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Morphogenesis of Isobenefit urbanism: Isobenefit-cities simulator

Luca S. D'Acci [a,b,*], Michele Voto [c]

[a] Polytechnic of Turin, Interuniversity Department of Planning, Regional and Urban Studies (DIST), Italy
[b] Erasmus University Rotterdam, The Erasmus Happiness Economics Research Organisation (EHERO), Netherlands
[c] Cerved Group Spa, Italy

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ABSTRACT

Isobenefit Urbanism is a spontaneous-guided planning approach based on a morphogenetic code inducing a walking city where one can reach within 1–2km: natural land, shops, amenities, services and places of work. We present the alpha version of a python code for the simulations of Isobenefit urban morphogenesis. It is a code to simulate urban growth scenario by modifying as one wishes the values of the parameters. The latter are related to densities, surface, population size, random factors and built probabilities. This urban growth model results in nearly infinite outputs all satisfying the Isobenefit urbanism objective function.

Code metadata

Current code version	v1
Permanent link to code/repository used for this code version	https://github.com/ElsevierSoftwareX/SOFTX-D-21-00102
Permanent link to reproducible capsule	https://codeocean.com/capsule/1568330/tree
Legal code license	MIT
Code versioning system used	git
Software code languages, tools and services used	Python 99.5%; Makefile 0.5%
Compilation requirements, operating environments and dependencies	required packages are listed in the requirements.txt file in the repository
If available, link to developer documentation/manual	https://github.com/mitochevole/isobenefit-cities/blob/master/README.md
Support email for questions	luca.dacci@polito.it

1. Motivation and significance

"One Size Fits All" is often the major failure of paternalistic policies. Conversely, a pure libertarian laissez fair could mislay long term and collective costs-benefits and lack the adequate knowledge to measure them or even be aware of them. The libertarian paternalistic approach I will present, aims to embrace both aspects allowing a certain freedom of individual choices and market forces, while under a benevolent scientifically-educated guide.

Cities evolve their size, shape and function by following internal and external forces such as demography, work places, real estate markets, societal needs-choice, regional-national-international networks, history, politics, technology, preferences, planning, spontaneous emergence, geography, climate, orography and randomness.

An immense literature using cellular automata for urban growths has been consolidated [1–5] after earlier models started three decades ago [6–12].

Urban morphogenesis [13–17] is a theme whose investigations is becoming more critical than ever due to the unprecedented and contemporary magnitude and speed of world population growth and urbanisation.

Based on the Isobenefit Urbanism morphogenesis code [18], we built a first simplified version of an urban e-planning tool useful for land use policies to generate walkable and sustainable urban settlements. Urban utopia [18–28] can, on occasion, provides worthwhile solutions and visionary ideas for our practical management and transformation of existing urban environments or for building new ones.

Isobenefit Urbanism is a model of libertarian paternalistic approach. It is a morphogenetic code to induce an X-minute

* Corresponding author at: Polytechnic of Turin, Interuniversity Department of Planning, Regional and Urban Studies (DIST), Italy.
E-mail address: luca.dacci@polito.it (Luca S. D'Acci).

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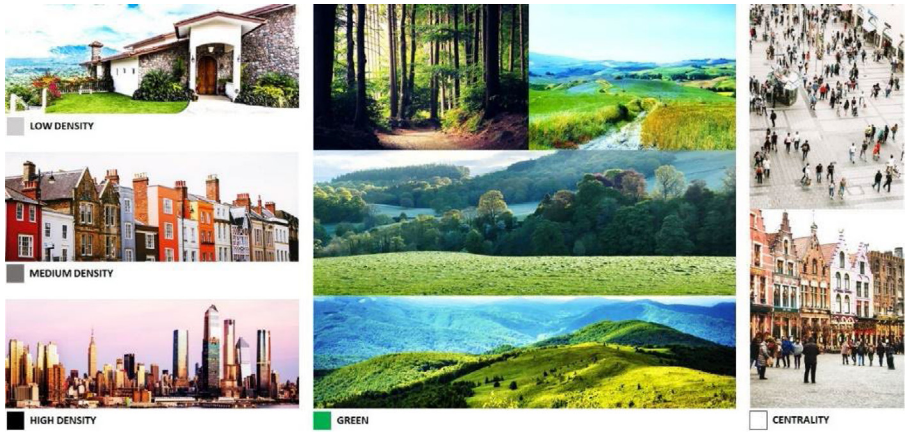

