International Journal of E-Planning Research
Volume 12 • Issue 1

GIS for Sustainable Urban Transformation in Countries With Emerging Economies:

The Case of Piura in Peru

Trinidad Fernandez, Fraunhofer Institute for Industrial Engineering IAO, Germany*
Stella Schroeder, University of Piura, Peru

ABSTRACT

In South America, the urban population has been growing rapidly over the last century, with a share of more than 80% expected by 2020. This trend has created new challenges for city planning because municipalities must address issues caused by horizontal urban expansion and the informal occupation of peripheral areas. Frequently, the latter are not designed or equipped for the basic needs of new inhabitants. This research is based on the work of MGI, an initiative for smart, sustainable development in Piura, an intermediate city with one of the highest rates of urban sprawl in Peru. This initiative promotes climate change adaptation and mitigation based on urban analysis embodied in a sustainability profile and an action-oriented roadmap with concrete, feasible, and replicable measures and projects. One such measure is a spatial analysis, prioritising small illegal dumpsites for recovery and converting these areas into a public space using digital planning tools. This study analyses the development of the intervention to be implemented against the city´s opportunities and challenges.

KEYWORDS

Digital Planning, Emerging Economies, GIS, Sustainable Urban Planning Strategies

INTRODUCTION

Climate change, natural disasters, pandemics such as COVID-19 and social inequality present global challenges. Thus, people must consider how future cities and communities will look. Currently, the most urgent concerns for citizens include those related to living, environment, mobility, health and security. Cities represent economic progress, job opportunities, social action, innovation and technological development, providing more than 80% of the global GDP (Worldbank, 2020). In 2018, 55% of the world's population lived in cities, a percentage predicted to be 68% by 2050. Population growth in emerging economies has accelerated considerably, from 2 billion people in 2000 to a projected 5.5 billion by 2050, representing 95% of the world's urban population (UN, 2018b). With increasing wealth and economic opportunities, cities are expected to continue expanding, following a car-dependent expansion trend apparent in developed countries.

DOI: 10.4018/IJEPR.319733
*Corresponding Author

The New Urban Agenda launched by the UN in 2017 states that cities must strengthen sustainable resource governance to facilitate the ecosystem's preservation, recovery, remediation and resilience against all new and emerging challenges associated with climate change and urban sprawl (UN, 2017). However, to reinforce such efforts, researchers must examine the urban ecosystem's social, economic, environmental and technological dynamics and its performance (D'Amico et al., 2022).

Strategic urban planning can prepare cities for future events, such as climate change, that affect urban infrastructure and urban life. A proper urban planning strategy supports both economic growth and sustainability by making cities more attractive for potential investors and citizens, ensuring high living standards (Carter et al., 2015).

Low-cost, high-impact, smart digital solutions are progressively being deployed in the Global South to tackle urban development challenges (Nagendra et al., 2018). However, despite these solutions' potential, many smart city projects have primarily focused on providing smart applications rather than data-driven city planning and management (Bibri, 2020). Consequently, the rollout of smart cities has revealed other challenges, namely a lack of competences and training opportunities for city professionals, a lack of digital skills among citizens, insufficient resources and inadequate city planning (OECD, 2019). Thus, to build smarter cities in emerging economies, cities must strengthen local government databases and exploit digital infrastructure within existing urban systems (Worldbank, 2021).

To accomplish this work, city planners need technical knowledge and tools facilitating swift, precise action in both the design and evaluation of urban plans. Along with technological advances in computing, many tools have been introduced to help planners, ranging from geo-referenced information systems (GIS) to complex urban system simulation models (Derix, 2012). Digital tools optimise and support the analysis and action of public policies to reach the sectors that need these services most, while creating capacities for urban project modelling and visualisation within the local administration (Kaluarachchi, 2022). Urban data can support cities and municipalities in decision-making; improving internal and external processes; and, most importantly, responding more efficiently to citizens' needs (GIZ, 2022). Introducing a system such as GIS should bring economic benefits, particularly for local authorities, through savings, reducing administrative costs, increasing efficiency, or improving effectiveness in management and operation (Obermeyer et al., 2016).

In 2020, Peru's Secretary of Digital Government of the Presidency of the Council of Ministers published the National Digital Transformation Policy to accelerate digital transformation at the national level and outline a digital agenda for the country. This document builds on the exponential growth of digital competences that emerged in public management and society from 2020 onwards due to the pandemic. Peru's government wishes to establish an active ecosystem, allowing public and private efforts to collectively facilitate digital inclusion and closing digital gaps at the national level. To this end, the country launched the Geo Peru Digital Platform, comprising more than 500 official publicly accessible digital maps, highlighting both progress and gaps in areas such as infrastructure, poverty, basic needs, education and security. This platform should strengthen local action strategies and support data-driven decision-making for the benefit of citizens (PCM, 2020). Peru's government has committed to promoting a digital transformation toward social equity, promoting a National Smart Cities Strategy to create sustainable, reliable cities. These efforts include offering technological solutions to facilitate digital governance and connecting decision-making with available data, accomplishing the country's Sustainable Development Goals (SDGs) set by the UN.

This research is based on the work of the Morgenstadt Global Smart Cities Initiative (MGI) in Piura, an intermediate city with one of the highest rates of urban sprawl in Peru. The MGI is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) through the International Climate Initiative (IKI). This project supports innovative urban development in the cities Kochi (India), Saltillo (Mexico) and Piura (Peru), concentrating on climate change adaptation and mitigation measures and fostering environmental awareness in the cities while contributing to the SDGs. Additionally, MGI bases its work on the Fraunhofer Morgenstadt City Lab methodology. This approach has been applied in numerous cities worldwide, including Prague

(Czech Republic), Berlin and Chemnitz (Germany), Tiflis (Georgia), Lisbon (Portugal), Coimbatore (India) and Joinville (Brasil). Such efforts have further developed a comprehensive, cross-sectoral analysis of the status quo to create a detailed sustainability profile for each city (Fraunhofer IAO, n.d.). Beyond this analysis, the initiative builds on a portfolio of projects that address the challenges identified during the analysis, using the city's opportunities to drive sustainable development in different sectors in the medium and long run. These innovative project ideas are incorporated into a roadmap for each city seeking a more sustainable, resilient future, improving processes or services in urban infrastructures (Fernández et al., 2021). As a part of the MGI, one of these projects is chosen for on-site implementation based on its priorities and potential contribution to the city's economy, environment and community. Mensah (2019) explained that sustainable development involves efforts to balance between ensuring economic prosperity, safeguarding environment protection and promoting social wealth. Based on the project's three main aspects, the MGI implementation in Piura should address these areas of sustainable urban development.

In Piura, the execution of the pilot project focuses on using digital planning tools to address the challenges of urban planning and cover the basic needs of its inhabitants. According to the UN Habitat III Issue Paper (UN-Habitat, 2015), basic needs sectors and infrastructure include water supply, waste management, social wealth, transport and communication, energy, health and emergency facilities, schools, public security and urban management. In this context, this study examines how a GIS can be used for evidence-based decision-making. In the pilot project, GIS analysis is applied to identify small illegal dumpsites with great transformation potential selecting one to reconvert it within the MGI framework into a new public space in the city. Small illegal dump sites are abandoned plots of land smaller than 1 acre where waste has been and continues being deposited directly on the ground and subsoil, without taking the necessary precautions to protect the environment and human health (Vivanco Font, 2021). The pilot´s goals are to define the urban characteristics of these areas in the city, including their spatial potential., Through acupuncture treatment, specific uses will be given to the areas to improve public life. The urban acupuncture concept aims to improve liveability through small-scale interventions in strategic locations with a great impact. By developing a systematic network of quality spaces, this theory responds appropriately to producing small-scale, ecologically and socially catalytic development in the human-built environment (Casagrande, 2016). Thus, the study explains the process of criteria definition, the spatial analysis of these criteria and the final definition of the first space to be converted.

