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Veloso e Zárate, H.; Triggianese, M.

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EDITED BY

Nacima Baron,
Nils Le Bot,
Pauline Detavernier,
Manuela Triggianese

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N. Baron,
N. Le Bot, P. Detavernier, M. Triggianese

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Greener, denser station areas? Geodesign and Green Transit Oriented Development in Los Angeles

Halina Veloso e Zarate
and Manuela Triggianese

The concept of sustainable development introduced issues of urban growth and climate change to the domains of geography, urban planning and architecture, becoming major components in research, teaching and practice. The IPCC reports have heightened awareness on climate change and put pressure on the need for action to bring about real-world changes to the built environment. Climatologists note that global urbanisation has greatly influenced the spatial distribution and intensity of carbon emissions and is having a negative impact on climate change. However, they emphasise that well-planned cities with densely populated centres produce numerous benefits if good access to infrastructure and services is guaranteed (energy efficiency and air quality in particular). In this context, Transit Oriented Development becomes a key concept for sustainable urbanization, and Geodesign gains stage as a method to support design decisions in such projects, across domains.

Transit Oriented Development (TOD) emerged in the late 1980s in major American cities as a response to the negative effects of urban sprawl (Cervero and Kockelmann, 1997; Padeiro et al., 2018). This model, strongly supported by international institutions, such as The World Bank (Salat and Ollivier, 2016), was adopted across the world. Site-specific TOD variants adjust to different geographies, engineering cultures, urban policies, and position in the transportation network (Thomas et al., 2018). Regardless of specificities, TOD aims to restructure urban regions around public transport promoting the concentration of dense urban development near public transportation stations (railway, metro, tram, bus). TOD stresses the importance of high-quality spatial and functional planning in urban areas around transport nodes, to configure vibrant transport nodes, where proximity and accessibility by foot or bike help reduce the modal share of private cars and, therefore, CO2 emissions (Bertolini et al., 2012).

When properly developed, these stations meet the three main criteria of sustainability: economic, environmental and social. For example, mixed-used developments (homes, offices and shops) conduce changes in land and property values and complementarity between functions, contributing to an enhanced quality of living within the node (Triggianese et al., 2018). That benefits economic interests and help to reduce household travel, reducing pollution. Transport nodes connected to public parks and gardens tackles the socio-environmental aspect of sustainability, where greenery has a role in climate-change mitigation (i.e. reducing urban heat island effects) and in the perceived experience of transport users, who can stroll and linger, giving such areas a distinctive identity and their own appeal. However, managing the compatibility between these goals adds to the complexity of the design process and requires the integration of very large volumes of data, pertaining to multiple disciplinary domains.

Data analysis methods contribute to the design of proposals for transport nodes, because they make it possible to deal simultaneously with several interdependent factors, across different scales (macro scale, at territorial level; meso scale at district level; micro scale, at building level). The software boom in the 1990s contributed to the massive shift towards computerisation in design methods (Veloso e Zarate, 2023), as numerous software applications (such as ArcGIS, Catia, Rhinoceros 3D, Grasshopper, Revit, etc.) became accessible to the domains of Architecture and Urban Design (Claypool, 2019). With GIS (Geographic information Systems) and BIM (Building Information Modelling), it is possible to visualise urban and building digital data relevant for station district projects, in two and in three dimensions.

Geodesign refers to a method in which urban and architectural designers use geospatial data analysis to produce reiterated visualisations and formal simulations. The first step in this process is to gather large quantities of input data and then spatialise them (using georeferenced coordinates) in GIS layers and via BIM (in the form of 3D models). This enables greater depth of contextual analysis, and swift shifts in scales. These tools are especially useful for the conceptualization and evaluation of multiple development scenarios, each offering relatively optimal variants between which balances can be sought or compromises made. This is our research field and in this chapter, we present an illustration of the heuristic scope of Geodesign. Following the example of (Lee et al., 2014), we believe that to better understand Geodesign as an integrative method, we must begin with real-world cases and to work directly with practitioners to test the potential and limitations of these tools.

