IHS
Making cities work

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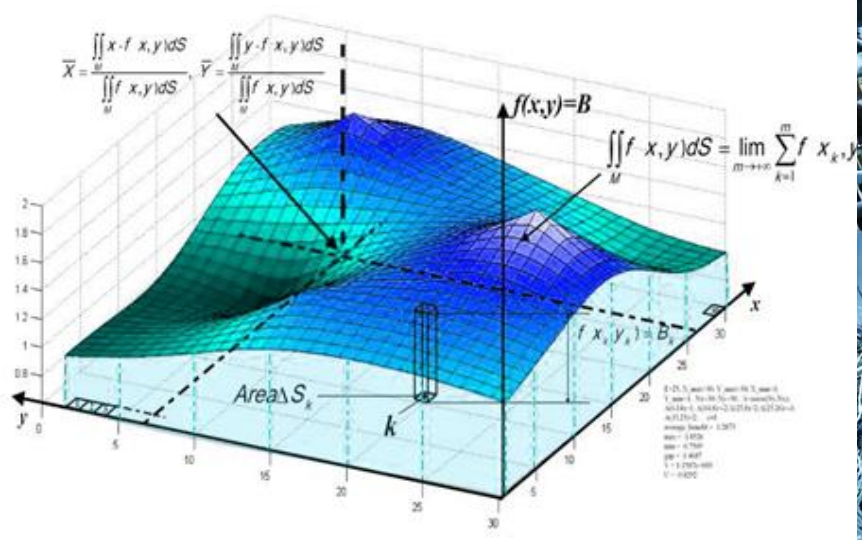
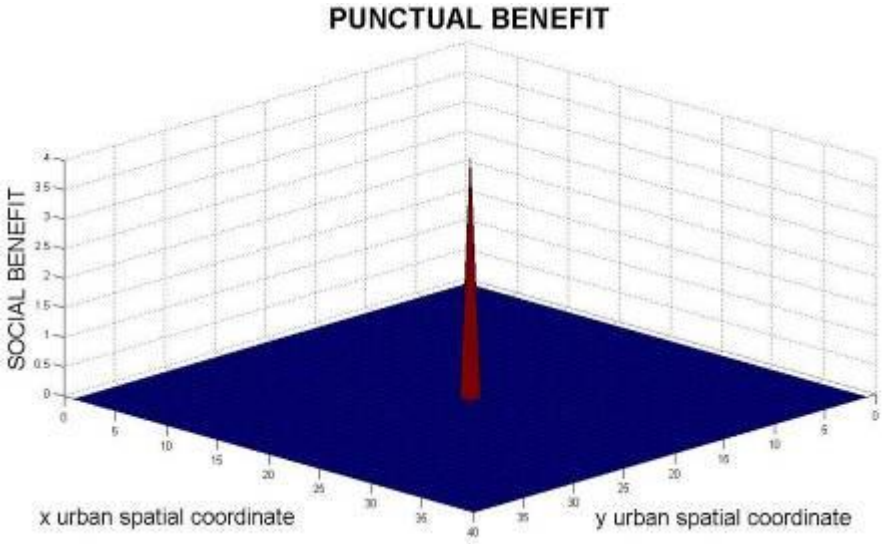
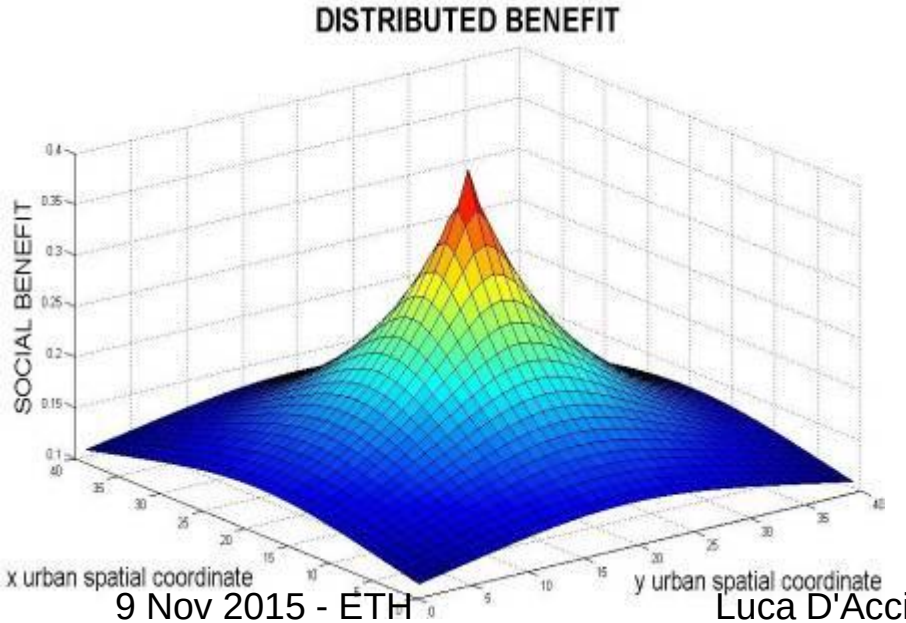
ISOBENEFIT LINES

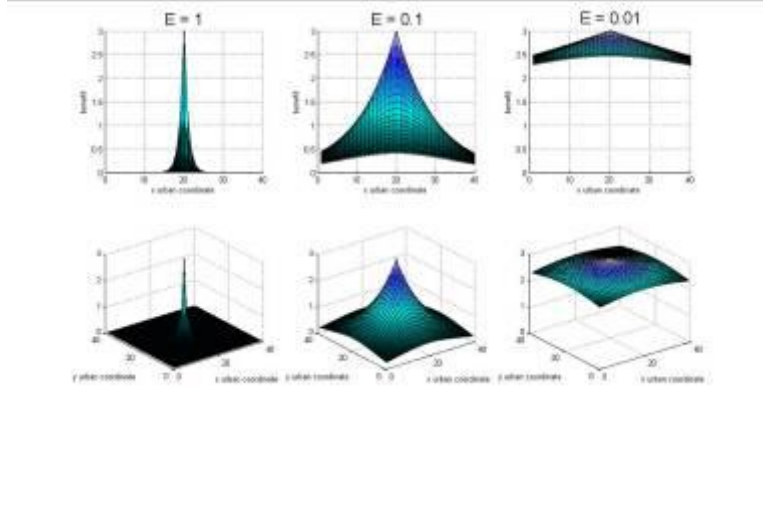


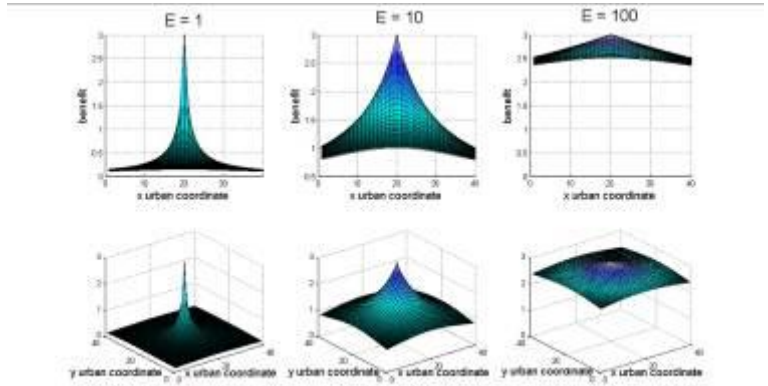


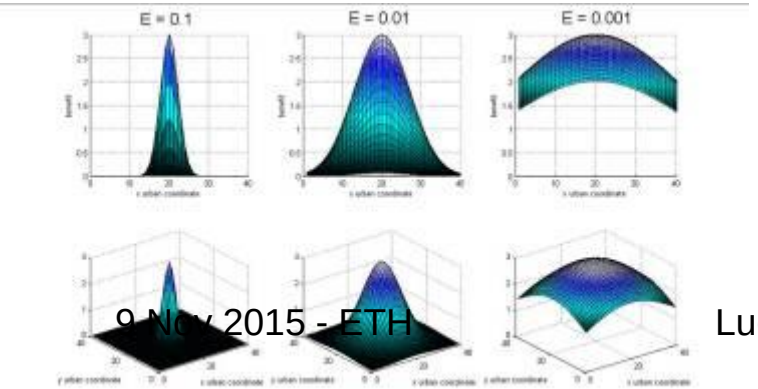
the benefit you receive
when you are ***directly*** enjoying the amenity



… how this benefit ***flows*** throughout the city:
how easy, cheap, pleasant is to reach the amenity







$$B_t = \sum_{i=1}^{n}\sum_{k=1}^{m} B_{i,k} = \sum_{i=1}^{n}\sum_{k=1}^{m} A_i \cdot M_e / (d_{i-k} + M_e)$$

$$B_t = \sum_{i=1}^{n} B_i = \sum_{i=1}^{n} \int_{a_i}^{b_i}\int_{c_i}^{d_i} \left\{(A_i \cdot M_e)\cdot[((x-x_i)^2 + (y-y_i)^2)^{1/2} + M_e]^{-1}\right\} dxdy$$

$$a_i = x_{\min} - x_i \qquad b_i = x_{\max} - x_i$$

$$c_i = y_{\min} - y_i \qquad d_i = y_{\max} - y_i$$

$$Bd_i = \sum_{k=1}^{m} (A_i \cdot M_e)\cdot[((x_k - x_i)^2 + (y_k - y_i)^2)^{1/2} + M_e]^{-1} = \sum_{k=1}^{m} \left\{z \middle| z = f(x_k y_k) \middle| x_k \in X_i, y_k \in Y_i\right\}$$

$$f(x_k y_k) = (A_i \cdot M_e)\cdot[((x_k - x_i)^2 + (y_k - y_i)^2)^{1/2} + M_e]^{-1}$$

$$X_i = (1 - x_i, x_{k\max} - x_i)$$

$$Y_i = (1 - y_i, y_{k\max} - y_i)$$

$$x_k, y_k \in \mathrm{N}$$

$$x_i, y_i = n \in \mathrm{N} \mid n > 0$$

$$m_{xy} = B_k = \sum_{i=1}^{n} (A_i \cdot M_e)\cdot[((x_k - x_i)^2 + (y_k - y_i)^2)^{1/2} + M_e]^{-1}$$

$$B_t = \sum_{i=1}^{n}\sum_{k=1}^{m} (A_i \cdot M_e)\cdot[((x_k - x_i)^2 + (y_k - y_i)^2)^{1/2} + M_e]^{-1}$$

$$SB_t = \sum_{j=1}^{r} D_j \cdot B_{t,j} = \sum_{j=1}^{r}\sum_{i=1}^{n} D_j \cdot \int_{a_j}^{b_j}\int_{c_j}^{d_j} \left\{[A_i \cdot M_e]\cdot[((x-x_i)^2 + (y-y_i)^2)^{1/2} + M_e]^{-1}\right\} dxdy$$

$$DBC = \sigma M / \overline{M} = \sqrt{\frac{\sum_{k=1}^{m}(B_k - \overline{B})^2}{m-1}} \Bigg/ \frac{1}{n}\sum_{i=1}^{n} B_i$$

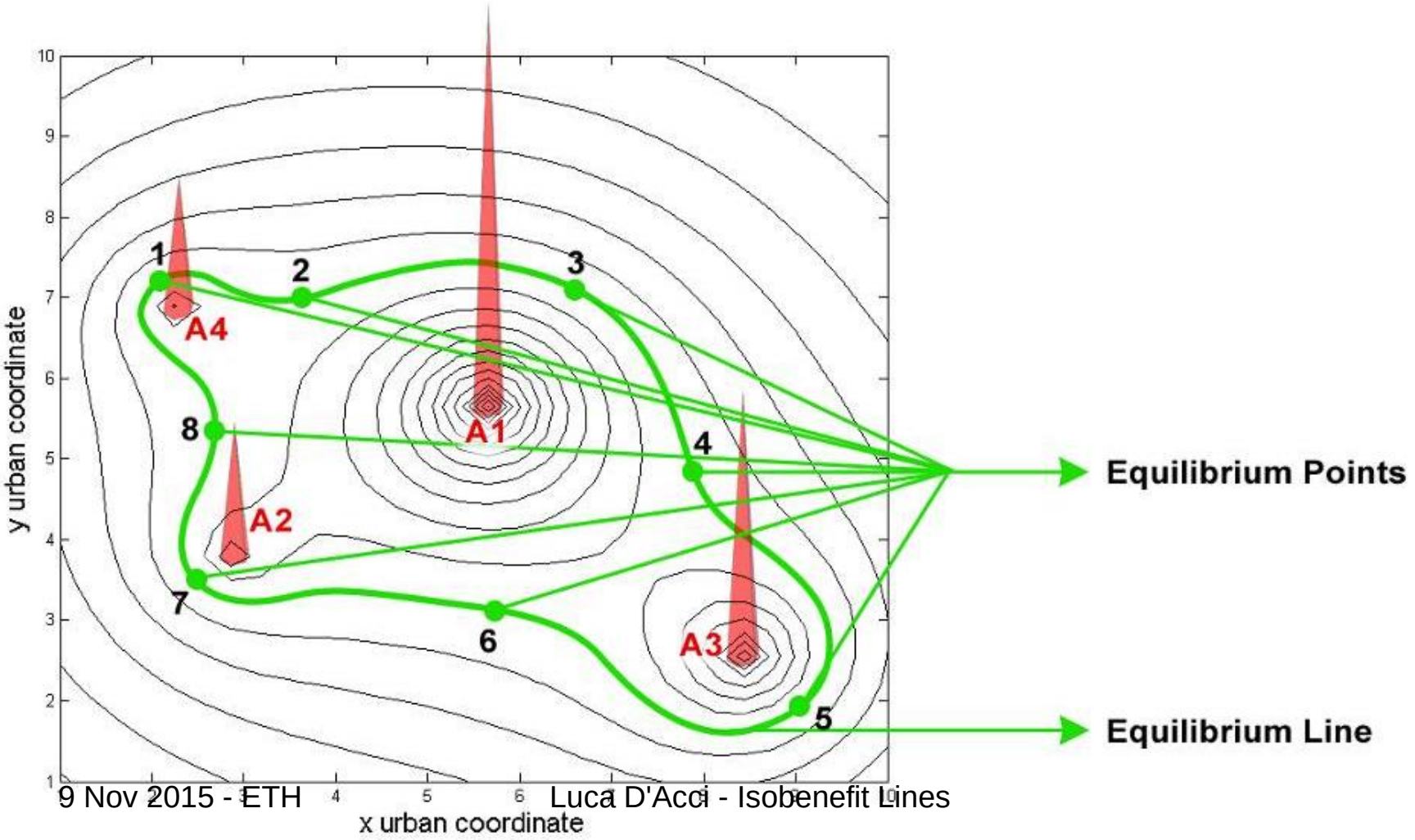
$$P = \sum_{k=1}^{m^*} v_k$$

$$m^* = x\%m, m^* \in \mathrm{N}$$

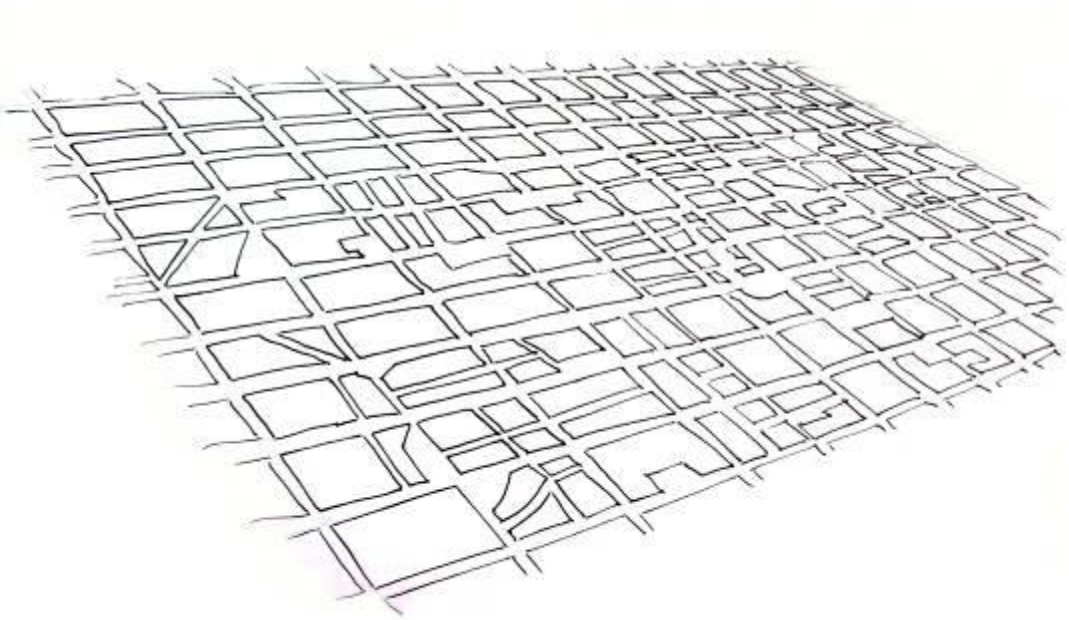
The benefit of a point *k* received from an amenity *i* distant *d*, and with a level *A* of attractiveness, is given by:

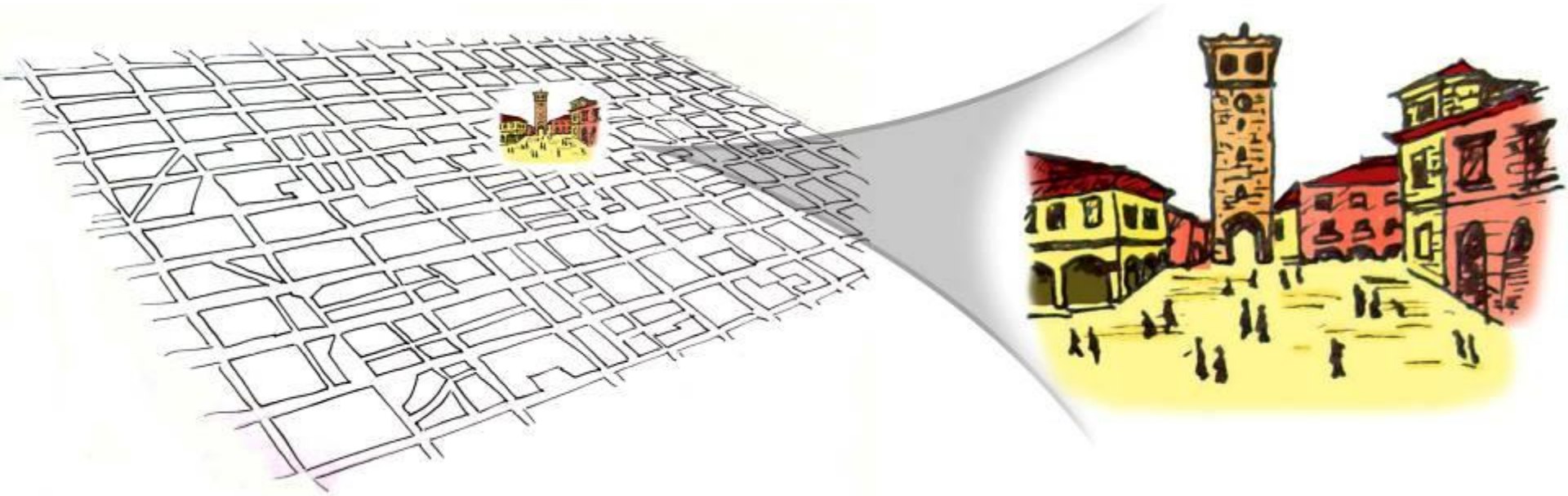
$$B_{i,k} = \frac{A_i}{1 + (d_{i-k} / E)}$$

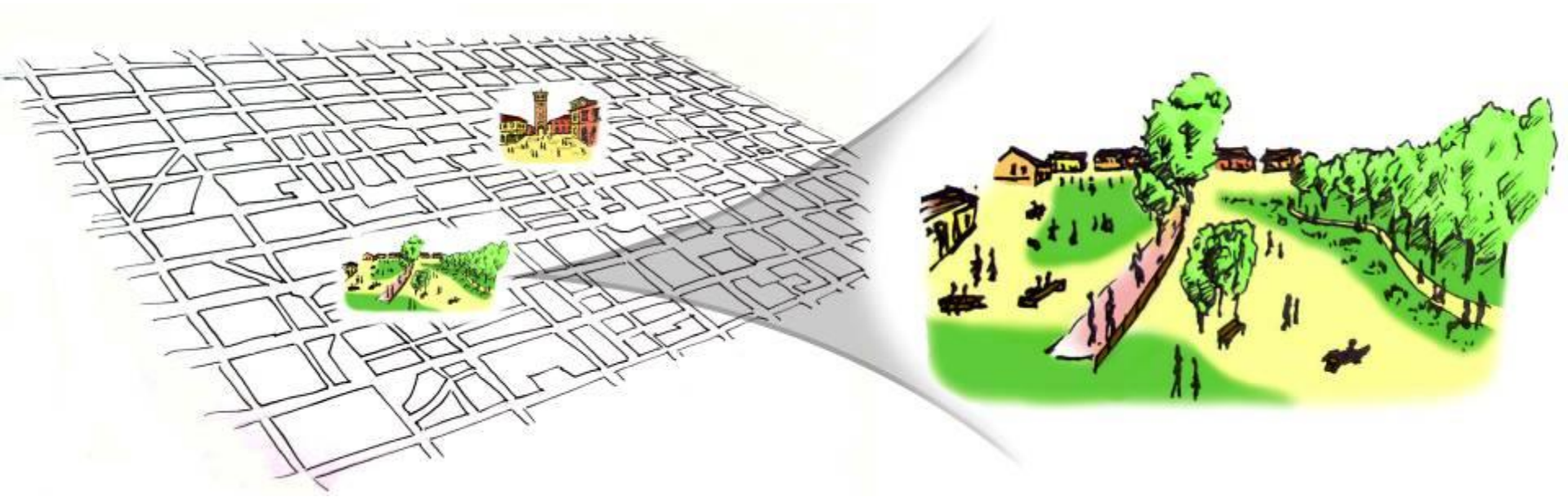
The Isobenefit Lines join the urban points with equal levels of benefit given from urban amenities

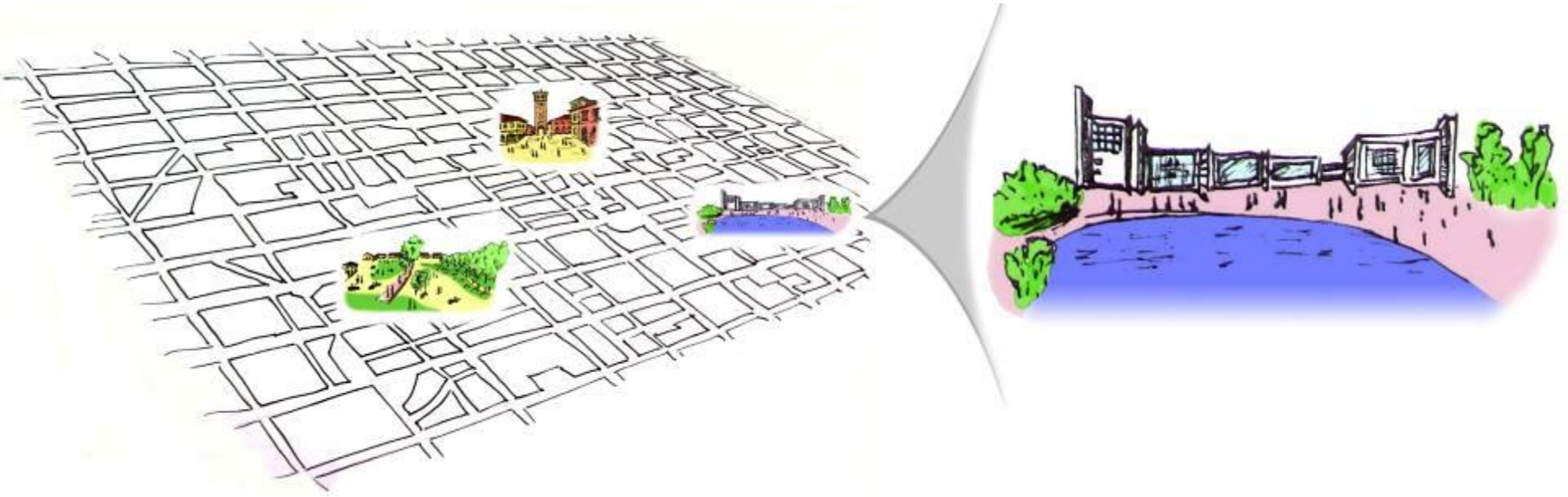


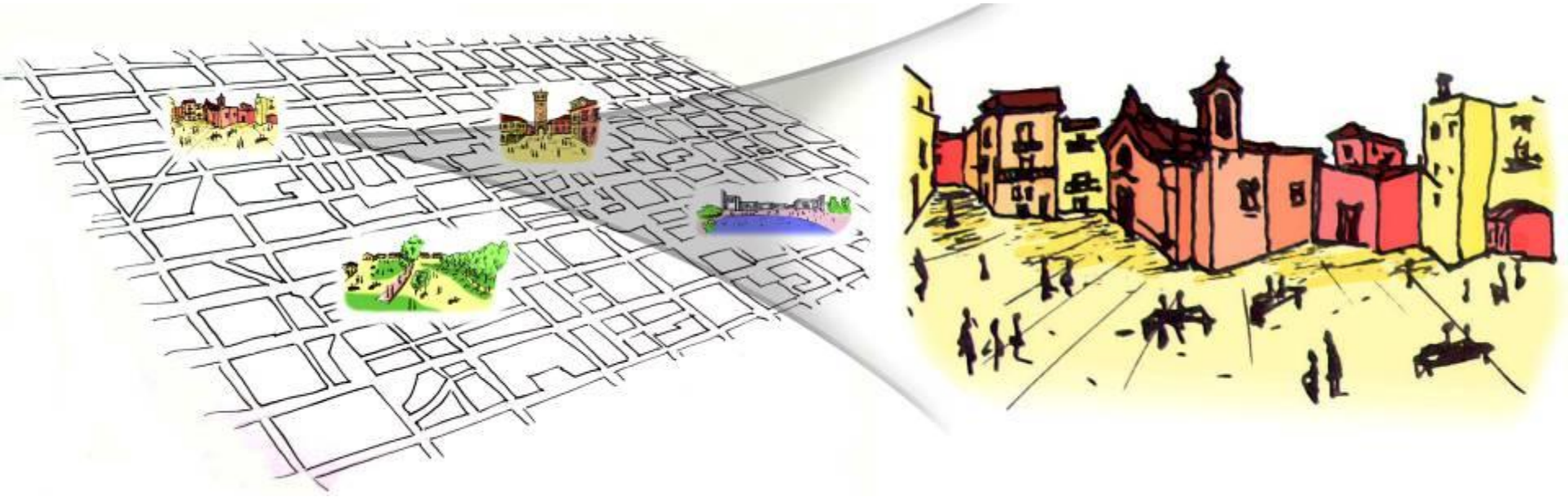
The change of city structures and of personal preferences/needs imply a change of the isobenefit city landscape which is the map of the benefit given from amenities and which depends from the benefit you receive when you are directly enjoying amenities and from how this benefit flows throughout the city.