Ideally, this new space will become a reference for sustainable urban development projects in Piura by demonstrating the potential to reuse spaces in a city where green areas and public spaces are scarce, a process easily replicated in other parts of the city. The city has only 1.75 m^2 of green area per inhabitant, insufficient compared with the WHO recommendation of 10–15 m^2 per inhabitant. In Peru, only Lima, Arequipa and Tacna exceed 3 m^2 of green area per inhabitant (Fernández et al., 2021). The project elaborates guidelines for revitalising small illegal dumpsites in the city, integrating them into the urban fabric through consolidation as a long-term solution to these areas. Additionally, this intervention aims to create opportunities and demonstrate the potential for empty spaces to be recycled, repurposed, recovered, refurbished and integrated as a new public space in the city. Thus, project actions involving citizen participation, urban acupuncture and diagnosing spaces using a GIS can be articulated through academic and social objectives to improve Piura's physical conditions. Within the MGI framework, efforts are focused on the reconversion of one site at a time. However, these actions will prepare the city to initiate actions in other areas in the medium and long run.

THEORETICAL BACKGROUND

Urban Planning Challenges

In recent decades, the urban planner's role has evolved from designing an area addressing socio-economic development trends and characteristics to becoming an integrated, strategic exercise in which various disciplines join to help the urban ecosystem function properly (Cajot et al., 2017). One of the requirements for proper urban planning is to operate with a holistic overview of what is happening in the city, including global competition, the employment market, environmental conditions and financial and human capital. Moreover, urban planners must act as interfacing agents to engage the private sector, understand local needs, explore with community leaders what local governments with constrained resources can offer and build partnerships both vertically with the national central government and horizontally across municipalities (Freire 2006). Subsequently, strategic urban planning must consider impacts at different scales and long-term perspectives because cities must adjust for the effects of climate change, building on resilience-based thinking techniques, keeping urban planning and management as flexible as possible, preparing to adapt when new developments arise on the economic or social front (Asian Development Bank, 2014).

Traditionally, many urban plans have been created to anticipate the future of cities in a systematic and predictable way (Rickwood, 2011). Particularly in the urban sphere, planning is mainly conducted through Master and Development Plans. These tools are conceived as the main management mechanisms for addressing urban sprawl, relying on rates and quotas of specified zoning regulations. However, urban planning faces several challenges which, due to the time pressure of urban expansion, often produce numerous problems (Russo, 2014). One such issue is related to the lack of preparation of municipal staff, who often must subcontract the development of plans to consultancy firms with scarce resources. This situation causes several municipalities to have the same zoning formula. Beyond this, most of these plans concentrate services in various urban nodes, encouraging the use of transport and maximising the problem of urban sprawl. Additionally, the construction of low-cost housing on a large scale at the outer city boundaries exacerbates urban sprawl, complicating urban planning (Polidoro et al., 2012).

Smart Cities' Digitalising and Using GIS

Urban spatial organisation trends have been changing, along with the development and use of new technologies and tools, driven by the smart cities concept underpinning technological development for urban regeneration and efficiency. Linking smart technologies with digital spatial planning can facilitate responsible decision-making and promote local democracy and transparency. Regarding the development of smart city initiatives, Kitchin (2015) explained that there is a gap between smart city theory and urban processes marked by the growth (or in some cases shrinkage), governance and socio-economic development of cities.

However, the use of smart city tools includes challenges and risks as technology begins to become a fundamental element in spatial planning, communication and decision making (Douay & Lamker, 2022). Planning involves major negotiations and agreements between urban stakeholders. Such negotiations involve various urban stakeholders who are affected by policy and planning decisions regarding the urban environment. Within these negotiation processes, the city must make decisions regarding city development and implementing relevant instruments, such as property rights, zoning plans or environmental legislation (Bisschops & Beunen, 2019). In *The New Science of Cities* (2013), Batty emphasises the need for a systematic urban analysis approach to embrace the complex nature of current trends of modern urbanisation, explaining how its dynamics relate to multiple forms of social and ecological processes. Thus, integrated city planning facilitates the formulation of medium- and long-term objectives designed to fulfil a common vision and efficient resource allocation, serving as a key vehicle for decision-makers at the city level to achieve sustainable development (UN, 2018a).

One of the key aspects of urban planning and management is the importance of data, particularly spatial data. A significant portion of the information and data used by urban planners comprises geographic content involving topographic maps or associated with a geographic location using coordinate reference, a street address, or an administrative area. In this vein, GIS is a system that integrates, processes, saves, edits, organises, analyses, displays and shares spatial or geographic information (van Maarseveen et al., 2018). The advent of GIS has created an opportunity to develop new approaches to spatially referenced data, adding a new dimension to the management, analysis and presentation of information required in decision-making processes (Healey, 1988). Additionally, approximately 80% of data used by managers and decision makers are geographical (Worrall, 1991).

Since the origin of GIS in the 1960, such systems have increasingly gained recognition within urban planning and design practice (Maliene et al., 2011). The increasing use of GIS in urban planning and design will enable a high quality quantitative and qualitative data analysis, improving the evidence and knowledge base for decision-making. Furthermore, GIS tools are a breakthrough for efficient and sustainable urban strategic planning and a major step toward fulfilling ambitious, complex global policy objectives, such as SDG 11, which aims to 'make cities and human settlements inclusive, safe, resilient and sustainable' (UN, 2015). Moreover, Babinski (2020, p. 1) explained, 'A geographic information system (GIS) is a powerful tool to analyse social justice issues and help government agencies apply an equity lens to every aspect of their overall administration of public resources'. Beyond this, De Falco, Angelidou and Addie (2018) explained that smart cities help cities both implement local strategies and cope holistically with climate change, sustainability challenges and unequal spatial and spatial development phaenomena associated with urban sprawl.

When GIS implementation began worldwide, the most significant challenge was the limited availability of digital geographic information. In emerging economies, this situation remains prevalent. That is, the lack of available digital geographical data, outdated maps or missing mapping efforts at the national level are considerable disadvantages in regional and urban planning (Trainor, 2020). Furthermore, local authorities' lack of awareness and insufficient use of digital planning tools are key drivers for market- and politic-driven decisions, though not necessarily the most efficient or sustainable ones. The latter is especially true in Latin America and the Caribbean, where only a few major metropolitan areas are equipped with urban observatories that systematically collect citywide data, such as those in Santiago de Chile (Municiaplidad de Santiago, n.d.) or in Guadalajara, Mexico (Gobierno de Guadalajara, n.d.). The remaining cities lack adequate quantitative tools to discuss, analyse and support effective urban planning and efficient resource allocation. However, in the last 25 years, there have been several geoinformation initiatives in cities within emerging economies (Sarvajayakesavalu, 2017). Additionally, technological advances, from using satellite images to specialised applications to process and analyse data, are enabling these countries to progress beyond previous efforts of gathering, archiving and exploiting geospatial information (Shaaban, 2019; Trainor, 2020).

Urban Acupuncture

Using spatial information and potentially a multi-criteria decision-making process, governments can analyse urban development and define concrete projects to support city improvement on many scales. To safely and strategically convert urban spaces into pleasant places to live, the spaces must be subjected to therapy through 'urban acupuncture'.

This concept was proposed by various urban pioneers, combining urban design with the traditional Chinese medical theory of acupuncture, which involves inserting small needles in strategic positions along the skin all over a patient's body. Casagrande (2013), one of the proponents of this theory, described a city as a sensitive, multi-dimensional organism, a living environment. Thus, urban acupuncture is a cross-architectural manipulation of a city involving handling blockages and pushing relief energy around the city's 'body'. As in the medical treatment, this process can better address a society's needs and large-scale urban renewal interventions than other methods.

According to Morales (as cited in Al-Hinkawi & Al-Saadi, 2020), urban acupuncture can be considered a small intervention strategy because of its local, social approach that democratically and economically increases residents' comfort through compact urban interventions.

