plurality
Smart Governance Participatory decision-making Provision of public and social services	Smart Mobility Availability of ICT infrastructure Innovative and safe transport systems Local and international accessibility
Smart Environment Environmental protection Pollution levels Sustainable resource management	Smart Living Educational facilities Health conditions Housing quality Individual safety Provision of cultural facilities Social cohesion Tourist attractiveness

Source Giffinger et al. [31]

The purpose of a smart city initiative is embedded in the definition it adopts [12]. Furthermore, it could be deduced from Table 2, that there are recurring themes in the definitions of a smart city, which focuses on goals such as: connectivity; governance liveability and sustainability [31]. The following sub-section critically evaluates the characteristics of a smart city.

3.2 Smart City Characteristics

Giffinger et al. [31] drew up six characteristics for a smart city. The six main characteristics of a smart city are: (1) smart economy; (2) smart people; (3) smart governance; (4) smart mobility; (5) smart environment and (6) smart living. All six characteristics are encapsulated in Table 2.

These characteristics point to the areas of urban living where the smart city concept can be used to improve existing infrastructure with the use of data and ICT to provide efficient services for its citizens. Within each smart city characteristic outlined in Table 2 are the various areas of its application to urban living and problem solving.

- **Smart Economy**

The first characteristic of a smart city (smart economy) stresses on the need for a business led approach to urban development [31]. A smart economy lays emphasis on economic competitiveness for urban development, bordering on competition for economic activity as well as for people (Hollands 2008, [50]). A smart economy is a driver for growth because business friendly cities are those with reasonable socio-economic performance [31]. However, there are potential risks of putting a high premium on economic values, as the main drivers for urban development, against factors like innovation.

Soete [69] suggests that city planners should focus on innovation rather than just the economic competitiveness of the city, to ensure sustainable growth. This implies that planners should engage in a trade-off against each factor (innovation and competition). Incidentally, the innovativeness of a city affects the overall competition of the city. The rationale behind this school of thought is that through innovation, cities can remain sustainable while also remaining competitive. In other words, planning a smart city should be based on innovation as the cornerstone of competition.

Capello et al. [14] using data from EUROSTAT—via the community innovation survey—found out that a city's innovativeness was strongly linked to it urban industrial structure. Methodologically, the analysis was evaluated with industrialisation constructs, which could have impacted the results. However, such relationships depend on the presence of knowledge intensive services that are suitable for businesses to thrive. These further buttresses the point that a city's innovativeness has a direct impact on its competitiveness through the presence of knowledge intensive services and industries.

- **Smart People**

The second characteristic of a smart city (smart people) lays an emphasis on the role the high-tech and creative industries could play in the long-term sustainable growth of a city through the people that work there. This characteristic relates to fostering knowledge networks, which makes a city a suitable breeding ground for the creative industries. The creativity of a city will be the driving force of the 21st Century economy. This is because creative occupations are on the rise, businesses now position themselves to entice the creative.

Bayliss [10] argues that through an emphasis on creativity, a city can stimulate its growth by promoting itself on an international level, thereby attracting people and investments. However, Nijkamp [58] critically summarises the role of a creative culture in a city by noting that, although creative human capital jointly determines and fosters trends observed in skilled migration, a creative and skilled workforce does not inherently guarantee a high urban performance. Therefore, cities could consider strategies to attract and retain creative people.

- **Smart Governance**

The third characteristic (smart governance) lays emphasis on 'participatory governance' in a city. Participatory governance should do with the way residents of the city are included into the day-to-day decision-making for the provision of public services. In other words, smart governance entails to what extent all social classes are included

into the urban fabric of the technological and economic advancements of the city. Coe et al. [19] suggest that smart city initiatives that champion social inclusion should be encouraged as they enable social cohesion and a connected citizenry.

Nonetheless, social inclusion themed initiatives might prompt city planners to pay attention to the critical issue of fostering an equitable society. Mainka et al. [52] argue that through the integration of ICT in cities, smart governance can transform and add more value to the services provided by the city. This is because there would be a wider array of stakeholders participating in the decision-making process.