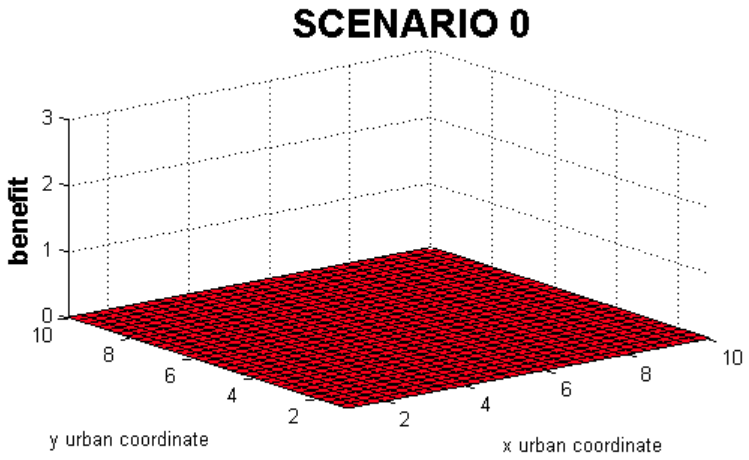


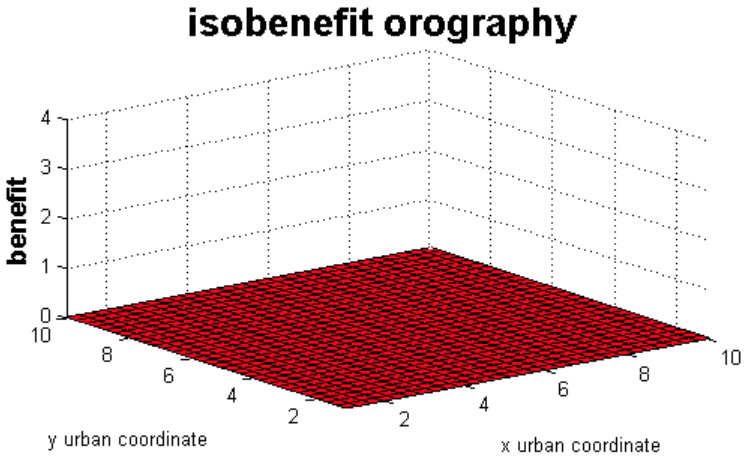


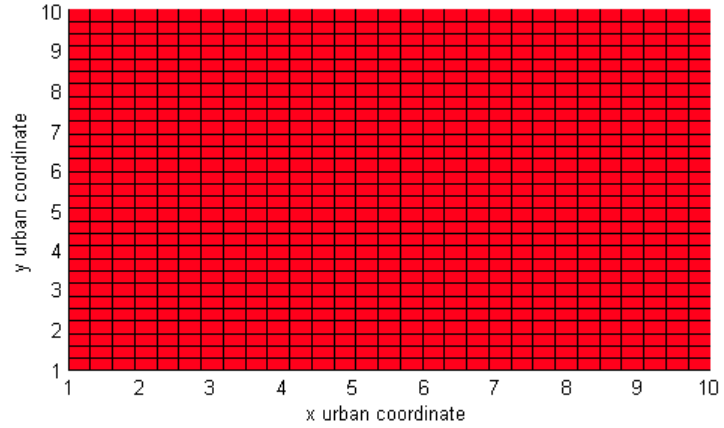


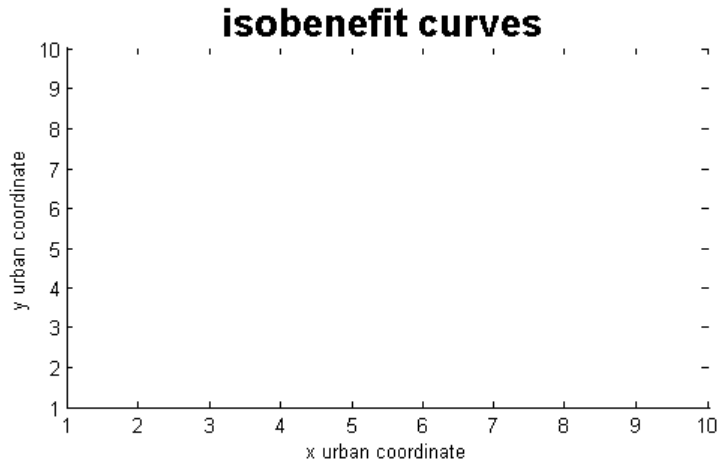


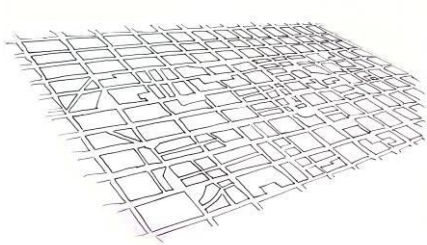


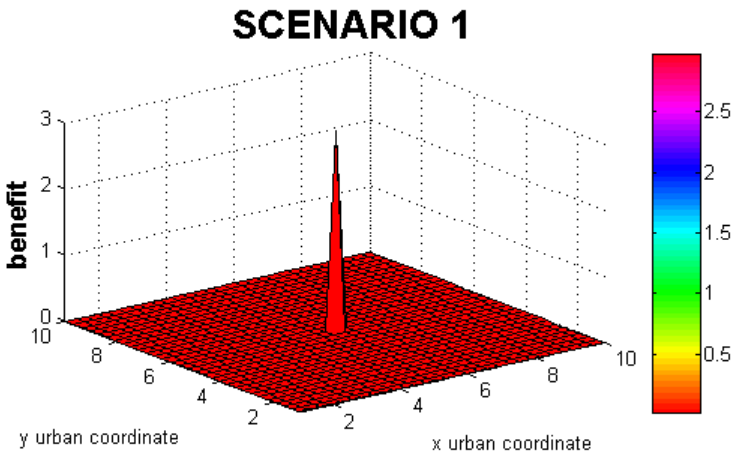

SCENARIO 0
benefit
y urban coordinate
x urban coordinate

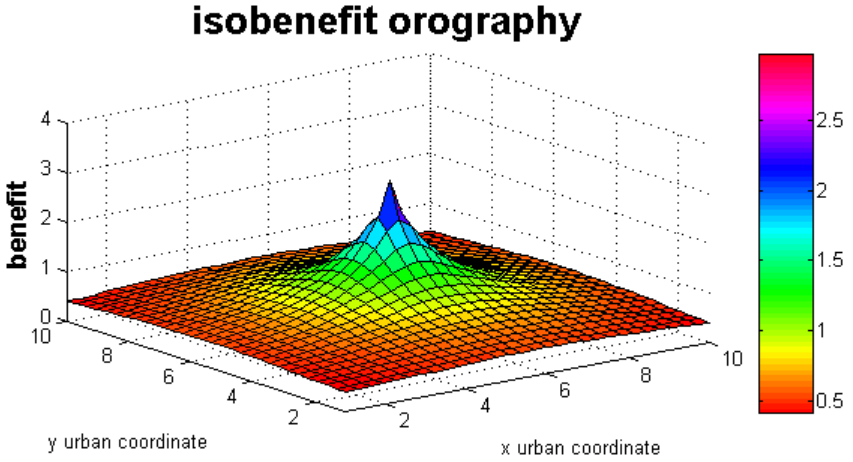

isobenefit orography
benefit
y urban coordinate
x urban coordinate

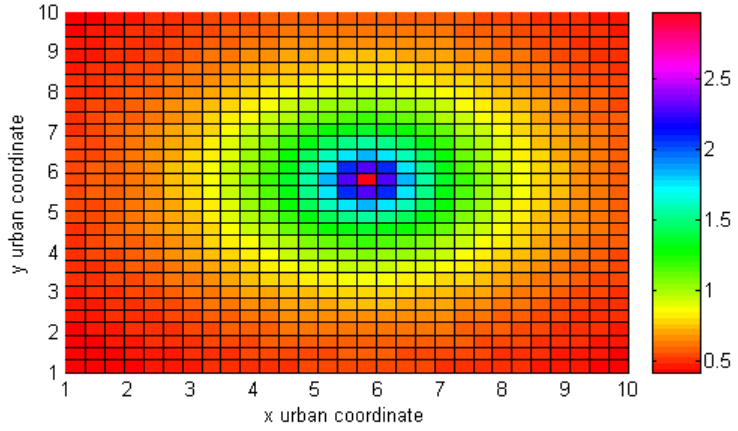

y urban coordinate
x urban coordinate

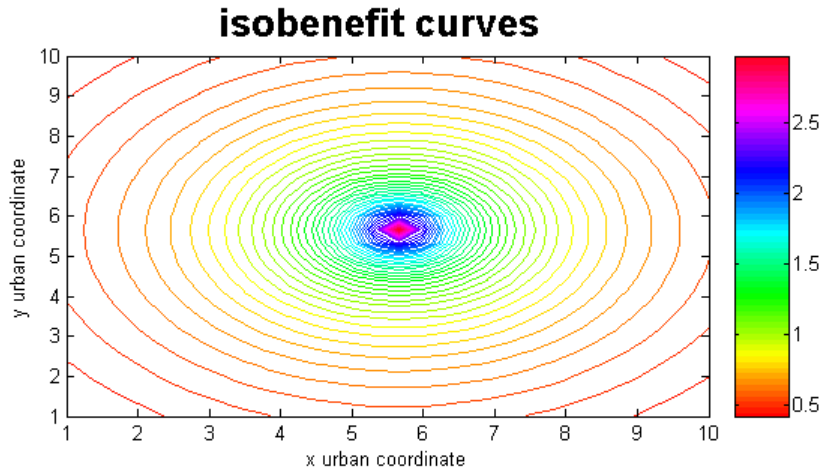

isobenefit curves
y urban coordinate
x urban coordinate

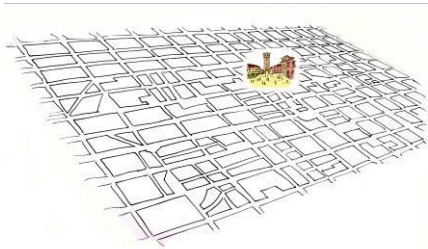


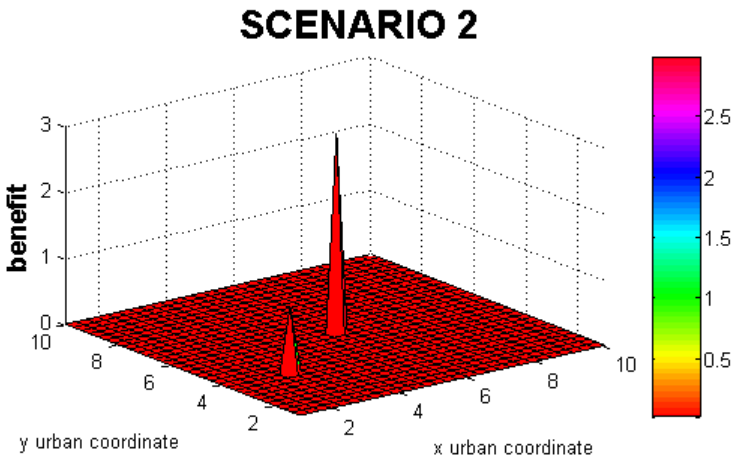

SCENARIO 1
benefit
y urban coordinate
x urban coordinate

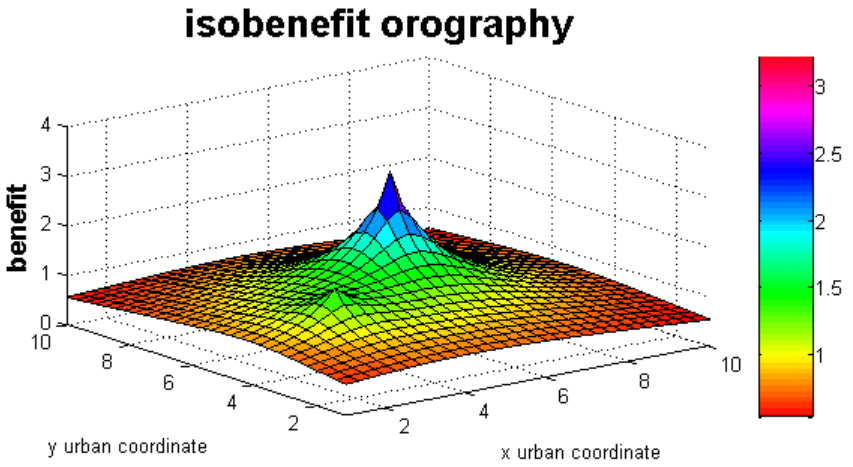

isobenefit orography
benefit
y urban coordinate
x urban coordinate

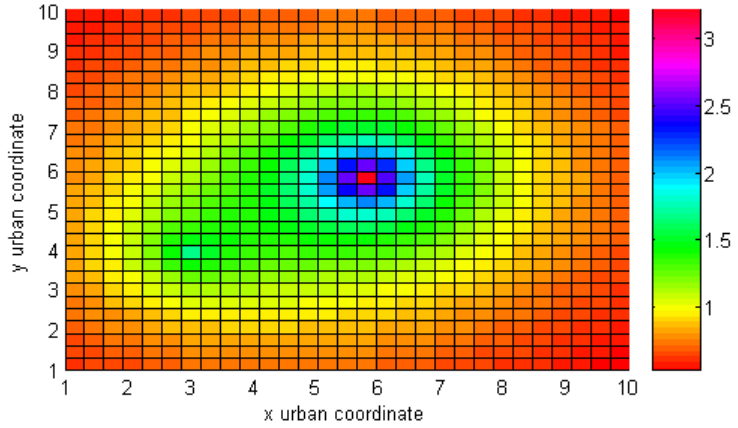

y urban coordinate
x urban coordinate

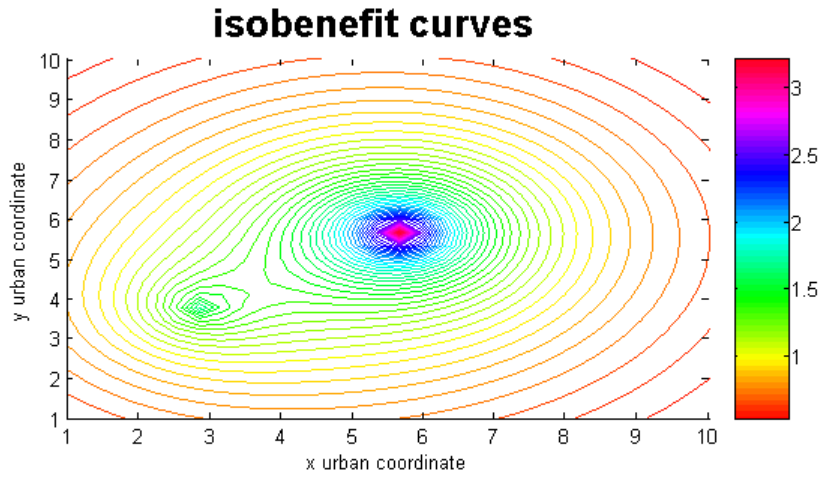

isobenefit curves
y urban coordinate
x urban coordinate

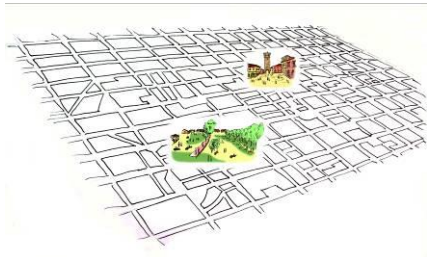


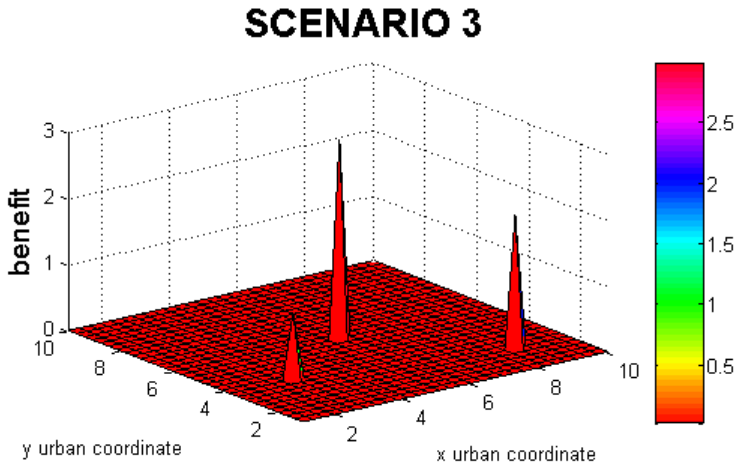

SCENARIO 2
benefit
y urban coordinate
x urban coordinate

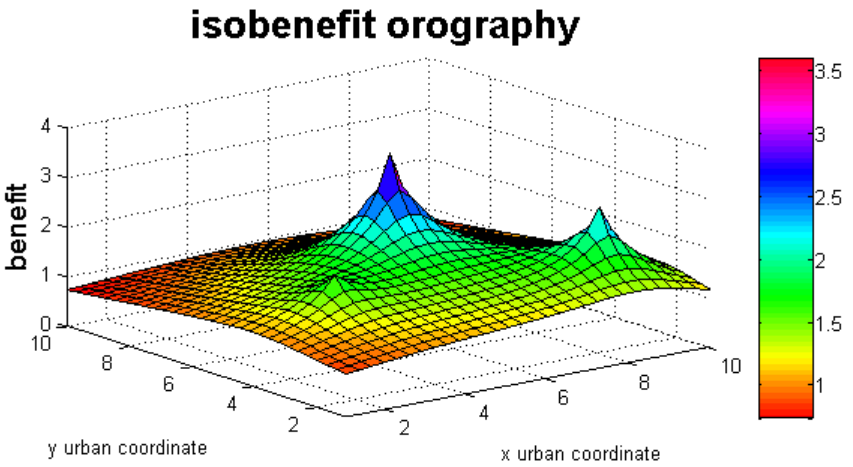

isobenefit orography
benefit
y urban coordinate
x urban coordinate

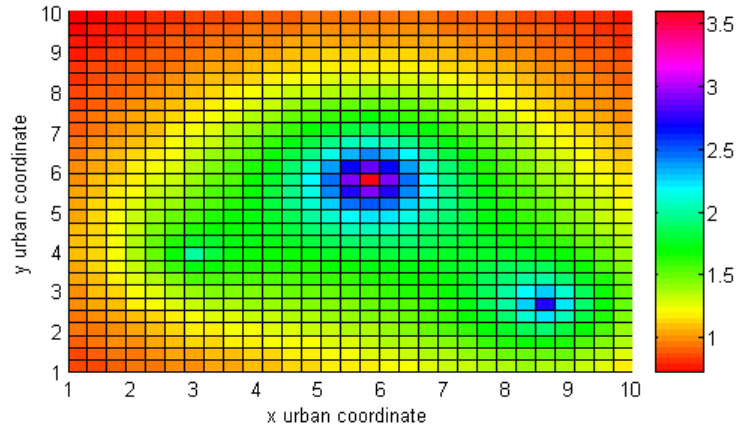

y urban coordinate
x urban coordinate

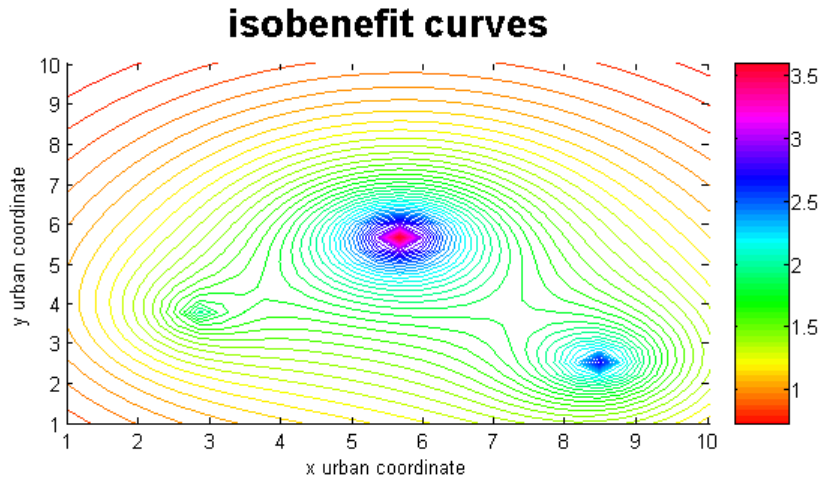

