FIGURE 11.1
SDGs in three tiers

ical progress and shaping a more sustainable future, which fosters economic development and promotes social progress and well-being. It also includes targets to promote inclusive and sustainable industrialization, adopt clean and environmentally sound technologies, enhance scientific research and development, encourage innovation, and increase access to information and communications technology. Moreover, G8, "Decent work and economic growth", aims to promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. Furthermore, G12, "Responsible consumption and production", aims to support the commodity cycle in the supply chain using the relevant information and awareness for sustainable development and lifestyles in harmony with nature [87].

In addition, the overarching SDGs' implementation framework is highlighted in G16 and G17, those are, G16 "Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels" and G17 "Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development" [87]. As suggested by Risse, "SDGs have a strong focus on the means of implementation, including the targets of finance, capacity building, trade, policy, institutional coherence, multi-stakeholder partnerships, data, monitoring and accountability, as well as public governance and technology" [74].

11.2.3 Means of Implementation - Data and Indicators

The measurement of SDGs by data and indicators is a scope that practitioners and researches focus on regarding the implementation of SDGs in cities. Normally, the different scales of measurement are regarded as keys to open the black box of SDGs at both global and local levels. Therefore, the massive indicators are developed by different authorities, for example, the UN Habitats Urban indicator programme, Commission for Sustainable Development's Sustainable Development Indicators, EU's Urban sustainability indicators, European Common Indicators, OECD's Better Life Index, ISO 37 120 indicators (Sustainable development of communities), and the indicator of SDGs reported by World Council of City Data (WCCD) [91, 95].

Those indicators cover the range of economic, social and environmental sustainability mainly in the theoretic study. However, as the regard of the value in practice, Roland Zinkernagel (2018) finds among the seven frameworks of indicators, the most popular indicator, the UN Habitats urban indicator programme which was launched in 1993 and adjusted respectively in 1996 and 2001, is merely used by 200+ cities worldwide. Following that, the European Common Indicators launched in 1998, is tested only by 42 cities. Many of the other indicators are not truly appreciated by cities. The data and indicator analysis have been over-emphasized for some years by regional authorities as well as researchers, which misleads the researches to purely develop the indicator from the perspective of science rather than focus on the localized solutions. Therefore, in fact, the adoption rate of indicators is relatively low [95].

In the regard of indicators covering the range of smartness and sustainability, Hannele Ahvenniemi (2017) analyzes that the indicators of smart cities cover 20% environmental, 28% economic, and 52% social sustainability whereas the indicators of urban sustainability cover 43% environmental, 10% economic and 47% social sustainability. The fact reveals that the evaluation emphasis of smart cities is on social sustainability whereas urban sustainable development is on the environmental sustainability [2]. That brings in the dilemma of mismatch of implementation focuses of smart city and sustainability.

11.3 Smart City Context

11.3.1 Smart City Concept

The definition of a smart city was firstly introduced in the 1990s [23]. And focuses of the smart city extend gradually afterwards in accordance with the updated knowledge of effective and sustainable city development. For example, the focuses include ICTs' facilitation as a key to the smart city [41, 44, 48, 69], improvement of quality of life to achieve prosperity, effectiveness, and competitiveness [4], the role of stakeholders of influence on social, economic and environmental sustainability, including the six smart domains, those are, the smart economy, smart mobility, smart environment, smart people, smart living and smart governance [43, 66, 33, 67], utilization of technological network and digital infrastructure as the enabler of sustainable urban development [43] and the involvement of capital and business to form the integrated innovative ecosystem as a whole, network and linked system [26, 55].

In regard of what the smart city is by definition, there are diverse concepts, for example, technological and human demands' driven city [43], green and sustainable and informational city [89], collaborative and participative city [58, 1], multi-disciplinary and developmental city [6], creative and innovative city [40, 57, 90], governmental and infrastructural city [66, 93], lively ecosystem and service city [22, 81], data-driven and open data city [47, 56] and etc.

In fact, such vast coverage of focuses diminishes the core strategy of city development. For the most circumstances, the concept is accepted as a fuzzy idea to attract capital investment in city infrastructures. However, the truth is with the permeation of technologies into the business services and governmental policies, the smart cities form the capacity of the self-configuration, self-healing, self-protection, and self-optimization, which maintains the city growth on a higher level of sociology. But the question is, is the smart city sustainable?

11.3.2 Argument of Smart City and Sustainability

As the discussion of smart cities gets heated, the argument of the difference between smart city and sustainability is raised by practitioners as well as researchers. The common misunderstanding is that smart cities are sustainable. However, the smart cities can only be sustainable on conditions of holistic and integrated framework towards the goals of sustainability.

Currently, the overarching approaches of smart cities are focused on the technology-driven method (TDM) and human-driven method (HDM). The former regards that smart cities are networked places where deploying ICTs into each activity in the city would improve standards of living. It is further emphasized that the use of ICTs by communities will enable them to participate more fully in so-called knowledge societies [24]. However, ICTs alone would not contribute to achieving the desired improvements in living standards, and there exists a need for enhancing human capital and other forms of skill development among the citizenry [67]. The argument is that these dichotomies generate a critical knowledge gap because they suggest divergent hypotheses on what principles need to be considered when implementing strategies for enabling smart city development [65]. Margarita Angelidou (2017) also suggests that the smart and sustainable city landscape is extremely fragmented both on the policy and the technical levels. There is a host of unexplored opportunities toward smart sustainable development, many of which are still unknown [5]. Other proponents of smart cities emphasize the potential for promoting economic prosperity, ecological integrity and social equity which would advance the larger goal of urban sustainability [32, 55].

11.3.3 Making Cities Smart and Sustainable

The smart city is regarded as a strategy as well as the center of solutions to alleviate demographic pressure and urban problems [20, 83]. The connective network and interconnected system facilitated by massive amounts of digital data leverage the complex information to make a better decision and resolve the problems [45, 84]. There have been several schools of smart cities in the research field since the 1990s. The main focus of defining smart cities is on the digital (ICT) infrastructure development to improve the living standards of people, which can be observed from the papers published between 2010 and 2014 [9]. In the regard of digital facilitation, for example, cities are expected to sustain the development enabled by a virtual and interconnected environment [80, 52]. Therefore, the smart city is also possible to be an intelligent city, techno-city, well-being city, wired city, ubiquitous city, information city, knowledge city, learning city, green city, and sustainable city. Making cities smart and sustainable means the integration of development strategies regarding the local choice, combining ICTs and data infrastructure with the sustainability concerns, generating the economic, social and environmental influences on long-lasting development without the consumption of resources of the next generations. Cities are expected being "smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory governance" [17]. In addition, specific factors that influence the cities in regard of smart and sustainable are tested, for example, "the size" of a city is considered as a crucial driver towards sustainable economic development in the study of making smart cities sustainable. Considering the effect of agglomeration economies for productive use of resources at the moderate cost of living and expense of social and environmental degradation [31, 63, 75], small and medium-size cities are intended to be the places where creation and innovation happen towards a friendlier and more ecological environment comparing to large cities [30, 29, 16].

11.3.4 Needs of Digital Tools and Living Labs

The SDGs emphasize the importance of technological support and digital infrastructure to developing countries. for example, in G9, the highlights are the facilitation of sustainable and resilient infrastructure to support domestic technology development and increase the access to information and communication technology by 2020 in the sub-targets 9.a, 9.b and 9.c. Digital tools are regarded as an innovative instrument to boost the knowledge and innovation economy, which is crucial to driving the smart city discourse [3]. The advancement of technologies has a strong effect on the sustainable development of smart cities. The endowment of big data and digital tools can meet with the challenges that smart cities face regarding socio-economic development as well as the quality of life [79]. The common understanding of the use of digital tools is to transmit information from stakeholders to form the core of the public-private-people-partnership ecosystem and agglomerate the advanced competitiveness of citizens and business to create added-value of current circumstances.

The digital tools can also provide the opportunities of sharing-economy. On the basis of knowledge of communities, data and tools provide the resources for citizens to 'shape urban change' in smart cities [78, 39]. The communication of information connects the social network, particularly, with the aid of Internet of Things (IoT), the data-based commodity and service in the smart cities provide social mobility, which minimizes the social cost but maximizes the economic benefit.

The concept of digital-driven life is tested in the living labs for the experiment and validation of future smart cities. The living labs consume the labs to unite the participants and stakeholders and consider them as the bodies involved in the business ecosystem. Normally, the stakeholders include citizens, organizations and local governments in the cities. The benefit of labs is open access to the public information, data mobility anywhere, high-level of interactions, reshaping and operating the innovative social ecosystem [78]. The labs provide the information platform with the facilitation of digital tools, which self-involved and updates by the users[1]. Therefore, the living labs are the user-driven information ecosystem.

In the common understanding, one of the large advantages is the living labs provide real-time platforms engaging participants, particularly the stakeholders, to share the activity information targeting on co-creation, exploration, experimentation, and evaluation [7].

Researches also reveal that the living labs create an open ecosystem for either user-end or supplier-end, which brings the government, business and citizens together, engaging the willingness of all stakeholders in the economic and social activities. Furthermore, the living labs concept has formed a unique methodology regarding the innovative and collaborative interactions shaping the urban norms in a new form in the social ecosystem [77].

As the living labs rely on digital tools and technological networks, the adoption in smart cities is in accordance with the trend. In activities, living labs in the smart cities practice the innovative technology and connectivity to move the smart cities to provide the conditions and resources for citizens

[1] The successful cases of living labs the European Network of Living Labs (ENOLL), such as, Smart Santander (www.smartsantander.eu), Experimental Living Lab for Internet of Things (ELLIOT) (www.elliot-project.eu), Peripheria (www.peripheria.eu), Open Cities, EPIC, Apollon (www.apollon-pilot.eu). And only Europe has 319 living labs, which grows fast worldwide (European Network of Living Labs, 2013).

to shape urban change. In this way, "the smart city is an urban innovation ecosystem, a living laboratory acting as an agent of change" [78]. Particularly, the endowment of big data, smart mobility, and the internet of things facilitate the development of living labs in the informational ecosystems [39] .

In general, there are several groups of focuses on the key components of smart cities. For example, resource endowment [18], self-decisive system [34], digital facilitation such as ICTs, IoTs and big data [61, 23], participation of citizen and government [18] and optimization outcome through infrastructures [37]. Therefore, there are several key components of smart cities beyond digital tools undiscussed. The following section, the networked infrastructure, knowledgeable community and intelligent governance are to be focused.

11.4 Key Components Beyond Digital Tools

11.4.1 Networked Infrastructure

The data infrastructure enabled by digital tools is the foundation of an integrated platform supporting users' communication. The ICTs and IoTs are the special focus regarding the infrastructure. However, the separate data infrastructure is not well established regarding forming effective communications among stakeholders unless the well-connected infrastructure is set up. The networked infrastructure forms the foundation of informative society, which "improves economic and political efficiency and enables socio, cultural and urban development" [43].

The mobility of big data is vital regarding the establishment of networked infrastructure, which is enhanced by ICTs. With the advantage of data mobility, the provision of services and commodities become smart and convenient. Moreover, the interconnected infrastructure provides a sufficient channel to collaborate, stakeholders, particularly, the end users on the smart platform to communicate thoroughly of the needs and requirements. The feedback can also be timely reflected the counterparts in the communication, so that the prompt response and adjustment are well functioned during the process, which enhances the resilient capacity of the networked group of people. Therefore, the networked infrastructure offers the network instrument, and well-functioning infrastructure to provide the opportunities for reshaping the communication process, enabling the communities' inclusiveness and stimulating the resilience of infrastructure [27].

11.4.2 Knowledgeable Community

Improving communities living is the core of making cities smart and sustainable, particularly, in the process of smart city development. As discussed by Hollands, "a smart city is a city that aims at connecting the physical, IT, social and business infrastructures in order to leverage the intelligence of the city's community" [43]. A smart community is a broadly defined group of people of common or shared interest, "whose members, organizations and governing institutions are working in partnership to use IT to transform their circumstances in significant ways" [66].

The smart community is the end user and major benefit receiver, who is most likely to take the position of advocating smart cities. Without the support of a knowledgeable community, the smart city is merely a shell of technology and infrastructure. In that sense, the knowledgeable community is crucial in regard to implementing SDGs in smart cities.

However, recent practice in smart cities is not fully understood by local communities. There are several reasons for this. First, advanced digital tools are not close to communities' lives excepts for smartphones. The data infrastructure is mostly developed for the working environment of business and government but not close to people's daily lives. Second, the communities are not clear about the benefits that they can get through the tools and infrastructure. Therefore, the training and education processes through various channels are vital regarding delivering the information and technology to communities to make them knowledgeable.

On the basis of networked infrastructure, the knowledgeable communities can form the communication capacity at their choices to function the social system towards a more sustainable way.

11.4.3 Intelligent Governance

The data-driven revolution transforms the citizens' living style as well as governance structure in a great manner through various aspects. First, the data-driven manner transforms the city growth to knowledge-sharing and sharing-economy, involving communities into the decision process, which drives the decision smarter and closer to the end-needs. Second, the integration of disaggregated data improves the governments' decision-making process [64], which enables governance structure towards a more intelligent gesture. Third, the open data provided by the public sectors creates the transparency of information, and ensure the accountability of counterparts in the connections, monitoring the right role of decision-makers and actors in the well-informed partnership.

Governance is the central core of responsibility to connect citizens with businesses and the living environment to foster a culture of innovation and sustainable economic development. Particularly, governance networks are more or less stable patterns of social relations between mutually dependent actors, which form around public issues, and which are formed, maintained, and changed through interactions between the involved actors [53, 88]. In that regard, the governance needs to be intelligent to perceive the right timing for the proper decision, connecting both "top-down" and "bottom-up" communication process and integrating eight factors of good governance[2] with the digital facilitation [94].

The governance structure is more important than ever before regarding shaping the growth path of smart cities. The ICTs change the traditional governmental process to the network governance interconnecting the dependent actors due to social relations on one governance platform [53, 88]. The intelligent governance structure adjusts itself to a flat manner forming the service ecosystem in cities [21].

11.5 Action Agenda of Smart Cities Towards SDGs Beyond Digital Tools

11.5.1 Integration of Innovation Capacity in Smart Cities

The smart data generates the innovation capacity in smart cities. Specifically, the smart data and technology enable the communities to acquire the information of know-how. The wide use of ICTs forms digital infrastructure improving the quality of life as well as enhancing the efficiency of economic transactions by the manner of innovations. The SDGs sub-target 17.8 suggests the technology and innovation capacity-building mechanism, particularly for the least developed countries. Particularly, on the basis of UN Economic and Security Council 2016 Session, the "fostering statistical capacity-building, partnerships and coordination" is introduced as an optimism [13] that brings the knowledge to share and transform among the responsible stakeholders in the commitment of partnership, which drives the future direction of smart cities towards SDGs.

In fact, the recent proliferation of big data has contributed to smart city transformation regarding the establishment of innovative capacities [11, 14, 42, 50]. "Big data" generally refers to large and complex sets of data that represent digital traces of human activities and may be defined in terms of scale or volume, analysis methods[19], or effect on organizations [62]. The enhancement of big data improves the decision-making process by the integration of disaggregated data, fostering the intelligent governance, innovative business, and empowerment of participatory citizens (Higher Level Panel, 2013). Moreover, the use of big data also promotes transparency and accountability, enhancing the efficiency of SDGs' implementation at the local level [76, 85].

The general aim of capacity-building is to motivate smart cities know-how to become self-regulating and responsible upon certain and uncertain social interactions through participation as well as market-based relations. In the

[2] The particular emphasis is on the roles of government and community, aiming at the enhancement of transparency, responsiveness and effectiveness and efficiency by the methods of participation, rule of law, consensus, equity and inclusiveness, and accountability.

contrast to the data and indicators suggested in the previous section regarding the measurement of performance, innovation capacity is more related to the participants and stakeholders involved in the smart city ecosystem, therefore, it is the social-context capacity in the business environment beyond the technological capacity.