- **Smart Mobility**

The fourth characteristic (smart mobility) drawn up by Giffinger et al. [31] focuses on the deployment of network infrastructure to increase the cultural and socio-economic development of a city. Here the term 'infrastructure' denotes to business services, housing and ICTs such as satellite TVs, e-commerce, mobile and fixed phones and computer networks [50]. This characteristic has guided several developmental smart city models such as the T-City project in the city of Friedrichshafen in Germany (Hatzelhoffer 37).

In this case, connectivity is perceived as the source of growth and the level of infrastructure available to the population. From a policy point of view, policy-makers tend to struggle to maximize the potentials of carrying out projects that could ensure the networking of a society. To achieve the optimum networking of a city requires a combination of technology, infrastructure development, institutional reform, education and business to lever the ICT and big data to become a networked society.

- **Smart Environment**

The fifth characteristic (smart environment) focuses on social and environmental sustainability as a significant strategic component for actualising smart city plans [31]. This is because a city should be environmentally conscious and at the same time able to make use of its natural resources to sustain itself. Smart city initiatives often adopt this dimension if there is a focus on sustainability. As such, smart cities must be physically and spatially enabled to foster environmental sustainability.

For example, the way ICT is embedded into an environmental strategy of a city, i.e. where digital sensors embedded in a city enables planners to know what ways natural resources can best be managed. Given that cities tend to compete for not just people but on harnessing resources, such as in tourism, there arises a need to optimise already existing infrastructure [53]. In other words, this characteristic entails what ways natural resources are exploited for urban sustainability.

- **Smart Living**

The sixth characteristic (smart living) focuses on combating social inequality. Coe et al. [19], drawing from the absorptive capacity theory, argue that citizens are meant to be able to benefit from growing technology available in the city. A possible interpretation could be that social and economic problems that affect a city's capacity to innovate should be considered, if not it stands, the chance to be socially polarised.

Conversely, Poelhekke [61] argues that the concentration of highly skilled people in a city is adequate for urban growth despite the polarising consequences. Thus, the impact this might have on a city may have mixed results. The impact could range from a schism between the rich and poor as well as the skilled and unskilled citizens, which might invariably hinder social mobility and increase inequality.

The divisions brought about by social inequalities in cities manifests themselves in certain parameters amongst various social and economic groups. The outcomes could raise issues around life expectancy, individual safety, poor health outcomes, life prospects, poor housing, lack of social amenities, lack of social cohesion etc. In this instance, smart city initiatives would have to look for ways to address the problems around smart living, such as the provision of educational facilities

These six characteristics encapsulate the objectives of various smart city initiatives. Overall, the purpose of a smart city initiative is to address key aspects of urban living [5]. The integration of ICT ensures that cities do become smart, but this might differ depending on the initiative [9], [53]. What this then suggests is that depending on the problem to be solved different approaches can be espoused [3].

Nevertheless, regardless of the smart city characteristic chosen, it is still pertinent to probe the assertions and associations that make a city smart. From the above characteristics, and the previous analyses on the meaning of a smart city, a smart city is what the stakeholders want it to be in relation to the aforementioned six characteristics.

The section has critically analysed the meaning of the smart city concept and its characteristics. A working definition of smart city by Marsal-Llacuna et al. [53] has been adopted for this paper. The six smart city characteristics form the different areas in which the concept can be applied to address urban problems. Marsal-Llacuna et al. [53] particularly emphasise the involvement of various actors (multiple stakeholders) in a smart city initiative. Therefore, the following section critically examines the structure in which the collaborations between different stakeholders could take place in a smart city initiative.

4 Collaborations for Smart Cities: Public Private Partnerships & the Triple Helix

The purpose of this section is to critically examine the concepts of public-private partnerships (PPP) and the Triple Helix in relation to the creation of smart city initiatives; to demonstrate the shifting innovation landscape in smart cities that is typified by the participants involved and the level of intensity of their participation. In a smart city initiative, there are multiple stakeholders involved in the process of problem solving [2], [44], [53]. To address complex problems, such as wicked problems/urban problems, problem-solving heuristics can be central in determining what solutions are deployed in a smart city initiative.

