

ISOBENEFIT CITIES

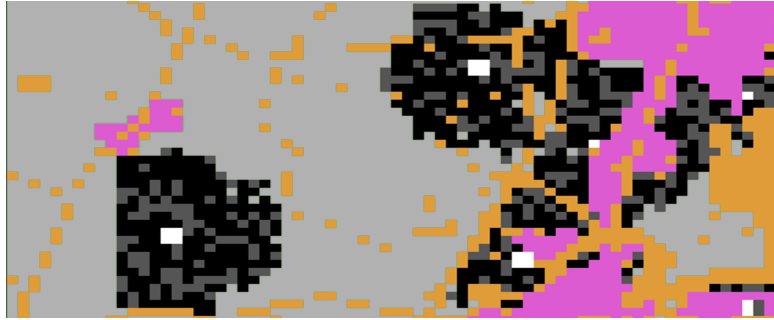
STEPPING INTO THE URBAN GROWTH LAB

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Supervised by Dr. Tommaso Gabrieli



ACKNOWLEDGMENTS



I would like to express my deepest gratitude to the Laidlaw Foundation and its dedicated staff for providing me with this incredible opportunity. Their support has allowed me the space to learn, explore, and innovate.

Stepping into this project has been an immensely enriching experience, having learned about a myriad of subjects and methods of exploration in the urban planning field.

I extend my heartfelt thanks to Dr. Tommaso Gabrieli for his generous guidance and unwavering patience throughout the research and output process. Additionally, I am grateful to all those involved in the Future Urban Growth Lab project, who introduced me to a wholly new perspective on urbanism and way of thinking.

ABSTRACT

ISO - A prefix that means "equal," as in isometric, "having equal measurements."

In the context of a growing global population and an increasing demand for green urban spaces, the concept of livable cities has gained significant attention. My research project, 'Stepping Into The Urban Growth Lab,' centres on the application of the isobenefit code to simulate potential evolutionary trajectories of urban growth in cities. Derived from cellular automata, this computational framework serves as a versatile platform for exploring emergent urban phenomena. Through the examination of these scenarios, the aim is to foster dialogues among urban planners, architects, and residents, with the ultimate goal of creating safer, more livable, and happier urban environments.

Project Background

How do we envision the cities of tomorrow?
And more crucially, how can we translate these visions into tangible urban environments?

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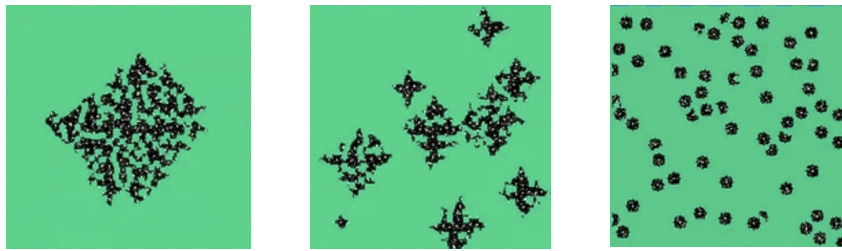
This is a question which was the seed to the Future Urban Growth Lab's research team whose objective was to operationalise an urban growth model prototype of cities for liveable futures.

Within a world with an exponentially growing population and desire for access to greenery, livable cities are becoming increasingly more discussed. Introducing walkable cities has become increasingly important in today's world due to a variety of interconnected social, environmental, and economic factors.

From an architectural point of view, through this project I hoped to understand the role of the wider context of the built environment.

The aim was to simplify and operate the model (initiated from the computational model "cellular automata") and apply the software to an actual city, in order to visualise different morphological scenarios and evolutionary rules.

The urban morphogenesis model operationalization would enhance sustainable city attributes within market dynamics and policy constraints, promoting increased daily interactions and reduced commuting, emissions, and car dependency.



Luca D'acci's and Michele Voto's Isobenefit simulation prototypes

Understanding the Isobenefit model

Walkable cities entail distances that allow easy access to everyday necessities from residences. These can range from shops to schools to hospitals, reducing the need for cars and simultaneously allowing for more green design of cities.