Phillips and Ilcan (2003) conceptualize capacity-building as a technology of neoliberal governance, an apparatus of rule that requires a diverse range of new rationalities that aim to 'grow' institutional frameworks, enhance the skills of people, and transfer knowledge through the formation of new partnerships for international development [71]. Such a building process enables the process of knowledge development and knowledge sharing, which is crucial for the enhancement of innovation capacities. In addition, the integration of innovation capacity in smart cities facilitate the diverse possibilities regarding the growth of economy, data mobility, friendly environment, knowledgeable community, better living standards, and effective governance of cities contributing to the implementation of SDGs [1, 18, 6, 89].

11.5.2 Transformation of Smart Growth in Smart Cities

The idea of smart city originates in the smart growth in the 1990s [15], pursuing the ideal solutions of urban problems such as urban sprawl, traffic congestion, air pollution, loss of open space and etc. due to the ill-planned and ill-coordinated development [66]. Particularly, smart growth is indicated as an ideology facing the problems that urban sprawl brings in due to the fast urbanization. The smartness is paid attention to the economic growth especially aiming to achieve policy performance and success. Meanwhile, the smart growth builds up the community group involving stakeholders in the urban planning phase, seeking the applicable measures to achieve the smart decision. The concept of smart growth initiates the use of smart tools and technology in urban planning as well as the rethinking of governance necessities in the face of the smart community.

However, the argument of smart growth never ends as the complicated situation change via ages in cities. Wey and Hsu (2014) argue about the new urbanism and smart growth concept to deal with city problems especially environmental, housing and citizens' well-being [92]. European Parliament (2014) argues the aim of smart growth is to create a smart city "where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefits of its inhabitants and businesses" [54]. In general, the smart city transforms the growth pattern to a smarter choice, particularly in terms of the intelligent governance structure and strong partnership in social aspects [11, 14, 42, 50, 73].

The SDGs are universal on the main focuses of 5 key elements: people, planet, peace, prosperity, and partnership. The partnership unites the communities, business, government and other interest-related organizations in the involvement of sustainable development in smart cities.

As discussed earlier, the dilemma of dichotomous understanding of smart cities relies on the divert directions of the technology-driven method (TDM) and human-driven method (HDM). The integration of TDM and HDM needs the focus of partnership existing in the stakeholders who have a different emphasis on benefits. The partnership is first of all the awareness of the importance of a holistic approach to applying smart instrument in the united group including the public sector, private sector as well as communities on the integrated platform.

Moreover, the global partnership is a well-established framework for the collaboration of local governments, private organizations, social communities, academic institutes, and other participants. The partnership is a mechanism to implement SDGs in the more rooted grass field on the national and local levels with the cooperation of all the participants and stakeholders, which is the core driver of means of implementation [46].

The SDGs form the arena of global partnerships, which enables the multi-stakeholder getting involved in the partnership, ranging from the provision, supervision, evaluation to the analysis of information, covering all the participants with the interest, keeping the direction of sustainable development of smart cities. Particularly, with the facilitation of techno-partnership, the people are well-connected and kept informative to reinforce the long-lasting collaboration.

11.5.3 Evolvement of the Socio-Economic Ecosystem in Smart Cities

Smart cities are regarded as intelligent digital ecosystems installed in the urban space [67, 72, 25, 92, 60, 33]. Particularly, the ecosystem consists of complex interactions and inter-dependencies, which keeps evolving with the progress of digital advantages. As suggested by Angelidou (2015) "A smart city is a multi-agent ecosystem comprised of kinds of societal actors like public sectors, private companies, non-profit organizations, and citizens; it also represents a multidisciplinary field constantly shaped by advancements in technology and urban development" [6]. Komninos (2008) also suggested that "smart cities are the consequence of a dense innovation ecosystem that creates value through the use and reuse of information that may come from many different social connections and highly skilled human capital" [51].

The metabolism of such an ecosystem is crucial regarding the sustainable movement of the system. The released data of a smart city nurtures a lively ecosystem composed of agents (i.e., groups of companies and non-profit organizations) that create innovative products and services [22, 81].

Therefore, the smart city ecosystem is generally operated and maintained by the diverse businesses, promoting the growth of the economy, harmonizing the social community, sustaining the built environment so that the ecosystem maintains the self-organizing and self-evolving continuity particularly with the enablement of digital technologies. The so-called metabolism is actually through the service mobility to generate the advantage of economic agglomeration. And by the effect of agglomeration, the large cities become the hubs of business attracting intelligent labors to reside in and contribute to the city growth.

The merits of the ecosystem, such as interaction, balance, loosely coupled actors with shared goals, self-organization [36] are enlarged by the adoption of ICTs in the business environment, reinforcing the information flows and forming the digital business ecosystem [8]. The digital business ecosystem fosters the demands of citizens regarding the services and end-needs, facilitating the service deliveries out of the strains [28]. That means the larger digital human ecosystem is enabled by the integrated business environment through the information flow.

In the environment of alliances of smart business and knowledgeable community, cities attract the important edge of innovation [70, 69], which is also recognized as a biological system[12] as it has the capacity to self-regulate and self-evolve. Such advancement promotes the adjustments the socio-economic goals towards the SDGs.

11.6 Discussion and Conclusion

The basic understanding of smart cities is the facilitation by digital tools in the city development although the concept of smart cities is multi-faceted and multi-disciplined. However, the smart city concept can be distinguished from other similar ideas such as the digital city or intelligent city in that it focuses on factors such as human capital and education as drivers of urban growth, rather than singling out the role of ICT infrastructure. [59].

In recent years, the digital infrastructure is so much developed that the mass investment is not fully recognized. In addition, the argument is raised regarding the relationship between smart cities and sustainable goals, however, the path of achieving the sustainability of smart cities is unknown. Therefore, the gap exists between the smart cities and sustainability, particularly, the implementation framework of SDGs in smart cities is not clear.

Implementing SDGs in smart cities is a complicated issue. The reasons are as follows. First, cities are complex ecosystems, relying on inputs of recourses, generating outputs of commodities; second, cities divert due to different urban forms and features; third, cities have to achieve smart growth to maintain the sustainability; fourth, cities are the places where agglomerations happen; government, business and community influence the direction of cities. Therefore, to achieve SDGs, it requires a long-term transformation in cities. It is impossible to find an instant solution to all nor universal panacea to solve all problems.

In the regard of making smart cities sustainable, the possibility exists, because smart cities are the arena of implementation of SDGs at local levels not only because the common innovation of technology forms the digital ecosystem of the both, but also the future direction of city development coincides the concept of each other. However, it is also can be impossible if smart development is not towards SDGs.

To re-adjust the sustainable path of smart cities, researches during the period of 2017 and 2018 transits from the surface talk of the definition to the deeper insights of the truth of smart cities. For example, the paper was written by Maria Kaika (2016) strongly rejected the hypothesis of smart cities being sustainable and resilient [49]. This relatively simplistic imaginary of the smart city has been roundly critiqued on a number of fronts, especially around the entangling of neoliberal ideologies with technocratic governance and the dystopian potential for mass surveillance [83, 35, 38, 43, 50, 82, 89].

The inner goal of smart cities is to improve the living quality of people with the facilitation of digital solutions, such as ICT, big data, Internet of Things (IoT). The initiatives of smart cities are mostly encouraged by local governments in regard to ICT infrastructure development. Under such conditions, the fast effect of enhancement of digital living manners, such as mobile phone communication, broadband construction, online trade and service and etc. is duplicated preliminarily globally. However, the consideration of the accomplishment of smart cities is not directly linked to sustainability. There exists a vast gap in the ideology of both terminologies. Particularly, the experience of the implementation shows the smart city strategy cannot lead to sustainability if the emphasis based on digital development. Thus, the recent researches show the doubts of simply linking the smart cities with sustainable cities. In the face of such a dilemma, a few types of research start to dig into the institutional instruments of smart cities beyond digital tools. Therefore, the updated understanding is that smart cities can achieve the SDGs on conditions of understanding the key components to form a holistic implementation framework.

The chapter focuses on the non-financial instruments as well as the local implementation particularly in smart cities under certain jurisdiction and level of operation as the means of implementation are in response to local needs upon global imperatives.

Upon the framework of implementing SDGs in smart cities beyond digital tools, the research delivers a holistic implementation framework, including deployment of key components and action agenda of SDGs at cities levels.

In the contrast to the smart city initiative framework as suggested by Hafedh Chourabi et al. (2012) "management and organization, technology, governance, policy context, people and communities, economy, built infrastructure, and natural environment" [20], the chapter proposes three key components of smart cities beyond digital tools, those are, networked infrastructure, knowledgeable community and intelligent governance. The networked infrastructure is the foundation of networking facilities, enabling the inclusiveness of stakeholders on the integrated platform and enhancing the efficiency of

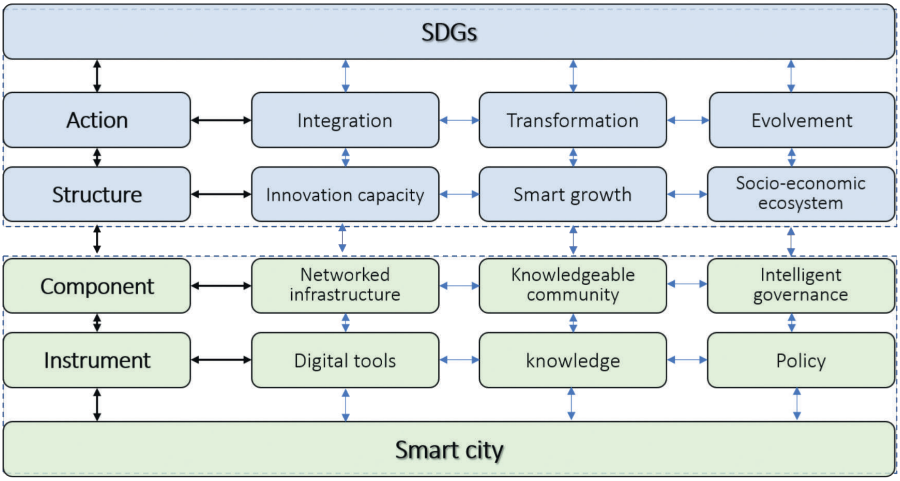

FIGURE 11.2
Framework of implementing of SDGs in smart cities beyond digital tools

communication. The knowledgeable community is information-rich end users in the smart cities, participating the communication in the spectrum of city development and building up the capacity to improve the decision-making process. The data-driven intelligent governance forms the inter-connected institutional structure among government, business, and citizens, driving the governance to a networked and demographic process.

The smart city action agenda is sophisticated in the combination of key components and structure regarding envisioning smart cities in the implementation of SDGs. The chapter proposes the action agenda consisting of three layers, those are, integration of innovation capacity, the transformation of smart growth engine and evolvement of the socio-economic ecosystem in smart cities.

The following-up research will focus on the deep insights into the three-layer implementation framework of SDGs in smart cities.

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12

Spatial Enablement to Facilitate the New Urban Agenda Commitments for Sustainable Development

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In the context of SDGs, this chapter talks about spatial enablement to facilitate the New Urban Agenda commitments for Sustainable Development. It discusses historical account of how global began to be considered a threat and how it ended up as a potential development tool for the future generation established by the New Urban Agenda. The Chapter introduces the elements of action framework for the implementation of a selected case studio in Singapore. The chapter will come to an end with describing the future opportunities in research and capacity development in support of evidence-based and data-driven urban policy and planning.

12.1 Introduction: Background and Driving Forces

In light of rapid urbanisation worldwide, the complexity of cities is ever increasing, which complicate urban planning and management tasks. One of the major challenges is the limited capabilities offered by conventional approaches to urban and regional development and management [12]. Addressing current challenges created by urbanisation requires cutting-edge, interoperable tools and expertise, localised for each country and domain of application adopted and adapted from best practices worldwide to meet international standards (e.g. Sustainable Development Goals) [17].

Over the last four decades, several international organisations have developed standard indicators to foster nations to set, measure, monitor and evaluate development policies. Examples for these standards are Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) adopted by the United Nations and member states in 2000 and 2016 respectively [18, 8]. Accordingly, other international and national organisations have developed initiatives, indicators and indices such as the New Urban Agenda, ISO 37120 urban sustainability indicators, and the City Prosperity Index for ensuring quality of life challenges are linked to sustainable development policies, strategies, and decision making [6, 12, 20].

In 2016, the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in Quito, Ecuador, adopted the New Urban Agenda (NUA). For the first time, Habitat III acknowledged cities as potentially the source of solutions rather than the cause of challenges the world is facing with. The NUA declared that, if well-planned and well-managed, urbanisation can be a powerful tool in achieving the sustainable development status in developing and developed countries [17]. Five main pillars of NUA implementation lay out the standards and principles for planning, development, construction, improvement, and management of urban areas:

1. National urban policy; *"the National Government is the level that holds the sovereignty of the nation, and it establishes the rules and functions of the subnational and local governments."*

2. Urban legislation and regulations; *"good urbanisation cannot be conceived without a good regulatory framework."*

3. Urban planning and design; *"urban planning and design is an essential technical part of the urbanization process and it refers to the physical layout of buildable plots, public space, and their relationship to one another. In line with the NUA, UN-Habitat believes that urban planning of design is a fundamental priority to achieving sustainable urban development."*

4. Local economy and municipal finance; *"one of the novelties of the urban paradigm shift of the NUA is the contribution of urbanization to the national economy. Urbanization should be approached not as a cost, but as an investment, because the cost of urbanization is minimal compared to the value that it can generate."*

5. And local implementation; *"as an important action plan, this pillar encourages spatial development strategies that take into account, as appropriate, the need to guide urban extension prioritising urban renewal by planning for the provision of accessible and well-connected infrastructure and services, sustainable population densities, and compact design and integration of new neighbourhoods into the urban fabric, preventing urban sprawl and marginalisation."* [17]

There have been extensive works to adopt the above-mentioned initiatives, standards and indicators to local policy and development strategies. As an example, UN-Habitat drafted an Action Framework for Implementation of the New Urban Agenda (AFINUA), which aimed to guide the implementation of the NUA, with necessary ingredients to lead each, identifying methods of measurement and their link to the provisions of the NUA. There are 35 key elements that group into the above-mentioned five main pillars of NUA [16].

However, recent studies indicate a weak connection between some of the indicators and government policies and decision making. Deng et al., (2017) highlight that city managers have been slow to adopt the urban sustainability indicators in their decision-making process due to the lack of unique interpretation by the urban experts [4]. Other barriers in adopting such indicators are the cost of adaptation, specifically for smaller governments, and lack of perceived benefit from international exposure and comparison. Other studies indicate a problem that arises in indicator-based comparisons, as the comparison might be invalid due to inconsistencies in the data used to derive them [19]. These studies highlight that the international standards should not only be considered for benchmarking but also be valued for the opportunity they present for comparative learning. In addition, data provenance, reliability, and consistency of analysis need to be evaluated for standards. It is significant and timely to investigate the role of spatial technology and underpinning frameworks such as hierarchy of Spatial Data Infrastructures (SDIs) [7] for supporting the implementation of sustainable development standards in different levels of government.

The crucial role of spatial technologies in capacity building across different levels of governments is emphasised in Articles 159 and 160 of AFINUA. While there are some initiatives for spatial enablement of governments in implementation of SDGs and NUA, there is limited understanding of how these technologies will be helpful. As such, this chapter explores the 35 key elements established by AFINUA and highlights the current spatial enablement initiatives that provide opportunity to implement these elements. This chapter is for decision-makers and urban and regional planners at different levels of government in local, state and national scales.

This chapter continues with providing a historical account of how global urbanisation began to be considered a threat and how it ended up as a potential development tool for the future generation established by the New Urban Agenda. The next section introduces the elements of action framework for the implementation of NUA. The principles of spatial enablement and some of the international initiatives will be presented in section three. The fourth section draws links between spatial enablement concepts and principles and the key elements of AFINUA. Finally, the last section of the chapter discusses some implications of implementing the spatial enablement framework for successful achievement of sustainable development. This chapter will come to an end with describing the future opportunities in research and capacity development in support of evidence-based and data-driven urban policy and planning.