The planning structure of a smart city is carried out in public-private partnerships (PPP) [37], 40, [51], [60]. The collaborative structure in which a smart city is planned depends on the stakeholders involved in the process, such as a domain-specific of smart city initiative. For example, a smart city initiative that requires more active citizens. Despite the widespread adoption of PPP, there is no single definition for the concept and few scholars agree on what it means ([24], [39]). However, a PPP has served as a replacement to traditional contracting arrangements and to get private organisations to deliver public services [45].

These perspectives on PPP are consistent with the views by Mckee et al. [54], who argue that a PPP occurs when a governmental body contracts the delivery of a service to a private organisation. On the other hand, a PPP could be an arrangement whereby private organisations are given the right to operate a service, conventionally the responsibility of the public sector. Thus, a PPP could be referred to as inter-institutional arrangements between public and private sector organisations on certain projects for the public's benefit ([45], [60]).

Within the smart city domain, a PPP could occur when services are delivered mainly through a public system for the public by private organisations. The involvement of private organisations could be because of public organisations lacking the level of expertise to provide such a service, knowledge, capability or finances for an initiative. Therefore, such collaborations are not joint ventures in a business sense, but a partnership between two or more participating organisations in the private and public (and not-for profit) sectors. However, for the development of smart cities, the input or ideas for the provision of support services are sourced from what could generally be termed as the 'private sector' [37]. Hatzelhoffer (37) demonstrates that the process of developing a smart city involves a wider array of stakeholders, namely academia. Consequently, a PPP for smart cities can be referred to as a joint venture that brings various organizations from different sectors that share certain attributes and, most importantly, a shared objective.

The participation and involvement of different stakeholders are pivotal to the creation of a smart city, especially through the triple helix model. Deakin [25] suggests that the triple helix provides the opportunity for planners to study a community in terms of getting the wider society's support for the development of an innovative eco-system that promotes environmental and cultural development.

There are two main strands of the Triple Helix concept ([25], [49], [70]). The first is one where universities play a pivotal role, which could be on par with that of industry (Etzkowtiz 2008, [27]). The second is one where there is collaboration between the three key main stakeholders—academia, industry and government—in the innovative process for smart cities [55]. The latter is more in line with the Triple Helix system of innovation proposed by Ranga and Etzkowitz [62]; the process synthesises the key features of Triple Helix interactions into an innovation eco-system format, based upon a set of components, relationships and functions.

The relationship between these components is, then further, synthesised into five main types: technology and knowledge transfer, collaboration and conflict moderation, collaborative leadership, substitution and networking ([16], [55], Nijkamp

et al. 2011, [62]). Thus, the overall function of the Triple Helix system serves for knowledge generation, innovation, diffusion and application.

Moreover, Meyer et al. [55] highlight that the literature on Triple Helix has tended to focus on universities being the central body in this relationship; however, the perceived role played by universities has begun to disintegrate given the change in the innovative landscapes, especially because of new non-technological driven innovations, such as service innovation. Similarly, new institutional arrangement and advances in computing and communication technologies have created a space for the participation of new and more stakeholders in open and user-driven innovation eco-systems; thereby, moving the locus of problem solving away from a single organisation to then include multiple—in this context more than three main—agents. However, within the smart cities' domain, there is a shift in the innovative landscape, which has been facilitated by the widespread applicability of ICT and big data.

Regardless of the form a Triple Helix takes, the roles between the actors involved in creating a smart city is becoming increasingly blurred. In other words, this can be described as a hybrid helix of organisation. The blur emerges because of the core focus and interests of the respective actors in a smart city initiative and the inclusion of more stakeholders outside the traditional three. Meyer et al. [55] argue that the sphere of interest of various actors has been halted and, in some cases, began to retreat to their core businesses; for example, universities on teaching and research. Anyhow, from the Triple Helix concept reviewed for this paper, from a smart city perspective, there were no research that included the direct involvement of its citizens in the innovation eco-system. This could be due to the form and structure smart cities assume when they are commissioned. Smart city initiatives could vary in terms of how active their stakeholders can be compared to others. Consequently, mutual platforms can also involve the establishment of committees, teams and organisations. As a result, Carayannis and Rakhmatullin [16] have argued for a quadruple, and where necessary, a Quintuple Helix.