Fig. 1. Visual example of Built cells sub states, Green and Centrality cells. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Source: Images from https://unsplash.com.

walking city (introduced since 2013: "The Isobenefit Urbanism approach aims to create cities in which each dweller can do her/his usual main daily activities by walking or at maximum biking" [29] within 30 min walking/10-15 min biking) where one can reach within 1–2 km[1] natural land, shops, amenities, services and places of work. It does so by leaving free the actual urban development and growth to follow spontaneous random – or locally/collectively desired – patterns of functional locations and of density across the urban planimetry liberally driven by market forces and/or genius loci. The outputs are in fact very numerous, though all satisfying the design objective function. Any of such urban morphological patterns, by evenly and walkabily mixing urban and natural land, reduces urban heat island effects, flooding and particulates, and their walkable daily life settlements imply a carless urban society with the related advantages in terms of air and noise pollution, commuting time, space saving, aesthetics, and ultimately physical and psychological wellbeing.

I sketch the five transition rules of the Isobenefit cellular automata:

1. Each citizen reaches within 1–2 km: (a) a centrality; (b) a green area;
2. (a) buildings are close to each other and interconnected, (b) green areas are interconnected and at least 1 continuous sq. km main size.

Centralities are here intended as multifunctional places where to find a variety of services, amenities, functions (e.g. shops, restaurants, libraries, workplaces, universities, theatres, promenade, vibrant streets, history…). They are interconnected via sky-trains, underground and cycle paths.

Regarding point 2b, the green here intended is a ranging from urban parks to agricultural (with public paths) land and wild forests. These green cells are physically interconnected, while the built cell physically and/or by public transport lines.

Therefore, the urban cells can have three states: green, built and centrality, whose size can be decided by the modeller via the interface window (Fig. 3). The simulations in this paper consider a square cell of 200 meters' size.

This cellular automaton uses three sub states of the cells "Built" (Fig. 1): High density: black, Medium density: dark grey; Low density: light grey.

Starting from an initial scenario (e.g. all green land apart from a small group of houses in the centre) we see the evolution along time according to the above five rules.

[1] Elsewhere is indicated 1 mile, or 2–3 km.

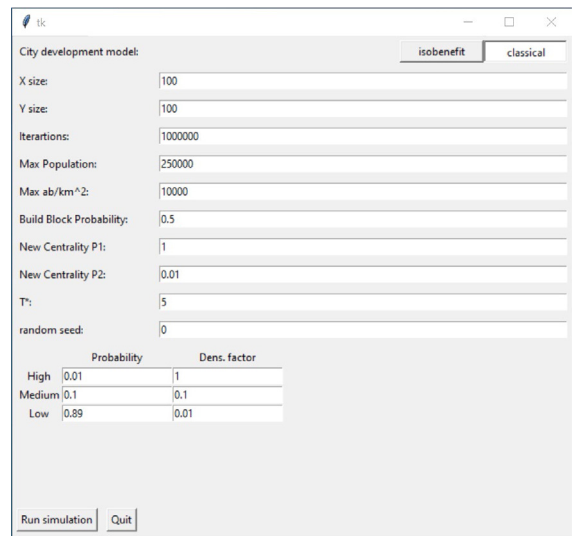

Fig. 2. Simulator parameters window.

It can take nearly infinite paths, as per each step of the evolution if several alternatives satisfy each of the five rules, a random component would decide which alternative to select.

This "top-down" simple code enables infinite "bottom-up" spontaneous forms and many different ways to keep natural/rural lands we have in alternative to the green belt geometrically strict zooning policies.

The flexibility and endlessly that this dynamic and malleable growth process can allow is relevant in an era of fast urbanisation and perpetual changes.