Additionally, Lerner (2014) said urban acupuncture is a type of punctual intervention in a city, characterised by being concrete, offering extensive regeneration potential and benefiting a large part of the city. As in medical acupuncture, urban acupuncture triggers positive reactions, helping to heal and improve the entire existing system. Lerner explained that a healthy city must follow a sustained process of long-term preventive care, which depends on a good relationship between urban planners, designers, and the city, just as medicine relies on an excellent doctor–patient relationship. Interventions in the urban space are necessary to increase the quality of public spaces and the interactivity of these areas for both the existing population and new groups of users. This concept implies that even minor urban strategies trigger processes that affect much larger areas than those directly involved in the interventions (Huertas Nadal, 2012). Therefore, reactivating certain spaces in a city is useful on a spatial level and functions as a catalyst for transforming spaces into platforms for citizen participation, creating an experimental opportunity for an urban platform for democratic action and human expression (Haydn & Temel, 2006).

A small urban intervention can change that area's value. For a location to succeed as an active urban point and for urban acupuncture to function as a sustainable urban planning tool, the intervention must be conducted appropriately, meeting certain requirements, such as accessibility and the ability to improve urban conditions. Additionally, digital planning tools affect urban acupuncture's success. As mentioned by Nicholas de Monchaux from the University of California (Kaye, 2011), software packages using GIS can locate several thousand sites of interest in a few minutes. In turn, GIS can support site selection by understanding how spatial and temporal impact assessment contribute decisively to the city's improvement (González et al., 2013).

METHODOLOGY

The pilot project focused on using geo-referenced data and urban analysis to identify a small illegal dump site with the potential to reconvert and consolidate it as a new space for public use. The methodology was based on work with spatial data, facilitating the mapping and analysis of information and data on small illegal dump sites to identify the dump site to be reconverted. The selection criteria were used to determine the intervention area and prioritise the areas with the most local impact. The methodology was divided into three parts. First, this work covered the contextualisation of the case study and analysed the illegal dump sites in the city. Second, the study involved gathering and preparing data in a GIS tool. Finally, the study defined criteria for the spatial analysis and the point of intervention.

Case Study

The city of Piura is in the northwest of Peru (Figure 1). As the capital of the region by the same name, Piura has experienced accelerated urban growth, including an increase in informal housing and unplanned territorial expansion. With an intercensal growth rate of 2.3%, Piura has the eighth highest population growth in Peru (Zucchetti & Freundt, 2018). The city has an estimated 70% of urbanised land occupied by informal or spontaneous constructions (Rivera Saavedra, 2016), marked by the lack of one or more essential services (e.g. water, sewerage, electricity, paving). This situation has become a significant challenge for numerous governments (Ministerio de Vivienda Construcción y Saneamiento, 2019) attempting to implement public policies and management actions, programs and projects designed to solve those urban challenges (Jones, 2017).

A lack of urban planning and climatic events affecting the city (such as the floods caused by the El Niño phenomenon) have contributed to a temperature increase. This situation has been exacerbated by growing urbanisation and de-ruralisation processes and migration from the Andes to the coastal areas due to the region's economic growth. Moreover, rapid urbanisation is related to reduced biodiversity and a loss of agricultural land. Similarly, this phenomenon produces more congested cities, increasing air pollution and energy consumption.

Piura does not have an approved Urban Development Plan, complicating urban planning strategies and their implementation. Due to problems such as a lack of access to basic infrastructure and services, the MGI pilot project focuses on the solid waste sector, essential in the district's municipalities. On the other hand, water, sanitation, and electricity depend on the service providers EPS, Grau and ENOSA,

Figure 1.
Location of Piura (source: Fernandez et al., 2021)

respectively. Furthermore, the MGI aims to foster climate adaptation and mitigation in cities, and municipal waste accounts for about 3–5% of GHG emissions (including CO_2e), though this number is estimated to rise from 1.12 to 2.38 billion tonnes of CO_2e by 2050. Additionally, improving waste management and reducing waste generation could reduce urban emissions by 15–20% (C40 Cities, 2023). Thus, these statistics influenced the sector selection so that the pilot project focused on the urban waste sector. One problem identified by the municipality in this sector was the existence of small illegal dump sites, with 14 registered by the municipality in 2021. These areas have become infectious hotspots, posing a health risk for the population (Defensoría del Pueblo Peru, 2017). Currently, the municipality invests $400,000 per year (equivalent to 100,000 USD) to control and clean these small illegal dump sites (only related to solid waste collection).

Furthermore, small illegal dump sites are not considered within the urban planning instruments in Piura since they are not regarded as green areas but as vacant lots. According to information provided by the municipality, these spaces are considered both sources of infection and unsafe areas or potential vandalism sites (Fernández et al., 2021).

Data Gathering and Data Preparation

As a first working step, all existing geo-referenced data is gathered and prepared for analysis. This data helps illustrate the status-quo of current situation of the small illegal dump sites in Piura and can be used to evaluate possible causes, consequences, impacts and influences of them and the need to create a new urban space. Next, the city considers geo-referenced data from the Metropolitan Development Plan (PDM), developed in 2020 and still in the process of approval. This dataset includes various layers analysing the status quo of the metropolitan area, including different types of geometry, such as points, areas, or lines. For this study, relevant data from the dataset were selected and are available at the block level. Next, the data were prepared in a shared map as layers in an Open-Source Geographic Information System Quantum GIS (QGIS). Beyond this, QGIS was developed as an alternative to traditionally expensive commercial GIS software and is employed by a wide variety of users, to view, edit and perform complex spatial analysis (Moyroud & Portet, 2018).

For this study, the data considered were categorised into seven groups: population, infrastructure, participation, basic services, accessibility, physical vulnerability and risk of contamination. These categories were based on the criteria used by the solid waste unit of the municipality as criteria for action prioritisation at small illegal dump sites and established by the Peruvian Ministry of Economy and Finance (MEF) . Additionally, elements that would enhance and secure the use of the new public space were included when developing the categories. The population aspects were linked to urban density to provide a space where many people could benefit. For infrastructure, green area density and proximity to recreational areas, the study included health facilities and other relevant economic infrastructures, such as shops and markets. Regarding citizen participation, the criteria included whether educational institutes were nearby so that the spatial use could be strengthened through environmental awareness, recycling activities and programs involving neighbouring schools. Beyond this, the criteria included information on water and energy supply coverage to connect the urban space to the existing network.

Concerning accessibility, urban centrality was considered the proximity to a central business district and level of density (Pereira et al., 2013) and the road systems, ensuring citizens can easily access the site. The road system included both paved and unpaved roads, illustrating the consolidation state of the urban area and if clear demarcation of streets and pavement existed. Another criterion for site selection involved the physical vulnerability showing risks related to rainfall and fluvial flood and the existence of blind basins. The last criterion was the site's vulnerability to possible recontamination, including environmental exposure and the coverage of waste collection.

For the analysis of the sites, the data geometries analysed included 1) points denoting the locations of specific places in the city, such as educational institutions or urban infrastructures; 2) lines and city networks, such as the road system and its level of consolidation; and 3) areas per block, such as population density, vulnerability, and coverage of basic and municipal services. Over 16 geo-referenced layers referring to the seven categories explained previously were considered in the analysis. A detailed list of the layers is displayed in Table 1.

Table 1.
List of QGIS layers used for reconversion of small illegal dump site in Piura

Data cluster	Specific measure	Specific GIS information layer	Type of geometry
Intervention site	Small illegal dump site	Location of small illegal dump sites	Points
Participation	Educational infrastructure	Primary school, higher education, technical professional	Points
Population	Density	Number of inhabitants per km^2	Area (City block)
Accessibility	Centrality	Principal, secondary, tertiary, urban con-urbanisation	Area
	Road system	Local roads (not asphalted); Collector or arterial roads (usually asphalted); Intersection of two or more (asphalted)	Lines
Pollution risk	Environmental vulnerability	Level of vulnerability based on Physic Vulnerability Map of Peru (MINAM)	Area (City block)
	Waste collection coverage	Waste collection service coverage	Area (City block)
Physic vulnerability	Rain flood risk	Level of rain flood risk based on Risk Map of Peru (MINAM)	Area (City block)
	River flood risk	Level of river flood risk based on Risk Map of Peru (MINAM)	Area (City block)
	Blind basins	Location of blind basins	Area
Infrastructure	Green area	Location of public recreation areas	Area
	Recreation facilities	Pools, sports facilities, theatres, stadium	Points
	Health facilities	Clinic, hospitals	Points
	Relevant economic infrastructure	Markets, shops	Points
Basic services coverage	Water	Water service coverage	Area (City block)
	Electricity	Electricity service coverage	Area (City block)

Data Analysis

On the first step of the data analysis, the team conducted an early revision of the potential sites, finding that some of the sites did not have the potential for public space due to reasons such as spatial ownership and geometry. For ownership, the areas located in a private site were excluded because the municipality lacked the faculty to work on them. For geometry, spaces located in median strips or that were extensions of the road were excluded because most of them were small linear areas parallel to the road or fence or just small waste accumulation points, so they could not be used as public spaces. Figure 2 shows all illegal dumpsites in the city of Piura. Based on this preliminary revision, eight sites were shortlisted and further analysed in detail in a second stage, excluding 15 of the 23 illegal dumpsites.

