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Placemaking in the Design of Knowledge-Based Urban Developments

Extending CIM Capabilities in the Planning Phase

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In this paper, we review the concept of science parks and their culmination as knowledge-based urban developments (KBUDS). Next, we describe the upgrading of second-generation science parks in urban fringes to knowledge territories based on the quintuple helix innovation model. This research aims to study planning and design tools that can be used to foster serendipity, vitality and high-quality living environments in otherwise sterile landscapes from a human point of view, as is generally the case in second-generation science parks. In this context, we discuss how city information modelling (CIM) capabilities can be extended with three placemaking aspects that are important to this type of development: social negotiation, urban vitality and legibility. Finally, we present the International Hub for Sustainable Development (HIDS), which is currently being planned in Campinas, Brazil, and some examples of the use of CIM in this project. We conclude that CIM can be used to increase public engagement in participatory processes by facilitating communication between stakeholders. In addition, it improves data collection in these processes and supports decision-making.

Introduction

In 1969, Peter Drucker stated "that knowledge has become the central 'factor of production' in an advanced, developed economy," using the term "knowledge economy" to describe this shift. For knowledge to be an economic driver it cannot be static, like the information contained in a book.[1] It must be dynamic and applied, generating technological innovation. "Knowledge, like electricity or money, is a form of energy that exists only when doing work."[2]

In 2000, the European Council, during a meeting in Lisbon, agreed to adopt "a new strategic goal for the Union in order to strengthen employment, economic reform and social cohesion as part of a knowledge-based economy," which confirmed an important change in the European economy that had already been underway since the last decades of the 20th century.[3]

Gerd Leonhard's famous allegory of the knowledge revolution illustrates this disruptive change, picturing the future as a non-male, non-white character, full of colours, shedding flowers and hearts, as opposed to a dull, white-collared white man with polluting chimneys coming out of his head. The image's title reads "Industrial & Mechanical x Digital & Exponential."[4] The image effectively conveys the shift observed by Yigitcanlar and Velibeyoglu "from industrial and mass production to knowledge-intensive goods and service production" economies, also referred to as knowledge-based economies.[5]

In cities, the knowledge economy concept was brought to fruition in science and technology parks. Also referred to as research parks or technopoles, they are used as a public policy to foster economic growth and urban development, and have been around since the 1950s.[6] According to Annerstedt, a science park is the result of an association between specialized professionals to foster a culture of innovation and knowledge exchange between its associates as well as increasing their competitiveness in a global market.[7] They usually result from the association between universities and research and development institutions. The most successful examples provide high-quality spaces and are equipped with "state-of-the-art telecommunications gear" in order to become more attractive to workers and users. These associations are usually set in a space in which the associates are close to each other. While this spatial element should not limit knowledge exchange, the availability of specialized infrastructure, services and equipment can be increased by it.[8]

Science and technology parks have, however, evolved and changed with the knowledge revolution. The author classifies these parks into three different generations: a) the first were developed on university campuses aiming at directly applying research results to generate economic opportunities for the host institutions; b) the second are those created and managed by the private sector and are usually located on urban fringes;

1 Peter F. Drucker "The Knowledge Economy," in *The Age of Discontinuity: Guidelines to Our Changing Society,* ed. Peter F Drucker (Oxford: Butterworth-Heinemann, 1969), 248, https://doi.org/https://doi.org/10.1016/B978-0-434-90395-5.50016-X.
2 Ibid., 252.
3 European Council, "Lisbon European Council 23 and 24 March 2000 Presidency Conclusions." Lisbon, 2000.
4 Gerd Leonhard, "The Future of Knowledge," *Inside Learning Technologies & Skills* (December 2013): 7-8.
5 Tan Yigitcanlar and Koray Velibeyoglu,"Knowledge-Based Urban Development: The Local Economic Development Path of Brisbane, Australia," *Local Economy 23,* no. 3 (August 2008): 196, https://doi.org/10.1080/02690940802197358.
6 Laura Lecluyse, Mirjam Knockaert and André Spithoven, "The Contribution of Science Parks: A Literature Review and Future Research Agenda," *The Journal of Technology Transfer* 44, no. 2 (April 19, 2019): 559–595, https://doi.org/10.1007/s10961-018-09712-x.
7 Jan Annerstedt, "Science Parks and High-Tech Clustering," in *International Handbook on Industrial Policy*, ed. Patrizio Bianchi and Sandrine Labory (Cheltenham: Edward Elgar Publishing, 2006), 279–97.
8 Ibid.

and c) the third generation, aimed at fostering feedback-based innovation between research and business sectors, involving universities, private sectors and local government, are typically located in urban centres.[9]

As the different models of innovation evolved, some older science parks had to adapt to include new functions such as housing, cultural centres and a living environment. This adaptation is especially needed in the case of second-generation parks, that do not adhere to contemporary urbanism concepts such as compacity, diversity, walkability, etc. This is a recurring problem that must be tackled. Furthermore, since these areas are typically located in urban fringes, their densification is challenging from the environmental point of view. This is a complex transformation that requires interdisciplinary collaboration and specific planning and design tools.

This paper is part of a larger ongoing research on the concept of science parks in the wake of the knowledge revolution. We propose a fourth generation of science and technology areas which results from the upgrading of second-generation suburban science parks. It applies the quintuple helix innovation model as a paradigm to develop sustainable knowledge hubs as living laboratories, with living areas and high-quality daily life. However, achieving the required serendipity and vitality through urban planning alone is no trivial matter. Our aim is to discuss how to create welcoming environments with their catalytic role in the development of a sustainable life in this evermore common challenge.

We begin by reviewing concepts such as the knowledge economy and the helix models of innovation. Next, we review three generations of science parks and propose a fourth. We illustrate the concept of urban fringe KBUDs with an example in Paris, France. In addition, we discuss how this concept is being applied in the development of the International Hub for Sustainable Development (HIDS) in Campinas, Brazil. Finally, we present preliminary studies that will be further implemented through city information modelling (CIM) to contribute to placemaking: public participation, urban vitality metrics and landmark placement for legibility.

From the Knowledge Economy to the Quintuple Helix Innovation Model

The knowledge economy is defined by INVESTOPEDIA as "a system of consumption and production that is based on intellectual capital. It refers to the ability to capitalize on scientific discoveries and applied research." It corresponds to "a large share of the activity in most highly developed economies" and is based on "intangible assets such as the value of its workers' knowledge or intellectual property."[10]

A knowledge-based economy is the result of a broader contemporary phenomenon, the knowledge society, which is defined by UNESCO's International Bureau of Education as a society that is able to "identify, produce, process, transform, disseminate and use information

9 Ibid.

10 Adam Hayes, Toby Walters and Amanda Jackson, "What Is the Knowledge Economy? Definition, Criteria, and Example," Investopedia, 2021, https://www.investopedia.com/terms/k/knowledge-economy.asp.

to build and apply knowledge for human development."[11] This type of evolved society is also associated with plurality, inclusion, solidarity, and participation.[12]

In the 1990s, Etzkowitz and Leydesdorff realized how the roles of universities, companies and government were changing in different countries in the emerging knowledge society:

> In some countries with a laissez faire capitalist tradition such as the U.S. government is playing a greater role in innovation in the civilian economy (Etzkowitz 1994a) while in former socialist societies government has withdrawn from its previous position of total control of science and technology policy; adopting a stance more in accord with laissez faire principles. Multi-national institutions such as the European Union, the World Bank and the U.N. are also moving to embrace concepts of knowledge based economic development that bring the knowledge, productive and regulatory spheres of society into new configurations. In this conference, we wish to study the role of the sciences in this changing environment with a focus on the university's position in the newly emerging knowledge infrastructure.[13]

They called this academic–industry–government relation a "triple helix." It was largely illustrated by graphics that show three overlapping circles, with the different levels of interactions between the actors represented by the larger or smaller intersection areas. Later on, Carayannis and Campbell extended the model to a quadruple helix to include communication with civil society, via all forms of media, in order to obtain public support for innovation policies:

> The 'Quadruple Helix' emphasises the importance of also integrating the perspective of the media-based and culture-based public. What results is an emerging fractal knowledge and innovation ecosystem, well-configured for the knowledge economy and society.[14]

In a later paper, the same authors extended this model to a quintuple helix to include the perspective of the 'natural environments of society':

> Within the framework of the Quintuple Helix innovation model, the natural environments of society and the economy also should be seen as drivers for knowledge production and innovation, therefore defining opportunities for the knowledge economy. (…) The Quintuple Helix supports here the formation of a win-win situation between ecology, knowledge and innovation, creating synergies between economy, society, and democracy.