The Isobenefit model is a code through which a cell's state can be changed, based on set rules and restrictions, designed in a way to encourage more proportional and optimised growth of cities. These restrictions, (or parameters) can be taken from urban statistics of actual cities, breathing rational life into an abstract concept.

By running code with a series of different inputs, it helps us to imagine potential patterns of urban growth and population development.

The walking distance is determined by a key factor which is the T^* , a variable which represents the number of blocks/cells per walkable distance. This would mean that if there are 20 cells per 1 km, one cell would have an area of 50by50m (2,500m²).

This is a variable that decides the minimum distance between a centrality point and a house, or a house and an area of greenery.

This parameter is needed in urban planning using the isobenefit

In the code, two types of probabilities can be assigned. A **neighbouring centrality** can only be positioned next to a 'neighbour' (a cell considered a residential building),

while an **isolated centrality** has the flexibility to be placed anywhere within the constraints, not necessarily adjacent to existing developments. This distinction is significant because it accounts for scenarios where there is available land for city expansion that doesn't require high density. It works by providing on average a number of centralities per simulation, meaning if for example the isolated centrality is 2, there is an average of 2 isolated CP per run frame.

In cities where there are a lot of amenities, such as shops and schools, the need for them is smaller, therefore the situation can be tuned to have a higher probability of building spaces for inhabitants since there is a greater ratio of need for them, rather than setting more centralities. This is controlled by the **building probability** parameter. The amount of centrality points also indirectly navigates the density levels of a given area: since there are more centrality points, there are more opportunities for housing to be built.

Density and residential explanation

A crucial aspect of the simulations is the density of both the overall cell grid and the individual cells. These densities are controlled by various parameters, which can yield significantly different results. When applying the model to a specific location, these parameters become a determining factor in the simulations, as they allow for the utilisation of actual city statistics as input.

The **maximum population** (max-population) sets the building limit for the entire grid. Therefore, even if space is available but the maximum population is set too low, the construction will be limited to the number of inhabitants. This limitation is influenced by the **maximum density per square kilometre** (max-ab-km2), which plays a pivotal role in determining the spread of density.

For urban planners working with the Isobenefit model, the knowledge of these densities plays an important part in deciding what kind of building to introduce to that area. In a medium density area in the UK, there would be houses that accommodate up to 6 residents per 100m², for example. This can vary, depending on the density range of a specific location or the housing need for the area.

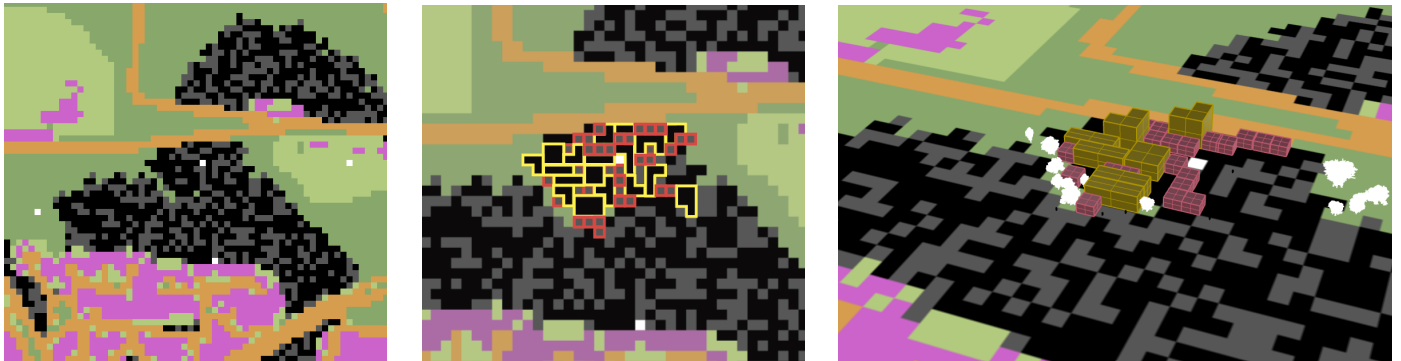
In my isobenefit model, there are 3 densities: high, medium, low, where the figure is 10% of the previous one. (high = 1, med = 0.1, low = 0.01), the probability of which I changed in the simulation to envision different scenarios depending on the actual future population growth. Each cell on the map corresponds to a specific land area, which changes depending on the scale of the map.