Theoretical background: Geodesign and Green TOD

Thanks to its integrative capacity, Geodesign can be used to simultaneously to analyse contextual data, help create design scenarios and assess their suitability and performance. It is part of a very rapid development of computer power and the ability to represent data in graphic form, which has been a tool to architects, geographers, town planners, designers, landscape architects. Such data and tools has been giving designers the capacity to work and create impact by means of geovisualisation (Bissell and Fuller 2017).

For example, when there is a need to create or alter the urban form of a district to promote transit oriented development, integrating design and geospatial sciences allows us to study density (the quantity of gross built floor area relative to the area of land available within walking distance of a transit station). Geodesign also allows to measure how this criterion impacts traffic, carbon footprints, etc. (Lee et al., 2014),. Density, depending on the provider, can be secondary data, not raw data. It is constructed from layers of data including cadastral maps of the study area, maps of road and energy networks, drawings of existing and future buildings, and the legally permitted height thresholds. The aim of a density study for TOD is to approach an optimal distribution of built-up space within proximity to the station, from a design-oriented urban modeling approach. That will determine where strategic interventions can take place and leave space for open, green unbuilt area, and help understand what is needed to finance the investment in public transport facilities. Such study also informs if a certain design proposal can ensure sufficient ridership, and hence economic feasibility, in the medium to long term. In sum, these technical tools have a threefold value: help researchers to acquire and analyse complex information for the coordination of urban and transport planning; aid public decision-makers to choose the extent, and location of transport facilities; help traffic managers and public space managers to decide on the form and phasing of redevelopment projects.

As the concept of TOD is multidimensional, its effects in practice can vary, in what refers to urban form, real-estate price, community life, etc. (Ibraeva et al., 2020). This variation depends on the decision-making considering multiple and interdependent factors, that can mean emphasizing one aspect over the others, in search for an optimum mix of design paramenters. Cervero, who largely researches TOD, speaks of different types of "specialised" TOD, referring to the special emphasis given to certain criterion. He introduced Green TOD (Cervero et al., 2017), a station district development strategy focused on reducing energy consumption, emissions, water pollution and waste, and at the same time creating parks and gardens. Cervero also evokes the need to combine an understanding of each of the individual nodes with awareness of the meso and macro scales, to harmonise public rail systems with metropolitan grids and green belts.

Cervero's view is widely supported by more recent work that stresses the importance of a cross-scalar approach to linking the redevelopment of public transport networks with urban planning, configuring polycentric systems (Mayne et al., 2016 a and b). On a neighbourhood or micro scale, the design principles of Green TOD include strict targets for energy and water consumption and tend to focus on synergies between access to green spaces and access to transport. On the network or macro scale, Green TOD analysis tools should help designers to find innovative solutions to tackling the constraints of urban sites (splits in the urban fabric, heat island problems, extreme urban sprawl, traffic jams, smog, drought and forest fires). Green TOD becomes a suitable framework for the analysis and future development of cities in the 21st century, especially Los Angeles, for its extreme urban sprawl configuration and climate change vulnerability. With the rise in temperature forecast for 2050, Los Angeles will suffer from more extreme and more frequent heatwaves and from a reduction in snow accumulation to replenish local water reserves, while having to accommodate 1.5 million new residents.

Against this challenging backdrop, this chapter attempts to answer the following question: how can Geodesign methods be integrated in the design of sustainable transport nodes that incorporate Green TOD criteria? To answer this question, we present the stages of a case study that is part of a vision project called Sustainable Los Angeles 2050 conducted by the University of California at Los Angeles (UCLA). The aim of the project was to support Los Angeles County's transition towards a target of 100% renewable energy, 100% local water and regeneration of the urban ecosystem by 2050.