isobenefit curves
y urban coordinate
x urban coordinate

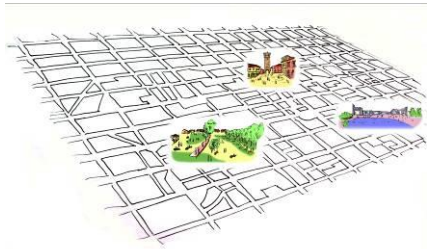


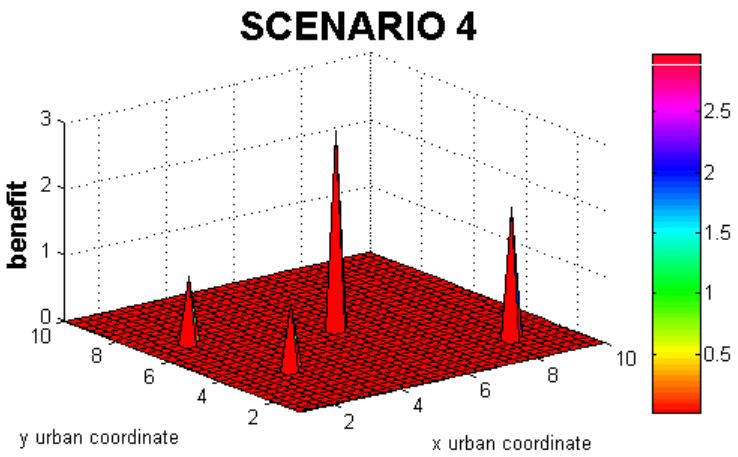

SCENARIO 3
benefit
y urban coordinate
x urban coordinate

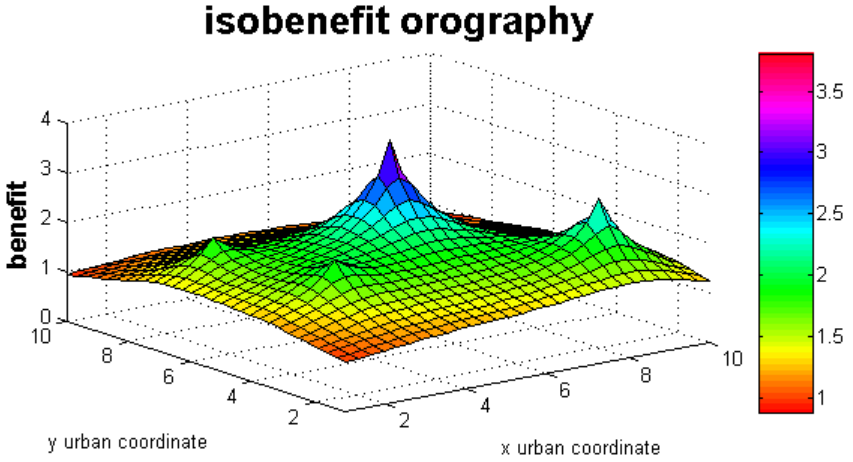

isobenefit orography
benefit
y urban coordinate
x urban coordinate

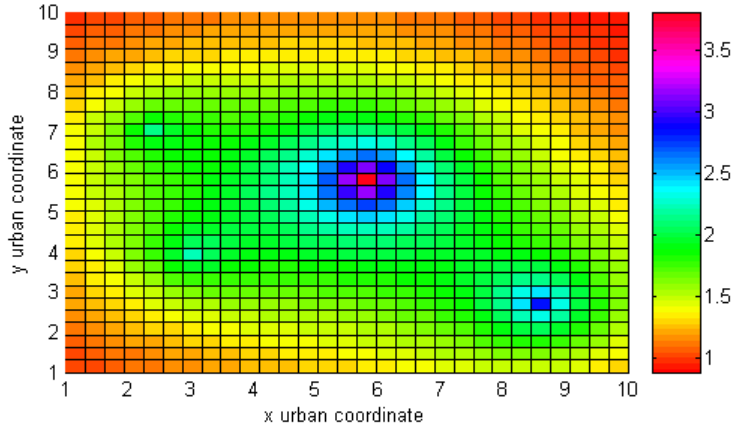

y urban coordinate
x urban coordinate

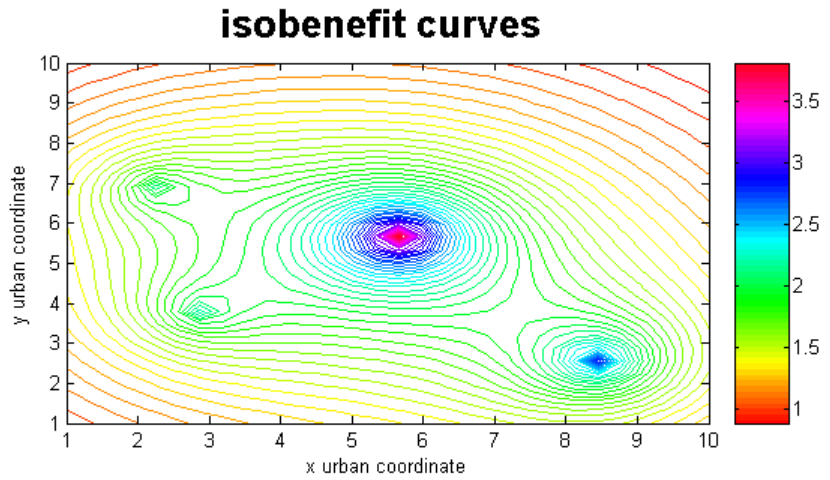

isobenefit curves
y urban coordinate
x urban coordinate

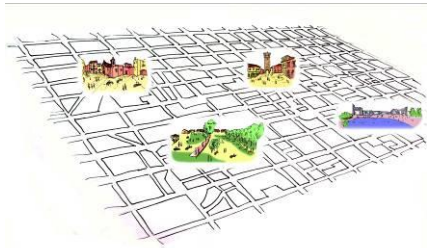


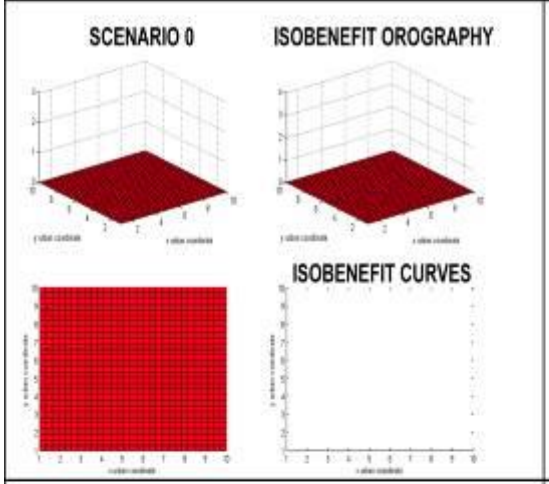

SCENARIO 4
benefit
y urban coordinate
x urban coordinate

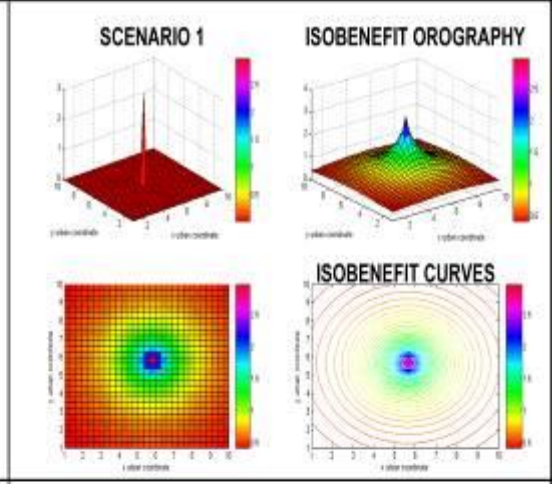

isobenefit orography
benefit
y urban coordinate
x urban coordinate

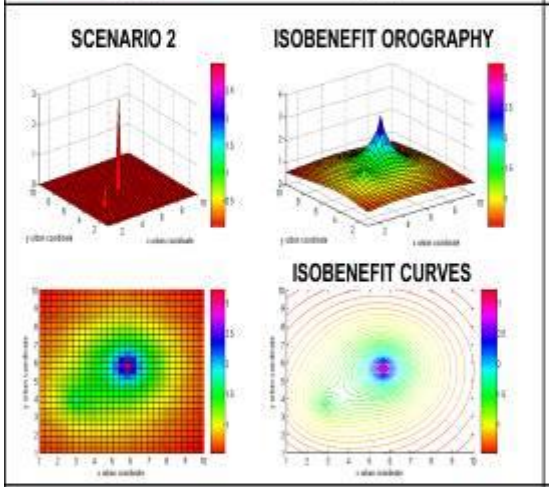

y urban coordinate
x urban coordinate

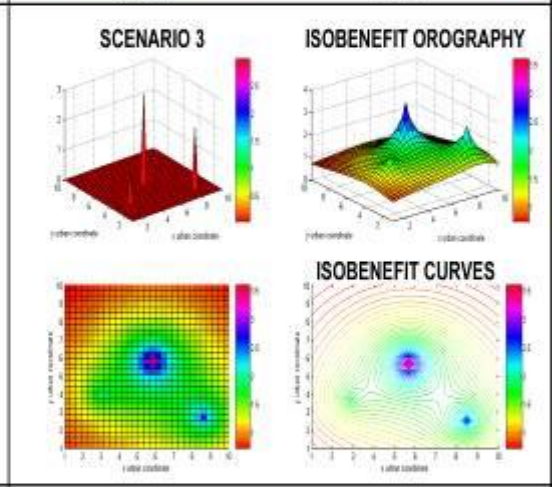

isobenefit curves
y urban coordinate
x urban coordinate

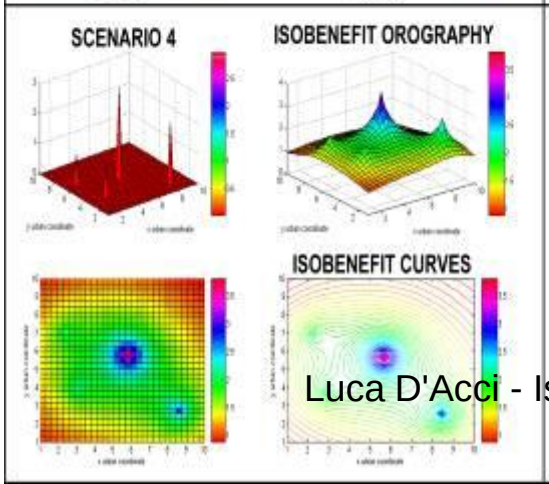












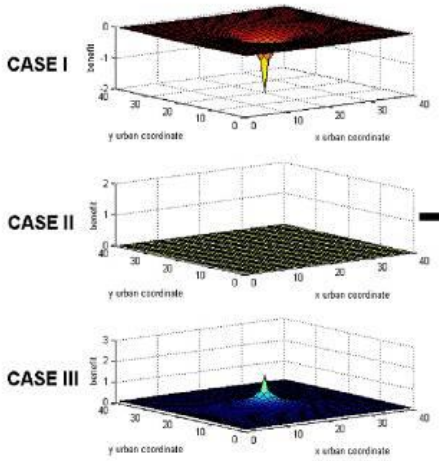
SCENARIO 0
U = 1
medium M = 0
max M = 0
min M = 0
gap = 0

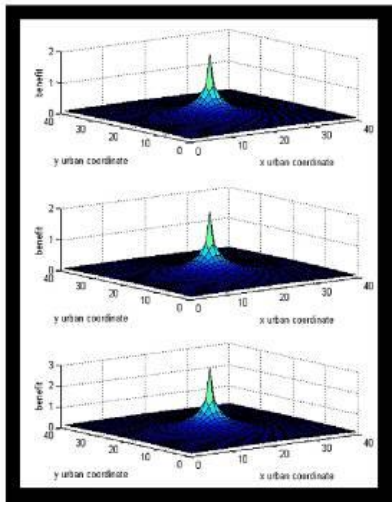
SCENARIO 1
U = 0.57
medium M = 0.74
max M = 3
min M = 0.4
gap = 6.58

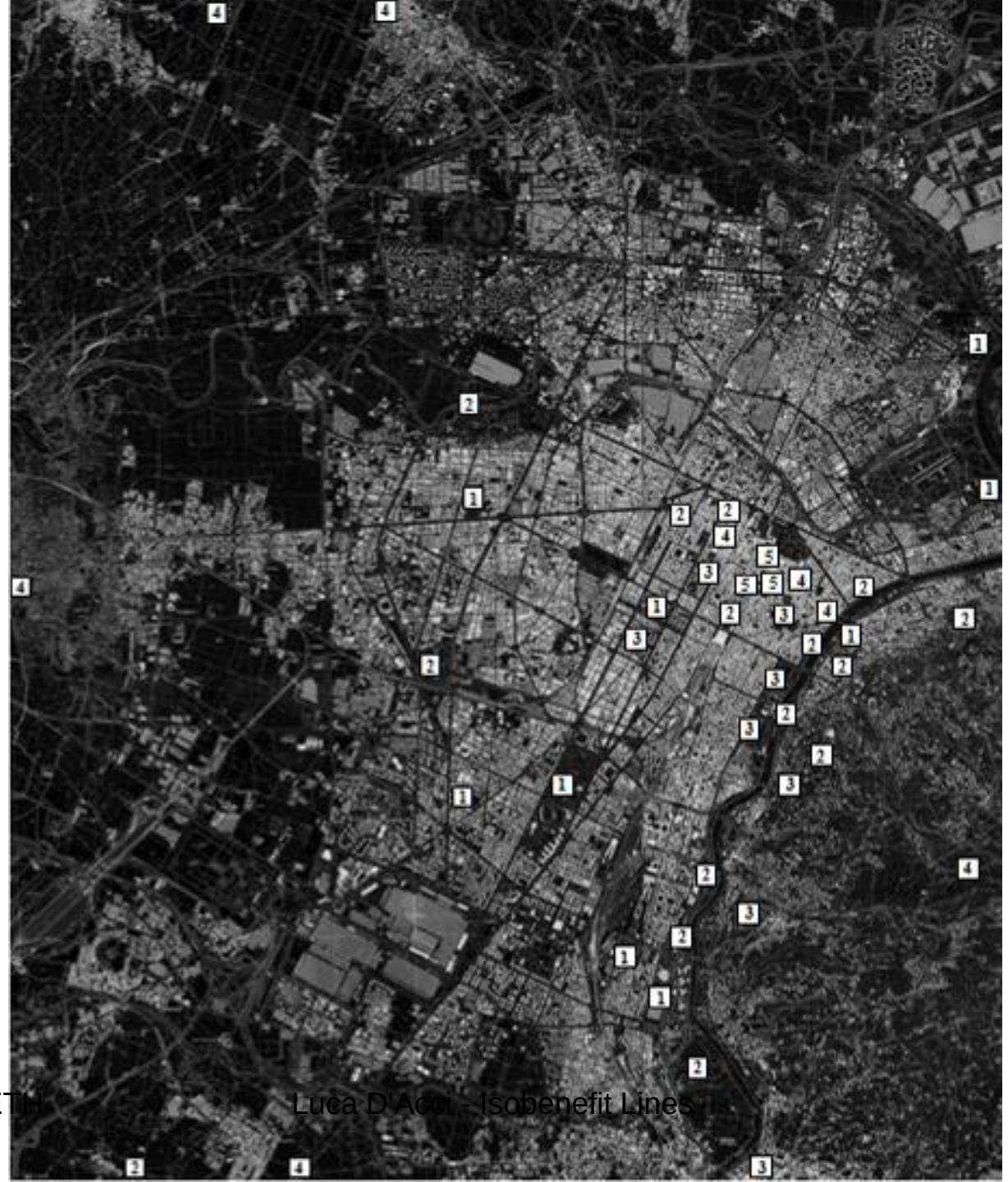
SCENARIO 2
U = 0.64
medium M = 0.96
max M = 3.23
min M = 0.52
gap = 5.26

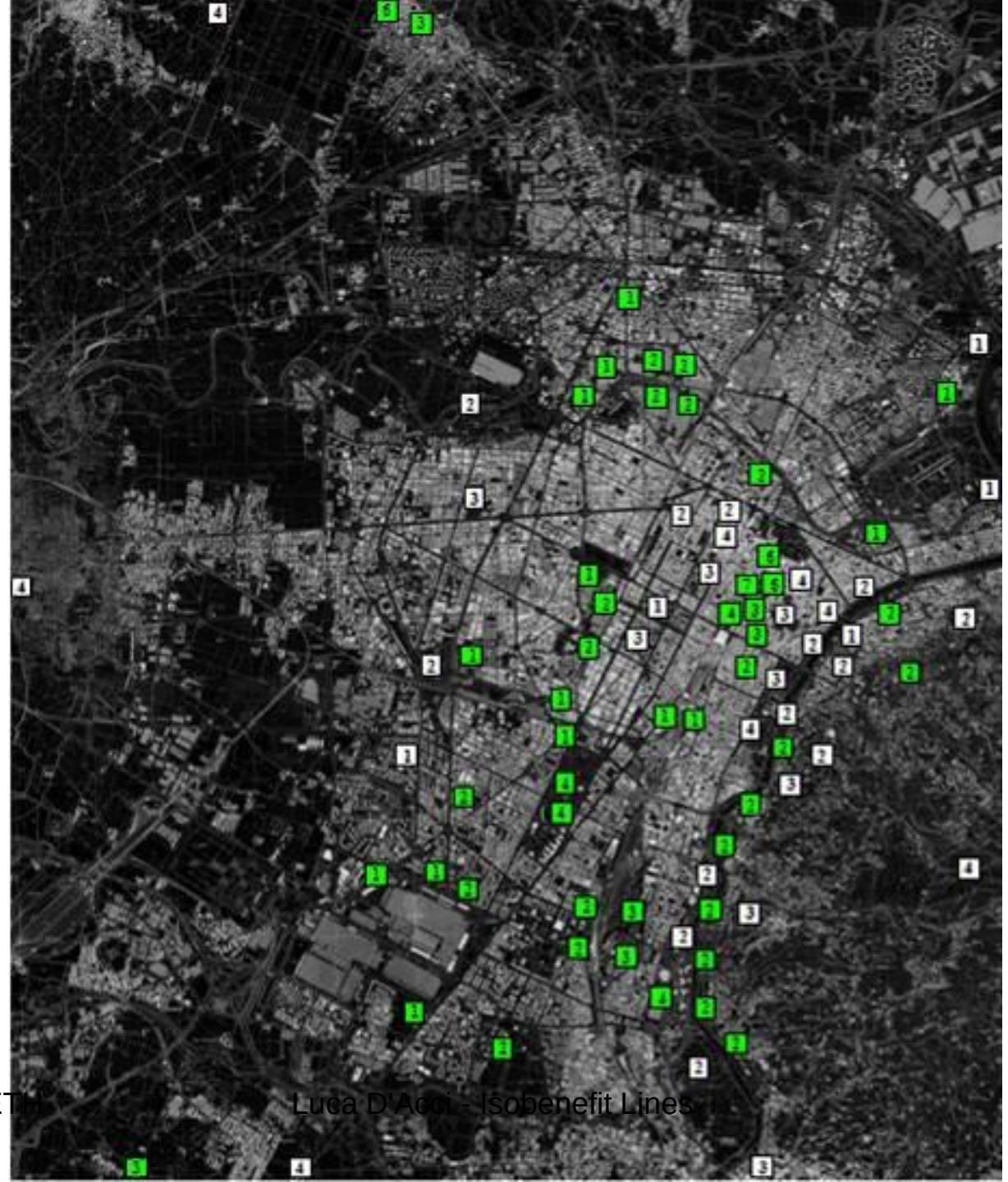
SCENARIO 3
U = 0.70
medium M = 1.37
max M = 3.62
min M = 0.71
gap = 4.06