11 IBE-UNESCO, "Knowledge Society," *Glossary of Curriculum-Related Terminology* (International Bureau of Education UNESCO, 2013), 35.

12 Jérôme Bindé, *Towards Knowledge Societies* (Paris: UNESCO, 2005).

13 Henry Etzkowitz and Loet Leydesdorff, "The Triple Helix – University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development," *EASST Review* 14, no. 1 (1995): 14.

14 Elias G. Carayannis and David F J Campbell,"'Mode 3' and 'Quadruple Helix': Toward a 21st Century Fractal Innovation Ecosystem," *International Journal of Technology Management* 46, no. 3–4 (2009): 201.

> Global warming represents an area of ecological concern, to which the Quintuple Helix innovation model can be applied with greater potential.[15]

In other words, in the quintuple helix model, the environment is not only seen as an ecological concern, but also as a business opportunity and a potential driver of development. Taking into consideration a wider scale, the shift towards a knowledge-based or 'post-industrial' economy should be seen in conjunction with the emergence of 'newly industrialized countries' and the new global divisions of labour.[16] We must, therefore, ask ourselves if a community that profits from intellectual activities and delegates extraction of natural resources and industrial production to other parts of the country or of the world (especially those with cheap labour) can in fact be considered sustainable. For this reason, we stress the importance of a knowledge-based society and economy in contributing to the sustainable development of not only their own community, but of the world in general.

Four Generations of Science and Technology Parks and Districts

As previously stated, Annerstedt describes three generations of science parks. He associates them with three styles of innovation: science push (in which innovations created at the university are offered to the industry), market pull (in which the industry asks for specific developments by universities) and interactive or feedback-based.[17] In the following subsection, we analyse, compare, and exemplify these three generations and propose a fourth. The latter is illustrated with an existing example in the second subsection.

Comparative Analyses of the Four Generations of Science and Technology Parks and Districts

According to Annerstedt, the first generation of science parks aimed to create economic opportunities for universities by applying their research results. For that reason, these parks were typically created by the universities themselves, usually next to or inside their campuses.[18] One of the first examples was Stanford Research Park, created in the early 1950s.

The second generation of parks aimed to "create technologies suitable for economic utilization and encourage university students to become entrepreneurs."[19] These were usually created by business organizations and managed by the private sector and were not necessarily located close to universities, but also not in city centres. An example of second-generation parks is Sophia Antipolis Technopole, created in the 1970s in southern France.

Third-generation parks were based on the interactive or feedback-based innovation model, were typically located in "bustling city centres" and were usually created by universities, businesses and the local

15 Carayannis, Thorsten D Barth, and Campbell, "The Quintuple Helix Innovation Model: Global Warming as a Challenge and Driver for Innovation," *Journal of Innovation and Entrepreneurship* 1, no. 1 (2012): 1 https://doi.org/10.1186/2192-5372-1-2.
16 Martin Sokol, "The 'Knowledge Economy': A Critical View," in *Regional Economies as Knowledge Laboratories,* ed. Philip Cooke and Piccaluga Andrea (Cheltenham: Edward Elgar Publishing, 2005), 272, https://doi.org/10.4337/9781845423391.00019
17 Annerstedt, "Science Parks."
18 Ibid.
19 János Gyurkovics and Miklós Lukovics, "Generations of Science Parks in the Light of Responsible Innovation," in *Responsible Innovation,* ed. János Gyurkovics and Miklós Lukovics (Szeged: University of Szeged, Faculty of Economics and Business Administration, 2014), 199.

government together. Feedback-based innovation results from the "cooperation between economic, academic and government players and the place of operation of organizations participating in global and regional innovation activities," and its aim is to "improve the welfare of the local community, through supporting efficient cooperation between the above mentioned three types of players," "contribute to the development of their regions' entrepreneurial culture and establish two-way communication between the creators and users of knowledge and technologies."[20] The third generation can thus be associated with the quadruple helix model, which includes society as a key factor. A good example of this type of environment is 22@, which is not exactly a science park, but rather a large urban renovation project located in Barcelona's Poblenou district, with the same aims. Barcelona was one of the first European cities to implement a plan to deliberately move from the industry-based economy to the knowledge-based. Since the early 2000s, this formerly industrial area (22@) was converted into a "platform for the knowledge economy and society" using heavy investments in infrastructure, mobility, housing (including social housing), cultural centres, green areas, universities and buildings for science, technology and business activities.[21] The idea was to attract a new class of talented and highly skilled workers to a neighbourhood that was full of empty, outdated, abandoned industrial plants.

We can extend Annerstedt's and Gyurkovics and Lukovics' proposal with a fourth generation of science and technology areas that corresponds to Carayannis, Barth & Campbell's quintuple helix innovation model, including the environment both as an ideological concern and a driver of development.[22] As in the third generation, this one is not exactly a park, but rather an urban district, and it has been called a knowledge-based urban development (KBUD). A KBUD is defined by the IGI-Global dictionary as:

> The new development paradigm of the knowledge economy era that aims to bring economic prosperity, environmental sustainability, a just socio-spatial order and good governance to cities and produces a city purposefully designed to encourage the production and circulation of knowledge in an environmentally conserved, economically secure, socially just and well-governed human setting, a knowledge city.[23]

The term was coined by Yigitcanlar, who has also published several papers in which he proposes different frameworks for these areas.[24] As in the quintuple helix model, KBUD framework diagrams include the natural environment and sustainability as key factors, by means of word combinations such as "environmental sustainability," "sustainable development," "sustainable urban development," "environmental and

20 Ibid., 198–99.

21 Josep M. Piqué, "Knowledge Cities on Smart Cities: 22@Barcelona Case," *Encontro Nacional Da Indústria Da Construção* (Rio de Janeiro: CBIC, 2019).

22 Annerstedt, "Science Parks"; Gyurkovics and Lukovics, "Generations of Science Parks"; Carayannis, Barth, and Campbell, "Quintuple Helix Innovation Model."

23 Yigitcanlar, "Knowledge-Based Urban Development," in *Encyclopedia of Information Science and Technology*, ed. D.B.A. Mehdi Khosrow-Pour, 3rd ed. (Hersey, PA: IGI Global, 2015), 7475–7485.

24 Yigitcanlar et al., "Understanding 'Smart Cities': Intertwining Development Drivers with Desired Outcomes in a Multidimensional Framework," *Cities* 81 (November 1, 2018): 145–60, https://doi.org/10.1016/j.cities.2018.04.003; Nimish Biloria, "From Smart to Empathic Cities," *Frontiers of Architectural Research* 10, no. 1 (March 2021): 3–16, https://doi.org/10.1016/j.foar.2020.10.001; D L Chang et al., "Knowledge-Based, Smart and Sustainable Cities: A Provocation for a Conceptual Framework," *Journal of Open Innovation: Technology, Market, and Complexity* 4, no. 1 (December 13, 2018): 5, https://doi.org/10.1186/s40852-018-0087-2; S Teriman, T Yigitcanlar, and S Mayere, "Sustainable Urban Development: An Integrated Framework for Urban Planning and Development," in *Rethinking Sustainable Development: Urban Management, Engineering, and Design.*, ed. T Yigitcanlar (United States: IGI Global, 2010), 1–14, https://doi.org/10.4018/978-1-61692-022-7.ch001; T Yigitcanlar, K Velibeyoglu, and S Baum, *Knowledge-Based Urban Development: Planning and Applications in the Information Era*, ed. T Yigitcanlar, K Velibeyoglu, and S Baum, Premier Reference Source (Information Science Reference, 2008).