Geographical context

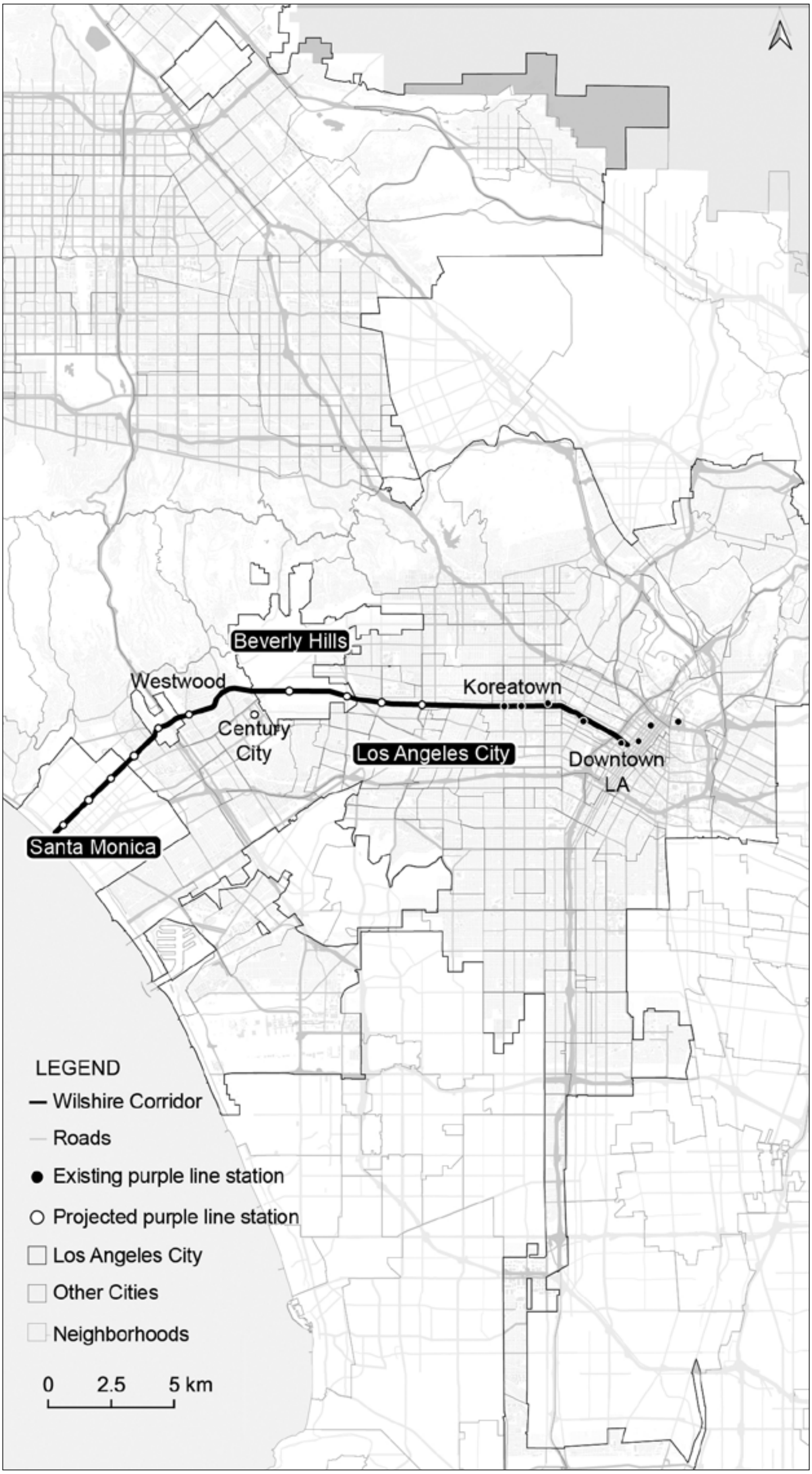
The major US cities have been studied extensively to assess whether forms of TOD are applicable, since from the nineteenth century onwards they were to a large extent structured by very long linear transportation infrastructure axis (Modarres and Dierwechter, 2015) and urban sprawl. In the case of Los Angeles (LA), sprawl led to increased greenhouse gas emissions, smog and water consumption - an evidently unsustainable pattern of living (Cohen 2022). On the 2010s, Los Angeles embarked on a strategic rethink about the revival of its rail system and the regeneration of neighbourhoods along the transport corridors (Ruggieri 2014). Authorities began thinking about the future of their station districts, with a redevelopment plan using Downtown LA as a case to demonstrate rehabilitation that would respect and highlight local history of the station site, improve the passenger experience, make the station a regional hub and also a pleasant public space integrated into its environment, preparing for the arrival of high-speed rail (Ruggieri 2014). Public agencies adopted polices establishing a framework for transit-oriented development, based on High-Quality Transit Areas. In Los Angeles that meant urban areas in proximity to subway (Metro) stations.