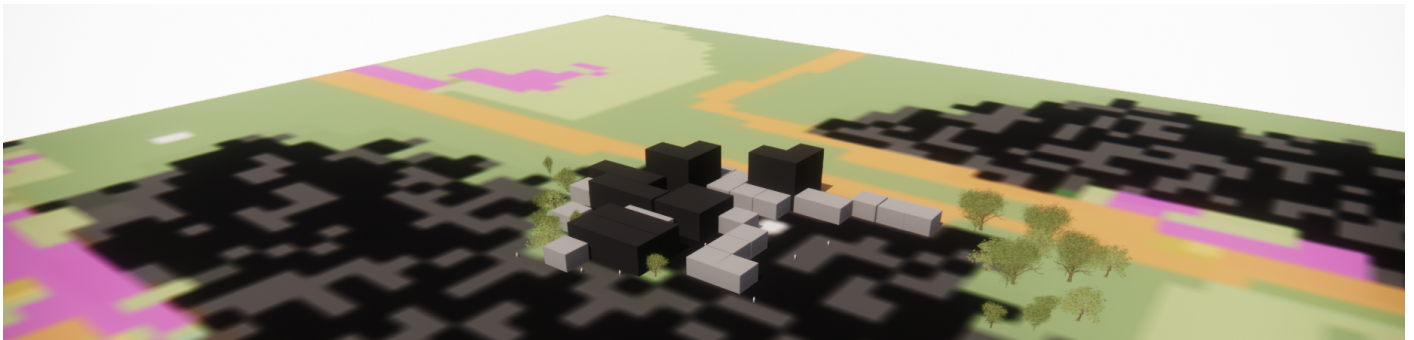
Left: Example High-Rise (For high Density)
Right: Example (small blocks of flats for medium density)
Bottom: Example (1-2+ family houses for Medium density)

When cells are larger with low density, for instance, at a scale of 1:1000 where each cell covers 1000 square metres, a lower population density is implied. This allows for various low-density housing configurations within the cell. Conversely, when cells are smaller, like 10 metres by 10 metres, each cell represents a single dwelling, such as a house. In high-density cells of this size, the structures must accommodate a greater number of residents.

From simulated cell growth I've imagined how the urban fabric might be planned out informed by smaller cells representing individual dwelling types by grouping clusters of the same density together:

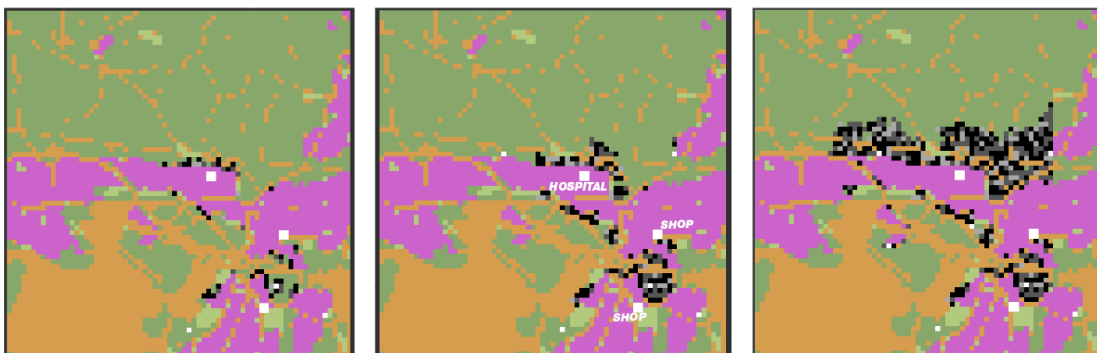


3D visualisation of types of residential buildings in the urban fabric:
Yellow- high density buildings; Red- medium density buildings