12.2 Urbanisation; From a Threat to an Opportunity

The United Nations Conferences on Human Settlements, where a significant number of city governments and urban management officials are in attendance, have sought approaches to improving the urban quality of life. In the early 1970s, the global strategy to address challenges of human settlements was sought and, at the same time, the United Nations Resolution on Housing, Building and Planning was produced. However, one of the major issues raised was rapid urbanisation, which required a response to the emergence of large unmanageable slums with poor access to basic services including water and sanitation.

Accordingly, in 1976 the Vancouver Declaration on Human Settlements highlighted critical actions and requirements to improve the quality of life in all human settlements. This was the time that the United Nations Conference on Human Settlements (Habitat I) elaborated on issues of unplanned urbanisation, which resulted in overcrowded cities without corresponding capacity to provide basic services. Addressing these challenges, the UN General Assembly established UN-Habitat as a focal point for human settlements action. In addition, a year after the Vancouver declaration, the UN established its Center for Human Settlements (UNCHS/Habitat). However, despite these advances, poor living conditions in human settlements remained a persistent issue.

The global urban population soared dramatically and by 1990 42.5% of global population was urban; during this time ten megacities emerged with populations of 10 million or more. This led to the 1996 Istanbul Declaration on Human Settlements and a strengthening in the role and capability of the UN Center for Human Settlements (UNCHS). UN-Habitat II was held at the same time and HABITAT AGENDA was adopted. This agenda particularly emphasised promoting the provision of adequate shelters and basic services to familiarise sustainable human settlements.

In 2000, eight Millennium Development Goals (MDGs) were adopted by the United Nations. These goals, which targeted for 2015, range from reducing extreme poverty rates by 50% to fighting against the spread of HIV/AIDS and providing universal primary education. The MDGs set to respond to the challenges of urban inequality, slums, poverty, and environmental degradation. As a result of implementing MDGs, between 2000 and 2014, more than 320 million people living in slums gained access to improved water sources, improved sanitation facilities, or durable or less crowded housing. However, in 2015 more than 880 million people were estimated to be living in slums, compared to 792 million in 2000 and 689 million in 1990.

The implementation of MDG targets worldwide had been recorded with some progress. Several countries included the Millennium Development Goals (MDGs) into their national and sub-national development plans and strategies, and adopted specific measures with the aim of achieving the associated targets [18]. However, the achievements have been uneven across regions and countries, leading to significant gaps [21]. According to the UN report on MDGs in 2015, millions of disadvantage people had not leveraged these goals due to factors such as geographic location, gender, age, ethnicity, and disability [8].

Reaching to the deadline of MDGs in 2015, the discussion around the results and barriers of implementation led to formulating the Sustainable Development Goals (SDGs). Given that the MDGs failed certain people and geographical locations, the SDGs' 2030 Agenda sets out to "*reach the furthest behind first*" and concludes with a pledge that "*no one will be left behind*" [18].

Accordingly, In October 2016, the New Urban Agenda was unanimously adopted at the United Nations Habitat III, with the aim of serving as a new vision for cities and municipalities worldwide for the next 20 years [17]. UNDP "*demonstrated its full support to the implementation of the New Urban Agenda with the official launch of its Sustainable Urbanization Strategy*". This was the first time urbanisation was considered an opportunity for achieving sustainable development, which addresses SDGs, especially Goal 11 on sustainable cities and communities.

In the reviews for implementing NUA the community consultations and inputs from two important expert group meetings held in Surabaya, Indonesia, in July 2016 and New York in April 2017 led to formulating an action framework for implementation of the NUA (AFINUA) [16]. This framework articulated that while the process of achieving the Sustainable Development Goals are important, it cannot replace the outcome. In fact, the specific attention of AFINUA is enumerating desired urban outcomes. As such, the framework set out to assist the local authorities, major groups and relevant stakeholders to measure and monitor the targets they are aiming for.

The AFINUA key elements are also connected to other indicators identified by UN-Habitat's City Prosperity Initiative (CPI). The CPI is a global initiative that aims to turn the data to information and knowledge for cities to measure their performances and establish an evidence-based policy dialogue among decision-makers. The CPI aims to facilitate a higher accountability in the implementation of the SDGs and NUA [19]. This initiative and associated tools have been used individually or in combination with other indexes in evaluating several cities worldwide in monitoring sustainability performance [23], multi-scale sustainability evaluation [22], environmental quality [1], and urban resilience [13].

Like AFINUA, there have been other action guidelines established for localising the implementation of SDGs. In Europe, the Association of Flemish Cities and Municipalities (VVSG) worked with local authorities to translate the SDGs at the local level [5]. They published several tools and guidelines to help local authorities in monitoring and exploring the ways to generate a broader SDG policy in their respective legislation. VVSG transferred the focus of achieving SDGs to taking specific actions and raising awareness of this global ambition among residents, in government, and in industry. In the next section, the principles of the AFINUA and CPI are described in terms of how they are set for global action.

12.3 AFINUA and Its Relation to SDGs and CPI

The action framework for implementing new urban agenda, groups 35 key elements into the NUA's five pillars: (1) national urban policies, with six key elements, (2) urban legislation, rules and regulations, with nine key elements, (3) urban planning and design, with eight key elements, (4) urban economy and municipal finance, with six key elements, and (5) local implementation, with six key elements. While the NUA is exclusive to SDG Goal 11, other goals and targets provide urban-critical sectoral and cross-cutting areas. Some examples are the food security and urban-rural linkage relevant to Goal 2; health as a critical urban factor in Goal 3; education and culture is considered in Goal 4; gender equity reflected in Goal 5; water challenges in Goal 6; energy as a major concern in cities reflected in Goal 7; employment and GDP indicated in Goal 8; sustainable consumption and production in Goal 12; and climate change impacts in cities included in Goal 13. As such, these relations are sought in formulating the AFINUA elements [16].

In addition, the connection of AFINUA to CPI is through six dimensions set by the UN-Habitat:

a. Productivity (CPI-P):*This dimension measures the average achievements of the cities in terms of creating wealth and how it's shared, or cities contribution to economic growth and development, generation of income, provision of decent jobs and equal opportunities for all.*

b. *Infrastructure Development (CPI-ID):The Infrastructure dimension measures the average achievement of the city in providing adequate infrastructure for accessing clean water, sanitation, good roads, and information and communication technology - in order to improve living standards and enhance productivity, mobility and connectivity.*

c. *Quality of Life (CPI-QoL):The quality of life dimension measures the cities' average achievement in ensuring general wellbeing and satisfaction of the citizens.*

d. *Equity and Social Inclusion (CPI-ESI):The Equity and Social inclusiEquity and Social Inclusion (CPI-ESI):on dimenion measures the cities' average achievements in ensuring equitable (re)distribution of the benefits of prosperity, reduces poverty and the incidence of slums, protects the rights of minority and vulnerable groups, enhances gender equality, and* *ensures equal participation in the social, economic, political and cultural spheres.*

e. *Environmental Sustainability (CPI-ES):The Environmental Sustainability dimesion measures the average achievement of the cities in ensuring the protection of the urban environment and its natural assets. This should be done simultaneously while ensuring growth, pursuing energy efficiency, reducing pressure on surrounding land and natural resources and reducing environmental losses through creative and environment-enhancing solutions. [15].*

Figure 12.1 summarises the connection of AFINUA elements with SDGs for National Urban Policies. The details of these connections and their local actors can be found in [16].

FIGURE 12.1
The Connection of AFINUA Elements for National Urban Policies Domain of NUA

One of the major requirements for ensuring implementation of items set by AFINUA is a robust data infrastructure. This is significant because the implementation needs ongoing control, measurement, and monitoring of the AFINUA-related SDG and CPI indicators. The next section briefly explains the overall components of a reliable data infrastructure for this purpose.

12.4 Spatial Data Infrastructure Advancements and Opportunities

The MDG report in 2015 indicated the importance of sustainable data for sustainable development [8]. This report regarded the data as an *"indispensable element of the development agenda"*. In particular, this report indicated how the local data is important for measuring and monitoring subnational performances. The demand and policy making are regarded as two significant drivers for data improvements, and while there have been several initiatives for improvements of data collection worldwide, the critical data for policy making was still lacking [18].

In transformation from MDGs to SDGs, one of the main issues was the lack of quality data to enable regular monitoring and support evidence-based decision making. As such, several suggestions were made by international entities including UNDP, World Bank Group, and UN-Habitat to support evidence-based decision making. These suggestions include using real-time data, adopting geospatial data, strengthening statistical capacity, utilising new technologies, changing the methods of data collection and dissemination, developing global standards for integrated statistical systems, and promoting open data [8, 18].

However, several studies reported that many governments worldwide lack awareness, realising the importance of geospatial information and related technologies in enabling the implementation of SDGs. This lack of awareness is particularly at the policy and decision-making level, which hinders enabling robust tools such as National Spatial Data Infrastructures [14].

While the national policy makers are yet to fully implement the data policy in support of sustainable development, the international entities have provided several frameworks and standard guidelines, which have been used for developing system architectures as enablers for deriving several city and regional indicators in an ad hoc fashion.

At the United Nations level, several initiatives including UN-Global SDG Database [1] is available for access to data, which is compiled through the UN System in preparation for the Secretary-General's annual report on "Progress towards the Sustainable Development Goals". However, this data is not spatially enabled and remains at a national level, which provides only a limited understanding of the local performances. In addition, recently an Open SDGs Data Hub [2] was developed to fully implement and monitor progress on the SDGs. This platform aims to support decision makers everywhere, who need accurate and timely data and statistics. So far, however, limited countries have committed to this platform and the available data has limited capability for local governments.

[1] https://unstats.un.org/sdgs/indicators/database/
[2] http://www.sdg.org/

In the international technology standard community, Open Geospatial Consortium (OGC) formulated an enterprise framework to derive indicators for sustainable development and resilience of communities (ISO 37120) [9]. The OGC framework is considered to be based on cloud computing. This framework, which is called the OGC Smart Cities Spatial Information Framework, incorporates four layers of sensing (real-time data), data (access and quality checking), business (analysis and visualisation), and application (e.g. health, education, public safety and security, and urban planning). Figure 12.2 shows the components of OGC enterprise framework for smart cities.

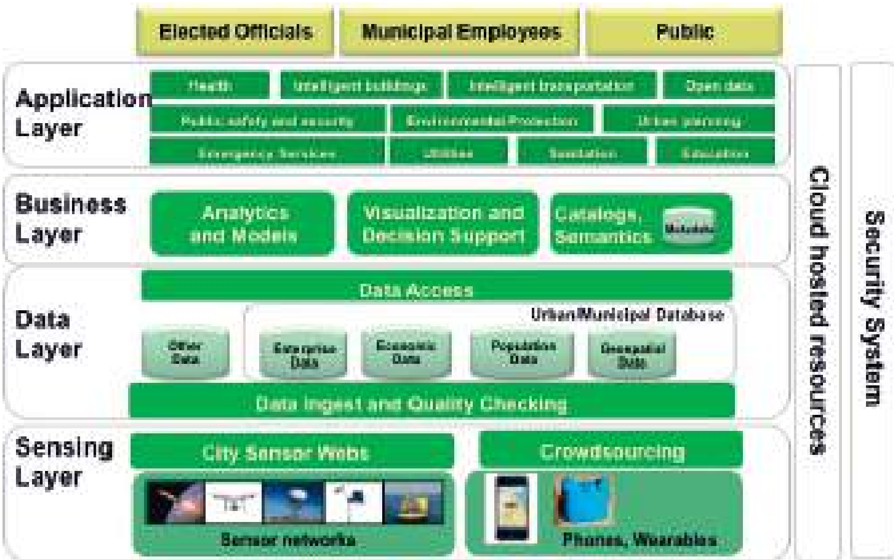

FIGURE 12.2
OGC enterprise framework for Smart Cities adopted from [9].

Several initiatives worldwide have implemented spatial data infrastructures addressing the components of the OGC framework. The examples are Australian Urban Research Infrastructure Network (AURIN), which is an e-infrastructure to support urban and built environment research in Australia. AURIN facilitates access to more than 2500 datasets across Australia, enabling researchers and data providers to integrate data, analyse and visualise several different urban and built environment data [11]. Another example is the Urban Big Data Centre (UBDC), an initiative by the UK Economic and Social Research Council at the University of Glasgow, in partnership with six other UK universities. The role of UBDC is to manage, link and analyse massive amounts of multi- sectoral urban open and authorised data in a portal allowing diverse users to conduct research and analysis [3]. Similarly, the

[3]http://ubdc.ac.uk/

Urban Centre for Computation and Data (UrbanCCD) at the University of Chicago has developed a platform called Plenarion to facilitate urban data discovery, exploration, and application of open city data [2]. However, most of these systems lack real-time data analysis as well as a semantic enablement layer for harmonising the fragmented and heterogeneous spatial data [10]. In addition, some of these infrastructures are yet to be used in deriving the SDG and CPI indicators as well as providing reliable sources for local, subnational, and national policy makers. A potential explanation for this might be that the sustainable development standards and indicators are too broad to be derived in smaller geographical boundaries than states and national levels. In addition, the national and international data policies are not reflecting the requirements of SDG and CPI.

Moreover, the lack of semantic enablement layer is an important one to address as AFINUA elements and associated SDG and CPI indicators are comprised of multi-disciplinary domains and fragmented data sources with heterogenous structures [3]. The semantic enablement methods and associated architectures will be presented in other chapter on enabling tools and technical components.

As such, while there are several national and international initiatives, standards and frameworks for spatial data infrastructures, they are not fully committed to enable the implementation, measuring and monitoring of the sustainable development indicators and localised NUA initiatives that set the future agenda for research and policy making.

12.5 Conclusion and Discussion

This chapter is intended to highlight the localising steps taken for implementation of SDGs in urban and territory environments. In addition, it highlighted several technological and spatial data initiatives worldwide that can potentially act as enablers for implementing, measuring, and monitoring the localised Sustainable Development Goals.

The literature and evaluation reports on SDGs indicated the weak connection between decision making and government policies and the standard indicators. This limited connection was attributed to the lack of robust data and various interpretation on the standards and indicators, and as a result the roles of Spatial Data Infrastructures and new technologies have been highlighted in several reports and studies.

While there is an emphasis on the critical role of spatial technologies for implementing the New Urban Agenda (articles 159 and 160 of AFINUA), this chapter highlights the lack of data standards and policy to address the AFINUA requirements. As such, two major aspects need to be addressed for local implementation and monitoring of New Urban Agenda and associated

Sustainable Development Goals. First, the broadness of the sustainable development standards and indicators and their definitions, which limits them to be derived in smaller spatial levels such as statistical areas or suburbs. Second, the national and international data policies need to be revisited to reflecting the requirements of sustainable development indicators such as SDG and CPI.

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13

The Geospatial Capacity Building Ecosystem - Developing the Brainware for SDI

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In the context of SDGs, this chapter aims at arguing for an ecosystem view of lifelong learning at the core of building and maintaining the brainware for geospatial information systems supporting our livelihoods.

13.1 Introduction

'Brainware', the human capacity and competence to manage Spatial Data Infrastructures (SDI) and related geospatial information frameworks is widely considered a bottleneck in generating decision support for societies, economies and environments [11]. This not only applies to technical skill sets for operating various systems of record, but even more so in leveraging the power of spatial thinking approaches towards reaching Sustainable Development Goals, most of which cannot be approached and monitored without a geospatial perspective.

Traditionally, higher education institutions (HEI) were and still are considered the places for academic capacity building, preparing and qualifying graduates for designing, implementing, maintaining and leading complex architectures like SDIs. Very few qualifications, though, today last a professional lifetime due to still accelerating cycles of innovation, technologies and disruptive changes. Capacity building today is far from a linear process, requiring a multitude of interventions, re-inventions, re-qualifications and actions by multiple stakeholders.

13.2 Status

Academic education in geospatial technologies, methods and applications have parallel roots in several spatially oriented disciplines [13]. Geography adopted quantitative methods and computer cartography as a pathway towards GIS. Surveying morphed into Geomatics through positioning technologies and automation. Remote Sensing emerged as an effective data acquisition and earth observation technology. Numerous application domains like planning, resource management, transportation or business intelligence took advantage of these emerging technologies (including ‘Open’ approaches – see [1]) and refined their respective business processes.