I list some practical utilities of the Isobenefit cellular automata spatial output: to keep a constant relationship between built and green areas regardless urban sizes; to maintain a walkable distance from residences to services, workplaces, green areas and amenities in any point within a city regardless its size; to enjoy economies of agglomeration while limiting their diseconomies; to have a flexible urban growth form without spatially prefixed designed shape, size, and land use; to mitigate the pressure posed from constrains like green belts by avoiding urban sprawl and green land consumptions in an alternative way.

While some of numerous indirect benefits involve the reduction of: urban heat island effect, flooding for over cementification, congestion, car dependence, pollution and emissions from road traffic, distance from natural land, dormitory areas and over extended mono-functional urban areas, peripheral areas with poor accessibility to services, green and amenities, daily commuting times, spatially disadvantaged urban location of the poorest, psycho-physical healthier environment.

2. Software description

Once opened the simulator parameter window (Fig. 3), there is the opportunity to indicate the value of several parameters whose meaning is:

X size and Y size: set the size of the map in X and Y direction in terms of number of cells.

Iterations: is the maximum number of iterations (if the maximum population is not reached yet, it will stop anyway)

Max Population: is the maximum population the simulation will reach (if there are still iterations left, it will stop them anyway).

Max ab/km^2: is the maximum population density of a cell in terms of inhabitants per square kilometres. The "isobenefit" and "classical" (Business as Usual) "City development model" selectable on the top right icons of the window will distribute the density of each cell as following: the "Max ab/km^2" sets the density of the high density cell (black cell); then other two type of cells will be automatically generated, the medium density (dark grey) having ten times less density than the black, and the low density (light grey) having 100 times less density than the black. Under the "classical" (Business as Usual) city development model, 1% will be high density, 10% medium and 89% low (at each iteration a low cell has 10% probability to become medium, and a medium 1% probability to become a high), while under the "isobenefit", 70% high density and 30% medium (namely the average population density is Max*0,73).

For the next simulations, unless it is indicated otherwise, we consider the above values of probabilities and density factors, but there is also a window to manually control the desired values of density factors and related probabilities.

Build Block Probability: is the probability of building a new urban block (provided that all the other conditions for constructions are satisfied). The closer to 0 the less geometric the output

New Centrality P1: is the probability of creating a new centrality adjacent to built areas. New Centrality P2: is the probability of creating a new isolated centrality. For the Punctiform City P1 is 0 and P2 is 1

T*: is the walkable distance (in terms of number of cells) within which centralities and green cells must be reachable from any built block; it indirectly sets the real size of a cell. Considering an average walking speed of 4 km/h (67 m/min), a 10-minute walking distance means 670 m, therefore by setting T*= 1 would mean that 1 cell is 670 m, if T*= 5 a cell is 134 meters' size. If we assume a 15-minute walking distance (around 1 km), T*=1 would mean that a cell is 1 km, and T*= 5 would mean that a cell is 200 meters' size.