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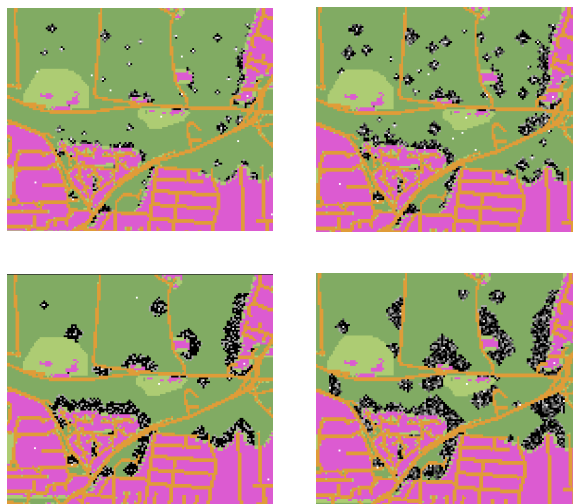
For the actual experimentation part of my research project, my initial tests were conducted on a larger scale, where each cell represented a larger area. This allowed for a greater number of residential buildings of the same type to fit within a single cell, forming clusters of the same building type.



This simulation was made on a larger scale, with 1 block representing 100m by 100m, gives a more general overview of the densities in the area, with the density levels [0.6, 0.3, 0.1.] This would mean at T* = 15, the walking distance is 1.5 km. (maximum population: 100,000, max ab = 1000)



Experimenting with the size of the cells, I found that keeping them at ten by ten metres, both allowed a more precise and straightforward planning of buildings on a smaller scale, and yet still left room for playful configurations of the buildings. In reality, this would not only allow the residential areas to be more varied and spread out, but also grants urban designers and architects the freedom to harmonise different-density buildings with the landscape, creating a more organic urban fabric. This way of organisation may also be useful when considering the planning restrictions, such as zoning restrictions, such as building heights or density limits.



The comparison of built growth with less centralities (represented by white squares) - [top] and more centralities [bottom]

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INTRODUCING DATA TO THE CODE - Applied Section

The isobenefit model code serves as a tool for conversation, a guide of communication between the urban planner, the architect and the wellbeing of the city and its inhabitants. For my project and my simulation outcomes, I have focused on a smaller system of urban growth, exploring my chosen area at different scales.

The city of Portsmouth in Hampshire, England was my prime focus of choice in exploring the isobenefit urban growth . In 2023, Portsmouth's population was 252,389, up from 219,700 in 2001, with an annual growth rate of 0.49%. It continues to grow with a medium destiny of 5,100, recorded from census data.

Looking at the walking distance of 100 metres, 250 metres and 400 metres, I wanted to observe the city's expansion at a more local scale. I have mostly focused on high and medium densities, considering the Portsmouth urban context and statistics: it is less likely to have a low density compared to the other instances.



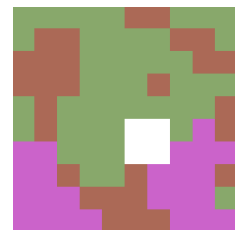


Context images
for geographic illustration



Experimentation

After exploring and understanding the original code by Luca D'Acci and how it can be manipulated, the first step was adjusting it so that it is able to read an image in order to apply the cell growth. I decided to approach this application part from a more visual side, so that the program reads different scales of darkness (which correspond to cell types) and then, after interpreting the image, it translates it to set it to easily-readable, colour-coded cell types and the urban growth.



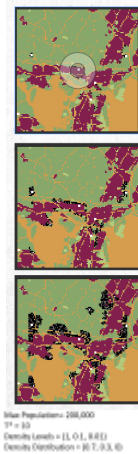
By refactoring some elements of the code,

```
def set_excluded(self):  
    self.built = False  
    self.centrality = False  
    self.nature = False  
    self.excluded = True
```

I was more easily able to refer to certain cell types and their states in the code, referring to them later when reading the map from a filepath, for example when certain areas are excluded from building but don't count as green spaces or neighbours (such as roads, or bodies of water.)

In order to manage inputting a “map” into the software, I had to manually redesign a raster map in order to make it monochrome and readable as pixels. This allowed me to start reconfiguring parameters in order to create different urban scenarios.