By the end of the 2010s, three lines were under construction and expected to serve Los Angeles and adjacent municipalities on the East-west direction: the Gold line, the Expo line and the Purple Line (Riggs and Chamberlain, 2018). The Purple line, along Wilshire Boulevard, is the subject of this chapter's analysis.

Almost 25 kilometres long, Wilshire Boulevard stretches from east to west between 3 cities (Los Angeles, Beverly Hills and Santa Monica) and 18 neighbourhoods (including Downtown Los Angeles, Koreatown, Century City and Westwood) before reaching the beach by the Atlantic Ocean (Figure 1). It represents a metropolitan backbone, alternating between business districts where the tallest office skyscrapers are concentrated, theatre and museum areas, parks, luxurious villas and hotels, from Downtown to Santa Monica Beach. The Purple Line or D line of the subway already runs through some of the eastern districts of lowest income, but for decades the high-income localities in the west refused to accept an extension of this infrastructure. Harris (2017) notes that the public image of transit has changed recently. Local resident groups in the most affluent neighbourhoods, which are also suffering from water and energy restrictions, have become less opposed to the idea of being served by public transport service, which was historically associated with not having a car, and hence with poverty. They have gradually adopted the concepts of Smart Growth and Transit Oriented Development, which are one aspect of this change of mind (Knaap et al., 2022). As a result, public and private sector players have revived the plan to extend the Purple Line westwards.

The study, based on a methodological framework explained below, was carried out by the Now Institute, a partnership between the University of California Los Angeles and Morphosis Architects, a firm that is a pioneer in the application of digital design methods based on big data tools. At the Now Institute, Master's students worked on this project for three consecutive years (2014, 2015 and 2016). The Wilshire Boulevard project here investigated was undertaken in the second year of the partnership under the supervision of two architects and involved twelve students over a one-year period. The project produced TOD scenarios to analysed, discussed and compare possibilities for sustainable urban growth. Two publications are available documenting this work (Mayne et al., 2016 a and b).

For the purposes of this chapter, the authors investigated the digital archive of this project to retrace the data, tools and skills involved in producing the design studies for Wilshire Boulevard, The work was carried out in several stages, starting with the acquisition of geospatial data used and other basic information, reconstructing a digital model of the boulevard and the building of the metro, documenting the energy and water production and consumption, and provision of greenspace in proximity to transit stations. The research was supplemented by consulting meetings with specialists in the urban development of Los Angeles and in urban and transport planning.



1. Map showing the location of Wilshire Boulevard and the Purple Line

@ H. Veloso e Zarate.

Through this investigation, we were able to garner the applicability of Geodesign methods in the different TOD typologies developed for Wilshire Boulevard's proposed nodes.

Construction of the database and findings

Our design process begins at regional scale, looking at the entire urban area and seeking to understand the major transport, housing and environmental challenges facing Los Angeles County. We had to identify the trajectories of urbanisation, changes in road networks, climate zones and urban morphology to obtain information about energy and water consumption and production and identify the sustainability objectives set out in existing government plans. This step enabled us to measure the gap between the current reality and the objective of a 100% sustainable Los Angeles conurbation, specifically to assess the importance of energy and mobility in achieving this objective. It would mean electrifying all forms of transport and significantly increasing the use of public transport, while radically rethinking the form and location of housing and offices. In pursuit of this goal, a 30% improvement in building energy efficiency through technology and typology adjustments (i.e. denser multi-family versus suburban single-family) would reduce demand by 25%, while covering all compatible rooftops in LA County with solar panels would increase the renewable energy supply by 25%. Regarding water, a transition to native landscaping in residential areas would reduce water consumption by 20%, and capturing only one more inch of the County's annual rainfall could result in a 10% increase in the local water supply. For ecosystem and human health, the study showed that the County needs to increase the number of parks by 2.5 to provide access to all nodes in Wilshire Boulevard within walking distance. The effectiveness of all these potential measures would depend on the appropriate distribution and location of urban amenities.