Fig. 1 The four generations of science and technology parks with their respective innovation models with examples, December 2021 (by authors).

developmental challenges," "sustainability capacity," "sustainable urban infrastructure," "enviro-urban", etc. These are not just related to the "quality of life and place" which is needed for attracting and retaining talents, but also as a source of innovative—and profitable—businesses that are needed more than ever in a world of climate change and ecological disaster.

Fourth-generation science and technology urban developments, proposed herein, can be defined as *KBUD*s located on the outskirts of cities, where there is an opportunity to apply the latest technologies to obtain a proper coexistence between human activities and the natural environment. A good example of this type of area is the *Établissement Publique d'Aménagement Paris-Saclay* (*EPA* Paris-Saclay), also known as *Campus Urbain*. A summary of the four generations of science parks and districts, their respective innovation models, and examples of each can be seen in Figure 1.

EPA Paris-Saclay: A Fourth-Generation Science Park

Launched in 2010 and located south of Paris, EPA Paris-Saclay aims to "Develop a centre of scientific and technological excellence in a sustainable and pleasant area to live in," as stated on its home page.[25] It comprises three different zones, two of which have already been labelled *éco-quartiers,* a definition created by the French government in 2012.[26]

The EPA Paris-Saclay operation consisted in creating a new mixed zone to connect some of these anchors, following sustainable urbanism principles such as compactness, mixed-use, social diversity, sustainable mobility, energy efficiency and soil permeability.[27] This took place in a suburban territory (the plateau of Saclay), which had been sparsely

25 Ministère logement habitat durable, "Les Écoquartiers," https://umap.openstreetmap.fr/en/map/les-ecoquartiers_116165#14/48.7058/2.1428; "EPA Paris-Saclay," 2022, https://epa-paris-saclay.fr/.
26 Ministère de l'Egalité des territoires et du Logement, "Dossier de Presse: Lancement du Label National ÉcoQuartier" (Brétigny-sur-Orge, 2012).
27 EPA Paris-Saclay, "Paris-Saclay, une opération urbaine pour un cluster scientifique et industriel," Plateau de Saclay, 2015, https://epa-paris-saclay.fr/; EPA Paris-Saclay, "Le Projet urbain de moulon," Plateau de Saclay, 2014, https://epa-paris-saclay.fr/

occupied by academic institutions and private and public research centres (but no residential or commercial areas) for more than 50 years.
The project comprises state-of-the-art environmental solutions, such as neighbourhood heating and cooling, which includes the reuse of waste heating from the IDRIS supercomputer Jean Zay and nature-based solutions for stormwater mitigation and managed aquifer recharge.[28] Moreover, as a result of a partnership with the association Terre et Cité, a natural and agricultural zone was established by law in 2010 on the plateau, guaranteeing the preservation of forests and traditional cultivation areas, and thus of water sources and the local biodiversity.[29] This partnership also resulted in the Manger Local programme, which fosters the consumption and valorization of local produce, circular economy and environmental education and consciousness, through an online platform that connects consumers to producers.[30]

The EPA Paris-Saclay is full of examples of the use of online digital technologies for gathering and distributing georeferenced information for inhabitants and visitors. This is important for creating a sense of community in this artificially developed urban environment, something that has also been called digital placemaking.[31] The *Carte Ouverte* platform, shown in Figure 2, is a good example of a tool they developed for sharing from cultural events to visitable heritage and locally grown produce.[32]

However, the Paris-Saclay project is not free of criticism, especially regarding social negotiation.[33] Moreover, once the first inhabitants moved in, the EPA Paris-Saclay had to create a special programme for urban activation, aiming to “encourage neighbourhood life, collective initiatives, and the mixing of audiences” and supporting “the appropriation of a new neighbourhood and to create the conditions conducive to the development of an urban life”, as stated on its “Activation” webpage.[34]

We hypothesize that city information modelling (CIM) could be used as a placemaking tool during the design phase of this type of urban development in order to help create a more active territory.

28 Yoann Verger et al., “A N, P, C, and Water Flows Metabolism Study in a Peri-Urban Territory in France: The Case-Study of the Saclay Plateau,” *Resources, Conservation and Recycling* 137 (October 2018): 200–213, https://doi.org/10.1016/j.resconrec.2018.06.007; Rafael Medeiros, “Reuse by the Paris-Saclay District Heating and Cooling Network of the Waste Heat from the IDRIS Supercomputer Jean Zay” (Paris: PRACE Session on Infrastructures, 2021).
29 Terre & Cité, “Protéger Les Terres Agricoles,” Plateau de Saclay, 2017, https://terreetcite.org/proteger-les-terres-agricoles/; EPA Paris-Saclay, “Zone de Protection Naturelle, Agricole et Forestière Du Plateau de Saclay,” Plateau de Saclay, 2018, https://epa-paris-saclay.fr/
30 Camille Tedesco et al., “Potential for Recoupling Production and Consumption in Peri-Urban Territories: The Case-Study of the Saclay Plateau near Paris, France,” *Food Policy* 69 (May 2017): 35–45, https://doi.org/10.1016/j.foodpol.2017.03.006
31 Jordan Frith and Jacob Richter, “Building Participatory Counternarratives: Pedagogical Interventions through Digital Placemaking,” *Convergence: The International Journal of Research into New Media Technologies* 27, no. 3 (June 12, 2021): 696–710, https://doi.org/10.1177/1354856521991956
32 Dorian Spaak, Léa Marzloff and Sabine Chardonnet-Darmaillacq, “Carte-ouverte du Plateau de Saclay,” http://www.saclay.carte-ouverte.org/#
33 Hervé Brédif, “Quel projet d’intérêt national pour le Plateau de Saclay ?” *L’Espace Géographique* vol. 38, no. 3 (September 11, 2009): 251–66, https://doi.org/10.3917/eg.383.0251
34 Paris-Saclay Version Beta, “L’activation du campus urbain, sur les communes de Gif-Sur-Yvette, Orsay et Palaiseau,” https://beta.epaps.fr/activation/

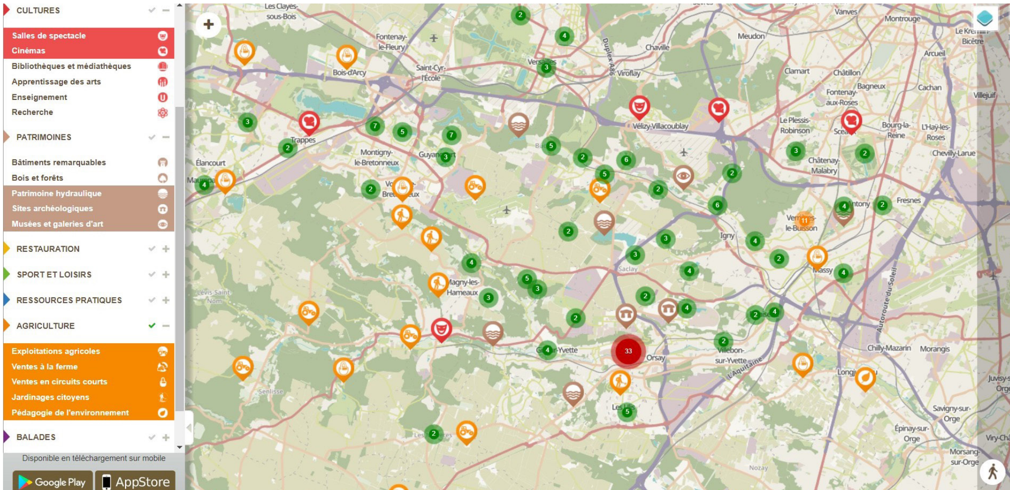


Fig. 2 The online interface of the *Carte Ouverte* platform, December 2022, (Dorian Spaak, Léa Marzloff and Sabine Chardonnet-Darmaillacq).