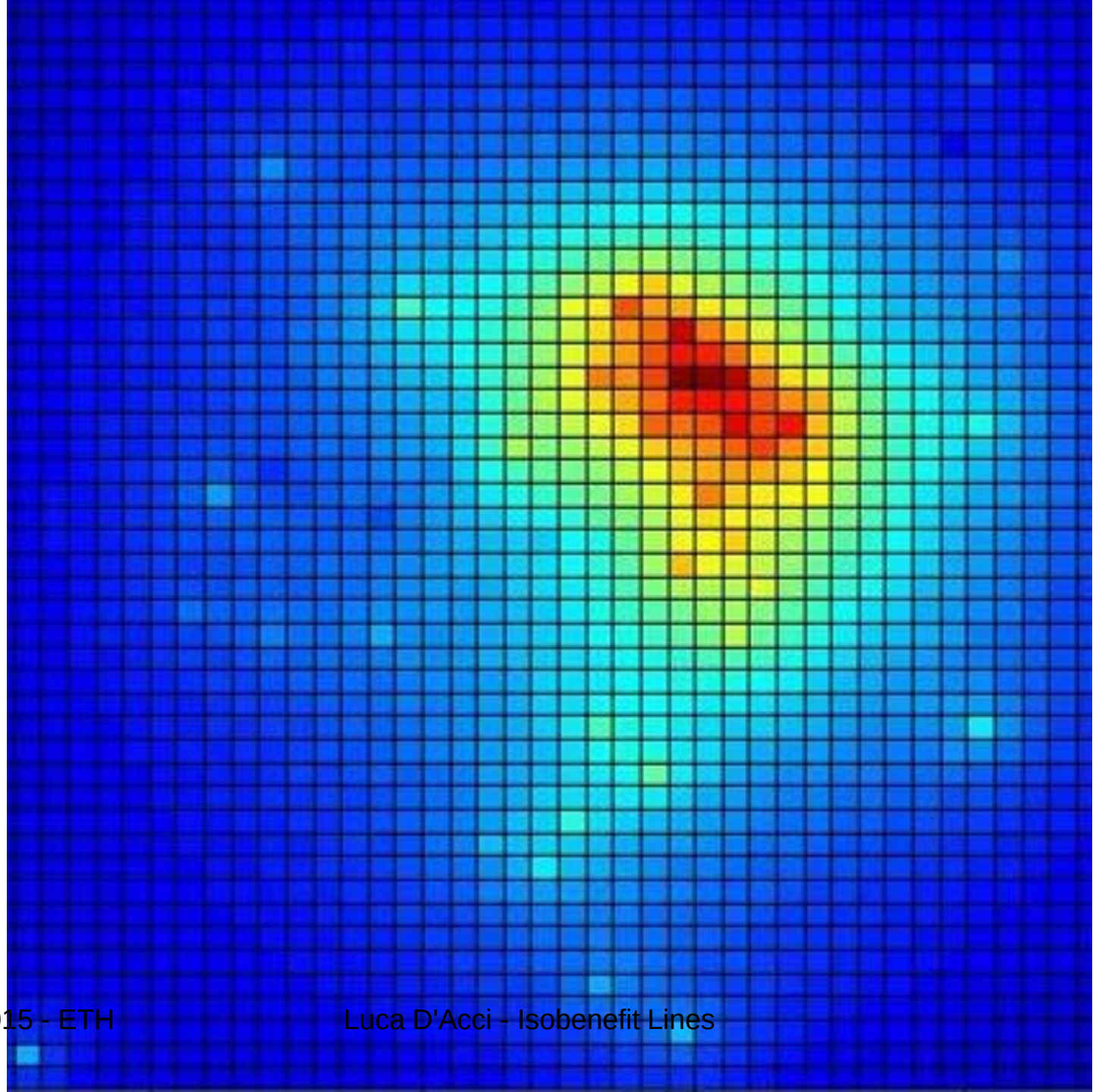
SCENARIO 4
U = 0.75
medium M = 1.58
max M = 3.83
min M = 0.85
gap = 3.48