The results show that across the County, the areas with a predominance of single-family houses are those where population density is lowest, while energy and water consumption is highest. They are therefore the area's most remote from Green TOD criteria. Multi-family housing with smaller gardens showed smaller water and energy consumption. Several zones crossed by Wilshire Boulevard match these types of urban form and therefore merited detailed analysis. Numerous thematic maps were produced with the aim of identifying the areas where the imbalance between supply and demand was most critical. Among the indicators relating to water, energy and the environment, the datasets extracted for analysis in this chapter focus on energy consumption from buildings and CO2 emissions related to transport.

In the next steps of the design process, the focus was on the transport nodes in this urban corridor, at the scale of the districts around the station. A very precise characterisation was drawn in the format of 2D maps and 3D models to depict and analyse the morphology of the buildings and roads, the land uses in the various districts, the traffic trajectories and the resource consumption. The Now Institute's proposal was to respond to the predicted increase in the population of Los Angeles by densifying less than 1% of its territory in the form of TODs along the Wilshire corridor, while leaving the rest of the territory unchanged. Of the 20 stops on the Purple Line projected extension, which will link Downtown to the Santa Monica coast in 32 minutes, five areas were identified as having the potential for higher land values and for leveraging the growth of housing, offices and commercial services. Evocative names were proposed for the stations: Ocean Edge City, in Santa Monica; City in the Park, in Century City; Culture Core, in Fairfax; The compact city in Koreatown; and City Stitching linear park, in Downtown Los Angeles. District level geospatial data were used to supplement thematic layers and to export the 3D model from the GIS software to the BIM software (in particular to set the building height standards in each of the districts and manage design interventions). The boundary for the design intervention was established by buffers, centered around key station. These circular boundaries indicated the areas that could be reached in 15 minutes on foot or 5 minutes by bike from each station and framed the detail level needed from the sustainability indicators, to be provided for an area of around 2 square kilometres.

The first sets of data analysed were about living environment and lifestyle, including housing and population density, average water and energy consumption in volume and kilowatts per inhabitant per day, and the ratio of green and open spaces (gardens, parks) in area of green per inhabitant. A second dataset was devoted to the landscape and morphological aspects of these neighbourhoods in the vicinity of public transport. In total, four key criteria (density, water, energy and open space) were used to assess the capacity of each scenario to ensure that the complete system achieves 100% clean energy, 100% locally sourced water and brings accessible greening to the neighbourhood.

In the final stage, the data visualized against the scenarios designed to provide visionary imagery portraying the redensified districts associated with the strengthening of public transportation access in the boulevard. Envisioned from the Santa Monica Beach district, the Ocean Edge City project would accommodate population growth from about 7,500 people per square kilometre (ppl/km2) to around 30,000 ppl/km2, while maintaining frugal water and energy consumption rates and providing around 19 square metres of green and open space per inhabitant. The scenario envisaged for Century City is twice as generous in terms of space per inhabitant but would accommodate an increase in density to around 25,000 ppl/km2 from a level that is almost ten times less than that (by way of comparison, the population density in central Paris is around 21,000 to 25,000 ppl/km2, according to INSEE). In Fairfax, in the neighbourhood of the Los Angeles County Museum of Arts (LACMA), there are currently about 4,000 ppl/km2. This demographic potential could be almost doubled under sustainable conditions of access to water and energy resources, while providing 10 square metres of open green space per inhabitant. Again by comparison, Parisians have access to only 20-30 square metres of green space per inhabitant, whereas Londoners have double. The other station district projects similarly evolve towards more compact urban forms (Koreatown from 19,000 ppl/km2 to 37,000 ppl/km2; Downtown from 15,000 ppl/km2 to 26,000 ppl/km2) or adapt to specific infrastructure constraints. Over in the east, the proposal for the Downtown Los Angeles station area is to cover over the expressway – which currently forms a physical barrier between Downtown and Westlake – and to create a linear park in the form of a green grid across the width of this amenity in order to revitalise the area.