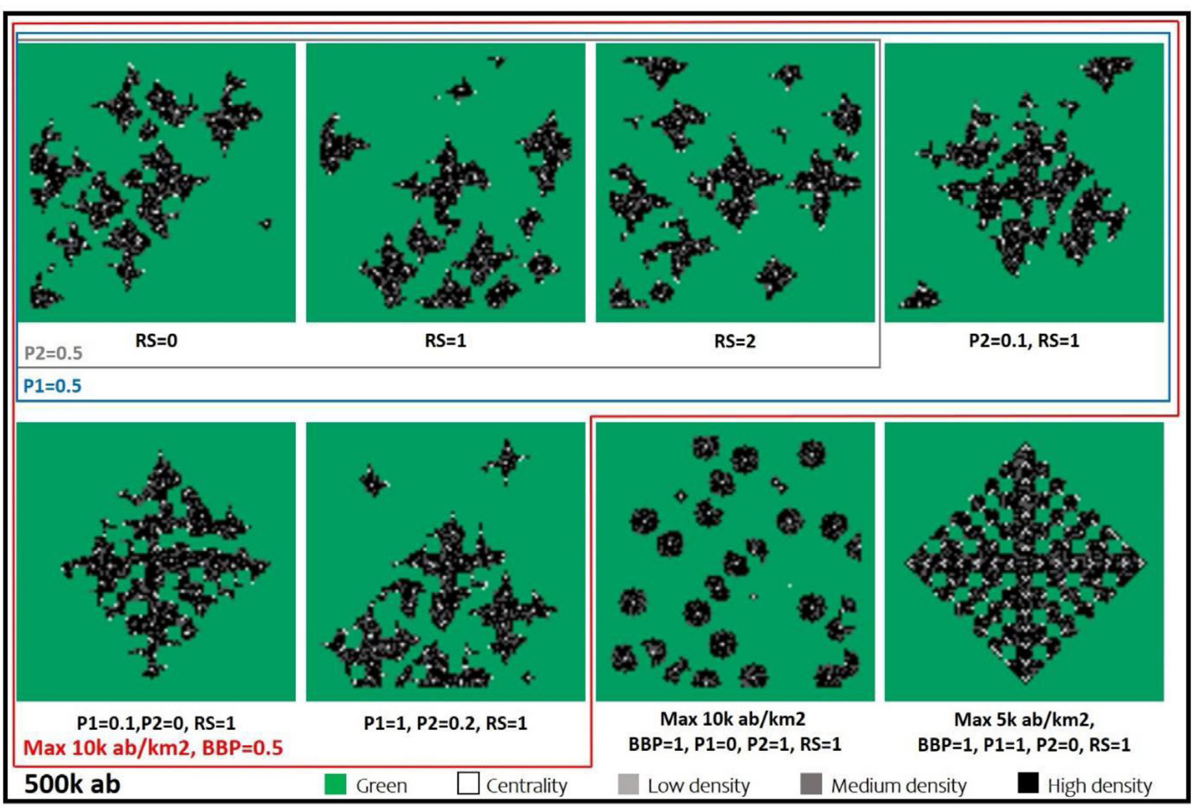

Fig. 3. Scenarios under different parameters' values. Centralities (white cells) are interconnected via sky-trains, underground and cycle paths.

Random seed: it sets the pseudo-random number generator: a same random seed value generates a same random number.

From a given population and densities, by changing the values of the parameters (Fig. 2) we obtain nearly infinite scenarios all satisfying the code, even when holding fixed all of them and altering only the random seed; the latter may be conceptually compared with random circumstances and decisions at local level in time and specific places, which, even under identical policies and even "identical" orography, would inevitably generate different outputs.

3. Illustrative examples

Fig. 3 shows an example of eight scenarios emerging from different parameters, sometimes only slightly different, or even identical apart from the random seed. The parameters for these eight scenarios, as well for Fig. 5, are randomly selected with the aim to illustrate, graphically and numerically, how an identical code (the Isobenefit urbanism "genotype") generates different scenarios (phenotypes) all satisfying it. The third scenario on the bottom of Fig. 3 represents a Punctiform City [18] while the others represent variations on various degree of physical continuity-discontinuity of the built cells.

Fig. 4 shows a comparison between a Business as Usual urban growths and isobenefit ones having the following values for the parameters: X size = 100; Y size = 100; Iterations = 1000; Max Population = 250 ·000; Max ab/km^2 = 10 ·000; Build Block Probability (BBP) = 0.5; T^* = 5, and with different values of P1, P2 and random seed.

Fig. 6 indicates the average and maximum distances from the built cells to the closest natural cell and to the closest centrality cell, for the last scenario (top part of the figure: 250 thousand inhabitants) and for each time step where to population gradually increases at each step from 0 inhabitants to 250 thousand.

Using the same density for every cells for both, the Isobenefit simulation and the Business as Usual, we can compare even more directly the different spatial outputs under identical parameters: population, density, total surface, BBP, P1, P2 and random seed (Fig. 6). These types of simulations are also offering a visualisation and quantification of the spatial benefits of semi-controlled morphogenesis, as the Isobenefit ones, in terms of distances from centralities (meaning services, amenities, workplaces, public transport) and from green areas to residences. The latter is a determinant factor for daily green contact, vibrant and walkable human settlements, regardless their sizes and densities.