This ‘transversal’, methodology-oriented approach to geospatial education required the creation of novel curricular pathways, implemented through a sequence of ‘core curricula’ initiatives [4, 14, 16]. ‘Transversal’ also refers to the need for integration of geospatial competences in the full range of spatially oriented disciplines, ranging from A like Archeology to Z like Zoology. One approach to ‘spatialize’ disciplines is through the option of including a ‘minor’ in one's academic coursework [3]. This can be aligned with a ‘spatial turn’ currently experienced in a variety of disciplines, including the boost for Digital Humanities.

All these curriculum and (partly) learning media developments did not fully succeed with satisfying the wider industry needs of qualified experts, though. Only few dedicated study programs(e.g. in Geoinformatics) have been implemented, with a majority of geospatial methods courses embedded in traditional ‘spatial’ and application discipline programs.

While these take care of educating competent users of SDI elements, managing core SDI architectures suffers from shortages of qualified staff bringing the right mix of computational, architectural and geospatial knowledge to task.

In addition, due to the dynamic evolution of SDI technologies and standards, initial cycles of academic qualification will not sufficiently support a lifetime of professional leadership in such a complex domain. Continuing education requires multiple actors supporting different modes and facets of ‘lifelong learning’. While dedicated online study programs like UNIGIS [12] facilitate in-service development of competences, the latter will not be sustained without involvement of a range of stakeholders.

13.3 Mix of Actors in an Education Ecosystem

An ecosystem, as defined by Encyclopedia Britannica, is understood as a ‘complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space.' Obviously, this concept is used metaphorically in non-biological domains, e.g. when referring to digital ecosystems as 'digital counterparts of biological ecosystems' [2].

To develop educational ecosystems, first the 'organisms', i.e. actors need to be identified before exploring potential relationships and interactions among these:

- Higher Education Institutions: universities continue to fulfill the roles of initial undergraduate and graduate education, continuously adjusting curricula, syllabi and pedagogical frameworks to evolving technologies and application demands [9, 10]. While in many cases undergraduate studies serve as an entry point into the geospatial domain, 'feeding' motivated youngsters into suitable academic tracks is an important task long neglected. Outreach initiatives like GIS Days, interaction with schools and participative activities increasingly are driven by HEIs. In addition, (some) HEI increasingly focus on mid-career continuing education – definitely a growth area with substantially more demand than current supply [15].
- Industry, composed of technology vendors as well as domain-oriented services, are addressing their need for talent by taking a stronger role in capacity building. This includes offering internships and dual-track study-while-working schemes, sponsoring of students, lecturing within academic programs, providing technologies and guidance for emerging innovations.
- Professional associations offer stimuli (like certification), sometimes arrange short courses and networking opportunities as well as conference services. These societies create professional identities which sometimes are limiting, but also help with motivating personal development.
- Media play an indispensable role not only as actors providing current updates on technologies and professional practice through web portals, magazines and conferences, but perhaps even more importantly as connecting facilitators enabling relationships among 'organisms' and individuals.

While considering these institutional actors, we need to focus on individuals as 'carriers' of brainware, developed while moving through the operational learning instances of this ecosystem. These students – in all stages of their professional lives – are exposed to these instances as opportunities for learning: academic courses and programs, short intensive courses and trainings, literature items and webinars, MOOCs and online trainings, mentoring, internships and many more.

Clearly, most of these learning instances cannot easily be provided by a single actor, therefore it is essential to establish a collaborative framework collectively generating the opportunities for personal development within an 'ecosystem'.

Individual learners can follow many different pathways through this ecosystem. While these pathways in many cases will start from undergraduate studies, progressing through various continuing education opportunities, they also can start from professional experience before turning towards formalized education. Pathways definitely are not only linear but also loop through re-tooling by continuing education, and also ‘change sides’ by swapping the roles of instructor and learner, moving towards a community-oriented common learning and support experience in later stages.

13.4 Case Study: the Copernicus Master in Digital Earth

Starting from 2019, the Universities of Salzburg (Austria), Olomouc (Czech Republic) and South Brittany (France) offer a joint international MSc program (https://www.master-cde.eu) with all students completing a first year in Austria before specializing in Geo Data Science (France) or Geovisualisation (Czech).

This kind of programme (based on experiences from [6, 7]) only is feasible within the context and with the support of organisations like Copernicus Academy, UNIGIS, Eurogi etc, numerous industry actors providing internships, professional placements and technologies, and geospatially oriented media outlets creating the required visibility. Supported through a generous European scholarship scheme, this MSc programme will lead the way towards qualifying global experts for the trend towards online geospatial technologies supporting societies, economies and environments, and indispensable for monitoring spatially distributed SDG indicators.

The European *‘Copernicus Master in Digital Earth’* is underpinned by a strong emphasis on international perspectives and mobility. SDGs and SDIs cannot be sensibly bounded by national boundaries, and reaching across national entities requires experience in different countries, languages, cultures, technological environments, industries and institutional settings. Programmes like this therefore will be leading the way towards introducing excellent students into the future geospatial communities of practice.

13.5 Educational Ecosystem Services

As demonstrated in the previous section, sustained positive outcomes from capacity building measures will rarely be achieved by single organisations providing specific study programs or learning instances. Curriculum development has to be a multi-stakeholder effort, shall reach beyond initial education cycles to cover lifelong learning perspectives, and primarily address fundamental concepts adaptable to technological evolution and updated methods.

Employing the concept of 'ecosystem services' [5], the joint and collaborative contribution of stakeholders to geospatial capacity building is considered an essential service to SDI brainware development, which cannot be rendered by any individual institution alone.

Only a multitude of services ranging from traditional educational programmes to targeted short courses and trainings, MOOCs, certificate-induced learning, informative updates through magazine articles and blogs, individual mentoring and social learning frameworks etc. will ultimately succeed with qualifying and maintaining a workforce able to support the needs of SDI-for-SDG monitoring and evaluation.

13.6 Conclusions

Geospatial technologies and methods have been identified as indispensable for measuring and monitoring many or most of the 232 indicators for SDGs. Access to these metrics serving as KPIs for SDGs is facilitated through online services integrated with SDIs. Competences to design, develop and maintain SDIs on one side, and to work with these geospatial services from an application domain perspective on the other hand thus are indispensible for any operational approach to SDGs. Above we outline an argument why capacity building towards these required competences has to be a community effort [8]. Any singular approach, like a dedicated study programme, will not be able to fulfil the long term qualification goals critical for contributing the brainware components of making the SDG framework successful across human societies.

This chapter therefore serves as a call to action, addressing all stakeholders identified above. A collaborative and concerted effort is needed to succeed, it can not only be the HEIs responsibility to supply talent to 'the geospatial industry', but rather everyone involved will need to contribute towards strengthening the critical element of human capacity in this field.

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Part IV

Enabling Tools and Technical Components

14

The Role of Geospatial Information Standards for Sustainable Development

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The purpose of this chapter is to illustrate how standards for geospatial information facilitate the implementation of United Nations Sustainable Development Goals (SDGs).

14.1 Introduction

The UN Millennium Development Goals Report from 2015 states under the heading "Geospatial data can support monitoring" the following phrase:

> *"Knowing where people and things are and their relationship to each other is essential for informed decision making. Comprehensive location-based information is helping Governments to develop strategic priorities, make decisions, and measure and monitor outcomes. Once the geospatial data are created, they can be used many times to support a multiplicity of applications."*

The notion of this sentence is not to be challenged but raises the very practical question: How exactly can this multitude of data uses be technically enabled? The obvious answer is standardization, more precisely, a standardization which enjoys universal acceptance and application. Section 14.2 explains why standardization is inseparably associated with the age of digitization. In section 14.3, background on international standardization for geospatial information is provided. Section 14.4presents the ecosystem of international standards. In section 14.5, several case studies are briefly presented to demonstrate how suitable geospatial information based on common standards supports the overarching aspiration of sustainability.

It should be noted that in 2015 the OGC, ISO/TC211 and IHO presented the first version of the Guide to the role of standards in Geospatial Information Management and its companion document to the UN Global Geospatial Information Management Committee of Experts. This chapter on geospatial standards for the SDGs should considered in relation to the fundamental principles and best practice guidance in these documents. The authors strongly recommend that anyone embarking on work that utilizes geospatial data for the SDGs should ensure they have familiarized themselves with this document.

Excerpt from the decisions of the Fifth Session of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). Held from 3-7 August 2015 at the United Nations Headquarters in New York.

5/108 Implementation and adoption of standards for the global geospatial information community The Committee of Experts:

(a) Welcomed the report by the Open Geospatial Consortium (OGC), Technical Committee 211 of the International Organization for Standardization (ISO/TC 211) and the International Hydrographic Organization (IHO), and thanked them and their many experts for their collaborative efforts in producing and finalising the Standards Guide and Companion Document.

(b) Adopted the final published "Guide to the Role of Standards in Geospatial Information Management" and the "Technical Compendium" as the international geospatial standards best practice for spatial data infrastructure, and encouraged all Member States to adopt and implement the recommended standards appropriate to their countries' level of spatial data infrastructure (SDI) maturity.

(c) Encouraged Member States to continue to work in cooperation with the international standards bodies, including participation, as appropriate, in the work programmes of the OGC, ISO/TC211 and the IHO, and requested the standards organisations to consider mechanisms to facilitate wider training programmes and to ensure the access to standards on reasonable terms, especially for developing countries.

14.2 Digitization Forces Standardization

With regard to standardization the age of digitization evolves tremendous changes along the whole chain of information processing. Starting with the acquisition and storage of so far unseen massive data amounts, continuing with the processing to normalize and interpret the gathered information through correlation and quality assessment up to the visual presentation and treatment through artificial intelligence procedures. Digital standardization has become the elementary requirement for all modern data appliances. Compared with the analogue treatment of information in the past, the digital handling of information as data enables the combining of information originally delivered from different knowledge domains. The phrase coined for this capability is "interoperability" and can be effectively achieved in a digital environment only. Interoperability is based in the first place on a consistent abstraction about a set of associated entities by means of attributed objects and their interrelations applicable across domains -the data modelling. Consequently, data modelling itself is a relevant subject of standardization- known as semantic standards.

Once such universal data model exists, a standardized form of digital encoding of the semantic information associated with the modelled entity can be applied. The result are machine readable data sets describing a situation generically. Encoding schemes does not need to be identical for all data sets as long as they are based on the same modelling paradigm, however, broad use of the same encoding eases the processing of the resulting data sets enormously and led to the dominance of a small number of such schemes. Well known ones are XML and its derivation for geospatial information named GML. These standards belong to the world of technical standards.

The semantic and technical standardization deliver ample foundation to create consistent data sets assumed there is prescriptive coding guidance to assign the raw information to a designated object and to form a inter object relations. Again, authoritative standardization is required here -at least within the knowledge domain to result in consistent data sets of the same theme but from different producers.

Once produced, the data sets have to be streamed to their users. Internet communication standards are ready to provide this carriage for geospatial information. There are basically two well-known concepts: the client-server architecture or the transfer of a copy of a data set toward the user to replicate the originating data base locally in parts or completely.

Today digital geospatial data sets manly contain pure information only, which means that different interpretations can be applied to. The most popular interpretation is visual presentation. Based on a consistent data model and universal encoding standards, customized presentation rules can be applied to the data set. End users software, commonly named *Geo Information Systems - GIS* - provide additional functionality to generate varying presentations of the same information content but customized to the task at hand. Like the data modelling and the encoding, presentation rules are subject to standardization as well since this supports identical interpretation through the user.

The visual presentation is still the most popular human-machine-interface for the provision of geospatial information. However, natural voice command and response gain more and more acceptance. The machine "reads and tells" the user the facts on his/hers vocal request. Even here standards in vocabulary and pronunciation are the prerequisite. But procedural interpretation of the transmitted information with little or without human intervention is about to become the mightiest tool to treat complex geospatial information-familiar to anybody who ever planned a route to drive by means of car navigation.

Semantic Standards and Technical Standards Combined

Over the last two decades, many information communities have learned the importance of data coordination and have learned how to do it. Information communities who depend on sharing information often put in place data coordination committees and processes for creating and maintaining standard data models and metadata content standards. The data model used by an information community is their standard way of describing spatial information. It provides a data dictionary and related details necessary for the sharing, aggregation and comparison of data within the community. Metadata associated with a data set includes the data model along with other data about the data - date of collection, person or organization responsible for the collection, etc. Data model development proceeds as a part of an information community's metadata standards development effort. Such standards are often referred to as "semantic standards". Because of these standards, different information systems used within the community can "speak the same language". Different data sets that use the same data model can be aggregated or compared. Semantic standards also facilitate communication between information communities: When each community's data model is published and relatively stable, translation between different data models is easier and more precise, despite some inevitable loss of information.

Data models necessarily evolve as information communities evolve, and so this data coordination process within and between domains is an ongoing activity. Data modelers working with other data modelers are key standards developers for the Anthropocene. Geospatial standards are important for environmental work because virtually everything in our environment has a spatial component and because interactions between environmental features and phenomena depend on proximity. In the geospatial world, an "information community" is an industry, profession, academic discipline or other domain that shares a set of spatial information communication requirements. Because the geospatial element is so important, many data coordination efforts have begun in efforts to create "spatial data infrastructures".

14.3 The Framework of International Standardization for Geospatial Information

There are three key international organizations with the objective of developing open standards for geospatial information.

ISO/TC 211, Geographic information/Geomatics, is a technical committee of the International Organization for Standardization (ISO). It works towards establishing a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. The Open Geospatial Consortium (OGC) is an international not for profit standards organization. The focus of OGC work is to define, document and test implementation standards for use with geospatial content and services. The International Hydrographic Organization (IHO) is an intergovernmental consultative and technical organization established in 1921 to support safety of navigation and the protection of the marine environment. Among its main objectives, IHO is to bring about the greatest possible uniformity in nautical charts and documents (i.e. standardization). The provision of hydrographic and nautical chart services is one of the obligations of coastal State signatories to the International Convention for the Safety of Life at Sea (SOLAS) under the responsibility of the International Maritime Organization (IMO).

Members of the international standards organizations represent government, industry, research, and academia, and develop standards through consensus. Together the standards developed by these organizations form an integrated ecosystem, e.g. OGC and IHO standards leverage the abstract standards defined by ISO/TC 211. This ecosystem facilitates the publication, discovery, access, maintenance and use of geospatial information across a range of applications, systems and business enterprises.

FIGURE 14.1
O Ostensen, D McKenzie & R Ward - Standards Report to UN-GGIM 2015

DGIWG	Defence Geospatial Information Working Group
WMO	World Meteorological Organization
ICAO	International Civil Aviation Organization
W3C	World Wide Web Consortium
OASIS	Organization for the Advancement of Structured Information Standards
IETF	Internet Engineering Task Force
IEEE	Institute of Electrical and Electronics Engineers
IEC	International Electrotechnical Commission
OMG	Object Management Group
ISO/IEC JTC 1	ISO/IEC Joint Technical Committee 1-Information Technology

To achieve interoperability, standardization in the field of geospatial information covers system heterogeneity (hardware, operating systems, communication systems, etc.), syntactic heterogeneity (physical representation of information), structural heterogeneity (concepts and the relationships between them) and semantic heterogeneity (meaning of concepts). In addition, service standards define interfaces for geospatial information functionality provided by a server, and procedural standards provide specifications for accomplishing a particular task.

Geospatial information standards rely heavily on general purpose information communication and technology (ICT) standards. Similarly, domain-specific geospatial information standards rely on generic geospatial information standards, as depicted below.

14.3.1 Technical Standards Link Environmental Standards to IT Innovations

Over the last two decades, the members of this integrated standardization ecosystem have developed policies and procedures for working together to develop consensus-based open interface and encoding standards that provide a way for any two computer systems to request and return any kind of spatial data. These "technical standards" are broadly useful within all spatial data information communities. They support inter-community communication and they are also essential for convergence and integration of different kinds of spatial technologies, such as 2D/3D/4D imaging, vector GIS, surveying, CAD, tracking, etc.