These frugal resource-use targets are achieved in the scenarios by using building design methods that include the installation of specific eco-technological equipment: the available roof surfaces are calculated to confirm the possibility of installing solar panels or wind turbines to produce clean energy, to allow rainwater to be collected and, in some cases, to extend the available areas of green and open space per inhabitant. The outlines of the buildings are drawn digitally, using a combination of mapping and 3D digital modelling to design solutions to the spatial constraints (towers and covered expressways). Streets are inserted in areas that are too densely populated to make the road structure suitable for non-motorised local travel, and construction zones have been created in infill spaces. All in all, when all the sustainability data and objectives considered are considered (Table 1), this corridor could accommodate the 1.5 million additional residents that Los Angeles County anticipates having by 2050, while providing 100% locally sourced water, 100% clean energy and more green spaces, by altering only small proportions of the existing built fabric, namely the neighbourhoods best served by public transport along Wilshire Boulevard.

Using Geodesign, it was possible to form neighbourhoods with distinct morphological and landscape features based on their existing socio-spatial characteristics, without rendering them completely unrecognisable. Some neighbourhoods absorb a larger proportion of demographic growth and become more densely populated, while others are reshaped through a drastic reduction in their consumption of resources. Overall, this outcome was judged acceptable, as each area has its own specific characteristics and spatial potential, which contribute in different ways to achieving Green TOD objectives.

<table>
<tr><th>Compo-nents</th><th>Stage of the design process</th><th>Geospatial data integrated into the design process</th><th>Objectives associated with the use of this data</th></tr>
<tr><td rowspan="3">Energy</td><td>Analysis</td><td>Networks: transmission lines, power plants, etc.

Emission data and consumption: solar and wind potential, carbon footprint, electricity consumption.

Spatiotemporal data: travel time, service areas, walkability</td><td>Better understand the context and dimensions related to the sustainability objectives, by working on both the energy efficiency of buildings and emissions linked to transport.

Identify opportunities for synergies to meet the characteristics of supply and demand for housing, mobility and services.</td></tr>
<tr><td>Synthesis</td><td>Criteria: position of nodes within the transportation network, node boundary (800-meter radius from the stations), building typologies

Urban Planning regulations: height envelope, 3D model of building height, historic preservation areas, legislation on built heritage, natural areas, schools and hospitals.</td><td>Establishing the boundary of the study area, defining the maximum densification potential, tracing the non-densifiable land.

Creation of densification scenarios within existing contexts, in which population density can be achieved.

Construction typologies and valorization of open spaces to generate green energy.</td></tr>
<tr><td>Assessment</td><td>2D maps and 3D model of buildings, netowrks and green spaces
Population density, energy consumption</td><td>Evaluate whether the design proposal can achieve the goal of 100% clean energy.</td></tr>
<tr><td rowspan="3">Water</td><td>Analysis</td><td>Drought, rainfall, water flows, water supply aqueducts, water consumption per neighborhood and per sector</td><td>Better understand the context and dimensions related to the sustainability objectives, by working on both the water consumption pattern versus the potential for rainwater capture to meet demand.

Identify opportunities for synergies to meet the characteristics of supply and demand for housing.

(considering lifestyles across the transportation corridor)</td></tr>
<tr><td>Synthesis</td><td>Node boundary area for potential rainwater capture (800-meter radius from the stations), building typologies and rooftop surfaces for rainwater capture, population density and water consumption patterns per district</td><td>Définition d'enveloppes bâties aux abords des gares dans lesquelles le niveau de redensification est compatible avec un objectif de consommation d'eau raisonnable.</td></tr>
<tr><td>Assessment</td><td>3D building model, building typologies, population density, rainfall, water consumption, water supply</td><td>Manipulation of multiple building typologies and densification scenarios to combine densification, water catchment and supply targets.
Assess if the proposed urban form may or may not achieve the goal of 100% water from local resources.</td></tr>
</table>