4. Impact

New research questions which can be pursued as a result of this software are related to how spontaneous growth at micro-level can be linked with macro-rules and how identical rules can generate different outputs.

The pursuit of existing research questions around sustainable urban forms and, especially, their generation is substantially improved via the possibility of playing with keys parameters which this code enables.

This software can change the daily practice of its users (urban planners, government departments, scholars) thanks to its relatively easy platform and free availability which allow its use for urban planning consideration for policies decision making processes.

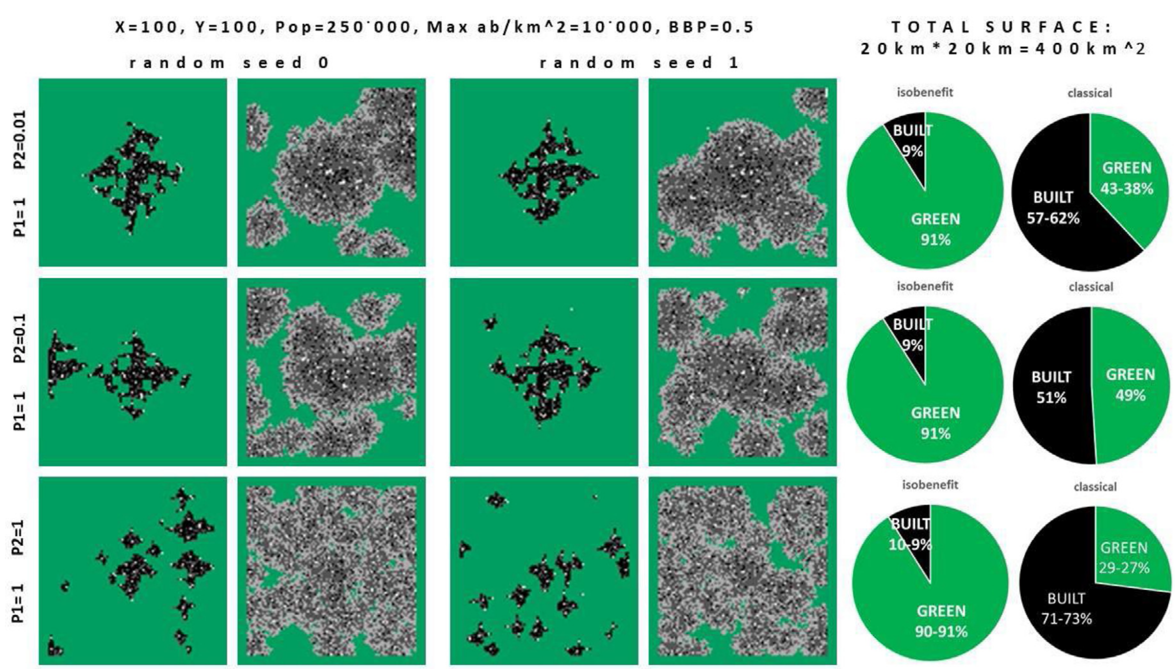

Fig. 4. Business as Usual, on the second and fourth column, versus Isobenefit cities holding constant total area (20 km*20 km) and population size (250 thousands), for T^* = 5 (15 min walking, 1 cell = 200 m). Cell legend: white=centrality; black=densest built; dark grey=medium dense; light grey=low dense; green=green land. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