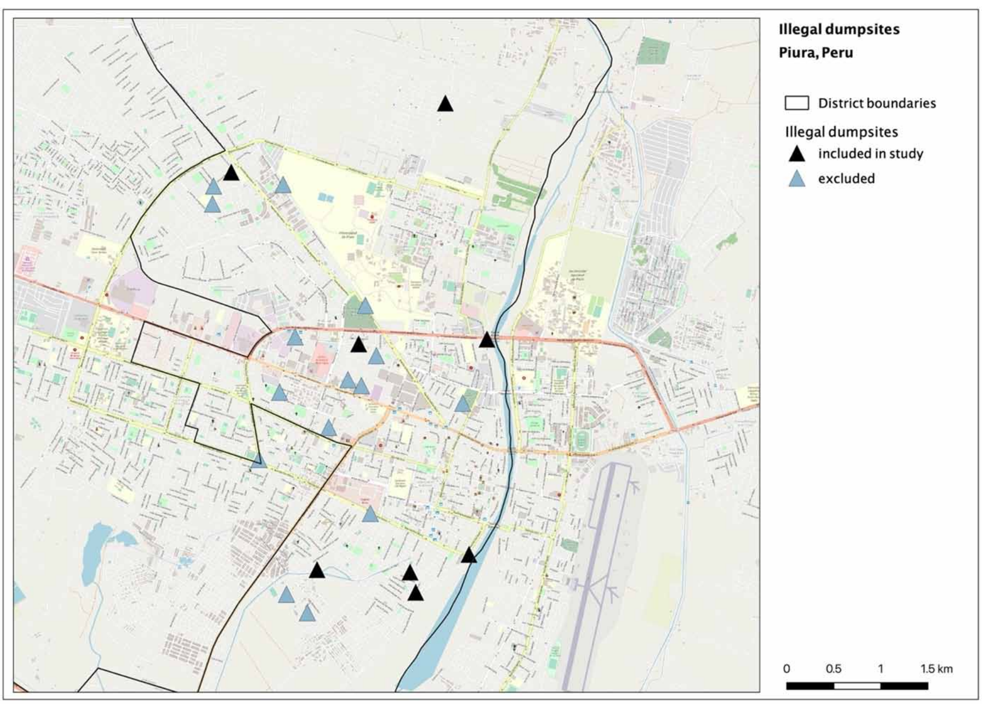
Subsequently, each data criterion was evaluated by assigning a value based on defining the most suitable site for creating a new public space. Values were discussed within the MGI research group and with city officials. According to each criterion, the possible values were set between 1 to 3 for questions about an incident range of compliance within a specific area of low, medium, and high score, respectively. For questions regarding whether an area fulfilled the specific criterion, a score from 1 to 3 points was assigned.

For the participation category, the education infrastructure layer displays the location of the different educational facilities, including elementary and secondary schools, universities, and professional training institutions. Therefore, the score assigned is linked to the number of facilities that could participate in environmental awareness programs, ensuring the proper functioning of the recycling facilities in the intervention and engaging them in the design of the new space.

In the population category, a layer related to the population density was considered and measured using a 500 metres radius. A value was assigned according to density level, meaning that more inhabitants living near each site raised the score because these people would be the potential site users.

Regarding accessibility, two layers were included in this category. The first layer of urban centralities was based on existing urban hubs, defined by the concentration of activities (e.g.,

Figure 2.
23 small illegal dumpsites in the city of Piura (source: own elaboration and Open Street Map, 2022)



businesses, services). A score of three points was given when the small illegal site lay within an urban centre close to services or commerce allowing people not living in that area to use the new public space. Additionally, in this category, the current road system layer shows the roads in the following categories: local, neighbourhood, departmental and national. Points were attributed according to the relevance of the streets, the first being those with the fewest points, as these places had less traffic, had streets of lower quality (e.g., generally not asphalted) or both.

In the pollution risk category, a layer showing environmental vulnerability areas is divided into low, medium, and high. Within the same category, the solid waste collection network layer shows the different pick-up routes to reveal which areas not covered by this service. One point was given if the area was located close to the routes because this could guarantee service and prevent litter accumulation in the new public space.

Another category includes physical vulnerability and contains three layers. The first two layers concern rain and fluvial flood risk, and the risk areas are divided into low, medium, and high, while the sites located in more vulnerable areas obtain a lower score. Lastly, a layer of blind basins existed within the city. If the critical point lay within an area indicated with blind basins, it was assigned a value of 3, as it would contribute to cleaning up and decontaminating the soil covered in waste.

Another relevant category is infrastructure, consisting of four layers. The first one is the green area layer, including all areas destined for that use. Next is the recreation layer, containing information regarding theatres, sports facilities and community centres. Another layer is related to health facilities. Lastly, if commercial premises, restaurants, or the like were present in an area, they could attract people and investors, so the more economical infrastructure existed around the area, the higher the score was.

Basic services coverage is a category examining how connected the intervention site is, considering water and electricity provision. Both layers illustrate these services networks, indicating whether the intervention site has coverage. For analysis, a score was assigned per the connection to these public utilities, with three points if the site was connected and one if it were not. Table 2 lists the categories with the evaluation rank applied accordingly.

Finally, the scores obtained were added, and the site with the highest score was determined to be the most appropriate for transformation, the site with the second highest score could be transformed next, and so on. Figure 3 shows the spatial analysis using the example of infrastructure.

RESULTS

Based on the methodology, the eight adequate small illegal dump sites with potential were evaluated and prioritised according to their scores. Table 3 displays the scores given according to the information obtained per layer for each evaluated site.

Of the critical points analysed, three stood out, each obtaining more than 30 points out of 45. Thus, Site 2 was be prioritised because it has a high potential for conversion into public space since it fits each category well. This area is in the human settlement 18 de Mayo (Figure 4), south of the centre of Piura.

This site is characterised by its criteria analysis with QGIS as follows:

- According to population statistics for 2020, those living within a radius of 500 metres with more than 10,000 inhabitants are expected to be the future users of the space. Analyses concerning the development of the neighbourhood revealed that there was already a high building density in 2005. By 2022, only a few plots are still undeveloped. With increasing urban density littering is a complex social behavioural problem that can only be remedied by social measures. This problem is related to the area's lack of environmental education and access to recycling, as well as a lack of identity or a sense of belonging to the space among the community. Thus, citizens are crucial in this project as dumping of garbage on the street causes the formation and recurrence of small illegal dump sites in Piura. One of the project's objectives is to foster a recycling culture

Table 2.
Evaluation range per specific measure used to evaluate intervention sites

Proposed categories	Specific measure	Radio	Evaluation range		
			1 point	2 points	3 points
Participation	Educational infrastructure	250 m	0–2 units	3–4 units	>5 units
Population	Density	500 m	0–1,500 hab.	1,500–4,000 hab.	>4,000 hab.
Accessibility	Centrality	-	Within the area	-	-
	Road system	-	Local roads	Collector or arterial roads	Intersection of two or more
Pollution risk	Environmental vulnerability	-	Within low-risk zone	Within risk zone	Within high-risk zone
	Waste collection coverage	-	Within waste collection route	-	-
Physic vulnerability	Rain flood risk	-	High rain flood risk	Moderate rain flood risk	Low rain flood risk
	River flood risk	-	High river flood risk	Moderate river flood risk	Low river flood risk
	Blind basins	-	Blind basins are not present	-	-
Infrastructure	Green area	250m	0–5,000 m2	5,000–10,000 m2	>10,000m2
	Recreation facilities	250m	0 units	1–2 units	>3 units
	Health facilities	250m	0 units	1–2 units	>3 units
	Relevant economic infrastructure	500m	0 units	1–2 units	>3 units
Basic services coverage	Water	-	Not connected to the water network	-	Connected to the water network
	Electricity	-	Connected to the energy network	-	Connected to the energy network