From Campinas High-Technology Pole to the International Hub for Sustainable Development (HIDS)

The city of Campinas, in a metropolitan area of 2 million inhabitants, 100 km north of São Paulo, plans to convert a former 2nd-generation science and technology park from the 1980s into a 4th generation knowledge-based urban development. The former Campinas High Technology Pole, approximately 11 km2, was originally created in the 1980s as an urban expansion designated as a strategic hub for the development of the city, envisioned as the future Brazilian Silicon Valley. However, over the past decades most of its land was left underdeveloped due to real estate speculation, lack of public investment in infrastructure, and urban regulation restrictions, which made the construction of residential and commercial areas unfeasible. In 2014, the University of Campinas (UNICAMP), a public research university, acquired a large parcel of land (still with agricultural use) adjacent to its suburban campus, located in the Campinas High Technology Pole. The original idea was simply to use the new land to expand the University's first-generation Science Park that was already located on its campus. However, soon it became clear that by owning this land the university could induce the transformation of the entire pole into a fourth-generation KBUD. Thus, the idea of the International Hub for Sustainable Development (HIDS) emerged.

In addition to UNICAMP's campus, the pole includes two other higher education institutions, public and private research and development centres, two hospitals and the largest and most modern synchrotron particle accelerator in the southern hemisphere. More recently, an international school was also installed in the area. The morphological characteristics of the site include flooding plains, springs and streams, natural forest patches that need to be connected through ecological corridors, according to the present law, and historic heritage sites. The need to reconcile the preservation of this natural and architectural patrimony with the potential for the urban and economic development of the region makes the new planning of the area a challenge.

Approximately half of the HIDS' area, 272 hectares, remains unoccupied, out of which 101.3 hectares are in the parcel acquired by UNICAMP. Another 170.9 hectares are private lands that, despite being empty, belong to owners who have expressed their intention to build gated communities, which could jeopardize the project by decreasing the area's regional connectivity. This complex scenario makes it imperative to develop policies and incentives for sustainable development in this region in order to make the best possible use of this unique concentration of science and technology infrastructure.

In March 2020, an agreement was established between UNICAMP, Campinas Municipal Government and the Inter-American Development Bank (IDB) for the development of a master plan for HIDS, which included multiple consultancies (on natural heritage, on business models and on

35 KRIHS, “HIDS Principles and Design Scenarios: Consultancy for Developing the Physical and Spatial Plan for Campinas” (Campinas, Brazil, 2022).

legal framework) as well as a preliminary urban plan designed by the Korean Research Institute for Human Settlement (KRIHS). After a series of workshops, the business model consultancy, a joint venture between *Sociedade Portuguesa de Inovação* (SPI) and International Association of Science Parks and Areas of Innovation (IASP), identified some vocations for the area, such as ICT, health and agricultural technologies, in addition to the opportunity for developing sustainable urban technology businesses in a living laboratory environment.

KRIHS’ methodology for the development of the urban plan was based on multiple cycles of meetings and workshops with the project’s stakeholders to define the visions, principles and strategies, and to discuss three possible scenarios before presenting a final proposal. KRIHS’ design principles and strategies were based on new urbanism and transport-oriented development (DOT) concepts, such as urban density and compactness, diversity of uses, promotion of active mobility for short journeys and public transport for longer journeys.

In this context, the company adopted six main strategies for HIDS’ urban plan: 1) create a nucleus that brings together innovation activities, businesses and development, and research centres to trigger the development of the area; 2) use the urban design of streets and blocks to encourage interaction and communication; 3) connect the HIDS road network with the surrounding roads; 4) consider the existing division between the plots for the implementation of the road network and land occupation; 5) emphasize the boundaries between public and private areas; 6) preserve the natural ecosystem through two different types of green spaces, the active ones (parks, paths and squares) and the passive ones (environmental preservation areas).[35]

The proposal provides for the perimeter occupation of blocks with an intermediate density in residential areas, with 10- to 15-storey apartment buildings with an average of 300 people/ha. Mixed use is advocated within buildings with a uniform division between residential, commercial and service uses, social housing and community facilities. For the other types of use, 5- to 7-storey buildings are proposed with floor-to-area ratios (FAR) between 2 and 3.

In order to promote active mobility, multifunctional streets of different hierarchies are proposed, with the location of shops, anchor facilities and public spaces on the ground floors of the buildings that combine a design oriented towards the integration between streets and blocks. Within the HIDS area, personal mobility is promoted, with the use of bicycles and other devices shared through mobile applications, while public transport will be prioritized to connect the site to other regions of the city through bus rapid transit lines. Connection with existing roads was prioritized to achieve a higher level of connectivity between HIDS and its surroundings.

The master plan developed by KRIHS contains of most of the premises of new urbanism, but this may not suffice to ensure the implementation of the quintuple helix model of innovation. The planning phase should allow for simulations that go beyond floor to area ratios and land-use distribution. Moreover, these new districts are often artificially and quickly created and lack identity and sense of belonging. There are subjective qualities that influence placemaking success and could be incorporated in the process to assure better urban quality.

HIDS as an Opportunity for Applying City Information Modelling

Traditional scenario-building methods are typically difficult to update and adjust in a collaborative and participatory process. Computational scenario-building and participatory tools allow manipulation of indexes, showing multiple alternatives and their outcomes and consequences. Moreover, being online they are easily editable and allow a greater number of local citizens to be reached, overcoming the limitations of traditional participation methods such as those described by Moughtin et al. based on static models.[36] The author, citing Gibson, points out that "nothing is more destructive of participation" than finished scale models, as people are intimidated to make changes to something that looks ready for presentation.[37] Thus, giving participants the opportunity to manipulate parameters and interact with an online urban scenario with the click of a mouse, to see the possible outcomes, can empower them in this process.

This type of participation is called participatory modelling and is defined as an "approach in which stakeholders from different domains come together for problem formulation and description, input collection, problem-solving, continuous validation, and finally decision-making."[38] For Singh, Baalsrud Hauge, and Wiktorsson, the ubiquity of computational methods in different fields of applied sciences is making computer-based simulation evermore present in the process. It enables the use of participatory modelling for quantitative and empirical purposes, leading to what they call simulation-based participatory modelling.[39] It has been used for different purposes in literature: to facilitate the communication and conflict resolution between different stakeholders; to support decision-making, and for knowledge integration and generation. More recently, it has evolved into empirical participatory modelling and is being used for the development and validation of computational and mathematical abstractions of existing scenarios and used to optimize systems and produce quantitative data to aid decision-making.[40] The aim of using simulation-based participatory modelling in a project is to collect data and process it using different methods and output results and presentation material to guide decision-making.

Data collection is often done using analogical methods such as focus groups, interviews, workshops, and surveys, that can potentially be

36 Cliff Moughtin et al., *Urban Design: Method and Techniques*, 2nd ed. (London: Routledge, 2012), https://doi.org/10.4324/9780080520254.
37 Ibid.; Tony Gibson, *People Power: Community and Work Groups in Action* (Harmondsworth, New York: Penguin, 1979).
38 Amita Singh, Jannicke Baalsrud Hauge, and Magnus Wiktorsson, "Simulation-Based Participatory Modelling in Urban and Production Logistics: A Review on Advances and Trends," *Sustainability* 14, no. 1 (December 21, 2021): 1, https://doi.org/10.3390/su14010017
39 Ibid.
40 Singh, Baalsrud Hauge, and Wiktorsson, "Simulation-Based Participatory Modelling," 8.

enhanced using computational systems, such as online questionnaires, word clouds generators, etc. However, for crowdsourcing information, public participatory geographic information systems (PPGIS) are more commonly employed.[41] For data processing, empirical modelling and presentation, city information modelling (CIM) can be used with inputs collected using PPGIS.

In the following subsection, we discuss CIM and its integration with PPGIS. In the next, we present and discuss three preliminary studies carried out for the purpose of implementing simulation-based participatory modelling in the HIDS project. The first was developed with the purpose of using parametric modelling in conjunction with PPGIS to crowdsource public input on different design scenarios. The second is an indicator to quantitatively evaluate vitality in design scenarios which can be implemented in a PPGIS software to aid communication, decision-making, and policy development. The last is a parametric empirical model, applying Space Syntax, with the purpose of supporting design decisions by evaluating scenarios on their legibility. It can be used to develop scenarios based on crowdsourced data using CIM–PPGIS, similarly to the first study.