Hypothetical Simulations



- Centrality point** (*Shops, Restaurants, School, Libraries, Important Community Spaces*)
- Non-buildable areas** (*Not nature*)
- Already built areas** (*Neighbours*)
- Buildable Nature**
- Non-buildable Nature** (*Parks, local greenery*)

High density (7,300 ppl per km²)

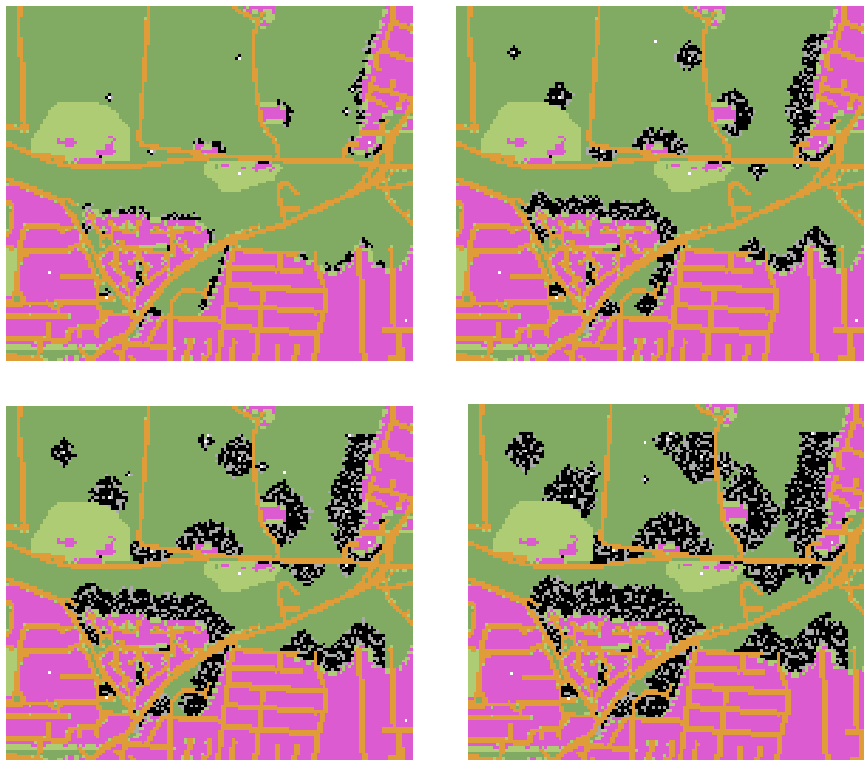


Medium density (5,100 ppl per km²)



In Portsmouth city, the population is rapidly rising, with 5,100 people per km². Below is a simulation with a set max population of 147,900, with the high density is 7300 people per km², while the medium density is 5,100. (setting the density distribution to (1, 0.1, 0.01)). In the edited visualisation, 1 block is 10m by 10m, the walkable distance set to 500m.

Case study 1.a



Max. Pop	Build Probability	Neighbouring-Centrality-probability	Isolated centrality probability	T*	Max-ab - km ²	Probability Distribution	Random Seed
10,000	0.8	5e-3	5	50	5100	(0.7, 0.3, 0)	43

Walkable distance; 500m (8min city)- Map context

This is an interesting example of a more optimal urban spread, with the blend of different densities, helping the city to breathe and find balance. This is due to the isolated centrality probability, allowing the building clusters to be spread out more.



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This trial illustrates how a smaller probability of isolated centrality points but high building probability can coordinate a lot of buildings being set around fewer centrality points.

Case study 1.b



In this scenario, I kept the density on high/medium as low indicates more of a countryside scale of density. The high density input with a low probability of centrality points results in larger clusters, which would require more transportation for good connections.