Figure 3.
Spatial analysis of infrastructure for eight small illegal dumpsites in the city of Piura (source: own elaboration, 2022)

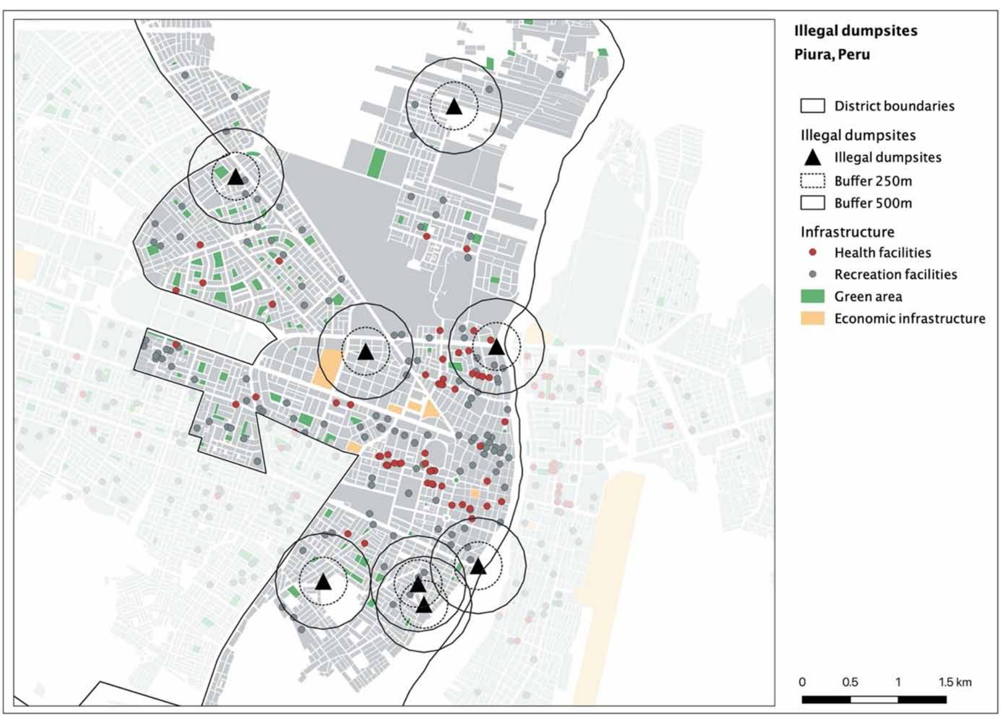
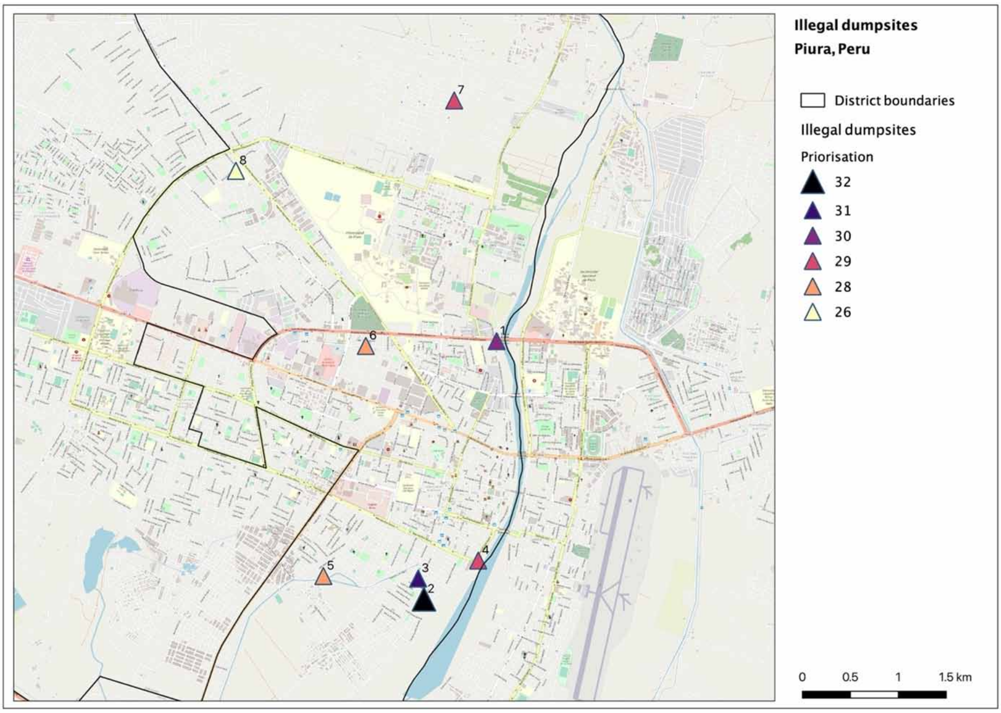


Table 3.
Evaluation of the potential sites in Piura, including their score per category

Small illegal dump site	Partic.	Pop.	Accessibility		Pollution risk		Physic vulnerability			Infrastructure				Basic services coverage		Scoring
	Educational infrastructure	Density	Centrality	Road system	Environmental vulnerability	Waste collection coverage	Rain flood risk	River flood risk	Blind basins	Green area	Recreation facilities	Health facilities	Relevant economic infrastructure	Water	Electricity	
1	2	1	2	3	1	3	1	1	3	2	1	2	2	3	3	30
2	**3**	**3**	**2**	**1**	**1**	**3**	**2**	**1**	**3**	**3**	**2**	**1**	**1**	**3**	**3**	**32**
3	2	3	2	1	1	3	2	1	3	3	2	1	1	3	3	31
4	1	1	2	3	1	3	2	1	3	3	2	1	2	1	3	29
5	1	3	2	1	1	3	2	2	1	2	2	1	1	3	3	28
6	1	1	2	1	1	1	2	2	3	2	3	1	2	3	3	28
7	1	1	1	2	1	3	3	2	3	3	1	1	1	3	3	29
8	1	2	1	1	1	3	2	3	3	1	2	1	1	1	3	26

Figure 4.
Prioritisation of illegal dump sites for conversion into public space (source: own elaboration and OpenStreetMap, 2022)



in Piura, promoting a sense of identity, awareness and care for public space and the environment and encouraging people to dispose of their waste responsibly.

- There are seven schools nearby that could support the site's usability and cleanliness through environmental awareness and recycling activities at the school level. This project includes designing an awareness-raising plan for neighbours and students from nearby schools on recycling and environmental care, exploring various aspects of household waste management and promoting waste reduction through recycling and potential energy recovery. Additionally, this intervention includes recycling containers for people to separate their garbage.
- Within a radius of 250m, there is no green area or public space available, so this reconversion will improve the citizens' quality of life. At the same time, this intervention involves actions dedicated to educating and awakening the citizens' interest in using the new public space, making it their own. Beyond this, the project encourages the participation of communities as users, potentially supporting the development of local solutions in the future.
- The site has no relevant economic infrastructure in the vicinity, so the site's development could attract economic activities such as small shops or restaurants, increasing the space's use. The wider area already contains numerous bodegas, a bookshop, and other restaurants.
- Some aspects of the site, such as rain and river flood risks and the connection to basic services, are not optimal. However, it is expected that those aspects can be overcome through expanding the current infrastructure network, including the lack of electricity coverage, and deploying new technologies or building techniques that include, for example, water-sensitive aspects of urban and landscape design.