City Information Modelling

Originally, city information modelling (CIM) was introduced as an extension of building information modelling for the urban environment, which can be understood as semantically enriched three-dimensional city models integrated with geographic information systems (GIS).[42] In other words, CIM can be used to extend GIS for applications at a smaller scale, i.e., for urban design. In a more recent review, Gil identified other types of applications for this technology that go beyond geometric and semantic aspects.[43] In combination with parametric, generative, and data-driven methods, CIM can be used to create possible scenarios and evaluate them based on objective information to inform policy and spatial planning decisions through the observation of existing phenomena and extrapolation of data.[44]

By using spatial and GIS data as inputs, CIM can be used for simulation-based participatory modelling as several GIS applications have also incorporated participatory tools to collect information volunteered by the public. As mentioned above, these tools are known as public participatory GIS (PPGIS) and can be used to crowdsource information that associates people's opinions, personal knowledge, "perceptions and emotions" with the territory.[45]

The main drawback of using PPGIS in participatory processes is its overreliance on the population's access to digital and connected technology, which, on the level of the individual citizen, can be a problem. Depending on the population to be engaged in the participatory process, this can be offset by using simpler web applications that are also accessible on smartphones. In contrast, the main advantage in the use of PPGIS is the potential to engage a larger population.[46] As noted by Haklay, Jankowski and Zwoliński, most

41 Ibid., 9.
42 Arivaldo Leão de Amorim, "Discutindo City Information Modeling (CIM) e conceitos correlatos," *Gestão & Tecnologia de Projetos* 10, no. 2 (November 6, 2015): 87, https://doi.org/10.11606/gtp.v10i2.103163
43 Jorge Gil, "City Information Modelling: A Conceptual Framework for Research and Practice in Digital Urban Planning," *Built Environment* 46, no. 4 (2020): 501–27, https://doi.org/10.2148/BENV.46.4.501
44 Tom Verebes, *Masterplanning the Adaptive City: Computational Urbanism in the Twenty-First Century* (New York: Routledge, 2013); Jorge Gil, "City Information Modelling: Framework."
45 Muki Haklay, Piotr Jankowski, and Zbigniew Zwoliński, "Selected Modern Methods and Tools for Public Participation in Urban Planning – A Review," *Quaestiones Geographicae* 37, no. 3 (September 1, 2018): 128, https://doi.org/10.2478/quageo-2018-0030
46 Ibid., 130.

people that attend public participation meetings do so because they have a negative opinion of a project and thus feel compelled to participate.[47] Therefore, PPGIS and CIM for the purposes of visualization, communication, empirical modelling and scenario testing employing a variety of methods, including web-based applications, can increase public participation by facilitating the engagement of people that do not have the option or drive to participate in person in workshops and open meetings. Wider participation generates a higher data volume and yields more reliable and significant results for the participatory processes.

In the case of HIDS specifically, and in other areas subject to real estate speculation and gentrification, the use of PPGIS with CIM for scenario building and economic evaluation has the potential to help convince developers to adopt alternative models to those commonly used in peri-urban areas, such as gated communities, which is not in line with the KBUD principles. Furthermore, information and communication technology (ICT) opens an opportunity for digital placemaking, i.e., in order to promote public participation, collaboration in the design process, and a sense of belonging to the place.[48]

Gil lists a number of concepts that have been successfully incorporated into CIM and cites the integration of parametric, generative and procedural modelling with geoprocessing and spatial analyses in the urban planning and design processes.[49] He expands this definition by relating CIM to smart cities:

> City information modelling is the practice of using interactive digital technologies in the process of urban planning, by all actors and stakeholders, to collaboratively deliver the vision of a smart city: a sustainable, inclusive, healthy, prosperous and participative city. CIM consists of an ecosystem of interoperable (open source) tools from different knowledge domains, for data processing, urban analysis, design, modelling, simulation and visualization.[50]

To achieve this broader scope, beyond PPGIS and CIM, opportunities for wider public and stakeholder participation must be created, such as digital placemaking. Halegoua calls for urban planners, developers and designers to "recognize and cultivate" the bond between people and places.[51] The specific qualities and the "character of places" should be evident in the design to inspire affection instead of awe, in order to become stimulating and lively instead of simply convenient or efficient. Thus, "developers need to consider the cultural aspects of intended innovation from the outset, not as an afterthought," focusing on factors such as legibility, local characteristics (environmental, climatic), human behaviour and cultural values.[52] This can be achieved by utilizing social media and ICT to promote the development, holding scientific communication events, maintaining a transparent planning process, hosting artistic exhibitions, performances,

47 Ibid., 128.
48 Germaine R Halegoua, *The Digital City, Media and the Social Production of Place* (New York: New York University Press, 2020), https://doi.org/doi:10.18574/nyu/9781479839216.001.0001
49 Gil, "City Information Modelling: Framework."
50 Ibid., 512.
51 Halegoua, *The Digital City,* 63–64.
52 Ibid., 65.

using PPGIS to engage public participation in planning decisions, attracting the public to activities to digitally map culturally important places and view sights, local knowledge, public memory and folklore, and general wants and needs. Furthermore, digital placemaking can be used pedagogically to continually instil a sense of place and belonging through continued efforts long after the development is implemented.[53]

However, not all the concepts related to the specific characteristics that we seek in urban fringe KBUDS are discussed by these authors. In the case of HIDS, the master plan is not enough to ensure that the required urban vitality is achieved. The HIDS project represents a unique opportunity for applying CIM to simulate different scenarios and the resulting levels of vitality. For this aim, we need to identify the proper vitality indicators and their effect on the area.

These disciplines have traditionally been heavily reliant on written plans, codes, manuals, textual rules and mapped zoning regulations that can be challenging to translate into computer programs and may lack sufficient information. The activities that do rely heavily on programming are analytical and usually apply geographic information systems (GIS) software, meaning geometric data is usually constrained to two-dimensional mapping capabilities.[54]

The opportunity to apply PPGIS and CIM in the HIDS project is particularly interesting. They allow the online publication of interactive design scenarios and collection of public comments. In the future, this can also be used as an information and management system (such as in Paris-Saclay's *carte ouverte* discussed above), and as a platform for the planned urban living labs to foster interactive, feedback-based innovation and co-creation processes. In HIDS, geotagging fieldwork data and images is already being employed for mapping natural and historical heritage, and for collecting community and stakeholder input.

Preliminary Studies

Preliminary studies were carried out with PPGIS and CIM tools to generate and evaluate models, simulations and interfaces that can be used for participatory modelling and employed in a future participatory process. Three examples are presented below. The aspects that were subject to evaluation in these tests were social negotiation, urban vitality metrics and landmark placement for legibility in the HIDS project.

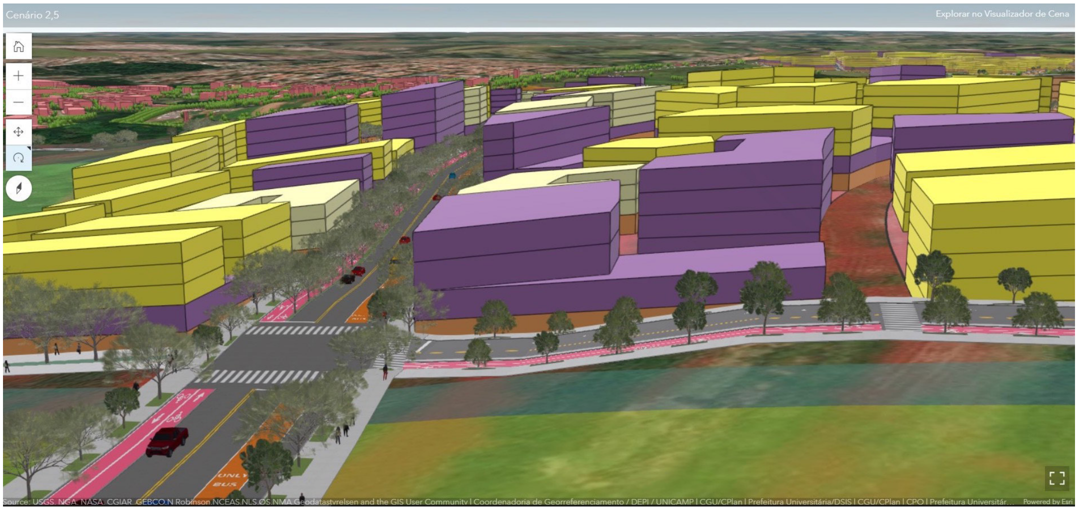
The first study was conducted to test the connection of PPGIS with a CIM tool to allow users to interact with design scenarios, visualize the effect of different input parameters on outputs, and to leave georeferenced comments. Esri ArcGIS Urban and Esri CityEngine were initially tested for modelling HIDS scenarios.[55] A web application to visualize scenarios with varying floor-to-area ratios (FAR) was published online, as shown in Figure 3.[56] Esri CityEngine was used to procedurally model the streets based on walkability rules developed by Sousa, as shown in Figure 4.[57]