14.3.2 Standardization Driven by Innovation and Technical Evolution

Standardization has always an aspect of consolidation, i.e. freezes technical progress for a distinct duration in favor of uniformity. Modern concepts of digital standards try to overcome this paradigm. The ISO 19200 series for geospatial information standards introduced the registry concept which means that adaptations and new model items can be applied to a web based register at any time. This register is basically open to the interested public but administered by designated and acknowledged institutions. Once registered, the enhanced model items can be exported to form the basis for the future coding of a data product. The data product "hooks up" its most recent model for implementation at the user's device after delivery. This mechanism guaranties the application of the most recent data model at any time.

Like semantic standards, technical standards evolve. The fundamental domain-neutral spatial technology standards framework is now in place, but rapid advances in technology require that this foundation needs continual attention. Such industry-wide advances force revision and rethinking of established technical standards. Discussions about revision invariably run into the issue of backwards compatibility, a standard's lifetime of usefulness, and the importance of stability to both technology providers and technology users who have made investments based on the standard. These are difficult but important issues. Mature standards development organizations and their long-term members have experience in negotiating these issues. They also have a keen awareness of the costs and risks associated with letting market leaders establish proprietary standards outside of an open consensus process. Industry market leaders work in standards organizations because they, like their competitors and despite their natural desire to "lock in" customers, have business reasons to implement and help develop open standards. Technical standards are in place that can provide access control, security and certain privacy protections, but development also needs to address other issues such as geospatial data rights management and data quality. Much work remains in the broad area of technical standards for geospatial interoperability, despite the fact that a mature domain-neutral open spatial technology standards framework is already largely in place.

14.3.3 New Information Communities Emerge

One reason work remains is that technology is advancing so rapidly. Another reason is that new information communities keep appearing.

In climate science, as in many domains, new disciplines arise, and they are new information communities. Their data models differ, but they need to share data and communicate. Communities in relationship need interoperability. The OGC Geography Markup Language (GML) Encoding Standard and other OGC standards can be used to develop international domain-specific encoding standards that bring semantic standards and technical standards together. This is a key cyber infrastructure innovation for environmental science, business and policymaking. A domain that develops a domain-specific data encoding standard based on OGC standards and on the domain's semantic standards gives domain participants much fuller access to developments in the mainstream digital technology world: Web searches, chained computer models, full use of cloud infrastructures, Big Data, data analytics, data fusion, management tools for open data, heterogeneous sensor webs and much more.

14.4 Case Studies

Each of the case studies in this section identifies geospatial information standards from the ecosystem and describes how they contributed or can contribute to achieving one or more SDGs.

Traditionally, addresses were used for delivery to individuals and organizations. Today, there are many more possibilities. Addresses are widely used as a locational reference for all kinds of information, such as information about people, buildings, organizations and services [2]. This makes it possible to spatially analyze and visualize the different pieces of information on a single map in support of planning, management and decision-making.

Addresses are a key element for delivering policies at national and international levels in support of the sustainable development goals (SDGs), specifically "with regard to governance, rule of law, poverty reduction, disease prevention and the provision of basic services such as electricity, sanitation and water". Also, without an address, an individual does not have a legal identity, does not have equal opportunities to finding employment and is not socially integrated [6]. There are thus direct links to at least 9 of the 17 SDGs and others are supported more indirectly through the linking of information to addresses.

A variety of address standards and/or specifications are in use around the world. They are typically well integrated into various operational processes and, in some cases, legally enforced. At the same time, some countries are rationalizing their addressing system or creating a new one. Addresses are also increasingly used to reference new geographic objects (e.g. road furniture) and are integrated in new technologies, such as in-vehicle navigation, for which digital interoperability is essential. The ISO 19160 series of standards on addressing facilitates the entire address lifecycle, from planning and assignment of addresses to using, changing and retiring addresses. The case studies from Australia, New Zealand and South Africa exemplify some of the benefits of standardized addresses.

14.4.1 Australia

Addresses in Australia are managed under the National Address Management Framework underpinned by two standards: the Australian/New Zealand Standard (AS/NZS) 4819 *Geographic information – Rural and Urban Addressing* for address creation and the Australian Standard (AS) 4590 *Interchange of client information* [1]. AS 4590 contains the data element requirements for digital address collection, interchange and storage. This standard references ISO 19160-1. Both standards are published through the Standards Australia IT-004 Committee, which mirrors the ISO TC-211.

Addresses in Australia are first created by the (537) local governments in Australia using AS/NZS 4819, which are maintained by a cross-jurisdictional Permanent Committee on Addressing [1]. This address information is aggregated by each state and territory governments and then contributed to a standardised, authoritative, national product - the Geocoded National Address File, or G-NAF®, which is made publicly available through the Commonwealth Government's open data portal [2] [5]. G-NAF is produced and maintained by PSMA Australia Ltd, an independent and self-funded company that is owned by the nine governments of Australia [4].

Standardised address data underpins Australian governments' services to its citizens. For example:

- The national addressing system, as described above, is central to the Australian national statistical process that is maintained and implemented by the Australian Bureau of Statistics (ABS). The ABS maintains an internal Address Register sourced from G-NAF® and internal address

[1] icsm.gov.au/what-we-do/permanent-committee-addressing
[2] data.gov.au

datasets. The Statistical Spatial Framework and National Address Management Framework (NAMF) [see Figure 14.1] provide the framework for the Address Register, which contains information on all addresses (e.g. their location, residential/non-residential status, etc.) and is processed to create residential dwelling frames for the five yearly Australian National Census of Housing & Population and most ABS social surveys.

Accurate census and survey information underpins key national population statistics. These statistics are critical to enabling governments to meet public health and educational outcomes, as well as providing the infrastructure that supports economic growth and sustainable communities.

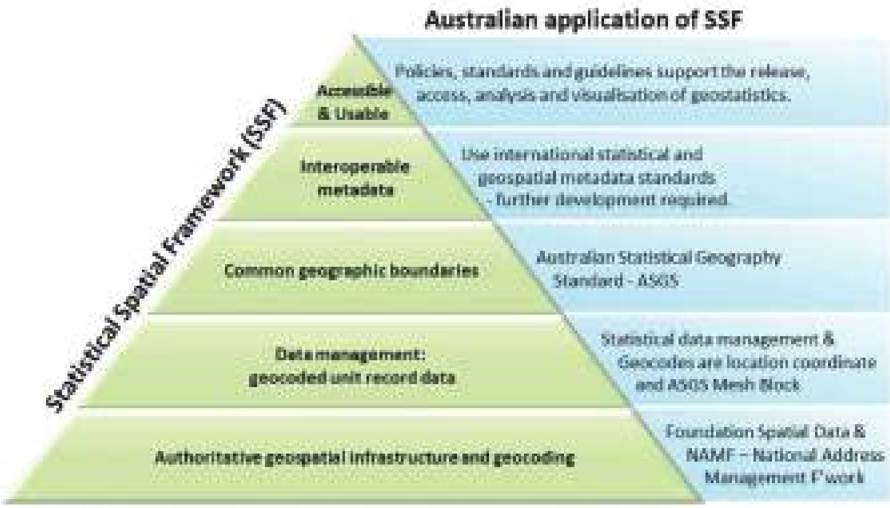

FIGURE 14.2
Australian Bureau of Statistics Statistical Spatial Framework

- The Australian Electoral Commission uses the G-NAF® to deliver an impartial and independent electoral system through active electoral roll management and maintaining equitable electoral boundaries. This underpins Australia's democratic process and stable governance through a transparent representation process.

- Geoscience Australia uses address information to inform the National Exposure Information System (NEXIS), which provides comprehensive and nationally-consistent exposure information that enables users to understand the elements at risk. Resident, Population, Commercial, Agricultural, Infrastructure etc exposure information is produced by sourcing the best publicly available information, statistics, spatial and survey data about buildings, demographics, community infrastructure and agricultural commodities.

This standardised and well governed structure for addresses in Australia has enabled a trial Linked Data API for delivery of the national address file [3]. The hope is that Linked Data will allow new applications of data presentation, access, mining and sharing that improve outcomes for Australians. The API allows users to request G-NAF® data mapped to any number of different 'alternate views', including one modelled on a profile of ISO 19160-1:2015–*Addressing, Part 1: Conceptual model.*

14.4.2 New Zealand

Land Information New Zealand and Statistics New Zealand implemented new systems for managing address data. These two systems, based on ISO 19160-1 and the associated New Zealand profile, manage the addresses used to support New Zealand's electoral system and the collection of official statistics. A standards based approach has made it easier for these two agencies to work together in the collection of up-to-date, authoritative, and accessible address data in New Zealand. ISO 19160 provides a shared understanding of the fundamentals of an address, for both the people involved and also for system interoperability.

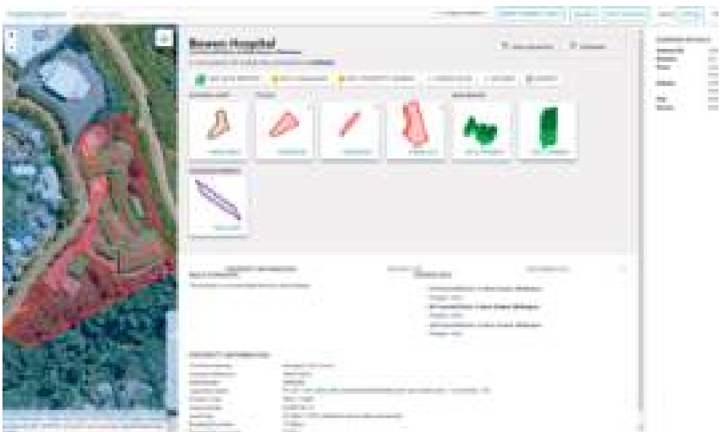

FIGURE 14.3
Example of a property that has multiple addresses

Standardised address data underpins New Zealand's electoral system. For example, electoral boundaries are dependent on accurately locating voters by address. To deliver sustainable development goals, a country relies upon stable governance that is perceived to be fair and representative. Standardised address data also enables critical linking of addresses to other property information, allowing delivery of reliable property-focused data that agencies can use to ensure the right services are delivered to the right citizens (see Figure 14.3). This includes government agencies providing critical social services and others working in fields directly related to the sustainable development goals relevant to address data.

Accurately sampling and capturing statistics requires standardised addresses. These statistics include census, household, economic, and social surveys. Analytics based on these statistics directly contributes to policy that supports citizens' wellbeing and allows outcomes to be measured against sustainable development goals. A standards-based approach to addressing has directly supported the development of New Zealand's Statistical Spatial Framework (see Figure 14.4) and contributions to the UN-GGIM Global Statistical Geospatial Framework.

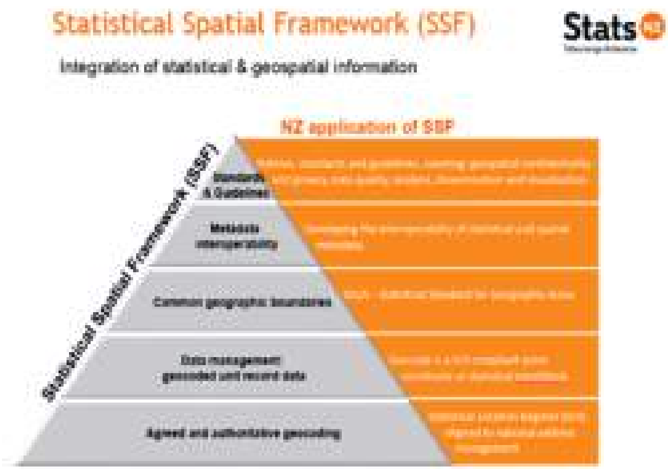

FIGURE 14.4
Statistical Spatial Framework

14.4.3 South Africa

South Africa is a diverse country with many challenges. Thanks to the guide of standards, the subject of addresses now has a solution and firm way forward.

AfriGIS is a private GIS company based in Pretoria, South Africa. 2019 marks our 22nd year of existence. The focus of AfriGIS is to provide actionable answers through location insights to improve decision making. The foundation of the insights lies in the quality of the data and information. At AfriGIS we identified a need for quality information that is accurate and maintained. The spatial data we base our decisions on should be reflective of the world we live in. In 2002, AfriGIS started building and maintaining a host of datasets to assist both private sector and government.

When the United Nations (UN) released the 14 Global Fundamental Geospatial Data Themes, AfriGIS could tick off at least eight of the boxes. We have maintained spatial data layers for South Africa in terms of:

- Geographical Names
- Addresses
- Buildings and Settlements
- Land Parcels
- Transport Networks
- Population Distribution
- Land cover and Land use
- Physical Infrastructure

Addressing is a complex item and challenge in South Africa. The various components that build up an address are divided between different custodians and entities. In order to create a national address dictionary, an estimated 250 different custodians from National and Provincial (9) and Municipal (226) level provide data. AfriGIS rose to the challenge.

SANS 1883-1:2009 was the first Address Standard AfriGIS ever implemented. The data sourced from the different entities are not standardised in any way. Several projects are in progress to ensure that best practices as prescribed in the conceptual model are adhered to.

AfriGIS became involved with ISO/TC211 to guarantee that our data and address offering to our clients remain world standard. Private sector companies have a multinational footprint and have to ensure that data shared across boundaries share the same profile. ISO 19160-1:2015 allowed AfriGIS to map our data to the South African profile as described in SANS 1883-1:2009.

The practical benefits to the company and our clients have been enormous. The following examples would not have been as successful without the foundation of a standard as a beacon in the dark.

Logistics

Ecommerce is one of the greatest emerging markets, not only in South Africa but also in the world. Accurate delivery address is crucial to make the model work. It empowers better delivery time, effective planning and accurate billing. The process works as the point of capture is accurate. The advantage of having a confidence level ensures that drivers have a clear view of the expectation with each delivery.

Emergency Services

In South Africa one of the first private companies to implement SANS 1883-1 is a prominent security firm. They have applied their own business rules to only accept confidence level 1 and 2 addresses. In their business the accuracy, or rather inaccuracy of the address could have life threatening consequences.

Financial Services

Through a host of services an address provides a vast amount of information about an area, a person and the potential of risk. In terms of the financial institutions the risk, the potential and the business profile of an organisation is dependent on the quality of the addresses in their database.

AfriGIS Search

These are just a few small high level examples. How did AfriGIS succeed to bring a Standards compliant address database to clients?

We have developed an API that serves the addresses. AfriGIS Search is an address verification, capture and geocoding tool. It contains intelligence to simplify the complex addressing system of South Africa.

There are six active address types (classes) incorporated into the solution:

- Street Addresses
- Building Addresses
- Farm Addresses
- Site Addresses
- Landmark Addresses
- Intersection Addresses

Informal addresses have been excluded in the product as there are currently no legal custodianship in place to maintain and verify an informal address.

AfriGIS Search gives clients up to 50 million searchable address combinations for South Africa. The reason the number appears to be so high is due to the fact that a single land parcel in South Africa can have multiple addresses; all relevant and legal. The API allows for all components of an address and its history to be maintained and captured.

AfriGIS Search provides a client with the tool to access an address with all the components required to understand the accuracy, maintenance, history and type.

Additional information available contains the land administration information with regards to deeds, ownership and contact information. All the additional information that provide a view of the address can be found within the AfriGIS Search API.

Addresses are a challenge in South Africa. We have multiple address types. We have unconfirmed assigning methodologies. We have numerous role players.

The standard was used as a road map to determine the important pieces of information. To order it within the boundaries of logic and accessibility. It guides us in terms of requirements and possibilities. It made the data sharable and interoperable.

The true test of the benefits of standards were when we took the ISO 19160-1 compliant datasets from different countries. Based on the methodology, the data had to be easily compatible. The results of the combination of the three southern hemisphere address datasets is a story of triumph. The tri-nations may be fiercely competitive on a rugby field. Our addresses work together beautifully. In terms of addressing the conceptual model proved to be successful.