The intervention site is part of the drainage system including a channel that normally does not carry water. Only during heavy rainfall does the water accumulate in the canal. The current photos

(Figure 5) display significant waste in the dry canal. This problem has existed for several years and attempts by the municipality to combat the problem and permanently remove the rubbish have failed. As a result of the litter problem a limited number of quality public places are available in the study area.

DISCUSSION

The paper details the selection of an intervention site using GIS as a tool in decision-making. Using different criteria, the researchers evaluated the site most suitable to become a public space, potentially impacting Piura's urban future and sustainable city planning. From this perspective, the pilot project in Piura will have a variety of outcomes with both direct and indirect impacts, bringing several environmental, social, and economic benefits to the city. The urban analysis component using the GIS tool evaluated four outcomes: data-based area selection, examples of smart city implementation, improved urban management and a new GIS database system for the municipality.

All these components contribute to the social, ecological, and economic development of the city. In the case of the municipality, the most tangible benefit from them is economic, as the intervention seek to improve its management and governance.

First, the study analysed the urban space to select the place to implement the project. The concept of urban acupuncture has potential as a model of sustainable urban transformation. Applied correctly, this method can address a variety of urban challenges. Certain researchers, such as Karvonen (2015), who studied interventions to increase urban greening; Apostolou (2015), who investigated how to improve social and environmental conditions by upgrading the functions of public spaces; or Al-Hinkawi and Al-Saadi (2020), who studied new strategies to revitalise city centres, have attempted to identify new pathways toward sustainable urban development using urban acupuncture. In this vein, the focus physical interventions can produce new knowledge on spatial dimension of sustainable planning. However, as mentioned by Hemingway and De Castro Mazarro (2022), more precise characterisation of urban acupuncture and its application is needed because it is more than a simple, small-scale intervention that can be replicated.

Second, this project could be seen as a smart city initiative whereby new urban designs and developments are driven by geo-referenced data with a strong focus on governance and digital infrastructures. Additionally, smart cities often seem to prioritise the use of technology to increase well-being and improve efficiency (Joss et al., 2019). However, on the ground, this construct often lacks holistic approaches to sustainability, especially regarding social equity or efficient (ecological and economical) resource management (Mora et al., 2017), which was not the case in this intervention. Thus, this project is expected to help improve urban territorial planning in the city and the quality of

Figure 5.
Detail of impact area (500m radius) and photo of selected site (source: own elaboration)

life of its inhabitants, regarding sustainability, resilience, and adaptation to climate change. Beyond this, the project supports decision-making based on up-to-date systematised information and correlations between different areas. Furthermore, the project was conducted to increase GIS knowledge and digital abilities to generate new interdisciplinary projects and apply smart, sustainable, resilient and climate change-adapted city concepts.

Third, from the demonstration of the project's interdisciplinary and inter-managerial character, savings on personnel resources by avoiding duplication of efforts are expected. Furthermore, improving the management of municipal economic and environmental resources is foreseen. The use of GIS tools and smart technology goes beyond seeking efficiency through digitalising planning processes, aiming to transform urban planning into a service-oriented process according to the requirements and demands of citizens (Rönkkö & Herneoja, 2021). A cost and benefit analysis was performed by one group member conducting a smart city financing analysis within the MGI initiative for the three cities. For Piura, this document highlighted that the intervention generates significant short- and long-term benefits. However, this information is included in this article because it goes beyond the scope of the current study.

Fourth, another outcome was the updated cartographic base in the municipality's centralised digital GIS data system. This system increases efficiency and enables work and data transfer between different departments while saving time and money in obtaining data to create projects. Additionally, the system facilitates the geo-referencing of all urban projects in the execution process, providing a systematic order and avoiding overlapping of civil works of any kind. Finally, maps are available to the public and citizens, raising awareness and empowering citizens to address urban challenges, planning, and developing new city projects. Providing a current overview of the municipality or region through maps with geo-referenced information increases public awareness of the deficiencies of the built environment, so it is important to provide access to and promote citizen participation in urban interventions (Mobasheri et al., 2018). Beyond this, the use of GIS and digital tools in urban planning contributes to the transparency of processes regarding public space decisions, because the maps will be made available on the municipality's website at a later stage, allowing citizens to easily access information about urban development projects in the city.

Furthermore, the pandemic positively affected the digitalisation of local administration, forcing officials to meet virtually and to work and provide certain services online. Working with online documents facilitated the exchange of information and enabled multi-stakeholder participation that would otherwise be difficult to access, enabling the elaboration of comprehensive and integrated development strategies. In this sense, the pandemic has hastened digital transformation, creating important opportunities for strategic urban planning and development. Beyond this, digitalisation has raised citizens' expectations regarding the quality of public services and the integrity, transparency and responsiveness of public institutions (OECD, 2021). This digitalisation momentum could be used in a modernisation and digitalisation programme within municipalities, including the deployment of GIS tools and the resources and capacities appointed to secure its use.

However, the methodology is limited to summarising the score obtained, independent of the importance of each of the categories. Thus, one could assign weights to the categories, both to highlight those categories that are of greater importance for the selection of the area to intervene and to homogenise them, as not all have the same maximum score. Weighting coefficients will be a challenge as many factors and reference are needed to ensure objectivity when setting them. Therefore, this process must be based on the work of recognised authors on the specific topic and international monitoring, impacting and benchmarking systems to ensure transparency.

According to the guideline of the initiative, a pilot project in this field should directly impact the field of climate adaptation. This is why a pilot measure should be directly linked to an adaptation action, such as providing urban climate services, such as vulnerability assessment, heat or heavy rainfall risk mapping, or identifying potential areas for more vegetation (e.g., green buildings). Therefore, such a project should include both the digital aspect with the use of the GIS tool and the climate change adaptation aspect, which is encompassed in the analysis and identification of a small illegal dump site with high potential to become a public space. The latter will increase the coverage of green space in the city.

However, data availability can be considered a constraint because it limits the possibilities of using the methodology in other sectors or other types of interventions in the city. In the same way, the maps and the GIS tool can suffer from hacking, misuse or information theft and actions must be taken to protect data. Another and common restriction is that once the project is implemented, it does not have sufficient human or economic resources to continue updating the information collected (using the GIS tool) or for the recovery of public space (reconversion of small illegal dump sites).

CONCLUSION

This article demonstrated how the MGI project developed evaluation criteria based on GIS information layers and applied them to select the most suitable site for the reconversion of a small illegal dump site into a public space in the city of Piura. A total of 15 geo-referenced information layers were considered, listed in seven relevant categories to benefit the city's inhabitants and ensure proper use and maintenance of the public space. The various GIS layers used in this study to select the site of the intervention are used to complement each other, especially because data on socio-economic indicators are usually not available at a local level. Each potential location was analysed according to its performance in the established categories, where the highest scoring site was selected and considered the most suitable one for the new urban space to be developed. This work demonstrates how the GIS tool can be used to make data-driven urban development decisions.

At the same time, this intervention aligns with the urban acupuncture concept through a GIS-based space diagnosis because it prioritises the spaces to receive intervention. Thus, the city will intervene at the site with the highest potential and the greatest need to be reconverted. After the first site has been converted, the city will continue with the site with the second highest score and so on. This project will include capacity-building activities to develop competencies and skills involving digital and strategic urban planning, increasing the potential to solve problems and prepare for upcoming climate change challenges.

In the long run, GIS will be integrated into university or school subjects to cultivate a spatial understanding of data-driven development information and fundamentals defining project design and implementation organisation models. Digital tools support planning a more equal and justice city, considering its citizen's needs, ensuring that the city provides basic services and education, reaching the most vulnerable population and preparing citizens for climate change. The project emphasises that smart city urban planning must incorporate the social aspect to be sustainable and consider resource efficiency as an economic aspect and environmental care as an environmental aspect.

This project demonstrates the potential and relevance of integrated digital urban analysis through using GIS tools to support municipal management decision-making in medium-sized cities in Latin America. It is desirable that the city of Piura will continue the legacy of the MGI initiative by applying digital data analysis for decision-making processes for new planning interventions in other infrastructure sectors, such as transport and logistics. Moreover, this pilot project is expected to be replicated in other parts of the city because it could be used in other districts within the metropolitan area or in other cities experiencing similar challenges related to small illegal dump sites. Future studies could integrate new data collected by the government or NGOs on income levels and poverty rates of different neighbourhoods. Therefore, more economically disadvantaged urban areas could be supported with future interventions in Piura and other cities.