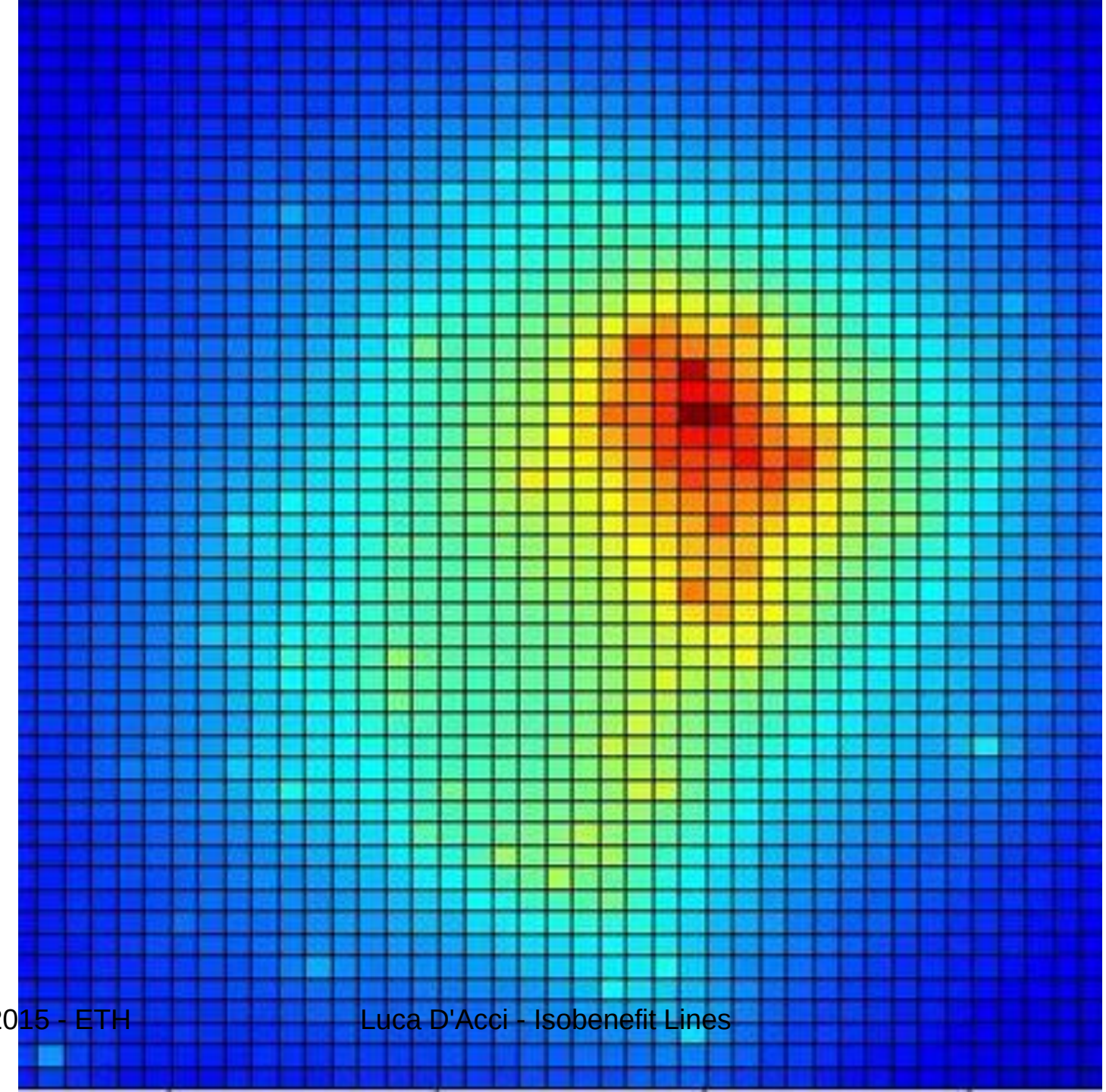

CASE I
CASE II
CASE III
benefit
y urban coordinate
x urban coordinate


benefit
y urban coordinate
x urban coordinate

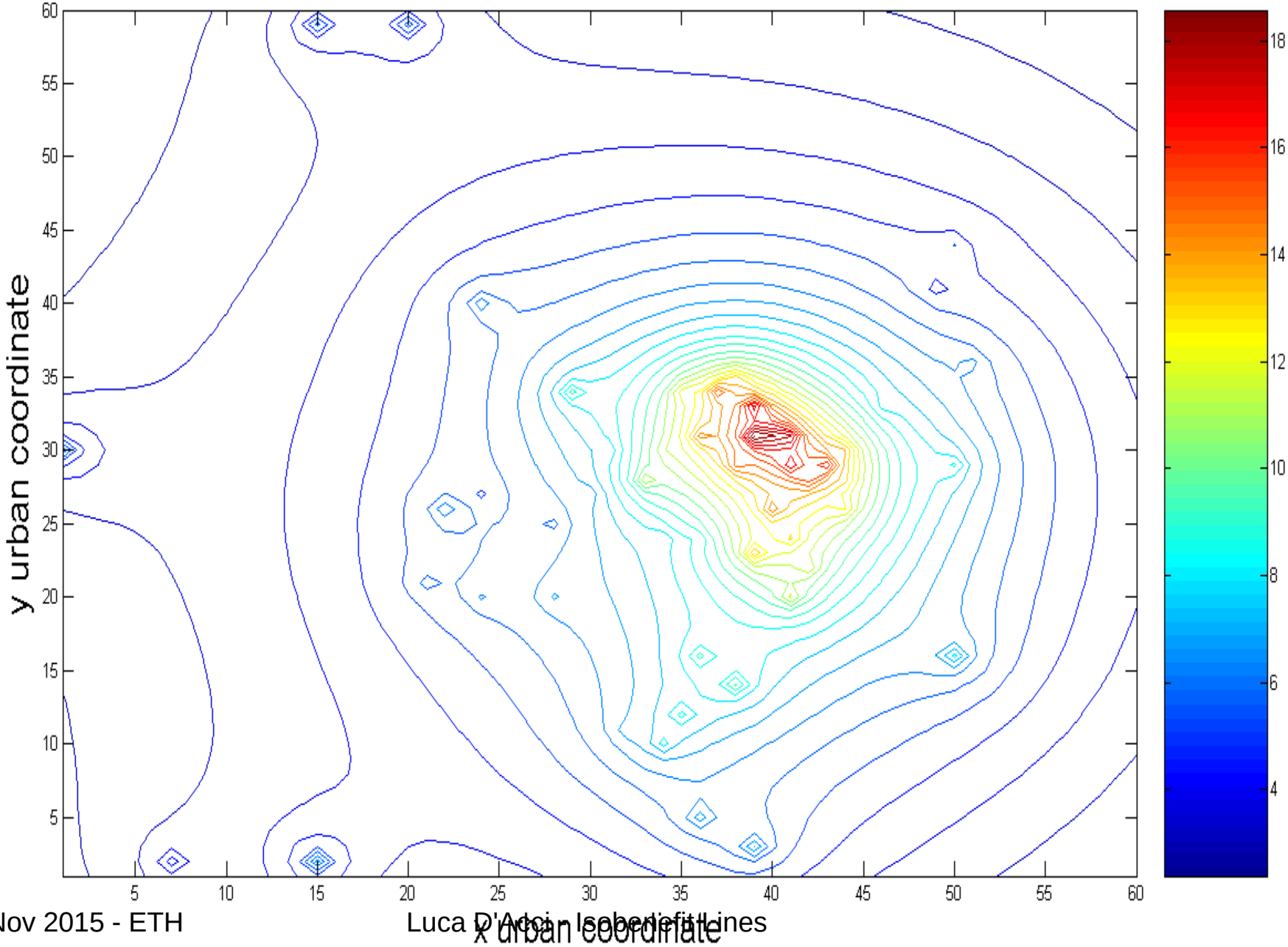


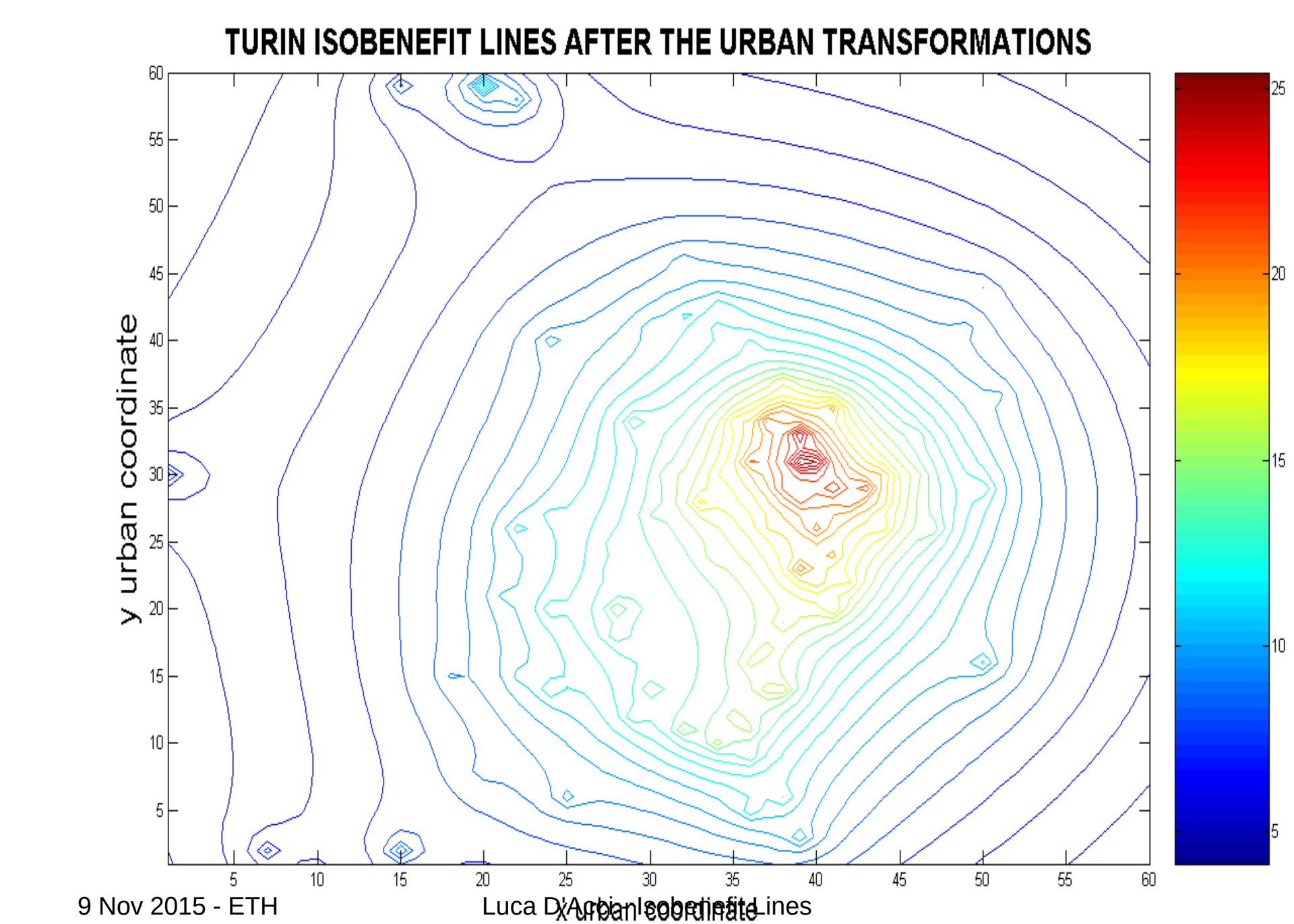


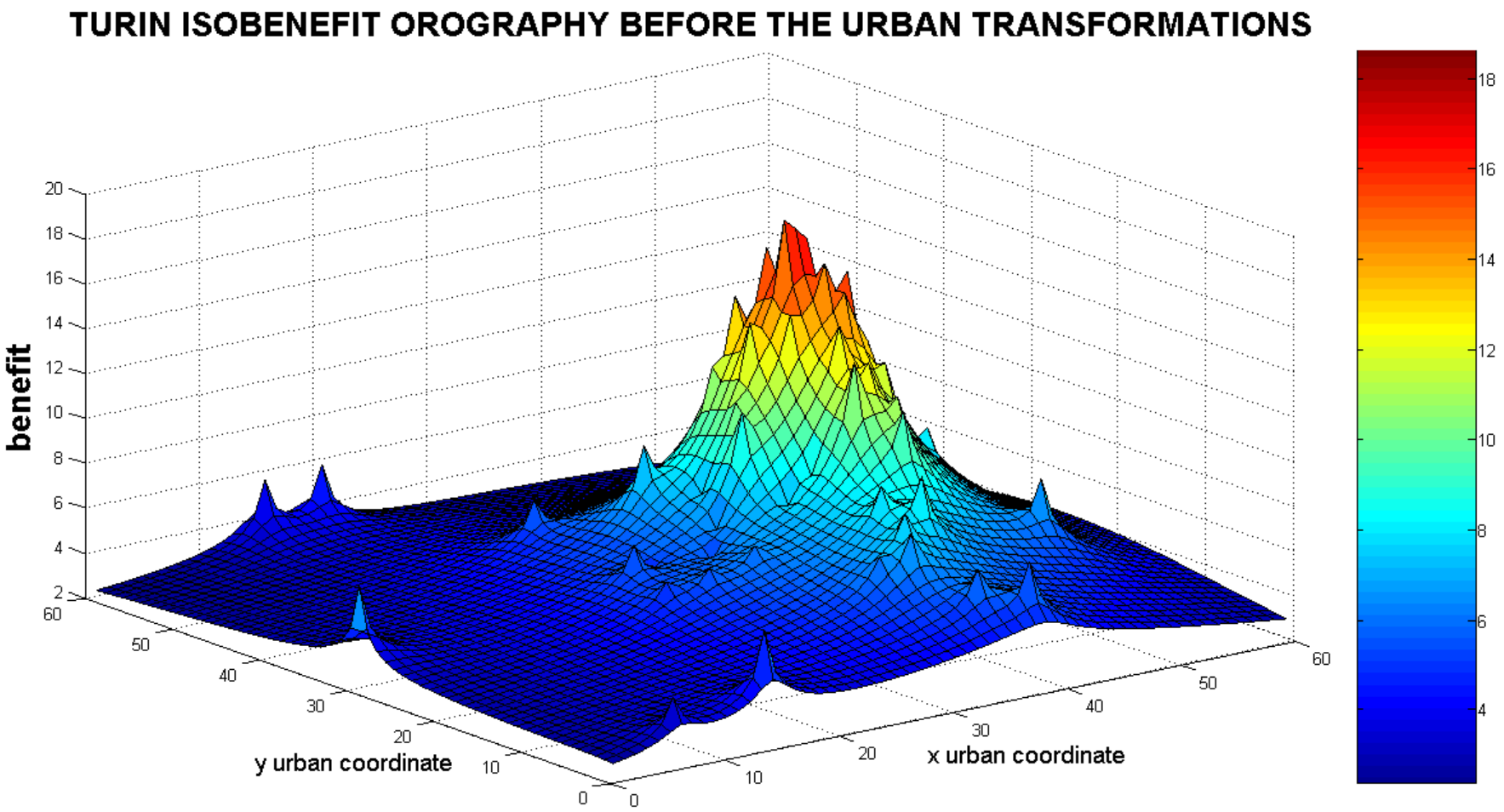


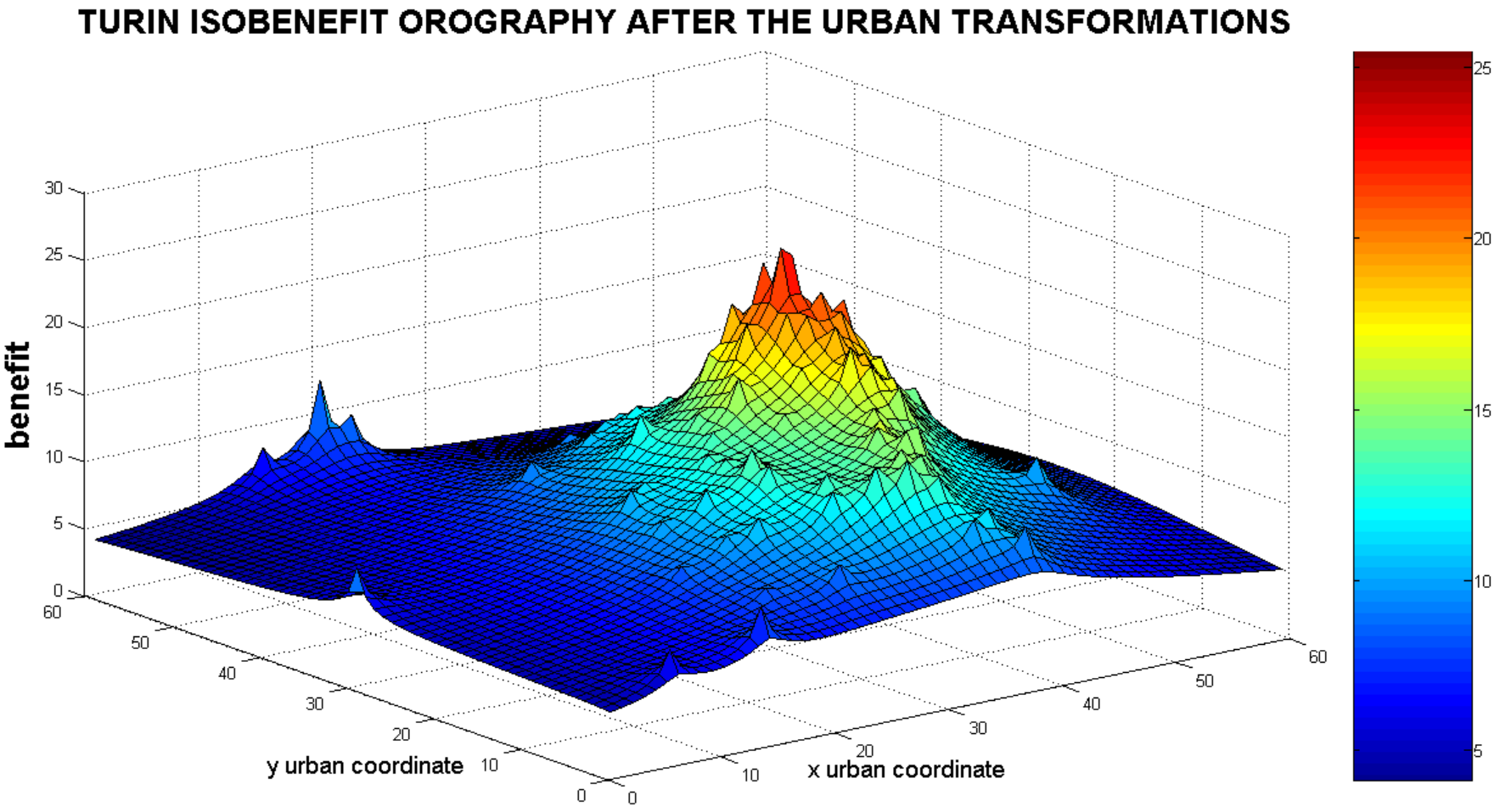


TURIN ISOBENEFIT LINES BEFORE THE URBAN TRANSFORMATIONS




TURIN ISOBENEFIT LINES AFTER THE URBAN TRANSFORMATIONS
y urban coordinate
x urban coordinate
5
10
15
20
25
30
35
40
45
50
55
60


TURIN ISOBENEFIT OROGRAPHY BEFORE THE URBAN TRANSFORMATIONS
benefit
20
18
16
14
12
10
8
6
4
2
60
50
40
30
20
10
0
y urban coordinate
0
10
20
30
40
50
60
x urban coordinate
18
16
14
12
10
8
6
4


TURIN ISOBENEFIT OROGRAPHY AFTER THE URBAN TRANSFORMATIONS
benefit
0
5
10
15
20
25
30
y urban coordinate
0
10
20
30
40
50
60
x urban coordinate
0
10
20
30
40
50
60
5
10
15
20
25

The benefit of a point *k* received from an amenity *i* distant *d*, and with a level *A* of attractiveness, is given by:

$$B_{i,k} = \frac{A_i}{1+(d_{i-k}/E)}$$

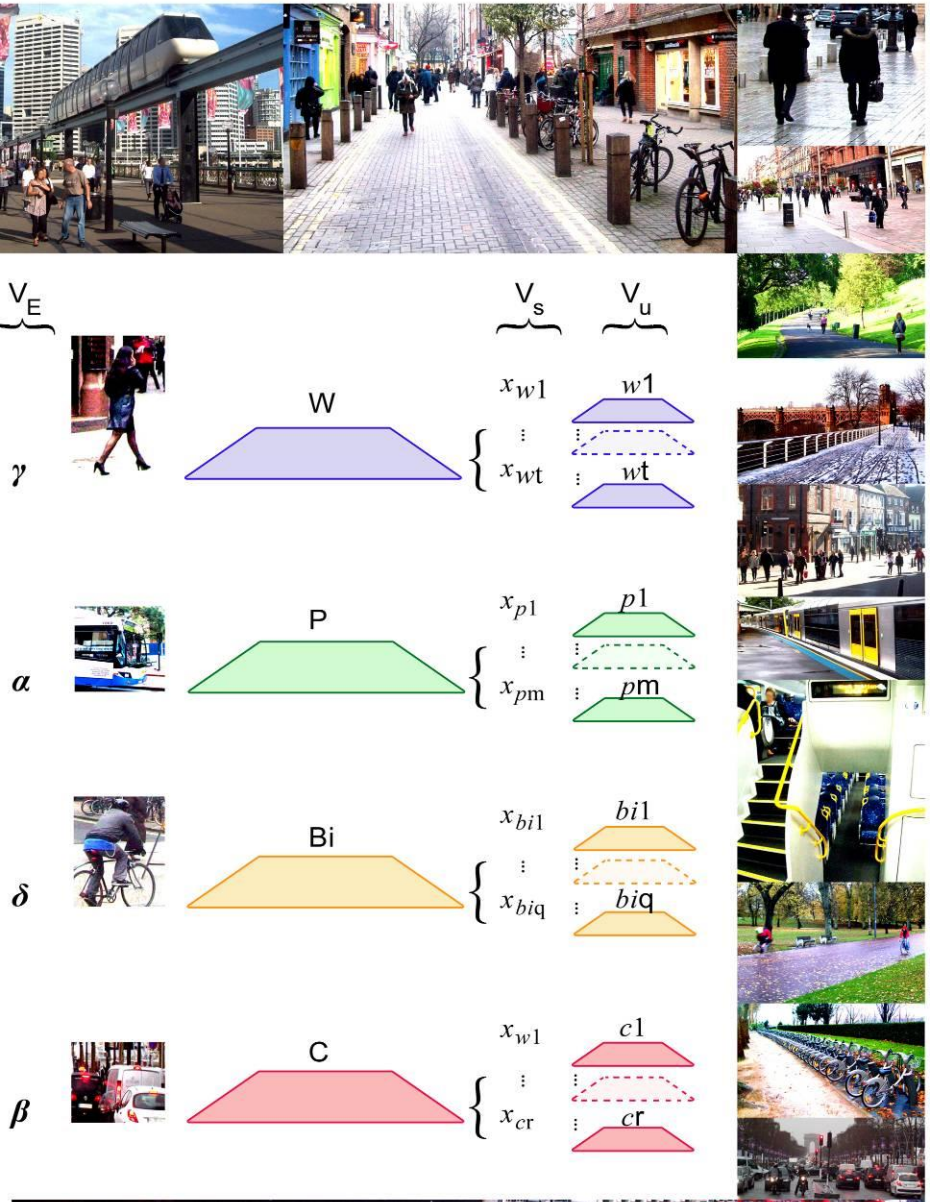
Where *E* is the variable which allows to transform the distances into ***Psycho-Economical*** distances.

$$E = \varepsilon \cdot E_{i-k}$$

$$E_{i-k} = \alpha P_{i-k} + \beta C_{i-k} + \gamma W_{i-k} + \delta Bi_{i-k}$$

Calculating equation 1 for all the *n* amenities present in the city:

$$B_k = \sum_{i=1}^{n} B_{i,k}$$



The ***objective*** status of movement possibilities offered by the city is expressed by $\mathbf{v_u}$.
The ***subjective*** status, 'transducer' of the preferences heterogeneity of citizens, is expressed by $\mathbf{v_E}$, $\mathbf{v_S}$ and ε

Therefore $\mathbf{v_E}$, $\mathbf{v_S}$ and ε

transform the Euclidean distance (*d*) into a ***Psycho-Economical* Distance**, where we think about time in monetary terms.
If we formulate *A* and *E* on aggregate statistics and habits by observing the majority of the citizens rather than each of them, we talk of ***Isobenefit Lines***.
When *A* and the full set of parameters of *E* are formulated on *personal* habits and preferences, we pass from *Isobenefit Lines* to ***Personal Isobenefit Lines***

$$P = x_{p_1}p_1 + x_{p_2}p_2 + \ldots + x_{pz}p_z + \ldots + x_{pm}p_m; \qquad v_p = (x_{p1}, x_{p2}, \ldots, x_{pz}, \ldots, x_{pm})$$

$$C = x_{1c}c_1 + \ldots + x_{cr}c_r; \qquad v_c = (x_{c1}, \ldots, x_{cr})$$

$$W = x_{w1}w_1 + \ldots + x_{wt}w_t; \qquad v_w = (x_{w1}, \ldots, x_{wt})$$

$$Bi = x_{bi1}bi_1 + \ldots + x_{biq}bi_q; \qquad v_{bi} = (x_{bi1}, \ldots, x_{biq})$$

$$v_u = \left(\sum_{z=1}^{m} p_z, \sum_{z=1}^{r} c_z, \sum_{z=1}^{t} w_z, \sum_{z=1}^{q} bi_z\right)$$

$$v_S = (v_p, v_c, v_w, v_{bi})$$

For example, a person can give more importance to libraries, parks and pedestrian areas, another to shopping malls and parking, another to hospitals and public transport, etcetera. In the same way, a person could give more value to aesthetics and silence, another more about speed and time, another more about costs, etcetera.

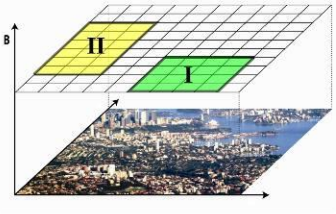
Also, a same person can change her/his needs/preferences along the years, as the daily life of children, teenagers, adults and seniors are different.
Again, a same person could change his/her habits when becomes richer or poorer, or get married or divorced, or have babies, or memories, etcetera.

To change needs, habits, preferences means to change the values of the parameters, which in turn means to modify personal *Benefit Orography* (the 3-dimensional visualization of equation 4, of the city, which we call also *Benefit Landscape*).

Person **1** and Person **2**;
Person **3** and Person **4**:
= $\mathbf{v}_S$ and qualitative criteria
$\neq \mathbf{v}_E$

Person 1

Person 2



$\alpha = \beta = \gamma = \delta = 0.25$

$\alpha = 0.2;\ \beta = 0;\ \gamma = \delta = 0.4$

I:
P=10
C=10
W=10
Bi=10

$\mathbf{E}/\varepsilon = 0.25*10*4 = \mathbf{10}$

$\mathbf{E}/\varepsilon = 0.2*10+0.4*10*2 = \mathbf{10}$

II:
P=3
C=10
W=4
Bi=1

$\mathbf{E}/\varepsilon = 0.25*3+0.25*10+$
$+0.25*4+0.25*1 = \mathbf{4.5}$

$\mathbf{E}/\varepsilon = 0.2*3+0*10+$
$+0.4*4+0.4*1 = \mathbf{2.6}$

Person **3** and Person **1**;
Person **4** and Person **2**
$\neq \mathbf{v}_S$ and qualitative criteria
$= \mathbf{v}_E$

I:
P=8
C=9
W=9
Bi=10

$\mathbf{E}/\varepsilon = 0.25*8+0.25*9+$
$+0.25*9+0,25*10 = \mathbf{9}$

$\mathbf{E}/\varepsilon = 0.2*8+0*9+0.4*9+$
$+0.4*10 = \mathbf{9.2}$

II:
P=7
C=9
W=7
Bi=2

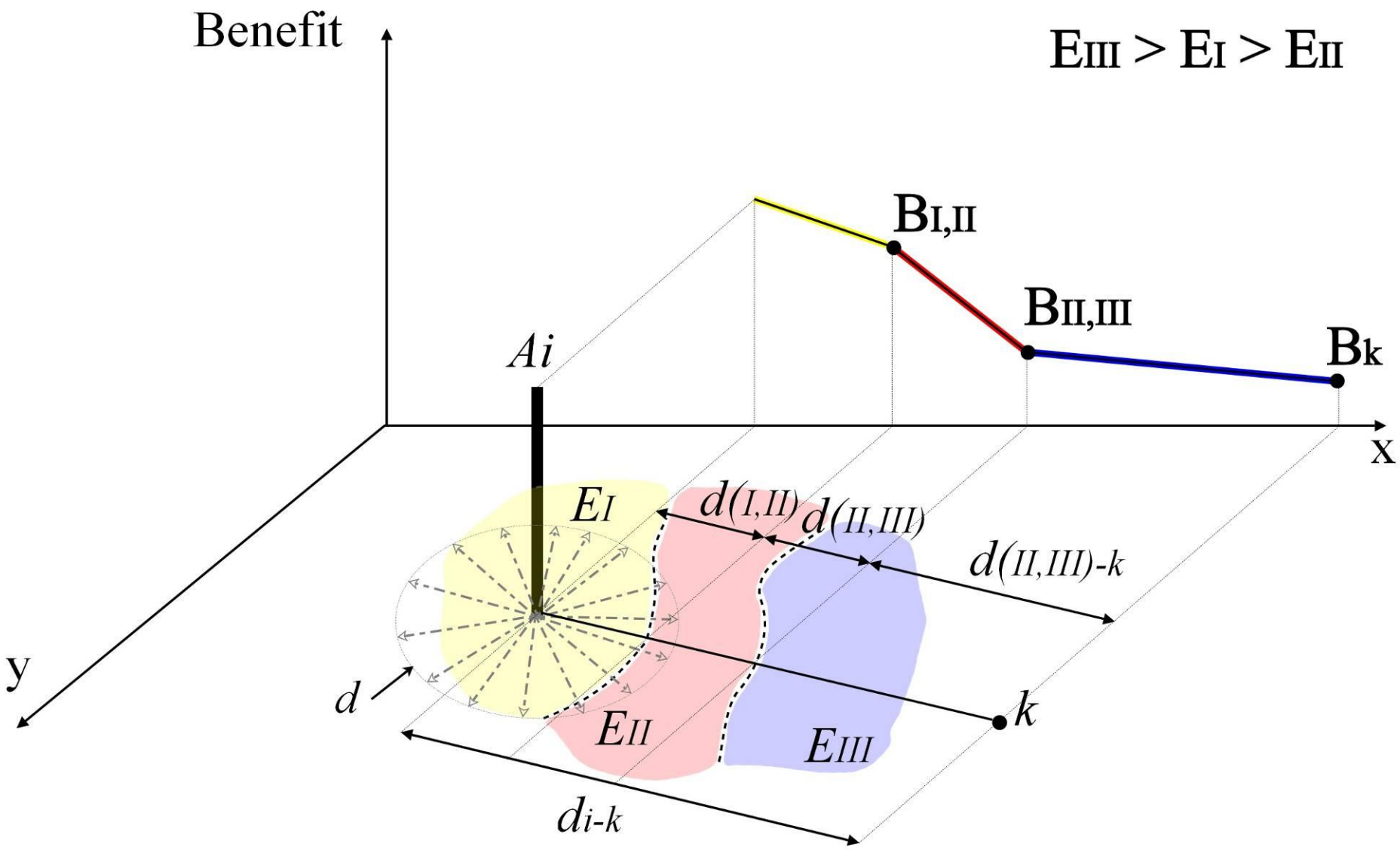
$\mathbf{E}/\varepsilon = 0.25*7+0.25*9+$
$+0.25*7+0.25*2 = \mathbf{8.25}$