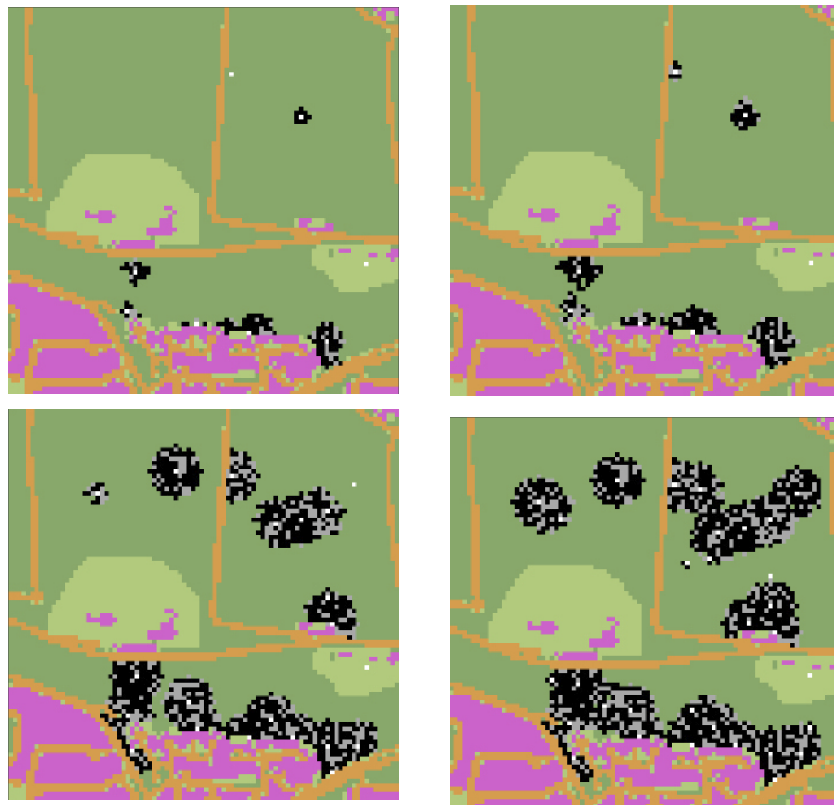
Land zoning could be especially important for urban planners to consider if there is a big cluster of the same population density. In such scenarios, it is essential to implement flexible land use zoning regulations that can evolve with shifting urban requirements. This adaptability allows for the promotion of mixed-use developments, which, in turn, nurtures dynamic and inclusive communities.

For areas characterised by tight density clusters, as seen in example 1b, local authority planners should place heightened emphasis on transportation systems within that region. This strategic focus ensures that despite the high density, all residents can enjoy equal access to essential amenities.

Max. Pop	Build Probability	Isolated-Centrality-probability	Neighbouring-Centrality-probability	Random Seed	T*	Max-a b- km2	Probability Distribution	Walkable distance
100,000	0.75	0.5	5e-3	77	25	5100	(0.5, 0.5, 0)	250m

A note to make when I was considering high-density cities, is that the growth happens much faster, and the grid is filled much sooner. This has to be taken into account so that the urban clusters don't merge .

Case study 1.c

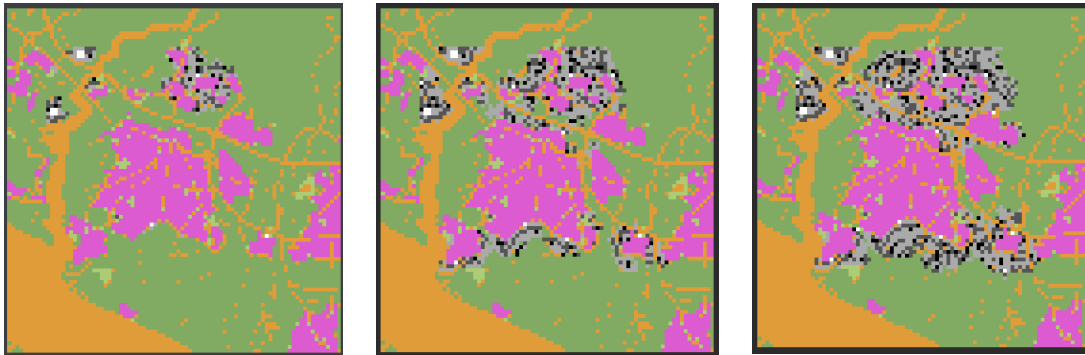


Max. Pop	Build Probability	Neighbouring-Centrality-probability	Random Seed	T*	Max-ab - km2	Probability Distribution	Walkable distance