ACKNOWLEDGMENT

This work was possible thanks to the collaboration of colleagues from the University of Piura (Oscar Guillen, Joel Villegas, Daniela Salazar, Gisella Hernandez and Birte Rüdebusch) and Fraunhofer IAO (Sebastian Müller and Julio Millan).

REFERENCES

C40 Cities. (2023). *Waste Management*. https://www.c40.org/what-we-do/scaling-up-climate-action/waste-management/

Al-Hinkawi, W. S., & Al-Saadi, S. M. (2020). Urban Acupuncture, a Strategy for Development: Case Study of Al-Rusafa, Baghdad. *IOP Conference Series. Materials Science and Engineering*, *881*(1), 012002. Advance online publication. doi:10.1088/1757-899X/881/1/012002

Apostolou, M. A. (2015). Urban eco-acupuncture methods: Case study in the city of Athens. *2nd International Conference on Changing Cities II: Spatial, Design, Landscape & Socio-Economic Dimensions*, 932–940. https://shs.hal.science/halshs-01798506

Asian Development Bank. (2014). *Urban Climate change Resilience: A Synopsis*. https://www.adb.org/sites/default/files/publication/149164/urban-climate-change-resilience-synopsis.pdf

Babinski, G. (2020). GIS&T for Equity and Social Justice. *EthicalGEO*. https://ethicalgeo.org/wp-content/uploads/2021/03/GIS-for-ESJ-Best-Practices-AGS-EthicalGEO20200721CC.pdf

Batty, M. (2013). The New Science of Cities. In *The New Science of Cities*. The MIT Press., doi:10.7551/mitpress/9399.001.0001

Bibri, S. E. (2020). The eco-city and its core environmental dimension of sustainability: Green energy technologies and their integration with data-driven smart solutions. *Energy Informatics*, *3*(1), 4. Advance online publication. doi:10.1186/s42162-020-00107-7

Bisschops, S., & Beunen, R. (2019). A new role for citizens' initiatives: The difficulties in co-creating institutional change in urban planning. *Journal of Environmental Planning and Management*, *62*(1), 72–87. doi:10.1080/09640568.2018.1436532

Cajot, S., Schüler, N., Peter, M., Koch, A., & Maréchal, F. (2017). Interactive optimization for the planning of urban systems. *Energy Procedia*, *122*, 445–450. doi:10.1016/j.egypro.2017.07.383

Carter, J. G., Cavan, G., Connelly, A., Guy, S., Handley, J., & Kazmierczak, A. (2015). Climate change and the city: Building capacity for urban adaptation. *Progress in Planning*, *95*, 1–66. doi:10.1016/j.progress.2013.08.001

Casagrande, M. (2013). *Biourban Acupuncture. Treasure Hill of Taipei to Artena*. International Society of Biourbanism.

Casagrande, M. (2016). From Urban Acupuncture to the Third Generation City. *Journal of Biourbanism, 4*(1&2), 29–42.

D'Amico, G., Arbolino, R., Shi, L., Yigitcanlar, T., & Ioppolo, G. (2022). Digitalisation driven urban metabolism circularity: A review and analysis of circular city initiatives. *Land Use Policy, 112*(October), 105819. 10.1016/j.landusepol.2021.105819

de Falco, S., Angelidou, M., & Addie, J. P. D. (2018). From the "smart city" to the "smart metropolis"? Building resilience in the urban periphery. *European Urban and Regional Studies*, *26*(2), 205–223. doi:10.1177/0969776418783813

Defensoría del Pueblo Peru. (2017, April 3). *Defensoría del Pueblo advierte acumulación de residuos sólidos producto de lluvias y desborde de río*. https://www.defensoria.gob.pe/defensoria-del-pueblo-advierte-acumulacion-de-residuos-solidos-producto-de-lluvias-y-desborde-de-rio/

Derix, C. (2012). Digital masterplanning: Computing urban design. *Proceedings of the Institution of Civil Engineers. Urban Design and Planning*, *165*(4), 203–217. doi:10.1680/udap.9.00041

Douay, N., & Lamker, C. (2022). New technologies, new tools, new organisation of the city : towards a new digital planning? In E. Gustedt, G.-K. Ulrike, C. Demazière, & D. Paris (Eds.), *Cities and Metropolises in France and Germany* (pp. 162–179). Forschungsberichte der ARL 20. https://nbn-resolving.org/urn:nbn:de:0156-11198

Fernández, T., Schroeder, S., Stöffler, S., Eufracio Lucio, D., Ordóñez, J. A., Mok, S., Atarama, E., Guillen, O., Hernández, G., Villegas, J., Garcia, J. C., Báez, M., Pudlik, M., Umana, G., Martínez, E., Rodríguez, H., Torres, R., & Zavala, D. (2021). *Summary Report of the full technical City Profile Piura within the Morgenstadt Global Initiative*. Academic Press.

Fraunhofer, I. A. O. (n.d.). *City Labs*. Retrieved 4 December 2022, from https://www.morgenstadt.de/en/projekte/city_labs.html

GIZ. (2022). *Data Strategies for a Common Good-oriented Urban Development International*. GIZ.

Gobierno de Guadalajara. (n.d.). *Visor Urbano*. Retrieved 23 January 2023, from https://visorurbano.com/mapa/

González, A., Donnelly, A., Jones, M., Chrysoulakis, N., & Lopes, M. (2013). A decision-support system for sustainable urban metabolism in Europe. *Environmental Impact Assessment Review*, *38*, 109–119. doi:10.1016/j.eiar.2012.06.007

Haydn, F., & Temel, R. (2006). *Temporary Urban Spaces: Concepts for the Use of City Spaces*. Birkhauser.

Healey, R. (1988). Geographic Information Systems: An overview. In R. Vaughan & R. Kirby (Eds.), *Geographical Information Systems and Remote Sensing for Local Resource Planning*. Remote Sensing Products and Publication Ltd.

Hemingway, J. M., & De Castro Mazarro, A. (2022). Pinning down Urban Acupuncture: From a Planning Practice to a Sustainable Urban Transformation Model? *Planning Theory & Practice*, *23*(2), 305–309. doi:10.1080/14649357.2022.2037383

Huertas Nadal, D. (2012). Arquitecturas ociasionales: Heterotopias. In D. Huertas Nadal, D. Esguevillas Cuesta, M. A. Fernández Nieto, M. García Carbonero, G. M. Cantos, J. L. Parada Rodríguez, A. Gemma Peribáñez, & E. Zamarro Flores (Eds.), *i making HETEROTOPIAS* (pp. 11–16). Universidad Francisco de Victoria.

Jones, P. (2017). Formalizing the informal: Understanding the position of informal settlements and slums in sustainable urbanization policies and strategies in Bandung, Indonesia. *Sustainability (Switzerland)*, *9*(8), 1436. Advance online publication. doi:10.3390/su9081436

Joss, S., Sengers, F., Schraven, D., Caprotti, F., & Dayot, Y. (2019). The Smart City as Global Discourse: Storylines and Critical Junctures across 27 Cities. *Journal of Urban Technology*, *26*(1), 3–34. doi:10.1080/10630732.2018.1558387

Kaluarachchi, Y. (2022). Implementing Data-Driven Smart City Applications for Future Cities. *Smart Cities*, *5*(2), 455–474. doi:10.3390/smartcities5020025

Karvonen, A. (2015). Pathways of Urban Nature: Diversity in the Greening of the Twenty-First Century City. In J. Hou, B. Spencer, T. Way, & K. Yocom (Eds.), Now Urbanism: The Future City is Here (pp. 274–285). Routledge.