14.5 Case Studies of Relevant Standards for Specific Goals

14.5.1 New Zealand Government Use of WaterML and SOS

Relevant to Goals - 6 Clean Water and Sanitation, Goal 14 Life Under Water

The OGC WaterML 2.0 standard, developed in a working group organised jointly between OGC and the World Meteorological Organisation (WMO). To support requirements for monitoring laid out in the New Zealand Resource Management Act 1991 multiple New Zealand agencies. Monitoring Standards and Technologies for the compilation and reporting of water quality data across New Zealand is underpinned by the WaterML 2.0 and unifies data across regional agencies.

14.5.2 Urban Environment - Multiple Urban Implementations Including UK, Singapore, Germany, Finland, Australia, USA, Canada. Key Standards in Use Include CityGML, SensorWebs, SensorThingsAPI and Others

Relevant to goals: 7 - Affordable and Clean Energy, 11 Sustainable Cities and Communities, 13 Climate Action Two sources of excellent guidance on the

broad range of use cases include the OGC's Future Cities Pilot[3].

The second source is the OGC's Smart Cities Domain Working Group list of use cases. These include topics such as waste management, planning,

[3] www.opengeospatial.org/projects/initiatives/fcp1

FIGURE 14.5
OGC Future Cities Pilot

disaster management, transport and others. Many of the use cases indicate which SDGs are relevant [4].

14.5.3 Arctic SDP

This project is an international exemplar in the efforts to share data across multiple nations and is perfect example of the vital role that geospatial standards play in striving towards Goal 17 - Partnerships for the goals.

The ArcticSDP proved the capacity of the international standards to achieve interoperability across all the Arctic nations in order to share environmental data vital to understand climate changes and animal migration and behaviour.

Further information on this project can be found at:
http://www.opengeospatial.org/pub/ArcticSDP/index.html

IHO and marine SDGs Goal 14
Standardization forces collaboration - a maritime use case
The maritime sector definitely holds the longest tradition in international

[4] external.opengeospatial.org/twiki_public/SmartCitiesDWG/UseCaseList

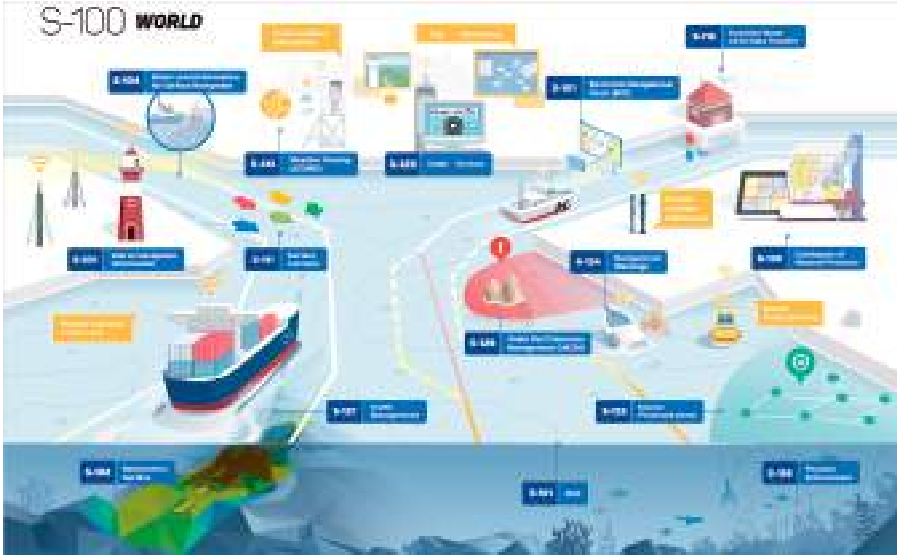

FIGURE 14.6
The S-100 Universal Hydrographic Data Model
The S-100 Standard is a framework document that is intended for the development of digital products and services for hydrographic, maritime and GIS communities. It comprises multiple parts that are based on the geospatial standards developed by the International Organization for Standardization, Technical Committee 211 (ISO/TC211).

standardization of geospatial information. It was the 23^{rd} President of United States, Benjamin Harrison who called for the first International Marine Conference in Washington D.C. in 1889. In order to facility safety of navigation the attending 28 nations agreed – among a good amount of ship's related issues - to improve the regular update of nautical charts and to start the harmonization of the publication of nautical warnings. It was then in 1919 there first International Hydrographic Conference in London agreed to develop firm standards how to technically conduct sea survey and nautical cartography and confirmed the installation of a coordinating intergovernmental body - the International Hydrographic Bureau - later the International Hydrographic Organization (IHO) in Monaco. Since then the IHO has adopted the leading role in global standardization of nautical charting - or in more modern words - to enable the provision of marine geospatial information interpreted and customized for surface navigation in a globally unified manner. Though nautical charts are mainly individually produced by the affected coastal state they all adhere to the same paradigm of information encoding and presentation thanks to the applying technical IHO standards. The late eighties saw the uptake of digital means for navigation and IHO standards for nautical cartography were turned into the digital domain too. Even thanks to Electronic Navigational Charts (ENC) shipping is comparably safe today but there is one significant change of the scenery: The application of nautical information is not limited to the purpose of surface navigation anymore. It likewise has to provide support for efficient and in particular resource saving navigation. Optimised route planning and tracking in terms of distance and speed can generate great savings in fuel burned for propulsion; the surveillance of proper fishery is based on precise charts and the preservation of habitats can be serviced much better if all available information is technically amalgamated. The response of the IHO to this is the installation of a modern standardization ecosystem - the IHO S-100 framework - which is not limited to means for surface navigation but utilizes a common model platform for all maritime geospatial information.

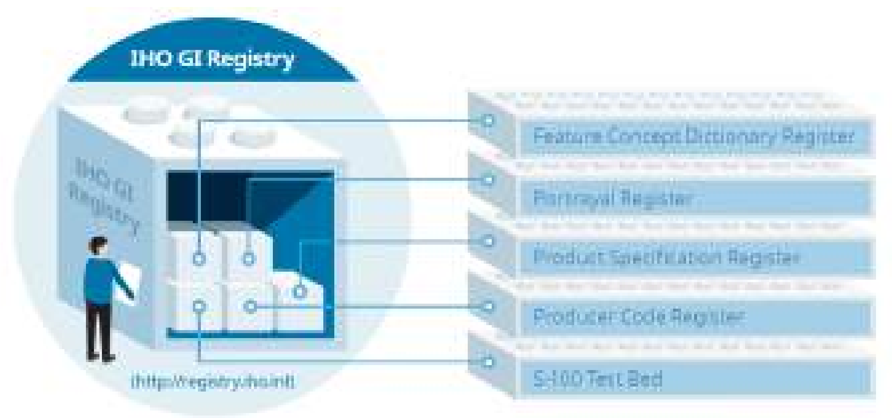

FIGURE 14.7
S-100 Geospatial Information Registry

S-100 basically adopts the fundamental mechanisms of the ISO 19200 series of standards for geospatial information and delivers the most important application of this suite.

The IMO as special UN Organization for the maritime sector has adopted the modelling part of S-100 as its “universal hydrographic data model”. In order to achieve interoperability between all data sets relevant for likewise safe and sustainable ship's operation all maritime data providers are called to develop data product specifications based on this model. To facilitate this the IHO runs the web based IHO Geospatial Information Registry which administers objects, attributes and presentation rules [5].

The IHO GI registry interfaces to tools supporting the generation of machine readable catalogues for customized modelling and presentation. The IHO

[5]http://s100.iho.int/S100/

GI registry itself is not limited to the hydrographic domain. Instead altogether nine domains owned and administered by other international and intergovernmental organizations active in geospatial information standardization, e.g. the World Meteorological Organization WMO and the International Association of Lighthouse Authorities IALA are already hosted and the IHO GI Registry is subject for grow further. The ambition is to consolidate comparable standardization activities in the domain of ocean sciences to eventually address all relevant maritime geospatial information in interoperable data product specifications.

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15

Urban Analytics Data Infrastructure: Critical SDI for Measuring and Monitoring The National and Local Progress of SDGs

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This chapter describes an innovative Spatial Data Infrastructure to support urban analytics and urban research capabilities focused on Australian cities, called Urban Analytics Data Infrastructure (UADI). The UADI provides opportunity for multi-disciplinary, and cross-jurisdictional analytics. The chapter highlights the UADI capabilities to be adopted for deriving the SDG indicators as a response to the UN-GGIM strategic framework 2017 – 2021 technical requirements.

15.1 Introduction

In 2015, the United Nations 2030 Agenda formalised 17 Sustainable Development Goals (SDGs), which consist of 169 targets and 232 indicators. Consequently, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) aligned their 2017-2021 strategic framework with the 2030 Agenda for Sustainable Development. With the vision of *"Positioning Geospatial Information to Address Global Challenges"* this strategic framework highlighted several key policies and technical points in their operating principles [12]. The technical points span from agreed standards and methods to integration and interoperability of national information systems as well as information sharing and knowledge transfer. These are important to support the evaluation of SDG indicators at a national level. This is with the assumption that these will enable evidence-based policy making and the development of effective implementation strategies towards achieving the goals set by the 2030 Agenda.

The SDGs have established methodologies that allow the generation of comparable indicators worldwide. Therefore, these methodologies, along with the UN-GGIM operating principles, present opportunities to formalise re-usable geospatial tools for producing the indicators. This will allow the UN, and subsequently Member States, to not only compare progress among nations but also to monitor the indicators over time. However, the implementation of the SDG proposed methodologies vary from one jurisdiction and government level to another. This may be due to different terminologies and the subsequent interpretation of their methodologies in various contexts, or the differences in the structural and semantics of the input data used for measuring the indicators. This can result in redundant work for measuring similar indicators and may compromise the comparability of these indicators.

Furthermore, the indicators set forth by governments or other institutions lack transparency of the measurement process and in the case of many existing platforms (e.g. World Council of City Data [WCCD] platform that attempts to present indicators for ISO 37120, urban quality of life), access to such information is limited, affecting the indicator's credibility [14]. These challenges hinder the development of a spatially enabled platform that adopts a set of re-usable geospatial tools for measurement, storage, and effective and transparent communication of the SDG indicators for UN Member States and their respective levels of government. Consequently, customised version of these methodologies are developed to address the subjectivity of indicators and to meet the needs of each jurisdiction. Specifically, this issue can be addressed by a geospatial platform with capability of minimising redundant efforts and encouraging cooperation between different levels of governments, the private sector, academic institutions, and civil society organisations. This is in addition to enhancing evidence-based policy making towards achieving the SDGs by providing a repository of a set of transparent and credible indicators.

At the moment, such a geospatial platform that enables the harmonisation of structurally and semantically heterogeneous datasets is lacking. This makes it difficult to work with an ecosystem of re-usable and shared set of user-generated tools for measuring and communicating the SDG indicators. This chapter aims to introduce a Spatial Data Infrastructure (SDI) developed for urban data analytics in Australia [7] and to highlight the capabilities to be adopted for deriving the SDG indicators as a response to the UN-GGIM strategic framework 2017 – 2021 technical requirements.

The next section explains the global indicator framework developed by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs). It explores data and analytics challenges inherent in the framework highlighted by the latest SDGs report. In section three, the chapter introduces Urban Analytics Data Infrastructure (UADI), the motivation for developing such SDI and its components. The section highlights how the UADI is capable of addressing technical requirements indicated in the UN-GGIM strategic framework 2017 – 2021. Consequently, section four explores the possibilities that UADI can contribute to SDGs. Finally, section five provides an account of ways forward in adopting the UADI for deriving SDG indicators in the global context and its implications in achieving SDGs.

15.2 Global Indicator Framework

The Inter-Agency and Expert group on SDG (IAEG-SDGs) developed the global indicator framework for the SDGs and targets of the 2030 Agenda for Sustainable Development. This framework, including refinements on several indicators, was agreed upon at the 48$^{\text{th}}$ session of the United Nations Statistical Commission held in March 2017. Accordingly, the global framework was adopted by the UN General Assembly on 6$^{\text{th}}$ July 2017. This framework is part of the Resolution adopted by the General Assembly on work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development[1].

The global indicator framework emphasised that *"Sustainable Development Goal indicators should be disaggregated, where relevant, by income, sex, age, race, ethnicity, migratory status, disability and geographic location, or other characteristics, in accordance with the Fundamental Principles of Official Statistics*[2]*"*. As at April 2018, 232 indicators were listed in this framework. The indicators will be refined annually and will be published in the official website of The United Nations. This will provide information on the develop-

[1]Resolution https://undocs.org/A/RES/71/31371/313
[2]Resolution https://undocs.org/A/RES/68/26168/261

ment and implementation of indicator frameworks to guide the follow up and review of the 2030 Agenda for Sustainable Development[3] .

While these indicators are defined for national level, several national and international organisations have attempted to localise them. For instance, the Association of Flemish Cities and Municipalities (VVSG), an association of 308 Flemish municipalities and cities, attempted to translate the SDGs at the local level [3]. The VVSG developed tools and guidelines to enable local authorities to develop policies to achieve SDGs. These initiatives require measuring, monitoring, and managing SDG's progress at the local levels. As such, the spatial scope of measuring the SDGs indicators defined at the global framework need to be smaller than what is obtainable at the national level.

From a spatial data point of view, some of the indicators are readily presentable in different geographical boundaries (subject to availability of data). For instance, in target 3.c of SDGs, governments in developing countries are required to *"...increase health financing and the recruitment, development, training and retention of the health workforce..."* Indicator 3.c.1 intends to measure *"Health worker density and distribution"*. This indicator potentially can be derived and measured in small geographical boundaries of census blocks or administrative boundaries. For other indicators which are not spatial (e.g. indicator 5.5.2 *""Proportion of women in managerial positions*), they can also be connected to a confined jurisdiction boundary smaller than a state or nation.

It is important to emphasise that the data availability is always a major consideration. As such, a digital platform that is capable of harmonising and standardising the data and analytics tools and then derive SDG indicators is necessary, considering the different data structure and quality. The next section discusses an innovative spatial data infrastructure developed for addressing these challenges.

15.3 The Urban Analytics Data Infrastructure

The Urban Analytics Data Infrastructure (UADI) project is a collaborative effort between a consortium of urban research centres across Australia and is funded by the Australian Research Council [7]. The UADI has been developed to enable multi-disciplinary, cross-jurisdiction, national-level analytics of ISO/DIS 37120 *"Sustainable development and resilience of communities - Indicators for city services and quality of life"*. It provides a digital infrastructure for urban researchers to overcome current challenges related to data access, integration, analysis and sharing.

Since its development, the UADI has improved the state of urban analytics

[3]https://unstats.un.org/sdgs/indicators/indicators-list/

in Australia, and capitalised on previous urban data initiatives, for example the Australian Urban Research Infrastructure Network (AURIN). This has provided opportunities to add more value to the existing initiatives. It also provides the capability to shift the current urban research and planning landscape towards one that is more consistent across jurisdictions. It builds up the requisite intellectual capital to support evidence-based decision-making that transcends traditional disciplinary domains.

In addition, the UADI facilitates analytics tool sharing and provides metadata for both data and tools. These capabilities in the UADI are developed to increase the reliability, trustworthiness, and useability of data, tools, and output information. As such, this Spatial Data Infrastructure (SDI) attempts to address several challenges related to the data and deriving city indicators recently raised by scholars worldwide [4, 14].

As a digital data infrastructure, the UADI enables the integration, harmonisation, connectivity and scalability of multi-source urban datasets. As applied, for an example, in the analysis of urban density, this infrastructure was able to integrate data related to population, building footprints, and land use, which could be used to compare different urban densities (e.g. residential/commercial built-up area per capita, and publicly available open space per capita) in local authorities across Metropolitan Melbourne. The infrastructure developed a new ontological framework [1] and a dictionary to underpin the next generation of data driven modeling and decision-support tools to enable smart, sustainable, productive, and resilient cities.

FIGURE 15.1
The UADI components and capabilities

The main objectives in developing UADI are as follows:

1. To provide an underlying framework for harmonisation and integration of urban data by adopting the ISO 37120 and ISO 19115 standards.

2. To develop core system capabilities including data registry, integration and access, as well as analytics tools registry, execution and publishing through web APIs (Application Programming Interfaces) by adopting the OGC (Open Geospatial Consortium) standards.