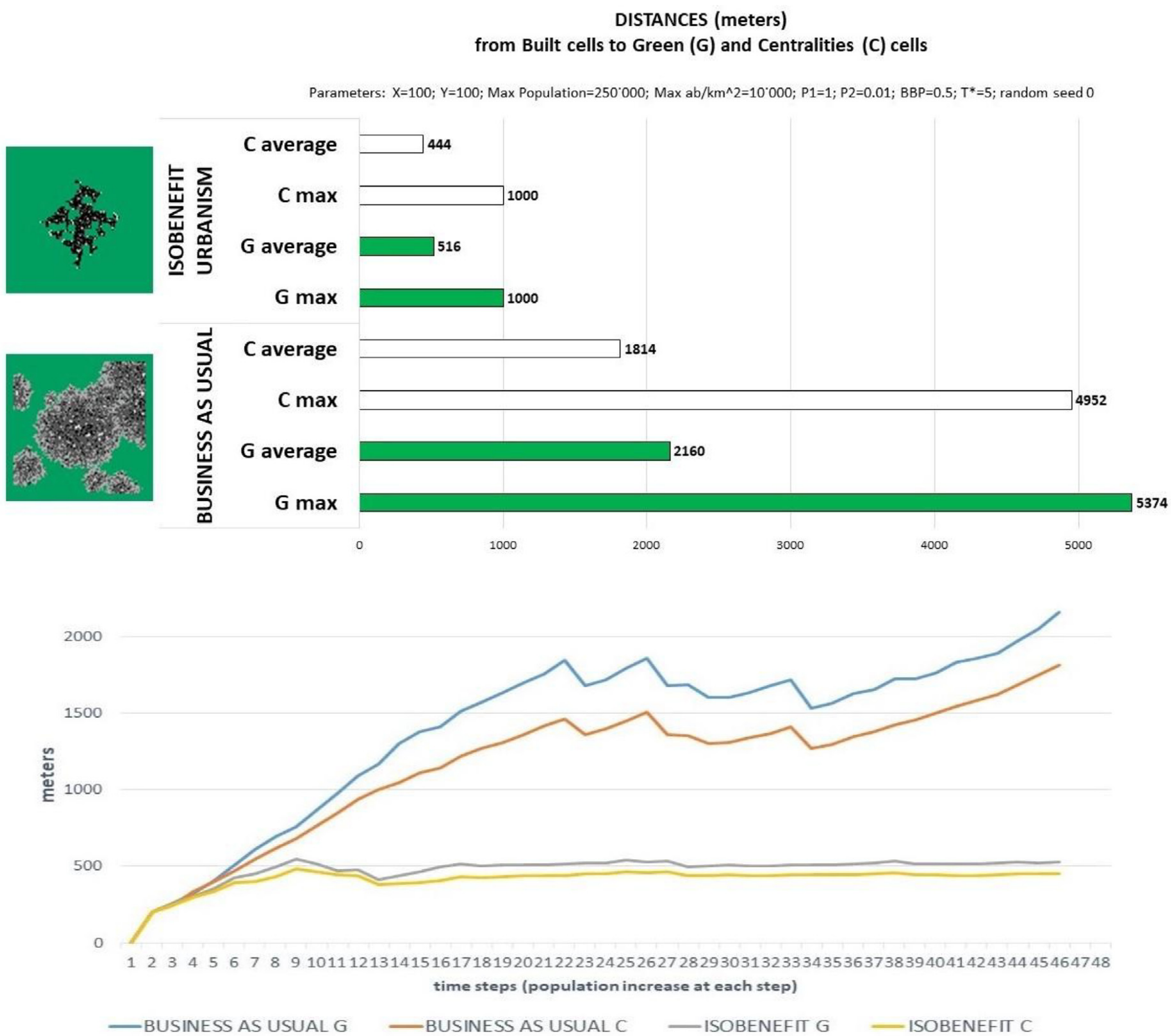

Fig. 5. Distances from Built cells to their nearest Green and Centralities cells.

5. Conclusions

The intention is to give everyone access to the code in order to play with parameters as they like and studying the diversity of scenarios resulting. This is the alpha version; lot of improvement are possible. The next step[2] would be to link it with GIS to carry on Isobenefit urbanism simulation on real territories and context. The ambition is to pack a toolkit for government and urban planners, as well as scholars of different disciplines, to use in both practical decision making for territorial transformation and urban growth policies, and theoretical considerations.

Useful simulations could be conducted for investigating phenomena such as urban heat island, flooding, commuting, air pollution related to the latter, and so on, in connection with different type of urban forms and function distribution.

[2] Currently being tested at the University College London under an UCL Grand Challenges Small Grant (https://github-pages.ucl.ac.uk/BSP-isobenefit-urbanism/).

CRediT authorship contribution statement

Luca S. D'Acci: Conceptualization, Methodology, Supervision, Project administration, Investigation, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Michele Voto:** Software, Data curation, Validation, Software methodology.