$\mathbf{E}/\varepsilon = 0.2*7+0*9+$
$+0.4*7+0.4*2 = \mathbf{5}$

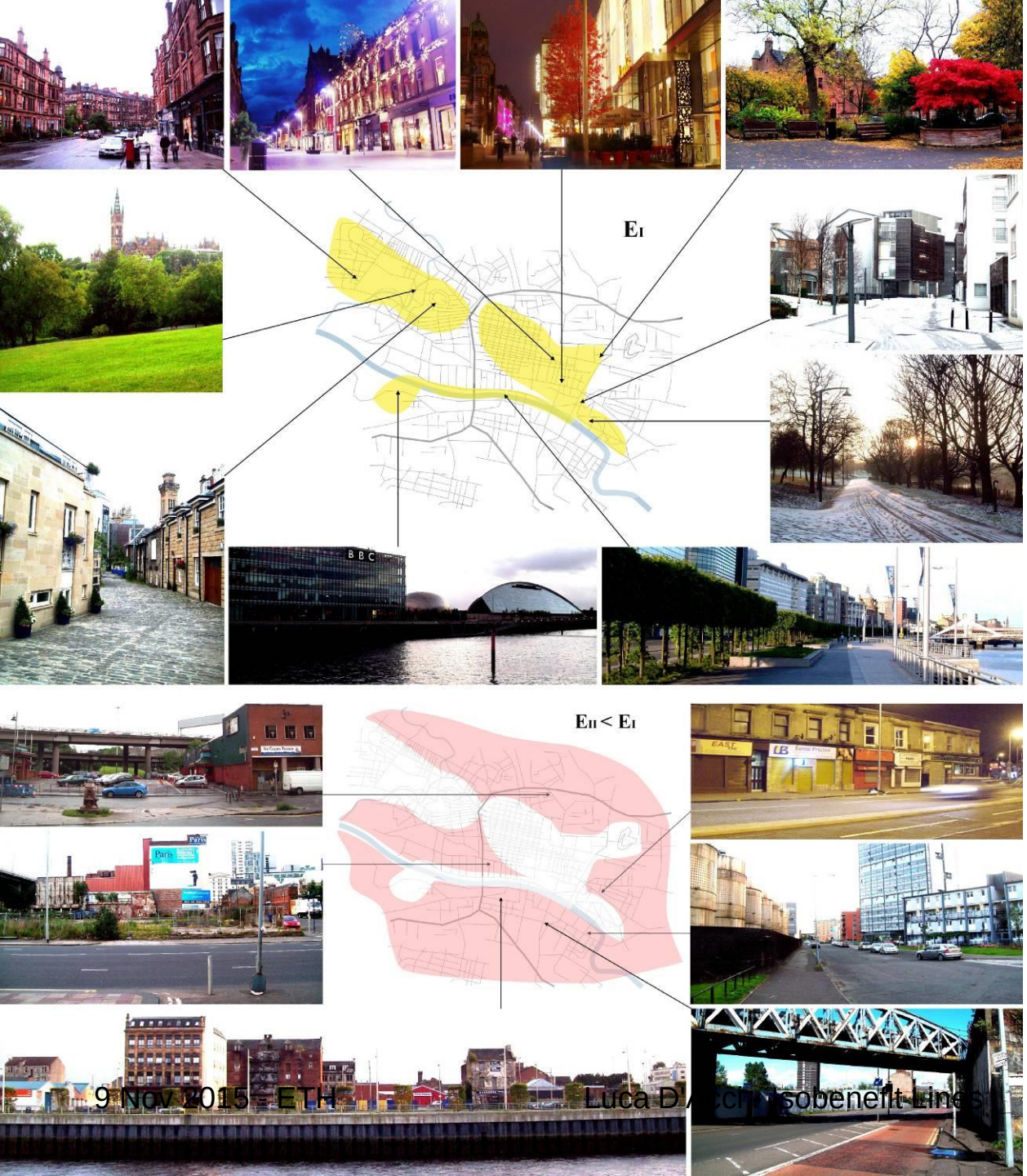
Person **4** and Person **1**;
Person **3** and Person **2**
$\neq \mathbf{v}_S$ and qualitative criteria
$\neq \mathbf{v}_E$

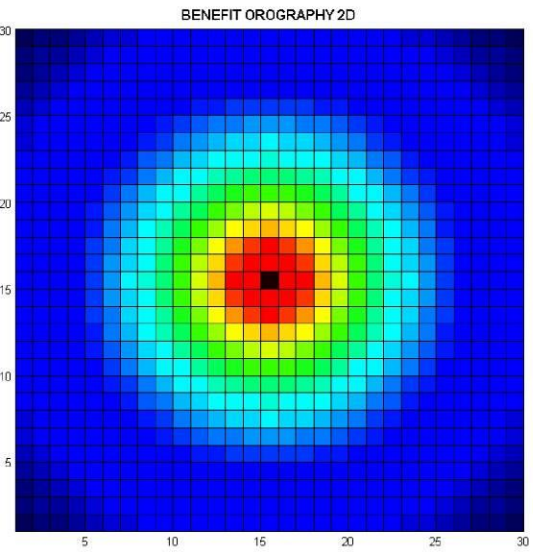
Person 3

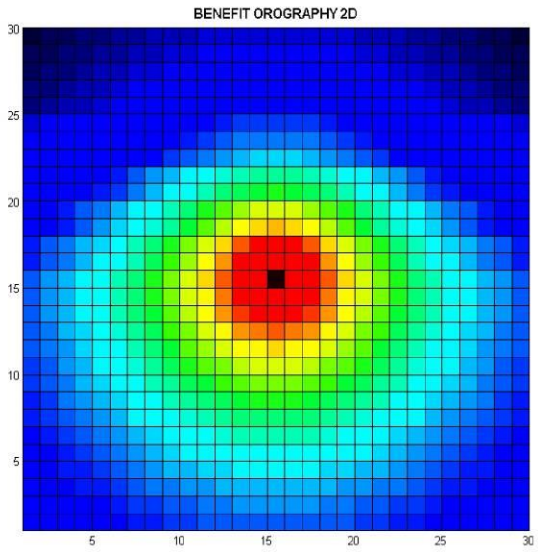
Person 4

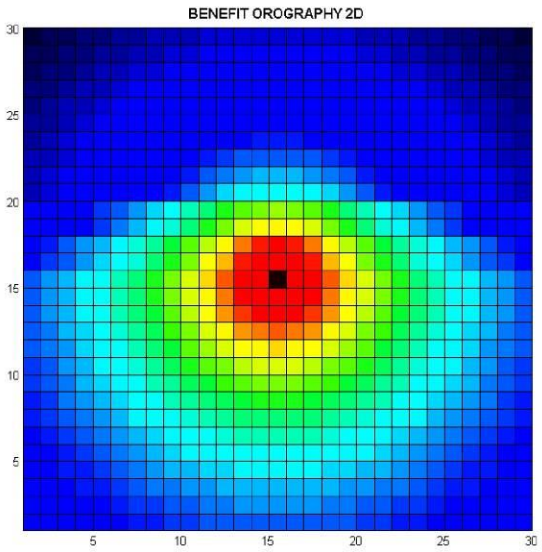

Benefit
EIII > EI > EII
BI,II
BII,III
Bk
Ai
x
y
EI
d(I,II)
d(II,III)
d(II,III)-k
d
EII
EIII
k
di-k

Different *E*


E1
EII < E1
BBC



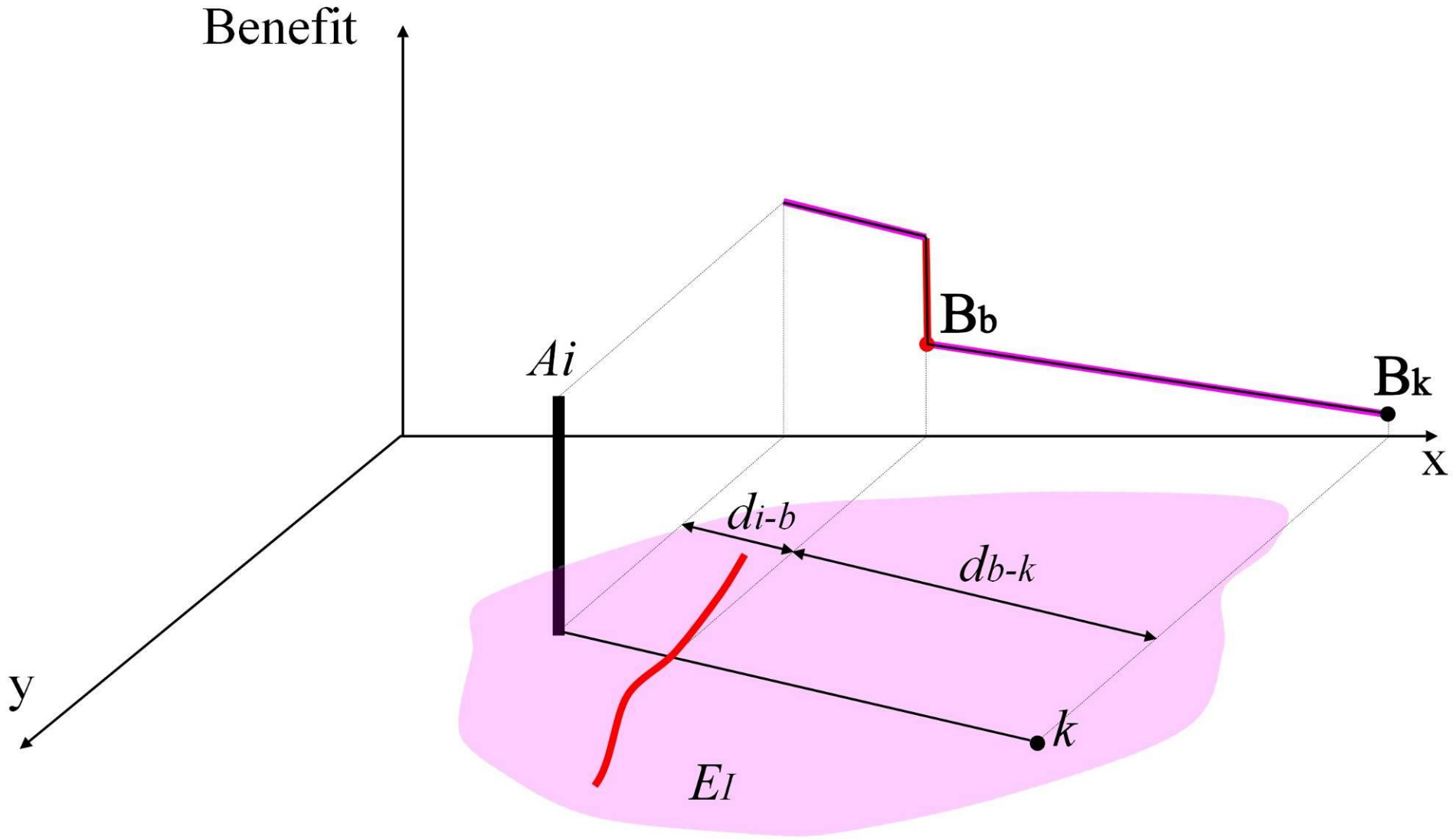


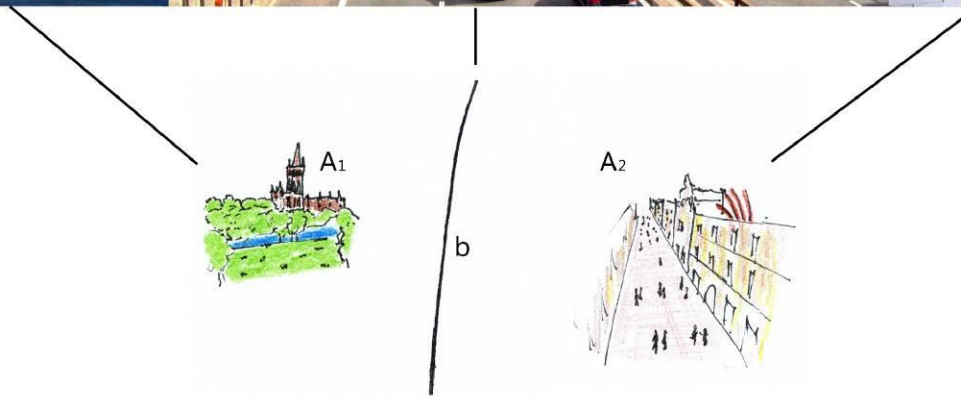


Left: example of one amenity in an isotropic area (*E* = constant).

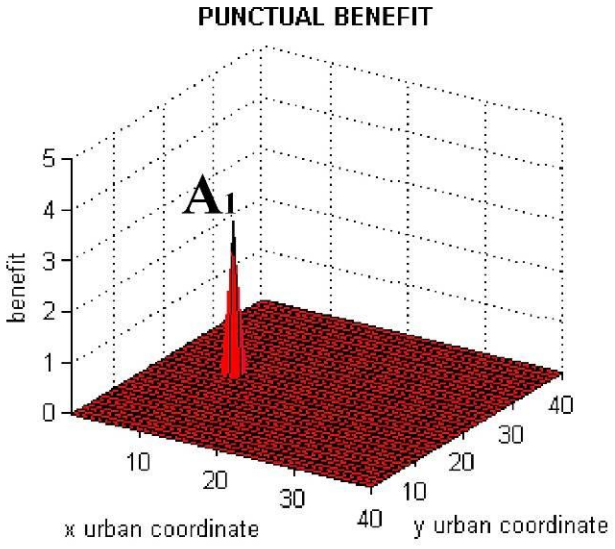
Middle: the same amenity but in un-isotropic area with a lower *E* on the north area of the city.

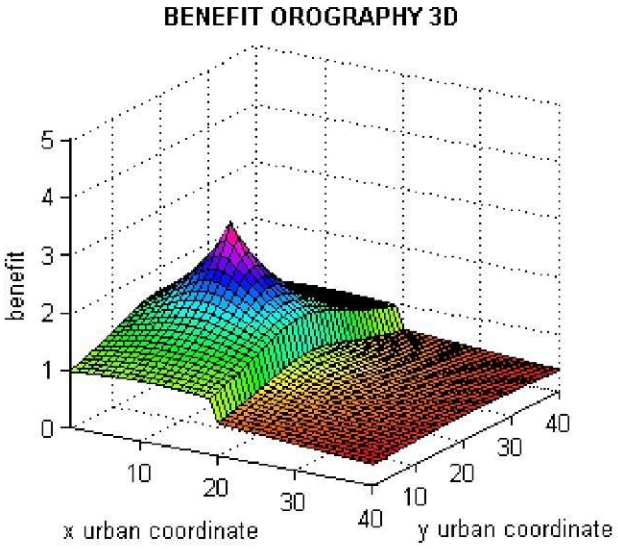
Right: same example of the “Middle” but with an even lower *E*.