3. To develop an integrated platform and web-portal to visualise and evaluate the cross-jurisdictional and cross-domain performances.

4. To facilitate open access to those datasets currently accessible through the AURIN Data Hubs and any new open data sets through the development of open access APIs.

The UADI addresses challenges such as those associated with data access, data integration, and the use of varying terminology between disciplines. This infrastructure is comprised of two main components (Figure 15.1):

1. UADI Dashboard: The aim of this component is to allow users to access, integrate, and semantically enrich the data as well as manage and execute their own or others' analytics tools. Users can also preview and publish the results of the analytics in the dashboard.

2. UADI Portal: The aim of this portal is to enable public users to discover, access, explore, and compare urban quality of life indicators calculated by a variety of contributors from different sectors such as research and development, government, and the private sector.

The core capability of the UADI is using ontology that consists of one (or more) upper-level and domain ontologies, describing the generic (e.g. space and time) or specialised concepts pertinent to one or more domains of knowledge [2]. As an example, one of the upper-level ontologies developed in UADI is for Austrian Statistical Geography Standard (ASGS), which determines the relationships of statistical and administrative geographical boundaries across Australia (Figure 15.2). Furthermore, using METHONTOLOGY [1], a number of application ontologies for urban density and urban accessibility measurements were developed.

In addition to the definition of concepts, their relationships are also defined by ontology in the UADI. Therefore, the mapping between any data and its attribute in a dataset to one or many concepts within the ontology can be used to describe the dataset for discovery, and also data integration purposes [1].

The data in the UADI model refers to the datasets that are available from the data providers through standard web services and over the Internet. The data can be spatial or non-spatial and can be structured and non-structured. This data should be exposed via the data custodians to UADI through standardised OGC protocols (e.g. Web Feature Services) [11]. These services can then be registered using their metadata and via the data catalogue component in the UADI.

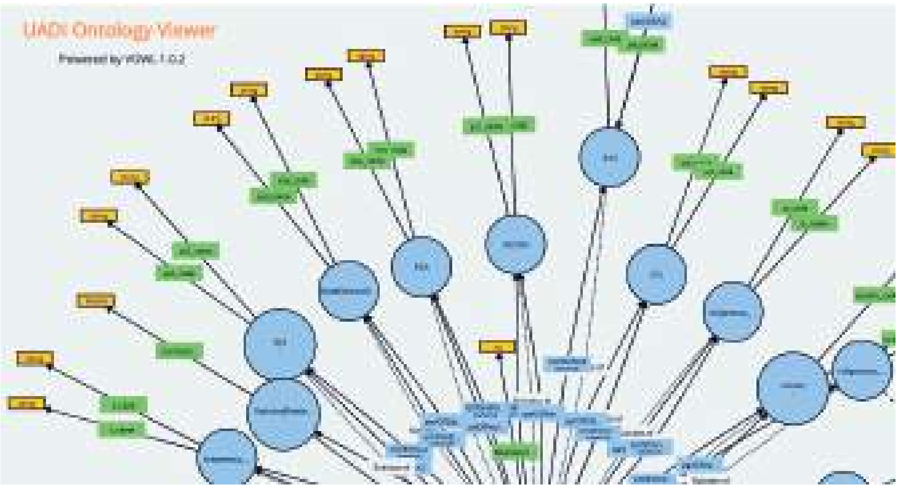

FIGURE 15.2
An example of using VOWL (v1.0.2) to show the concepts (blue circles), properties (green blocks) and relations (blue blocks) defined in the ASGS Ontology. The subclass of a concept is represented in dashed arrows.

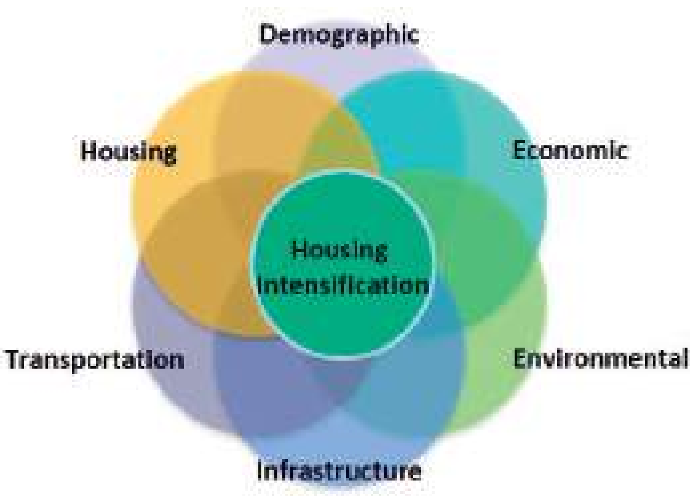

FIGURE 15.3
Housing intensification; a multi-domain urban planning approach.

This infrastructure is a smart technology that can be used to generate indicators for decision makers, such as urban density [1] and accessibility [10]. For this purpose, the UADI encapsulates and registers each indicator tool as a Web Processing Service (WPS) [11] endpoint, which can then be executed by users with various parameters as inputs for deriving the indicators. This functionality enables organisations to conduct more advanced multi-domain spatial analyses such as urban heat island (UHI) and housing intensification. For instance, as can be seen in Figure 15.3, housing intensification is an urban planning approach, which involves several integrated and overlapping domains which need to be analysed in an infrastructure that can integrate data from multi-domains.

Using the UADI, it is also possible to integrate data to do transparent and comparable analysis among different cities. Figure 15.4 shows the comparison of spatial distribution pattern for one of the urban density parameters (Plot Factor: The ratio of private land areas to land available for public use, distinguished by functionality and accessibility) in two local authorities of Moreland (an inner-suburb) and Whitehorse (a middle-suburb) in Metropolitan Melbourne. Figure 15.4 also shows how the results of analyses are normalised (the two lower maps) to facilitate the comparisons.

15.4 UADI's Contribution to SDGs

The literature on city indicators has highlighted several challenges about transparency, reliability, and usefulness of the indicators [4]. As explained in the first section, the lack of data provenance and uncertainty in indicator measurement process in the case of existing platforms limits the credibility of indicators. These challenges apply to SDG indicators as well as there are specific local conditions for one region which may have not been the case in others. So how can countries register the process based on which indicators are derived?

In 2016, when the transforming plan from Millennium Development Goals (MDGs) to SDGs was prepared by the member states, several limitations about data and decision making processes were highlighted. One of the bottlenecks was the lack of quality data to enable regular monitoring and support evidence-based decision making. Accordingly, international agencies including UNDP, World Bank Group, and UN-Habitat suggested using real-time data, adopting geospatial data, strengthening statistical capacity, utilising new technologies, changing the methods of data collection and dissemination, developing global standards for integrated statistical systems, and promoting open data [13, 5].

As such, in order to measure, monitor and compare the SDG's progress by the UN member states, a spatially enabled information decision making platform is critical. Such a platform should enable the member states to derive

FIGURE 15.4
Spatial comparison of plot factor in two local authorities in metropolitan Melbourne.

their indicators through data access and integration facility using reliable and replicable tools in order to visualise and share the outcomes of the SDG indicators (Figure 15.5). The UADI, as explained in the previous section, is a digital infrastructure with the capability to meet the SDG's progress management requirements in conceptual framework presented in Figure 15.5. Furthermore, the UADI is potentially an enabler to progress the UN-GGIM's strategic framework. It is also designed to operate the principles that allow the formalisation of re-usable geospatial tools in capacity building, thereby enabling the UN and member states to compare, monitor and manage SDG progress.

The UADI's capability in registering spatial and non-spatial data enables deriving SDG indicators that are non-spatial as well. In some cases, it is possible to connect the non-spatial indicators to a certain geographical boundary.

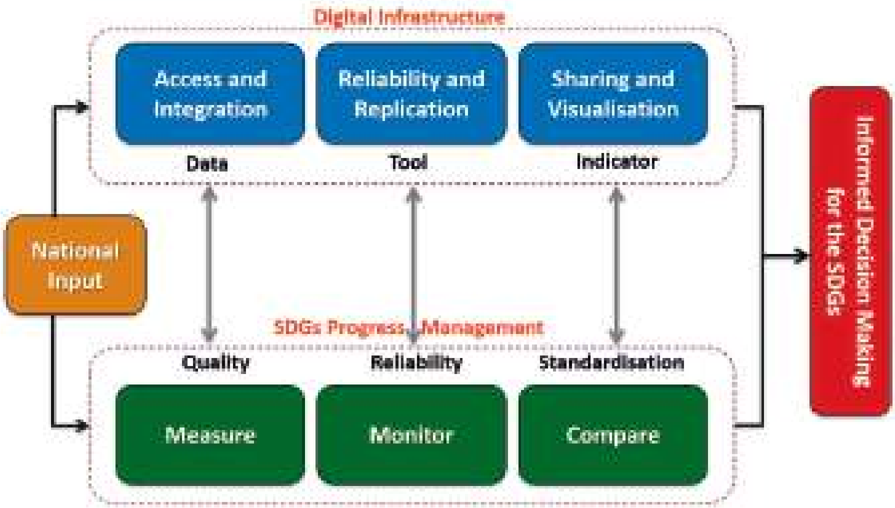

FIGURE 15.5
Conceptual framework for a digital infrastructure enabling the SDG's progress management.

As an example, as part of target 1.4 of the SDGs, governments are required to *"...ensure all men and women have equal rights to economic resources, and access to basic services, and control over land and other forms of property..."*Indicator 1.4.2 intends to measure *"proportion of total adult population with secure tenure rights to land, with legally recognised documentation and who perceive their rights to land as secure..."*. Subject to the availability of data, this SDG indicator can be attributed to a particular census or administrative boundary. As a result, regarding the 1.4.2 indicator, UN Member States can provide a better understanding of the rate of progress in a spatially and temporally visualised fashion, which identifies the deficiencies that require further improvement at local, state, and national government levels.

In addition, the UADI enables the evaluation for potential future scenarios. This capability can additionally facilitate strategic planning and informed decision making for optimal solutions amongst various alternative options. This capability of UADI enables defining use cases such as land development, housing affordability, emergency and energy efficiency, and inclusive infrastructure development (e.g. transport, telecommunications, and other utilities). The use cases along with indicators will enable different government levels to localise the implications of SDGs (Figure 15.6). It is also important to improve the UADI by using the live data (e.g. sensor network), and big data for advanced analytics.

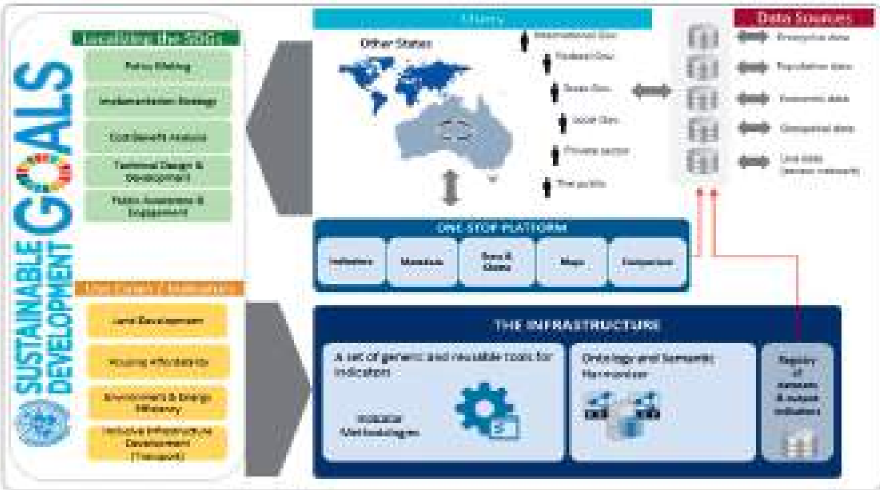

FIGURE 15.6
Potential contribution to SDGs and localising the SDG indicators.

15.5 Discussion and Conclusion

This chapter discussed how the development of national indicators for the SDGs and localising the 2030 Agenda for Sustainable Development require a digital infrastructure that can facilitate the registration and sharing of indicators locally and globally. The chapter then introduced a spatial data infrastructure (SDI) that enables the harmonisation of structurally and semantically heterogeneous datasets to work with an ecosystem of re-usable and shared set of user-generated tools for measuring and communicating the SDGs indicators.

The chapter has also discussed the capabilities that UADI platform offers for deriving the SDG indicators as a response to the UN-GGIM strategic framework 2017 – 2021 technical requirements. The UN-GGIM can facilitate the adoption of such a digital infrastructure for member states to register new indicators related to land administration, disaster risk reduction, food security, and the implementation of standards in order to measure and monitor the inclusive progress of the SDGs.

One of the major advantages of the UADI is its capability to spatially visualise the indicators, which help to benchmark and compare different jurisdictions. Each local, state, and national government can also compare their own progress in SDG management by investigating the changes of SDG indicators through time.

The chapter has also shown that the UADI system offers several innovations, which highlight future research directions for new developments in areas such as:

- Ontology and its role in national and international linked data projects. The UADI system has already addressed several challenges in the Australian National Linked Data project, which put Australia at the forefront of open data and semantic web development.
- Formalising the Open Geospatial Consortium (OGC) smart city framework [6] and a new agenda for incorporating sensor data, crowd-sourcing volunteered geographic information data (VGI) [9] for real time analytics in deriving SDG indicators.
- Adding more use cases related to sustainability, including liveability [8] and quality of life indicators facilitating the localisation of SDGs. The use cased will help in local policy making, refining strategies and public awareness and engagement for implementing SDGs.

Acknowledgment

The UADI project is supported by an Australian Research Council Linkage Infrastructure Equipment Facilities (ARC LIEF) grant (LE160100174). The authors would like to acknowledge the contribution of Maryam Rabiee in developing Figures 5 and 6 and Sam Amirebrahimi in developing Figure 6.

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16

New Technical Enabling Tools for Data Acquisition and Maintenance of Topographic Data of Urban and High Mountain Areas to Support SDGs

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This chapter discusses the need of geospatial data and the new technical tools for data acquisition and maintenance of (topographic) data to support SDGs. The chapter provides an example of data acquisition for urban and high mountain areas.

16.1 Introduction

The definition of Sustainable Development Goals depends on the availability of data. Most data required for this are geospatial. The data are dependent on resolution and their object definition at a specific resolution.

Traditionally geospatial information was displayed in the form of maps at different scales. In order to be able to display the information for a certain object location and object size an appropriate scale is required. For data concerning the environment small scales of 1:250000 or 1:500000 may be sufficient, for urban data large scales ranging from 1:1000 to 1:10000 are more appropriate.

The larger the scale, the more effort in data acquisition with respect to time and cost is required. This is the reason why historically the global coverages in map scales have increased from 1:1 million in 1950 to 1:50000 in 2000.

These changes have been made possible due to improvements in technology. While in 1900 only terrestrial surveys by many surveyors were possible, by 1950 the accepted data acquisition technology was aerial photogrammetry based on aerial photographs. The developments from analogue photogrammetry to analytical photogrammetry and then to digital photogrammetry between 1950 and 2000 have made significant improvements in mapping technology.

16.2 Global Progress in Mapping From 1900 to 2000

In 1900 terrestrial surveys were only permitted to generate maps in Europe, parts of India and parts of the United States of America (see Figure 16.1).