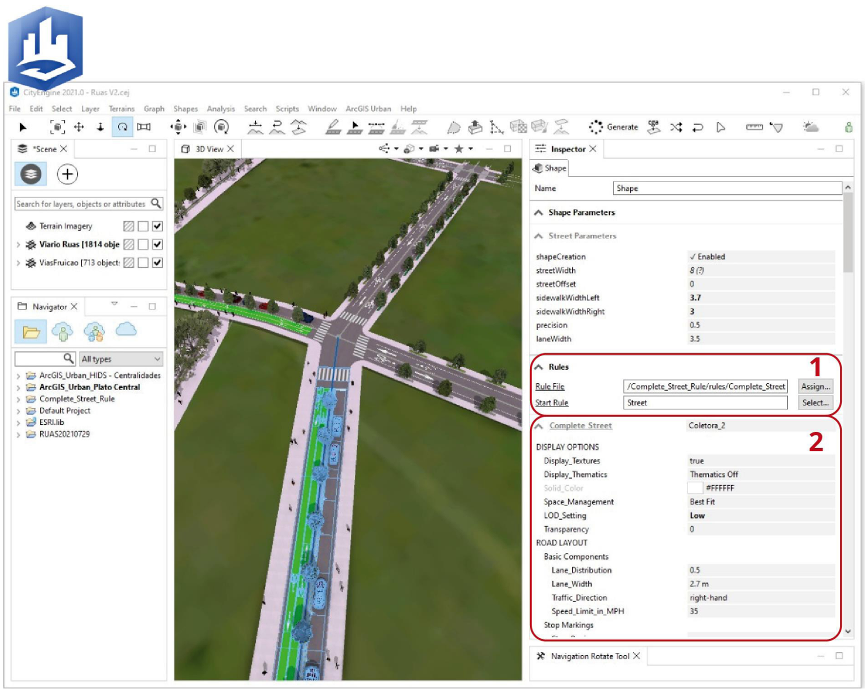
53 Frith and Richter, "Building Participatory Counternarratives: Pedagogical Interventions through Digital Placemaking."
54 Gil, "City Information Modelling: Framework."
55 Juan Pietro Cucolo Marçula, "Ferramentas computacionais aplicadas ao planejamento urbano: comparativo e estudo de caso" (UNICAMP, 2021), https://repositorio.unicamp.br/Acervo/Detalhe/1254861; Bárbara de Holanda Maia Teixeira, "Aplicação da modelagem da informação da cidade para planejamento urbano via integração dos softwares CityEngine e Urban" (UNICAMP, 2021), https://repositorio.unicamp.br/Acervo/Detalhe/1258451
56 Marçula, "Modelos 3D do exercício de projeto HIDS," Web Application, 2021, https://hids90e.web.app/home
57 Marcela N. P. O. Sousa, "Retrofitting Urban Streets: Parametric Modeling of Possible Scenarios for Mobility" (Universidade Estadual de Campinas, 2021), https://hdl.handle.net/20.500.12733/6262

[opposite page]

Fig. 3 HIDS Scenario visualization tool using the Esri ArcGIS Urban Platform, September 2021, (Juan Pietro Cucolo Marçula).

Fig. 4 Inserting a pre-defined rule (1) for complete streets and editing parameters locally (2) in Esri CityEngine software, September 2021, (Bárbara de Holanda Maia Teixeira).


Cenário 2,5
Explorar no Visualizador de Cena


File Edit Select Layer Terrains Graph Shapes Analysis Search Scripts Window ArcGIS Urban Help
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shapeCreation ✓ Enabled
streetWidth 8 (?)
streetOffset 0
sidewalkWidthLeft 3.7
sidewalkWidthRight 3
precision 0.5
laneWidth 3.5
Rules
1
Rule File /Complete_Street_Rule/rules/Complete_Street
Assign...
Start Rule Street
Select...
Complete Street Coletora_2
2
DISPLAY OPTIONS
Display_Textures true
Display_Thematics Thematics Off
Solid_Color #FFFFFF
Space_Management Best Fit
LOD_Setting Low
Transparency 0
ROAD LAYOUT
Basic Components
Lane_Distribution 0.5
Lane_Width 2.7 m
Traffic_Direction right-hand
Speed_Limit_in_MPH 35
Stop Markings
Navigation Rotate Tool
Terrain Imagery
Viario Ruas [1814 obje
ViasFruicao [713 object
Navigator
All types
ArcGIS_Urban_HIDS - Centralidades
ArcGIS_Urban_Plato Central
Complete_Street_Rule
Default Project
ESRI.lib
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The application allows users to explore the scenarios, from which several quantitative details can be extracted, as seen in Figure 5. It can also be used to collect citizens' opinions on proposed scenarios and to create interactive maps enriched with georeferenced images sent from contributors (see Figure 6). This can be used, for example, to create a map with wild

Fig. 5 HIDS scenario exploration app using the Esri ArcGIS Urban Platform, September 2021, (Juan Pietro Cucolo Marçula).

Fig. 6 Example of a user commenting on a plan in the Esri ArcGIS Urban platform, September 2021, (Juan Pietro Cucolo Marçula).

animals seen in the area by locals, or interesting vegetation. Interactive, web-based applications such as the one presented allow stakeholders and, potentially, communities to gain a higher level of understanding of the scenarios and individual proposals, which can, in turn, provide designers and planners with more qualified input and feedback. Further modelling and scenario building is planned for the coming months, as a decision-support and public participation tool. Further analyses of usability and interface user-friendliness still need to be carried out.

The second preliminary study was the development of an indicator to quantitatively evaluate urban vitality to aid decision-making and policy development aimed at future implementation in a PPGIS system.

Jácome studied different methods for evaluating urban vitality and proposed the adaptation of Koe's system to be applied in HIDS.[58] She conducted a validation study in a Brazilian downtown area acknowledged as very lively. The parameters used by Koe are population density, use intensity, mixed use, functional variety, and public-private ratio.[59] Despite the resulting level of vitality obtained by Gouveia's evaluation in her application study being relatively high, the public-private ratio needs to be adapted to the Brazilian reality. Nonetheless, with the use of Koe's indicators, multiple scenarios can be quantitatively compared. All these parameters can be easily represented and quantified in a city information model and dynamically changed in simulations, contributing to better design results.

Finally, Montefusco conducted a study based on Lynch's legibility theory to develop a parametric empirical model, applying Space Syntax to evaluate scenarios.[60] The procedure was validated by developing a computational model for a consolidated area and comparing the results with a mental map, developed using Lynch's traditional method. This model can be calibrated for different locations based on data crowdsourced using a PPGIS implementation like the one developed by Marçula.[61]

Originally Lynch's theory is applied to consolidated urban areas and uses surveys to map an area's legibility based on five elements: edges, districts, paths, nodes and landmarks.[62] In order to enable the theory's application in urban planning and design, Montefusco developed a procedure based on Space Syntax to evaluate how the location of landmarks and nodes contributes to a scenario's legibility. His procedure was tested using HIDS as an application study.