10,000	0.7	5e-3	43	6	5100	(0.7, 0.3 , 0)	60m
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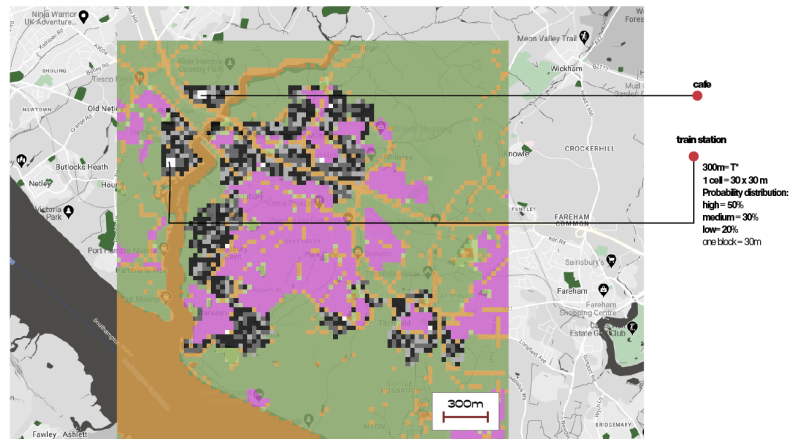
In this example, 60m would be the distance between an amenity/green space and a residential area. This could be useful for areas where there is a greater population of young families with babies/infants or for areas with a higher population of elderly residents who need quick access to care and daily necessities from the shops. A smaller T* (or distance to amenities) is also good to be taken into consideration for areas with higher density, as more residents require more amenities available in a smaller area.

Case study 1.d



Max. Pop	Build Probability	Neighbouring-Centrality-probability	T*	Max-ab-km2	Probability Distribution (Density) high/med/low
10,000	0.7	5e-3	10	1000	(0.1, 0.3 , 0.6)

In this case study, I tried making a hypothetical illustration of the low density growth, suggesting that the further out one goes from a core place of the city, the less dense it gets.



Case study 1.e



Max. Pop	Build Probability	Isolated-Centrality-probability	Neighbouring-Centrality-probability	Walkable distance	T*	Max-ab - km2	Probability Distribution (Density) high/med/low	Random seed
10,000	0.75	0.5	5e-3	400m	40	5100	(0.6, 0.4, 0)	7

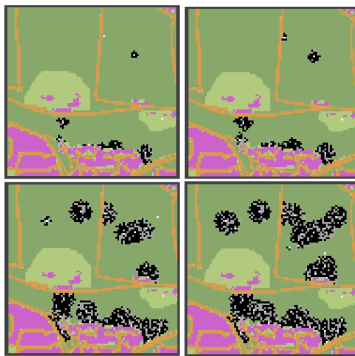
Case study 1.f



A greater T^* , like in the example above, could be helpful when thinking about more major amenities such as hospitals, which there would be fewer than shops. This small example shows a long walking distance with not as many centrality points, forming larger clusters. Because in a square with $T^* = 50$ there would be less need for centralities, but this could be altered by adding a higher probability for “isolated centralities”

Max. Pop	Build Probability	Isolated-Centrality-probability	Neighbouring-Centrality-probability	Walkable distance	T^*	Max-ab - km2	Probability Distributio n (Density) high/med/low	Random seed
10,000	0.5	2	5e-3	500m	50	5100	(0.5, 0.5, 0))	7

Case study 1.g i



Max. Pop	Build Probability	Isolated-Centrality-probability	Neighbouring-Centrality-probability	Walkable distance	T^*	Max-ab - km2	Probability Distributio n (Density) high/med/low
10,000	0.75	1	0.1	60m	60	7100	0.7, 0.3, 0

Case study 1.g ii



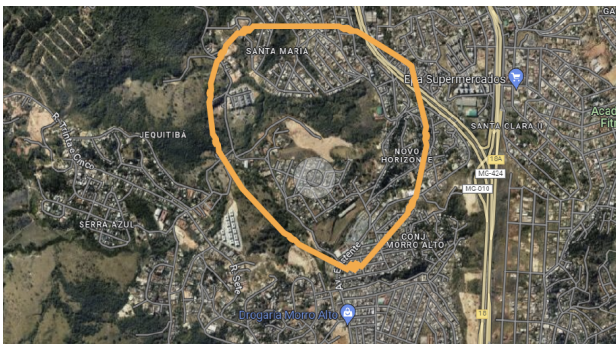
Max. Pop	Build Probability	Isolated-Centrality-probability	Neighbouring-Centrality-probability	Walkable distance	T^*	Max-ab - km2	Probability Distributio n (Density) high/med/low
20,000	0.75	1	0.1	250m	25	7100	0.6, 0.4, 0

Comparing these two simulations, I have experimented with the max populations and the green space and amenities distances. The top simulation gives more spread out and simulations that encourage green corridors to weave through the urban fabric.