Green Spaces	Analysis	Nature preservation zones, impact of climate change of ecosystem, climate zones, extreme heat days, habitats	Better understand the context and dimensions related to the sustainability objectives, by working on both the provision of green (public and private) per inhabitant, versus the potential for creating new public green spaces to meet the sustainability criteria. Identify opportunities for synergies to meet the characteristics of supply and demand along the network.
	Synthesis	Node boundary area for existing and potential access to green (800-meter radius from the stations), building typologies and rooftop surfaces for potential new green, population density and green per district. Analysis of the distribution of space to supply green on the Wilshire Boulevard area.	Building scenarios to make it compatible densification objectives and increasing the ratio of square meters of green spaces per inhabitant.
	Assessement	3D model, building typologies, population density, green space demand and supply spaces	Assessment of the increase in access to green spaces for city dwellers in terms of: – time distance, – higher environmental and landscape quality of spaces, – ecosystem benefits (air and water quality), – physical and mental health of populations, – built environment attractiveness

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The integration of Geodesign methodologies into the planning and development of Transit Oriented Development (TOD) represents a fruitful method in bridging domains by applying data sciences techniques. Following such methods, progress in Transit Oriented Development relies on the quality of the work involved in collecting and organising documentary sources and data (archives and open-source data); the technical handling of digital tools for geolocation and modelling; the collection of statistics (on consumption per inhabitant and per hectare); and further scenario modelling in greater detail.

Green TOD represents a major shift in this mixed field of research and practice, as it combines the criteria of access to public transport facilities, optimum use of land resources and denser urban development, with environmental objectives such as access to green spaces and frugal use of resources. The Green TOD neighbourhoods that are currently springing up in the heart of American cities incorporate styles and forms of urban planning that represent a transition from the car-centred urbanism that has shaped them for so long. They adopt models borrowed from Asian cities (generating density through high-rise construction) while drawing inspiration from European values (by emphasising the provision of public space and encouraging a human presence in the streets with facilities and amenities: green spaces, children's play areas, shared zones). Green TOD is also sensitive to the role of public transport in creating local hubs, when combined with intermodal facilities that are not only restricted to the automobile (parking lots), but encompass micro-transit services (Mobility as a Service, MaaS) such as bicycle fleets or self-service electric vehicles like scooters.

Data-oriented Geodesign therefore provides a means to characterise the problems arising from the mismatch between resource demand and supply at different scales. It offers a systematic approach to produce and select different design scenarios, matched to the specific features of the sites and projects at different scales.

It is important to reflect if case study transferable and generalisable. That raises the crucial question of data availability (which is generally increasing, but not always of open access), but also of data management and responsible use. In the initial stages of the process, large numbers of maps were produced to better understand the spatial characteristics of the challenges of sustainability in Los Angeles and how they relate to the reticular organisation of the rail infrastructure. In the end, many of these maps and the information they portrayed were not used in the final micro-scale design phase, especially when constructing the final storytelling. This project is revolutionary in the sense that it has the courage to radically redesign and transform specific parts of the metropolis. Nonetheless, is is shy in that it will not alter the highly unequal social conditions of most of the inhabitants of this sprawling metropolis, structured as it is around a system that is dangerously wasteful of increasingly scarce resources.

The methodological contribution of this study is twofold. On the one hand, there is an emphasis on the importance of integrating great quantities of data in the design process, preferably open source. In this respect, the students' contribution was important because the documentary research and data-science work can be time-consuming. In practice, resource-intensive design processes might be compromised in order to save time. However, we emphasize that cutting on the reiterative analytical character of Geodesign is a mistake: it is in through this method that the initial question is carefully constructed and tested throughout the process, and without it, it would be more difficult to truly measure the challenge of sustainable urbanisation in Los Angeles. On the other hand, it should be noted that emphasizing sustainability aspects must also take greater account of the socio-spatial realities that inform the analysis of the context, shape the morphology of urban development and influence the performance of each neighbourhood scenario in the vicinity of a public transport hub. Finally, we are aware that this study, which navigates from the regional scale to the local scale, does not drop down to the scale of individual buildings and the spaces immediately around the subway station. This leaves room for future research that can more easily involve communities of current and potential residents and users of these districts, and hence accommodate participatory planning practices and human-centric design practices that account for the perspective of the station user.