In the case of HIDS, Montefusco considered that edges, districts and paths were defined a priori by the area's location and municipal legislation and could be sourced from the city's GIS data directly.[63] To evaluate the effects of nodes and landmarks placement on legibility, the author used a scenario developed for a part of HIDS.

The procedure uses angular segment choice analyses to measure the centrality of different streets and isovist fields and cumulative isovists

58 Rita de Cássia Gouveia Jácome, "Vitalidade urbana: diretrizes para induzir padrões de vida urbana no Hub Internacional para o Desenvolvimento Sustentável (HIDS)" (Universidade Estadual de Campinas, 2021), https://hdl.handle.net/20.500.12733/5721; D.M. de Koe, "Urban Vitality through a Mix of Land-Uses and Functions: An Addition to Citymaker" (Wageningen University, 2013).
59 Koe, "Urban Vitality."
60 Marcelo Meloni Montefusco, "A Imagem da (nova) cidade: elementos da imagem da cidade como norteadores de novos projetos urbanos" (Universidade Estadual de Campinas, 2021); Kevin Lynch, *The Image of the City* (Cambridge, MA: MIT Press, 1960).
61 Marçula, "Modelos 3D do HIDS."
62 Lynch, *The Image of the City*.
63 Montefusco, "Imagem da (nova) cidade."

64 Lynch, *The Image of the City*.

65 Tasos Varoudis, “DepthmapX Multi-Platform Spatial Network Analysis Software” (Open Source, 2012); “OpenStreetMap,” www.openstreetmap.org

66 Ioulia Kolovou et al., “Road Centre Line Simplification Principles for Angular Segment Analysis,” in *Proceedings of the 11th Space Syntax Symposium* (Lisbon: Instituto Superior Técnico, 2017), 163.1–163.16.

with topographic models. This computational procedure was validated in the existing campus area. It was then applied to compare the legibility in two different scenarios developed using a preliminary mass study for part of the HIDS area, called Central Plateau.

According to Lynch’s theory, nodes and landmarks are visible from or located on or near the most important paths in a city.[64] To determine the location of these main paths, angular segment choice analyses were conducted in depthmapx using a road centre line map obtained from publicly available GIS files.[65] Before the analyses, the map was simplified and segmented in the QGIS software to reduce angular changes and approximate the results of an axial map, following the procedure described by Kolovou et al.[66] The results of these analyses, shown in Figure 7, are used to predict the most important paths in a scenario, i.e., with the highest potential for vehicle movement — global radius — and pedestrian movement — 400 m radius. This procedure was based on the computational street

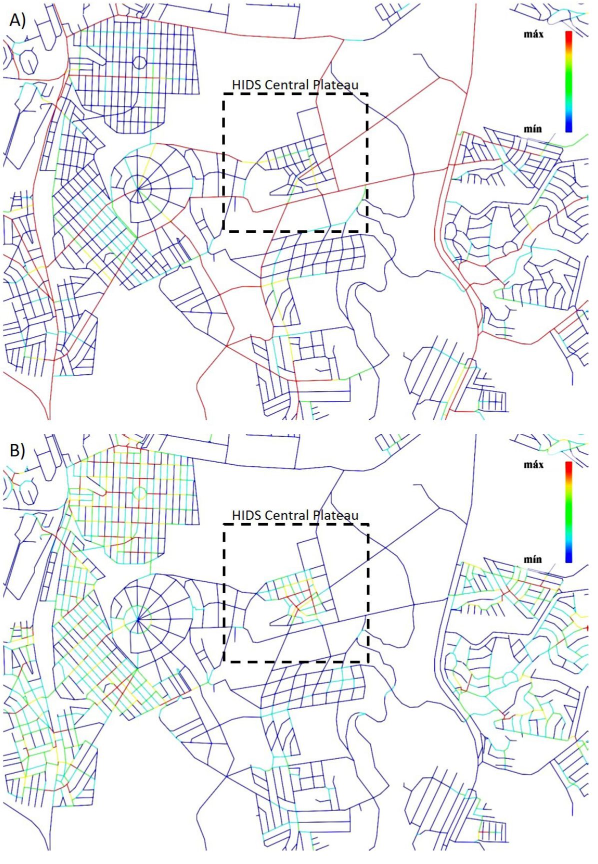


Fig. 7 Angular segment choice analyses for a preliminary scenario for HIDS.
A) Global radius;
B) 400 m radius,
September 2021, (Marcelo Meloni Montefusco).

Fig. 8 Changes made from scenario 1 – original – to scenario 2 – moving or suppressing masses – to evaluate the effect on legibility, September 2021, (Marcelo Meloni Montefusco).

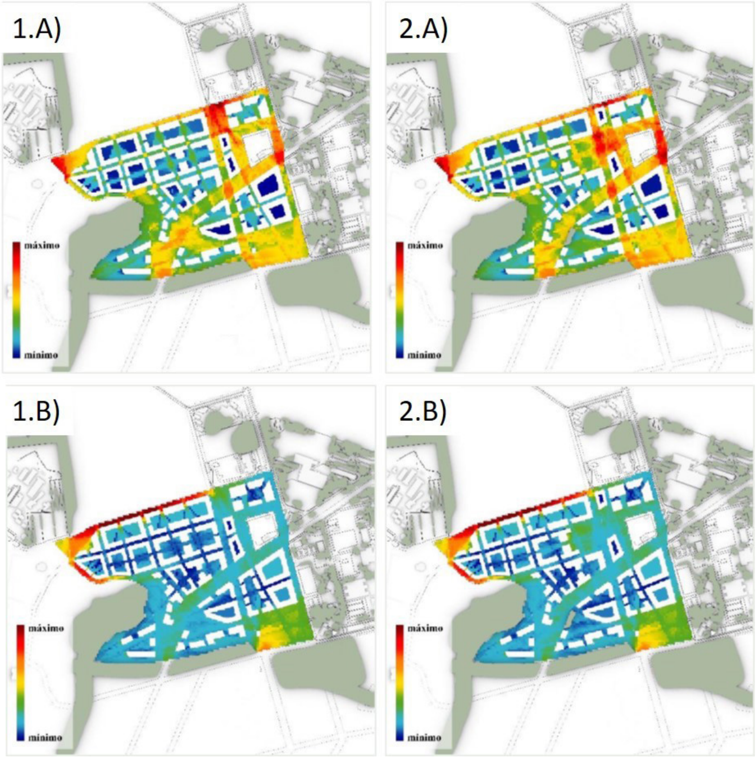
hierarchization method proposed by Sousa, Duarte, and Celani and provides information that, when applying Lynch's traditional method, would have been determined using interviews.[67]

To determine the potential of landmarks and nodes in the scenarios to fulfil these roles, isovist and isovist field analyses were conducted using a parametric model developed in Rhino3D using visual programming in Grasshopper with the DeCodingSpaces Toolbox.[68] The building, vegetation and topography data were also sourced from publicly available GIS files and used to automatically generate a three-dimensional model using attribute data.[69]

Two scenarios were analysed in order to understand the relation between legibility and the geometry of buildings and open areas such as public squares. As shown in Figure 8, small changes were made to the geometry of public squares and building locations from the first scenario to the second.[70]

In this study, Montefusco considered that higher isovist perimeter and occlusivity values define concave spaces.[71] Higher values of circularity and isovist area divided by isovist perimeter are seen in convex spaces with open areas and fewer obstacles. Both types are correlated with the formation of nodes when they coincide with paths with a higher angular segment choice. The highest occlusivity values are correlated with the definition of landmarks, as this is a measure of the place's visibility in the territory. The isovist analyses at eye level for a 400 m radius for both scenarios are shown in Figures 9 to 11. Higher isovist perimeter and occlusivity values are correlated with node formation.

67 Sousa, José Duarte, and Gabriela Celani, "Urban Street Retrofitting – An Application Study on Bottom-Up Design," in *Architecture in the Age of the 4th Industrial Revolution – Proceedings of the 37th ECAADe and 23rd SIGraDi Conference – Volume 3,* ed. J.P. Sousa, J.P. Xavier, and G Castro Henriques (Porto: University of Porto, 2019), 287–96, https://doi.org/10.5151/proceedings-ecaadesigradi2019_233; Lynch, *The Image of the City.*
68 "DeCodingSpaces Toolbox," www.toolbox.decodingspaces.net
69 Montefusco, "Imagem da (nova) cidade."
70 Ibid.
71 Ibid.