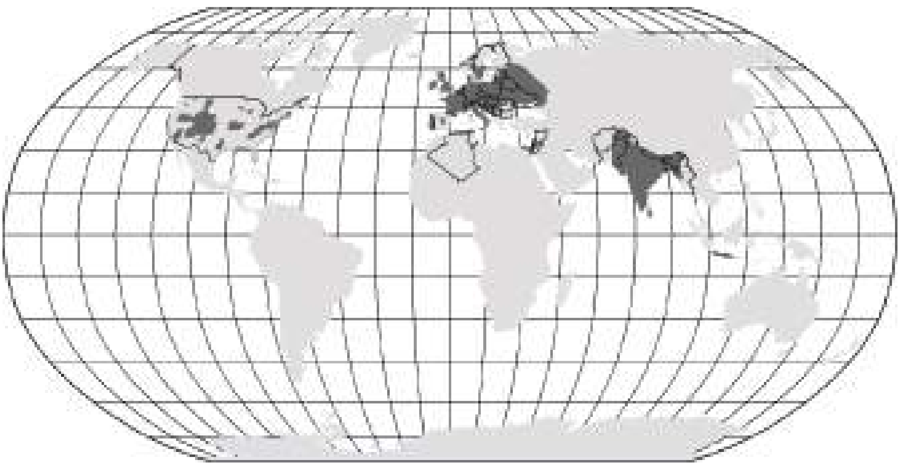

FIGURE 16.1
Global Topographic Mapping Coverage in 1900 [9]

Between World War I and World War II the mapping by photogrammetry was promoted by the International Society for Photogrammetry, founded in Vienna in 1910 [8]. Progress came about by the design and production of stereoplotting instruments in Germany, France, Italy, Switzerland and the USA and Britain. Russia and the soviet block had a rather independent development from the West developing its own instruments. This instrumentation was used greatly during the war-faring nations in World War II to produce maps for the areas affected by the military war operations in Western and Eastern Europe as well as in great portions of Asia and the Pacific.

After the war ended in 1945 the International Society for Photogrammetry met in 1948 in the Hague, Netherlands. Its President was the first post war Prime Minister of the Netherlands, William Schermerhorn. He convinced the Dutch government of the mapping needs of the third world countries. In order to cope with the problem the Dutch government made a donation to the United Nations by establishing an International Training Centre for Photogrammetry (the ITC) in Delft in 1950. This school in addition to the instrument industry became responsible for spreading the photogrammetric mapping technology to most countries of the globe with a total of 1900 students from 170 countries. When Schermerhorn retired as director of the ITC the institution was relocated at Enschede in the 1960s and still contributes to the further development of mapping technology.

In Russia a similar effort to make photogrammetry known in the Soviet controlled areas took place by the educational institutions MIIGAiK in Moscow and by NIIGAiK in Novosibirsk.

The United Nations Sectretariat in New York began to show an interest in the spread of photogrammetric mapping technology in the third world countries as early as 1955 when it organized the first United Nations Cartographic Conference for Asia and the Pacific and in 1976 for the Americas. These UNCC Conferences were the root for the establishment of the United Nations Global Geospatial Information Management (UNGGIM) Secretatiat in New York since 2011, now holding annual conferences.

Both UNCC as well as UNGGIM showed an interest in the global progress of mapping. The results of the progress of mapping document the global coverage for 4 scale ranges: range IV: 1:250000, range III: 1:100 000, range II: 1:50000 and range I: 1:25000 with the following figures for the global data coverage [7, 6] (see Table 16.1.).

TABLE 16.1
Global Topographic Mapping Coverage: Progress Between 1968 and 2012

Year	Range IV (1:250000)	Range III (1:100000)	Range II (1:50000)	Range I (1:25000)
1968	80.0%	38.2%	24.3%	7.7%
1974	80.0%	40.5%	35.0%	11.6%
1980	80.0%	42.2%	42.0%	13.3%
1986	87.4%	46.4%	49.3%	17.9%
2012	98.4%	67.5%	81.4%	33.5%

The second issue is the current state of these maps. The update rates have been determined for the years 1968 and 2012 as shown in Table 16.2:

TABLE 16.2
Global Update Rates of Topographic Maps in 1968 and in 2012

Year	Range IV (1:250000)	Range III (1:100000)	Range II (1:50000)	Range I (1:25000)
1968	27.7 years	37 years	55 years	31.2 years
2012	37 years	31.2 years	26.3 years	22.4 years

The regional update rates are shown in Table 16.3 for the year 2012:

TABLE 16.3
Regional Update Rates for 2012

Region	Range IV (1:250000)	Range III (1:100000)	Range II (1:50000)	Range I (1:25000)
Africa	43.7 years	36.3 years	35.1 years	24.2 years
Asia	38.0 years	35.3 years	27.2 years	22.8 years
Australia and Oceania	30.4 years	29.0 years	16.5 years	22.4 years
Europe	21.8 years	21.1 years	17.1 years	13.8 years
N America	44.0 years	29.2 years	26.3 years	35.4 years
S America	31.5 years	30.1 years	34.7 years	9.8 years

Global base data for SDGs are therefore not available in updated form at the listed scale ranges in the form of geospatial base data. At the age of high resolution space imaging there are, however multiple coverages of global geospatial image data, which can be geocoded and spatially referenced. These images often permit to update areas of the existing global dataset and extract the missing information at these scale ranges at a cost.

16.3 Large Scale Mapping of Urban Areas

No global information is available for the urban scales 1:1000 to 1:10000. If mapping at these scales exists, it generally originates from local administrations at unclear and often unacceptable specifications for a transfer to global datasets.

But the problems for large scale data coverage and map age are similar to what exists for medium scale datasets originating from national mapping agencies shown in Tables 1 to 3.

It is possible to obtain these data from countries, which have included the generation and the maintenance of large scale datasets as a task for the national map agencies, as is the case for the Kingdom of Saudi Arabia, in which the main concentration of development is in rapidly changing urban areas.

The relevant large scale mapping efforts made by the Ministry of Municipal and Rural Affairs (MOMRA) concentrate on the mapping of urban areas for the country of 2.15 million km^2 with a population of 33 million, of which the urban population is 83%.

The dense urban area of the country covers 24450 km^2 and the suburban area including the dense urban area covers 318278 km^2 [1].

The topographic map data coverage of MOMRA is as shown in Table 16.4:

TABLE 16.4
Topographic Map Data Coverage of Urban and Semiurban Areas in Saudi Arabia

Scale	(1:1000)	(1:2500)	(1:10000)	(1:20000)
Coverage in km^2	24450	39838	338278	1743032
Type of area	urban core	semi urban	rural	open country

In addition the topographic database contains orthoimagery coverage and DTM grid data for the mapped areas (Table 16.5):

TABLE 16.5
Orthoimagery and DTM Coverage of Urban and Semiurban Areas

Ortho Imagery Coverage in km^2 GSD		DTM Coverage in km^2 Grid Size	
10 cm	39838	1m	39838
20 cm	17000	2m	17000
40 cm	1781500	5m	1781500

These vector maps are administered in an ArcGIS geodatabase.

Updating using new aerial imagery by photogrammetric line mapping is currently being done. However, due to budget restrictions, it is not possible to schedule re-flights faster than every 5 to 7 years.

From these flights digital orthophotos are generated from that imagery within one year. The digital orthophotos may be overlaid for the mapped areas from 5 to 7 years ago. These overlaps will be able to assess the need for new map updating contracts within a 2 year period. Depending on priorities an update of the mapped areas is possible in 5 to 10 years. For advanced countries, typical of what exists in Europe, the base data situation is listed for Great Britain and for Germany:

16.4 Large Scale Mapping in Europe

Great Britain with a territory of 219931 km^2 and a population of 60 million is covered by the Ordnance Survey Master Map at scales 1:1250 in urban areas and 1:2500 in rural areas. The Ordnance Survey with a staff of 1190 and an operating annual budget of 83 million British Pounds keeps the topographic data system based on an object structure, up to date with help from outsourcing contracts within 6 months by terrestrial surveys with total stations based on GNSS CORS networks.

Germany with a territory of 357386 km^2 and a population of 82 million is covered by cadastral geometric records equivalent to a scale 1:1000 (ALKIS) including property boundaries and buildings. The topographic data for objects other than buildings are resurveyed for the topographic database (ATKIS) equivalent to a scale 1:5000. The cadastral records including the parcel boundaries are maintained by 226 survey authorities with a total staff of about 10 000 professionals in the 16 States of the Federal Republic on a transaction basis. These updates in ALKIS for parcel boundaries and buildings are available in the system within 1 to 2 months. The updates in ATKIS for other topographic data are available every 1 to 2 years using photogrammetry or GNSS based terrestrial surveys.

Both Britain and Germany possess a costly professional infrastructure, which does not exist in most countries around the globe, with the exception of some countries (in Europe, East Asia, Canada and Australia), and which cannot be built up in less than a generation.

For countries not having such a traditional professional infrastructure involving the legal, educational and cultural prerequisites the challenge must be in using digital automation technology to overcome the handicaps of traditional approaches.

16.5 Future Alternatives by New Technology

The alternatives for improving the situation are shown in Table 16.6:

TABLE 16.6
The Alternatives for Improvement by New Technology

Source	Frequency	Acquisition	Detail	Feature Accuracy	Problem Areas
high resolution satellite imagery	1 year	easy	moderate	0.5 to 1m	limited to 1:5000
mobile mapping	as per request	easy	high	0.2 to 0.5m	hidden areas
object oriented 3D oblique imaging via models	1 year	easy	high	0.2 to 0.5m	automation technology for object generation

These improvements by application of new technology need some further remarks:

16.5.1 High Resolution Satellite Imagery

The biggest provider of high resolution satellite imagery is Digital Globe.

Since 1999 Ikonos provides imagery with a GSD 0.8m. In 2007 the resolution was improved on World View 1 to 0.5m GSD. In 2008 a GSD of 0.41m became available on GeoEye 1 and since 2017 World View 4 images with GSD 0.3m are available on World View 4.

Similar imagery is also available from ESA for Pleiades and Sentinel as well as for Kompsat from South Korea.

After the images have been ordered, delivered and rectified on form of an ortho-image, multiple stereo coverages permit to derive DSMs and true ortho-images, which can serve to identify changes of topography, especially of buildings in urban areas. Investigations gave shown, that stereo images of satellites with 0.5m GSD can derive changes for monitoring data bases for buildings at the scale 1:5000. [2].

16.5.2 Mobile Mapping

The competitors for updating roads are Google, Here and Tomtom. Each update traffic routes by mobile vans. Some companies, such as Cyclomedia, use mobile vans with optical cameras to update building facades at high accuracy. Yet others, such as Tesla and the car manufacturing industry prefer high accuracy surveys by service companies in preparation for automatic driving.

The application of mobile mapping for map updating has nevertheless the handicap to overcome hidden areas by obstructed views.

16.5.3 3D Oblique Imaging via 3D City Models With Automated Object Creation of Buildings

A new more automated possibility exists by creating urban city models from overlapping oblique imagery. This imagery source may be combined with other airborne or satellite imagery, including UAV imaging and existing vector data and lidar surveys. The dataset is subjected to a sequence of algorithms using point cloud processing, image processing, computer vision tools, adjustments and deep learning for sparsity driven DTM extraction for optimized partial automation to generate DSMs and DTMs for later change detection, to extract LOD2 building models according to CityGML standards.

The semiautomatic deep learning based object extraction helps to generate building roof prints and to extract building facades for automated texture mapping.

The software system developed by the Turkish- Saudi Arabian company Geotech (headed by Kamil Eren) has been introduced internationally by the name 'CitiGenius'. It was used in a pilot project for Istanbul, in projects of Saudi Arabia, in the City of Hannover in Germany and in U.S. Cities. The point cloud extraction succeeded to extract DSMs and DTMs, true orthoimages and 3D building models according to City GML standards including object generation for buildings and their administrative use. An object-oriented database consisting of some 5900 buildings was obtained within one week. This database could be linked with relational data for property registration, which were generated and updated on a transactional basis.

CitiGenius follows the tradition of CityGML used for the urban city model of the city of Berlin. It covers within the city area of Berlin of 890 km^2 together with 590 000 buildings.

Urban change detection by CitiGenius promises to become an efficient tool for the acquisition and the maintenance of urban data, even though a number of steps are still required to customize it for use in a particular city or country, with a view to create an updatable urban information system.

16.6 The Use of New Stereo Satellite High Resolution Satellites by China for the Mapping of High Mountain Areas

A special application of the use of simultaneous stereo satellite high resolution images has been made possible by the launch of the Chinese satellite Ziyuan-3 in 2012, which permits near simultaneous stereo imaging with 2.1m GSD images. The imagery is particularly useful to map the neighbouring countries of China with high mountain areas at the scale 1:50 000. The simultaneous stereo views are imaged at the same illumination conditions. Combined with the utilization of accurate Beidou GNSS data it is said to be possible to survey mountain peaks within the accuracy of the Beidou positioning capability, estimated at 10 to 15m. As a result, an international cooperative project has been initiated to map the 14 highest mountain peaks of the world with an elevation of over 8000m.

Again this project involving partners in China, Germany, Austria and the USA can compare the stereo satellite capability with earlier attempts to produce 1:50 000 maps of the Nanga Parbat [5] and Mount Everest [10, 3, 4] with the stereo capability of new high resolution stereo satellites, such as Ziyuan-3.

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17

Night-Light Remote Sensing: Data, Processing and Applications

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Night-light remote sensing is a tool which can be used when working towards achieving the UN Sustainable Development Goals. It has attracted a lot of attention and brought many new research directions as an emerging subject.

17.1 Introduction

Night-light remote sensing has attracted a lot of attention and brought many new research directions as an emerging subject. Satellites acquire night-light images by detecting visible light sources such as city lights, fishing boat lights and fire spots under cloudless conditions at night. Unlike daytime remote sensing, night-time remote sensing has unique capabilities for reflecting human activities, which can be used to study in the following fields: regional development [9, 3], conflict evaluation [17], light pollution [1], and fishery [5]. At present, night-light data is mainly obtained through sensors in the visible and near-infrared bands, mainly including Defense Meteorological Satellite Program/Operational Linescan System (DMSP/OLS) night-light, Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band DNB (DNB), Earth Remote Observation System-B (EROS-B), Luojia 1-01, and Jilin1-03B night-light images. Besides, photographs taken by astronauts from the International Space Station (ISS) can also reflect night light on the earth's surface, and other research used aircrafts to take photos to study night light for cities. Figures 17.1 to 17.4 show the night-light images from different sensors.

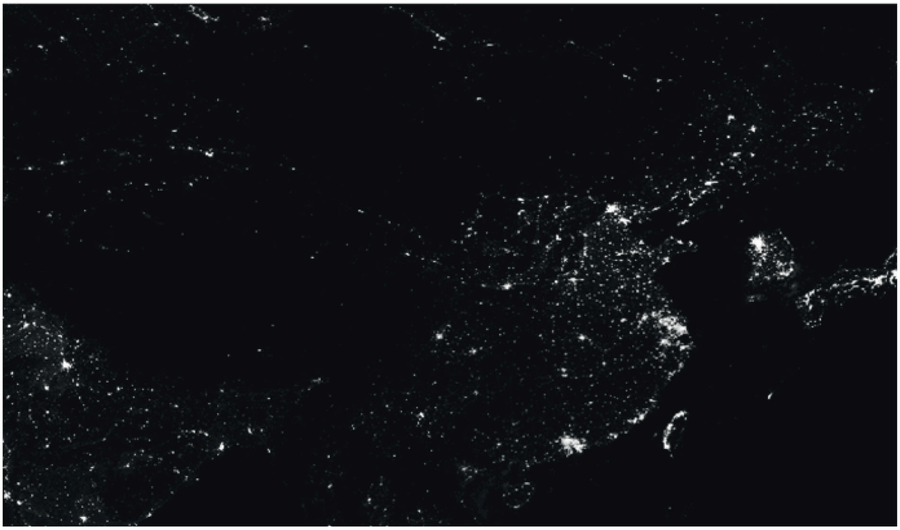

FIGURE 17.1
The DMSP/OLS night-time light image of East Asia in 2012.

17.2 DMSP/OLS Night-light Data

As the first night-time remote sensing satellite, DMSP has gradually been used to conduct research on night-time remote sensing. The DMSP/OLS was originally designed to detect night clouds, but scientists found that it also has the ability to detect night-time light on the earth's surface[14]. National Oceanic and Atmospheric Administration (NOAA) has released the DMSP/OLS night-light annual global composites (1992-2013) from six satellites (F10, F12, F14, F15, F16, F18) [1].The spatial resolution of the image is 0.0083 degree, and the images have only digital values and no radiation units. Because the DMSP/OLS image is pressed as 6 bits digital number (DN) values, saturation commonly exists in urban cores. Therefore, DMSP/OLS images are mostly used for macroscopic research.

[1] https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html