This section has evaluated PPP as an inter-institutional structure and the Triple Helix as an innovative model for the creation of smart cities. Collaborations in the planning and execution of smart city initiatives, however, still mainly remain a relationship between private and public sectors organisations. Even within a Triple Helix framework, the collaborations that occur do not have a triple inter-face. The multiplicity of stakeholders has a disrupting effect on the creative process in addressing urban issues through the development of smart cities.

5 Case Study

The purpose of this section is to present an example of a smart city situated in Glasgow in Scotland (United Kingdom) named *Future City Glasgow* (FCG) which operates on various work streams (see Table 3). In this case study, the smart city has been used by the city council to address urban problems by demonstrating how data and smart solutions can help in addressing urban issues.

Table 3 Overview of the Future Glasgow Project

Project stream	Scope	Current state (October 2015)
Active Travel	Mobility (Cycling)	Currently only 2% of journeys made into Glasgow city centre involve cycling. Increasing the number of journeys by bike and or foot should help the city cut carbon emissions, boost its air quality and help tackle obesity.
City Technology Platform	Governance (Participation)	The City Technology Platform (CTP) integrates and analyses different data streams. The data is presented in a machine-readable format, which is open for use to whoever wants to use it. It can be accessed through its website (MyGlasgow dashboard) and smart phone apps.
Energy Efficiency	Energy Consumption	The city authorities are working with housing authorities to address energy consumption in older, more difficult to heat properties.
Mapping Demonstrator	Culture and Tourism	The city has urged citizens to upload information about their communities online. This includes details of favourite bars, restaurants, shops and heritage sights.
Operations Centre	Security and Safety	The city has deployed safety cameras that detect unusual activities. Suspicious detection should trigger an alarm that would be investigated by the appropriate response service.
Social Transport	Mobility (Social Transport)	The city has deployed route optimising software and scheduling tools in conjunction with service providers to reduce route duplication—to reduce the number of unnecessary journeys made and to ensure that buses carry the optimum number of passengers. This should reduce traffic congestion, air pollution and the number of buses on the road (also cutting costs).
Street Lighting	Energy Efficiency	The city has deployed energy efficient LED lamps, which have demonstrated how the city could reduce its carbon emissions, reduce energy consumption and ensure safety.

Source Future City Glasgow [30]

FCG is a £24 million smart city initiative, which aims at demonstrating how technology can make living in the city smarter, safer and more sustainable (www.gov.uk). Glasgow beats 29 other cities to win funding for the programme in a contest run by the Technology Strategy Board (TSB), the British government's innovation agency [74]. The £24 million grant lasted for over a period of three years (2013–2016).

In doing so, the city authorities and planners are putting residents at the forefront of the technological integration and application ([4], [29], [71]). It is a data-driven process that is meant to assist policymakers and inform future investments to improve the efficiency of the provision of services. The initiative is encapsulated in Table 3, which covers areas such as healthcare, public safety, transportation and sustainability. This case adopts an inter-institutional arrangement that involves the public, academics and businesses, which is geared towards getting these stakeholders involved in using the data and contributing their own knowledge to the initiative.

For instance, the open data work stream deploys an intelligent data platform to store, analyse and publish real-time data on an online dashboard [30]. Data can be accessed on widgets and smartphone applications (apps). Another example was given, where one of the apps allows users/citizens to bring to the attention of city authorities uncollected trash and potholes—i.e. with use of smart phones—as well as receiving updates on the problem that was reported [30]. In line with open data principles, by opening data to the public, the city can engage with entrepreneurs and application developers who come up with useful ideas and solutions that help the city address urban issues.

More than 400 data streams have been identified in Glasgow; they include information on everything from bin collections to footfall in retail areas [30]. For the active travel, there is a cycling app that records the journey of cyclists, so that the council knows what routes are regularly used, which in turn allows stakeholders to know where and how to channel resources towards having an adequate cycling infrastructure. From its inception in 2013, the city has embarked on building three-dimensional (3D) model sensors in public housing buildings to help improve the energy efficiency of the citizens and city. The city council has demonstrated that they are able to redeploy these vehicles to other divisions when not being used.