Declaration of competing interest

No conflict of interest exists: we wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Data availability

No data was used for the research described in the article

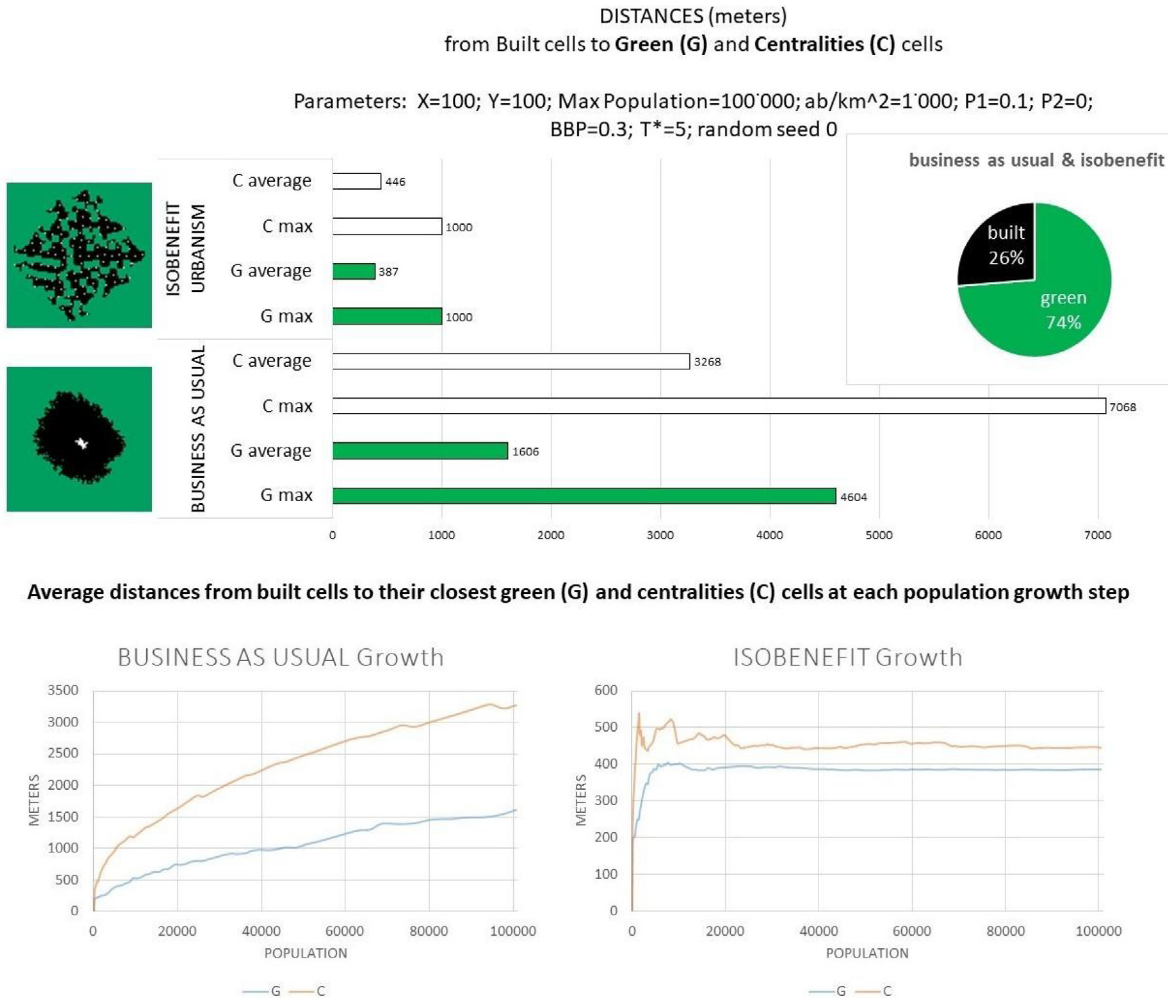

Fig. 6. Distances from Built cells to their nearest Green and Centralities cells with identical parameters and densities scenarios.

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