Kaye, L. (2011, July 21). Could cities' problems be solved by urban acupuncture? *The Guardian*. https://www.theguardian.com/sustainable-business/urban-acupuncture-community-localised-renewal-projects

Kitchin, R. (2015). Making sense of smart cities: Addressing present shortcomings. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 131–136. doi:10.1093/cjres/rsu027

Lerner, J. (2014). *Urban Acupuncture*. Island Press. doi:10.5822/978-1-61091-584-7

Maliene, V., Grigonis, V., Palevičius, V., & Griffiths, S. (2011). Geographic information system: Old principles with new capabilities. *Urban Design International*, *16*(1), 1–6. doi:10.1057/udi.2010.25

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, *5*(1), 1653531. Advance online publication. doi:10.1080/23311886.2019.1653531

Ministerio de Vivienda Construcción y Saneamiento. (2019). *Plan de desarrollo Metropolitano Piura - Catacaos - Castilla - 26 de Octubre 2020 - 2040*. Author.

Mobasheri, A., Zipf, A., & Francis, L. (2018). OpenStreetMap data quality enrichment through awareness raising and collective action tools—Experiences from a European project. *Geo-Spatial Information Science*, *21*(3), 234–246. doi:10.1080/10095020.2018.1493817

Mora, L., Bolici, R., & Deakin, M. (2017). The First Two Decades of Smart-City Research: A Bibliometric Analysis. *Journal of Urban Technology*, *24*(1), 3–27. doi:10.1080/10630732.2017.1285123

Moyroud, N., & Portet, F. (2018). Introduction to QGIS. In N. Baghdadi, C. Mallet, & M. Zribi (Eds.), *QGIS and Generic Tools* (pp. 1–17). John Wiley & Sons, Inc. doi:10.1002/9781119457091.ch1

Municiaplidad de Santiago. (n.d.). *Observatorio Santiago – Ilustre Municipalidad de Santiago*. Retrieved 23 January 2023, from https://www.observatoriosantiago.cl/

Nagendra, H., Bai, X., Brondizio, E. S., & Lwasa, S. (2018). The urban south and the predicament of global sustainability. *Nature Sustainability*, *1*(7), 341–349. doi:10.1038/s41893-018-0101-5

Obermeyer, N. J., Ramasubramanian, L., & Warnecke, L. (2016). GIS Education in U. S. Public Administration Programs: Preparing the Next Generation of Public Servants. *Journal of Public Affairs Education*, *22*(2), 249–266. doi:10.1080/15236803.2016.12002244

OECD. (2019). *Enhancing the contribution of digitalisation to the smart cities of the future*. OECD Publishing.

OECD. (2021). Rethinking public institutions in the digital era. In OECD (Ed.), *Latin American Economic Outlook 2020*. OECD. doi:10.1787/e6e864fb-

PCM. (2020, March 3). *PCM inicia ejecución de Agenda Digital al Bicentenario - Presidencia del Consejo de Ministros*. https://www.gob.pe/institucion/pcm/noticias/85311-pcm-inicia-ejecucion-de-agenda-digital-al-bicentenario

Pereira, R. H. M., Nadalin, V., Monasterio, L., & Albuquerque, P. H. M. (2013). Urban Centrality: A Simple Index. *Geographical Analysis*, *45*(1), 77–89. doi:10.1111/gean.12002

Polidoro, M., de Lollo, J. A., & Barros, M. V. F. (2012). Urban Sprawl and the Challenges for Urban Planning. *Journal of Environmental Protection*, *03*(09), 1010–1019. doi:10.4236/jep.2012.39117

Rickwood, P. (2011). Modelling in Urban and Regional Planning: Past, present, and yet to come. *MODSIM 2011 - 19th International Congress on Modelling and Simulation - Sustaining Our Future: Understanding and Living with Uncertainty,* 104–114. doi:10.36334/modsim.2011.Keynote.rickwood

Rivera Saavedra, J. (2016, April 19). El 70% de las construcciones de Piura son informales y no soportarían sismo. *El Tiempo*. https://eltiempo.pe/el-70-de-las-construcciones-de-piura-son-informales-y-no-soportarian-sismo/

Rönkkö, E., & Herneoja, A. (2021). Working across boundaries in urban land use and services planning—Building public sector capabilities for digitalisation. *Smart Cities*, *4*(2), 767–782. doi:10.3390/smartcities4020039

Russo, L. (2014). The Effectiveness of Planning Regulation to Curb Urban Sprawl. *TeMA, Journal of Land Use. Mobility and Environment*, *7*(1), 101–114.

Sarvajayakesavalu, S. (2017). *Ecosystem Health and Sustainability Addressing challenges of developing countries in implementing five priorities for sustainable development goals Addressing challenges of developing countries in implementing five priorities for sustainable development goals*. 10.1890/EHS15-0028.1

Shaaban, K. (2019). Assessing sidewalk and corridorwalkability in developing countries. *Sustainability (Switzerland)*, *11*(14), 3865. Advance online publication. doi:10.3390/su11143865

Trainor, T. (2020). *Countries Need an Integrated Geospatial Information Framework*. https://www.esri.com/about/newsroom/arcnews/countries-need-an-integrated-geospatial-information-framework/

UN. (2015). *Goal 11: Make cities inclusive, safe, resilient and sustainable*. https://www.un.org/sustainabledevelopment/cities/

UN. (2017). *New Urban Agenda, adopted by the United Nations. General Assembly at its sixty-eighth plenary meeting of the seventy-first session on 23 December 2016*. https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_71_256.pdf

UN. (2018a). *Working together: Integration, institutions and the sustainable development goals*. https://digitallibrary.un.org/record/3814708?ln=es

UN. (2018b, May 16). *68% of the world population projected to live in urban areas by 2050*. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

UN-Habitat. (2015). Urban Infrastructure and Basic Services, Including Energy. *Habitat III Issue Papers, 2015*(May). https://www.habitat3.org/the-new-urban-agenda/issue-papers

van Maarseveen, M., Martinez, J., & Flacke, J. (2018). GIS in Sustainable Urban Planning and Management. GIS in Sustainable Urban Planning and Management. doi:10.1201/9781315146638

Vivanco Font, E. (2021). *Gestión de residuos sólidos urbanos en microbasurales*. https://www.oecd-ilibrary.org/development/africa-s-urbanisation-dynamics-2020_b6bccb81-en

Worldbank. (2020). *Desarrollo urbano: Panorama general*. https://www.bancomundial.org/es/topic/urbandevelopment/overview

Worldbank. (2021, January 18). *Harnessing Smart Technology for Sustainable Development in Developing Countries*. https://www.worldbank.org/en/news/feature/2021/01/18/harnessing-smart-technology-for-sustainable-development-in-developing-countries-tdlc

Worrall, L. (1991). patial Analysis and Spatial Policy using Geographic Information Systems. Belhaven Press.

Zucchetti, A., & Freundt, D. (2018). Ciudades Del Perú. In *Primer reporte Nacional de Indicadores Urbanos 2018.* https://ciudadesdelperu.pe/ciudades/

Trinidad Fernandez is an architect and urban planner from the University of Chile and specialized in Integrated Urbanism and Sustainable Design (M.Sc.) at the University of Stuttgart, Germany. She works as researcher at Fraunhofer Institute for Industrial Engineering (IAO). She was the project coordinator of Triangulum, one of the first Smart Cities and Communities Lighthouse projects funded by the European Commission under Horizon2020 Research and Innovation Framework. Besides, she co-coordinates the MGI initiative that supports model cities in India, Mexico and Peru in the development and implementation of sustainable transformation processes and climate change mitigation through the integration of smart city concepts and solutions. Furthermore, she leads the City Lab in Piura (Peru) and supports the urban planning sectoral approaches in the two Latinamerican cities.

Stella Schroeder is urban geographer from the University of Bremen (Germany) and Master of Science in Urban Development and Urban Design from the HafenCity University Hamburg (HCU, Germany). Consultant for public and private sector projects. Currently PhD candidate in Urban Planning at the University of the Bio-Bio in Concepción (Chile) about urban informality. Academic teacher and Director of the Instituto de Estudios Urbanos y Territoriales at the University of Piura (Peru). She is the local leader of the MGI Project in Piura and investigator in sustainable urban development, innovation and small-scale transformation.