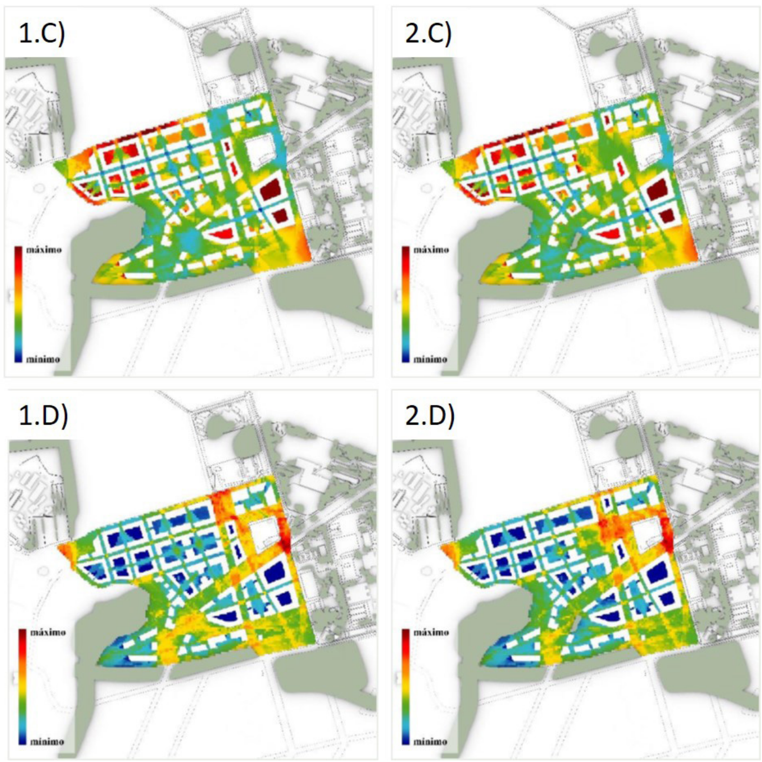
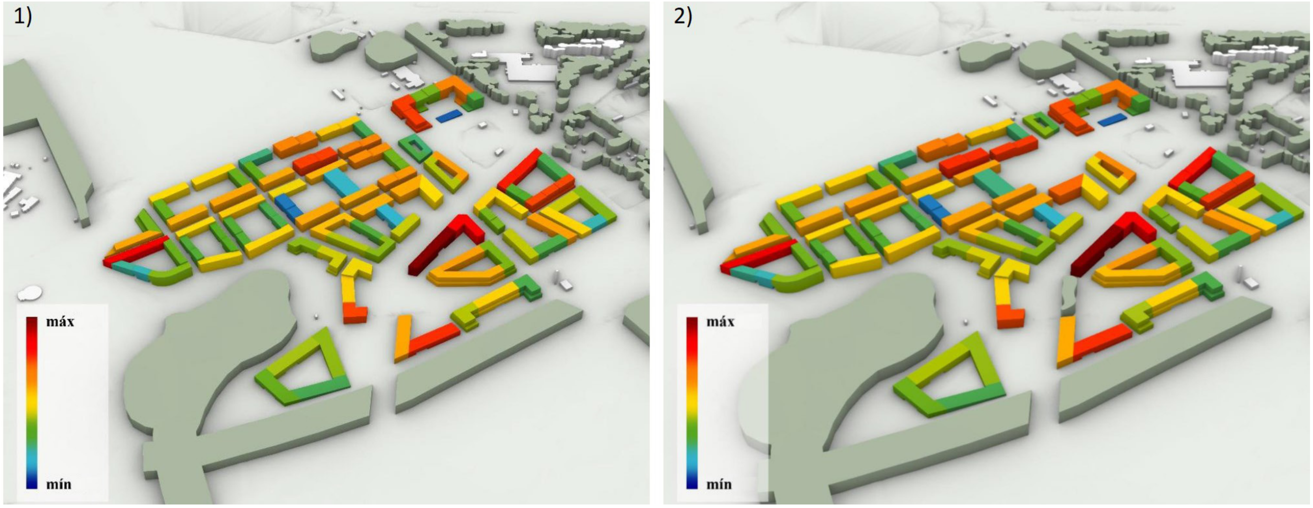


Fig. 9 Isovist analyses at eye level:
1.A) Isovist perimeter for scenario 1;
2.A) Isovist perimeter for scenario 2;
1.B) Ratio of isovist perimeter to isovist area for scenario 1;
2.B) Ratio of isovist perimeter to isovist area for scenario 2, September 2021, (Marcelo Meloni Montefusco).

Fig. 10 Isovist analyses at eye level:
1.C) Isovist circularity for scenario 1;
2.C) Isovist circularity for scenario 2;
1.D) Isovist occlusivity for scenario 1;
2.D) Isovist occlusivity for scenario 2, September 2021, (Marcelo Meloni Montefusco).

Fig. 11 [opposite page]
Cumulative isovists of HIDS Central Plateau
1) Scenario 1;
2) Scenario 2, September 2021, (Marcelo Meloni Montefusco).



72 Ibid.

From one scenario to the next, it can be seen how these small changes to building masses can change the location of zones with higher isovist perimeter, area and occlusivity values, making them coincide with important routes in the plan. This concurrence of different measures in the same place favours the formation of nodes and landmarks, contributing to an area's overall legibility.[72]

This type of empirical model implemented in CIM, shared and collaboratively evaluated using PPGIS, can improve data collection and support decision-making, while providing a more transparent design process to reduce conflict between stakeholders in a participatory design process.

Discussion and Conclusion

In this paper we presented a review of the knowledge economy and the different generations of science parks. We proposed a fourth generation that combines the concepts of knowledge-based urban developments and urban fringes, in line with the quintuple helix innovation model. Next, we illustrated this generation with the case of Paris-Saclay. Finally, we presented the case of HIDS, which is a retrofit of a second-generation park into a fourth-generation territory. We discussed how PPGIS and CIM can be used for different purposes in participatory modelling to help in the public engagement and placemaking of this type of development.

The preliminary studies presented in this paper are a contribution to participatory processes by aiding visualization and communication and by collecting knowledge and data that can be used as input for empirical modelling and scenario testing. We showed how these methods can be employed during the design phase to simulate and evaluate the often elusive urban qualities of vitality and legibility.

The main advantage of using PPGIS for participatory modelling is its potential to facilitate and consequently increase public engagement through web-based input collection and communication applications, increasing data volume, reliability and significance. When extended with CIM, parametric and simulation-based modelling, these tools can be used to improve citizens' comprehension of design, planning and legislative proposals. This increases their ability to make purposeful and knowledgeable contributions to the process, assisting in the reduction and resolution of conflicts stemming from poor communication between stakeholders.

These approaches are in line with the bottom-up, feedback-based innovation which KBUDs are based on. Nevertheless, the collaboration between academia and the public realm can be tricky since each of them operate on different timescales. In the case of HIDS, the application of the tools for simulation-based participatory modelling presented herein is largely dependent on a political process that cannot be accelerated. Still, we expect that these preliminary studies can contribute to other similar projects.

As the post-pandemic relationship between work and place dissolves and more of our activities migrate to the digital realm, so must the tools for urban planning and participatory engagement. Science parks and districts will have to engage firms, institutions and communities by offering more than just office space. They will have to contribute to a sense of place and belonging in order to be relevant in the digital culture. The use of PPGIS, CIM and digital placemaking are aligned with the concept of KBUD as they enable planners and designers to deal with complex phenomena, receiving feedback through simulations, and by engaging stakeholders and communities.

Beyond the issues discussed in this paper, urban fringe KBUDs pose many other challenges for traditional urban planning due to their complexity in terms of land structure, green and grey infrastructure, sustainable land use, science and research equipment, housing, etc. These are important issues that must be addressed in any KBUD, both in developed and developing countries.

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