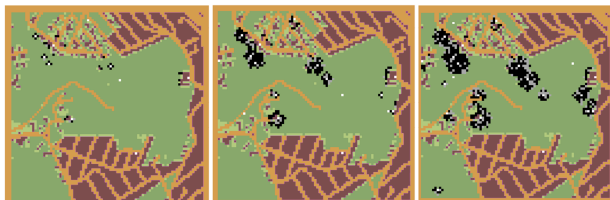
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Future Considerations

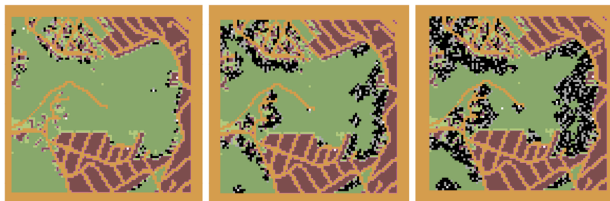
The beautiful thing about the isobenefit model is that it can be potentially applied to any chosen area in the world. This however, invites many different conversations relating to the given region, and the planning authorities would have to adjust the urban growth proposal to the needs of the citizens.



Below is a study of a Brazilian city, Belo Horizonte, which faces sprawl issues similar to UK cities, however also other issues such as informal settlements, which urban planners would have to take into consideration.



T* = 5



T* = 20



T* = 50

The isobenefit model would be helpful to the Belo Horizonte region because it can help face challenges regarding urban design and growth. Because of the more proportionate suggestions of the software, it can aid to develop comprehensive urban plans that consider challenges the area faces, especially environmental concerns, traffic congestion and informal settlements.

The isobenefit approach by considering the connection to different important facilities would also face the issue of access. In regions lacking robust transportation infrastructure, facilities like schools can become practically inaccessible, a challenge the model aims to address.

This prompted me to contemplate the definition of 'greenery.' Access to a well-maintained green park significantly differs from access to unmaintained green spaces, which, in the real world, must be taken into account to achieve a fair and optimised urban design.

This isobenefit project also sparks questions of convincing retailers to moving into new areas. It would require investment and time, but perhaps this application alongside existing planning decisions which are complex, institutional and political could be a catalyst for a greener and safer future of cities and its inhabitants.

Conclusion

The isobenefit simulations discussed in this research paper, currently are serving as a catalyst for conversations for urban design proposals. As we become an increasingly urbanised planet with 75% of the globe living in cities by 2050, it is crucial to have a more optimal and proportional way of guiding urban development. This is vital in order to control urban sprawl in order to protect green spaces and combat air and water pollution.

This research project, in fact, marks just the beginning of an exciting journey. As I wrap up this summer project, I find myself leaving with more questions than I had when I started. It's invigorating to think about its potential to evolve into something

incredibly beneficial with continued research and dedication, and with the different routes of approach finding solutions to current and future urban growth issues.

Reflections

I'm immensely grateful for the opportunity I had this summer, delving into the potential future of cities. The research, engaging discussions, and hands-on experiments not only provided me with insights into spatial modelling and coding but also kindled my passion for this topic and its related subjects. The discussions with my irreplaceable tutor encouraged me to push boundaries between the abstract and reality.

It has revealed the deep connection between my field of study and this research project. This experience has inspired me to approach my current and future architectural work with a heightened focus on resource efficiency, compact design, regulatory compliance, and, perhaps most importantly, community connectivity. The Laidlaw research opportunity not only allowed me to expand my technical and scientific skills, but also enhanced my ability to adapt to challenges and my problem solving skills and approaches.

What I found particularly beautiful and enticing about this method of planning, was the balance between the randomness of the cells (similar to mimicry of biological organisms) and the analytical proposal from a computational model.

Optimised urban planning that opposes urban sprawl is essential for architects and architecture projects because it aligns with sustainability, community well-being, economic viability, and regulatory compliance.

Sources:

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