Therefore, the smart city concept is a useful way to address complex urban problems. Stakeholders—in the public, private and academic sectors—involved in addressing urban problems can combine their expertise and deploy cutting-edge technology to better the day-to-day living in a city. Hence, the smart city initiative included:

- A smart street lighting demonstrator showing how the city can deploy smarter street lighting to improve the lighting quality, reduce energy usage and ensure efficient management. The other capabilities of this scheme could be transferred in other areas, such as: noise detection, movement detection, air pollution detection and wireless internet (Wi-Fi) service.
- The active travel demonstrator highlighting how the city could be more inclusive to accommodate cyclists and pedestrians.

- The integrated social transport demonstrator helped some of Glasgow's most disadvantaged citizens access social and educational services. A smart integration and route scheduling software, thus, increased the flexibility and responsiveness transport services.

6 Recommendations and Conclusion

The preference for people to live and work in cities has led to the growth (and predicted future growth) of urban areas. This growth poses challenges for planners and city-dwellers alike, such as in the development of infrastructure and the provision of basic services. The smart city concept is perceived to be a useful way to mitigate the challenges facing urban areas. Successful smart city initiatives can be categorised into the six characteristics discussed in sub-Sect. 1.3.2. For example, the city of Glasgow smart city initiative has successfully demonstrated how the smart city concept could be put into practice (see Sect. 1.5).

Multiple stakeholders working in a smart city project can define the structure that a smart city can take. For example, Glasgow wants its smart cities to be an eco-system of developers (a triple, quadruple or even quintuple helix) and data owners who work together to release, renew and update datasets that can be used to develop solutions for urban problems. Therefore, by adopting this model the city hopes to provide bespoke services that address particular problems, such as in security and safety. Thus, by opening up datasets to the public, the city hopes to build trust with its citizenry in order to enhance (data-driven) decision-making.

Becoming a smart city requires a city to be a living laboratory—a continuous 'test bed' for the experimentation of smart city ideas in the form of initiatives. To this end, living laboratories encompass societal and technological dimensions simultaneously through a business-citizens-government-academia partnership. In other words, smart cities are a continuous living lab process were stakeholders keep trying out different solutions to problems. There is also the potential for an increase in the participation of end-users. Thus, the nature of the living laboratories determines the type of helix a city should adopt.

Furthermore, stakeholders that adopt the living laboratory process also have the opportunity to incrementally enhance their existing infrastructure. This is because by embedding IT into existing infrastructure, cities are able to be more efficient in deploying their existing infrastructure. Therefore, by embedding new smart city technology with already existing infrastructure, stakeholders can at the same time integrate solutions to multiple areas of urban living. Moreover, the introduction of new smart city infrastructure can also be deployed to serve multiple areas of urban living. As demonstrated in the Glasgow case study, the intelligent street lighting scheme allowed stakeholders to efficiently light up the city and it also served as a way to measure noise and air pollution. Hence, in designing new smart city infrastructure, stakeholders should also consider the multi-faceted and inter-linked areas of urban living in respect to problems that need to be addressed in a city.

This chapter paper has critically analysed the smart city concept, its characteristics and the collaborative structure involved in developing smart cities. To understand smart cities, it was important to begin with exploring the nature of wicked problems. In doing so, it acknowledges that the kind of issues a city in the 21st Century poses to stakeholders are complex due to their intrinsic nature. These have been conceptualised as wicked problems given that they tend to be intractable, even on computational levels. Thus, the concept of smart cities was conceptualised to be a response to these wicked problems.

By identifying a working definition of a smart city and analysing the concept, the significance of its importance and relevance to the research problem was highlighted. In addition, how collaborations for smart cities are organised, through PPP and the Triple Helix, was critically investigated. The examination of the collaborative structures and processes emphasised the shift in the innovative landscape, which have been facilitated by the rise in the applicability of ICT and the growth of big data. A smart city case study situated in Glasgow; Scotland was described to have a real example. To this end, the paper offers empirically informed practical recommendations for actors in the smart city domain.

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