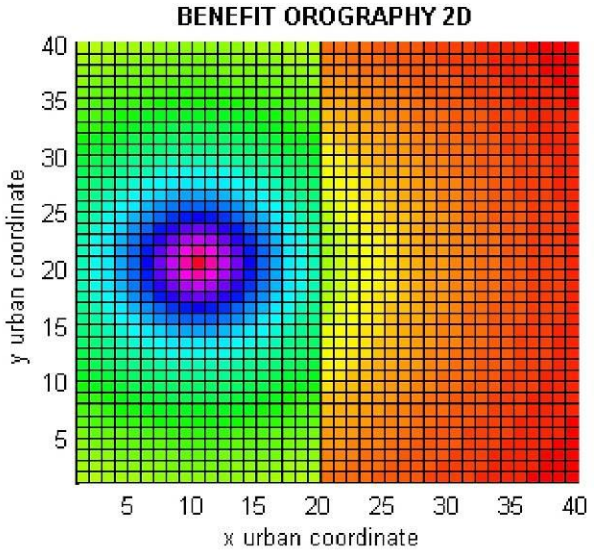

Benefit
Ai
Bb
Bk
x
y
di-b
db-k
k
EI

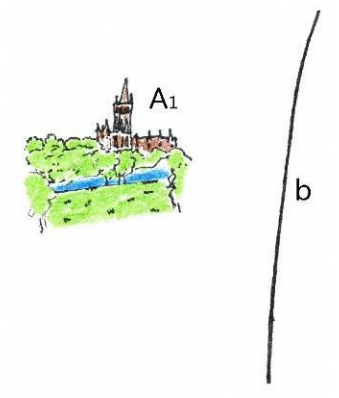

A1
b
A2

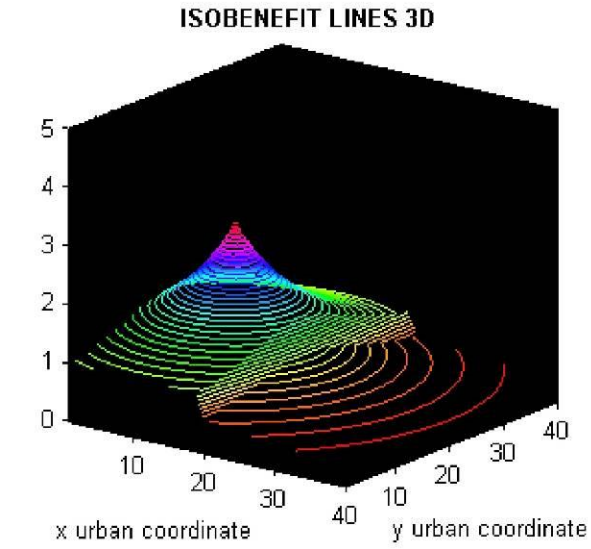

CHOCOLATE FACTORY

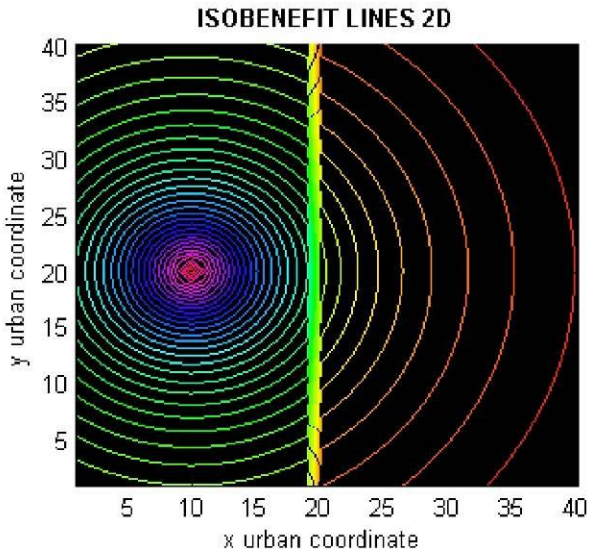

PUNCTUAL BENEFIT
A1
benefit
x urban coordinate
y urban coordinate

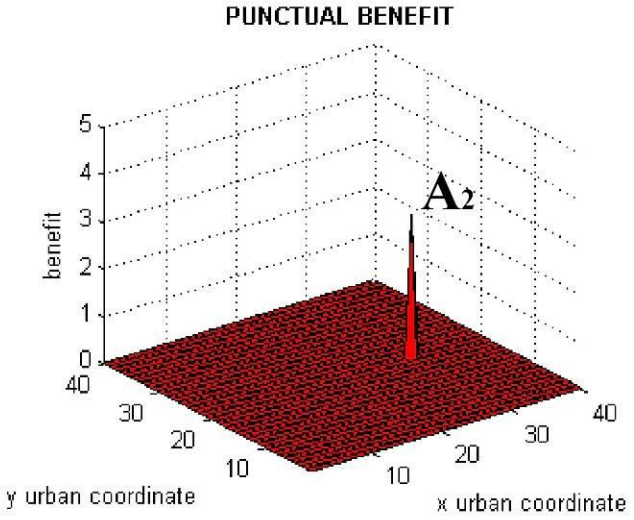

BENEFIT OROGRAPHY 3D
benefit
x urban coordinate
y urban coordinate

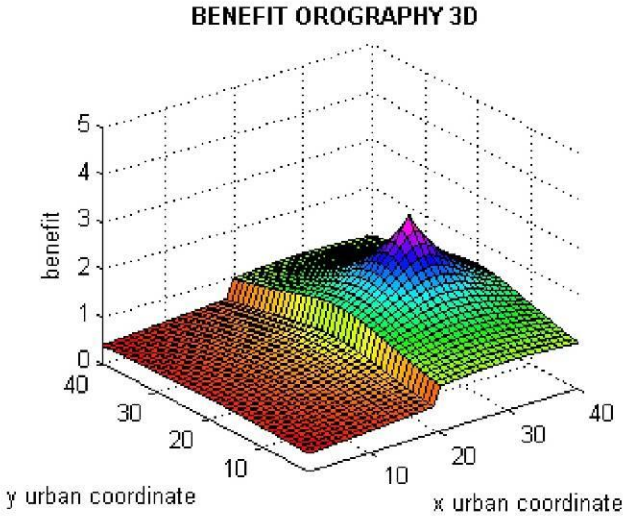

BENEFIT OROGRAPHY 2D
y urban coordinate
x urban coordinate

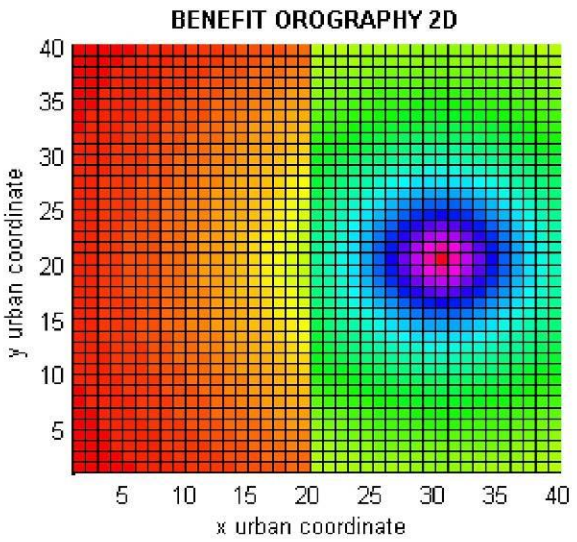

A1
b

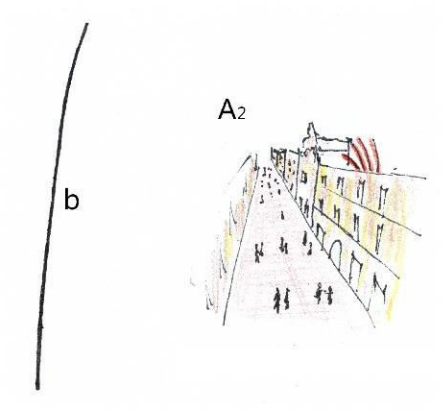

ISOBENEFIT LINES 3D
x urban coordinate
y urban coordinate

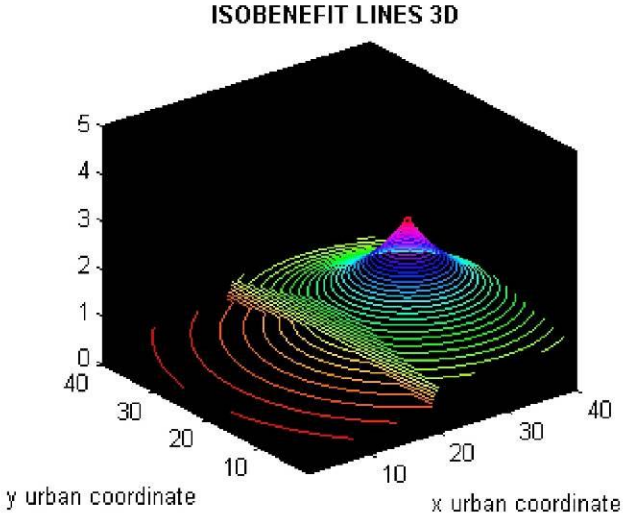

ISOBENEFIT LINES 2D
y urban coordinate
x urban coordinate

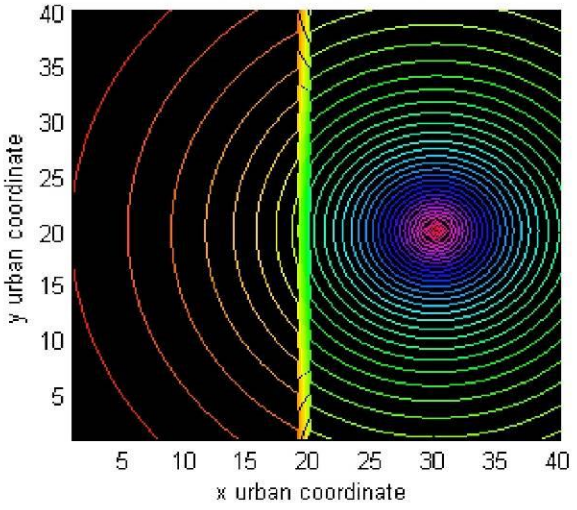

PUNCTUAL BENEFIT
A2
benefit
y urban coordinate
x urban coordinate

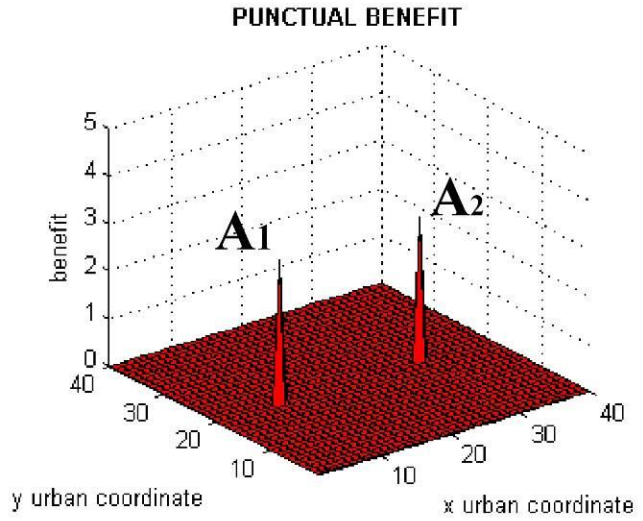

BENEFIT OROGRAPHY 3D
benefit
y urban coordinate
x urban coordinate

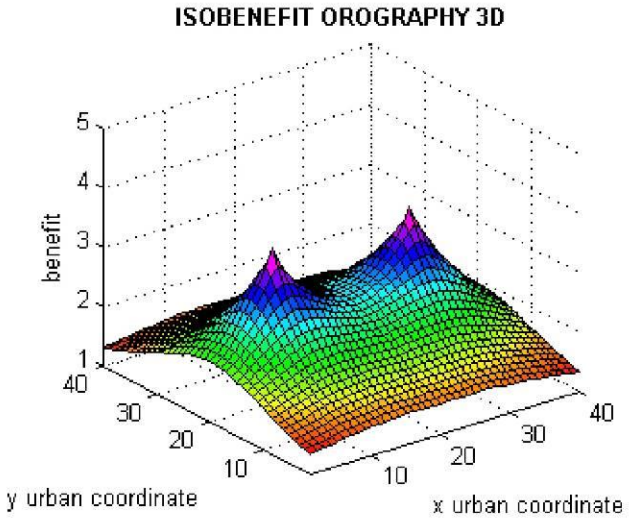

BENEFIT OROGRAPHY 2D
y urban coordinate
x urban coordinate

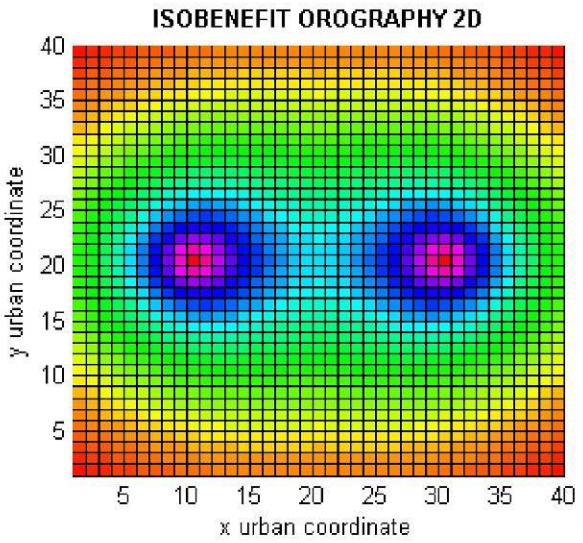

b
A2

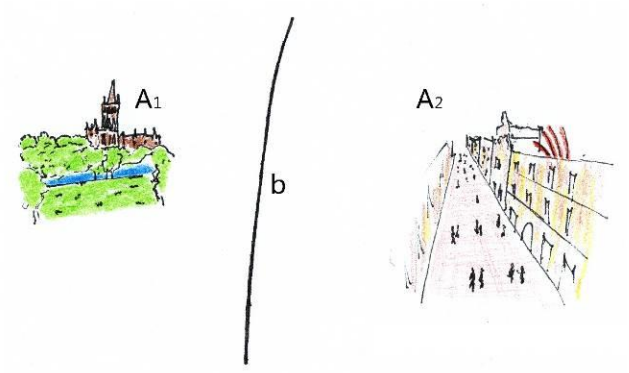

ISOBENEFIT LINES 3D
y urban coordinate
x urban coordinate


ISOBENEFIT LINES 2D
y urban coordinate
x urban coordinate









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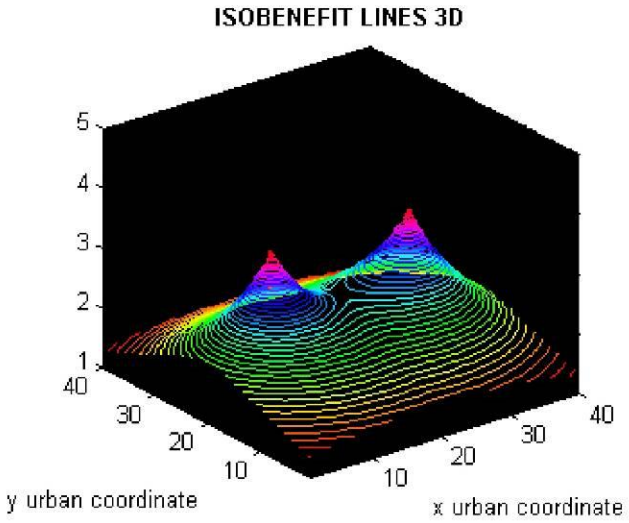
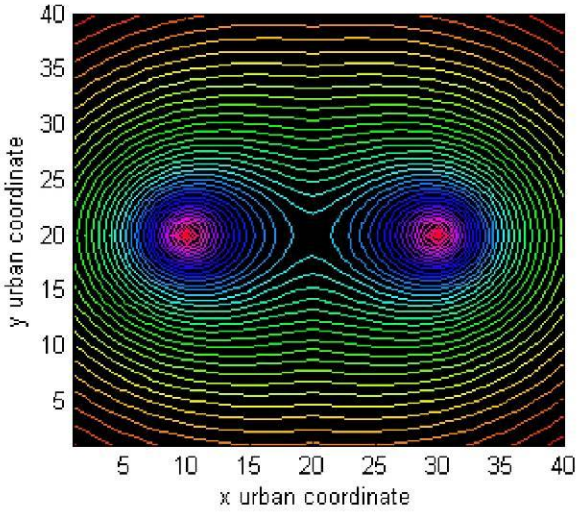
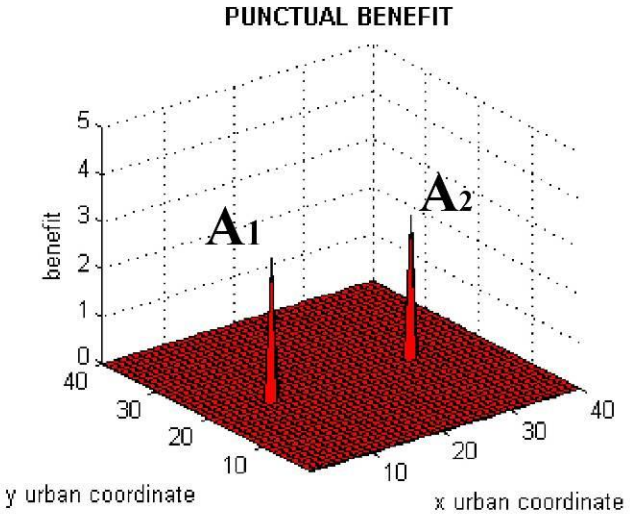
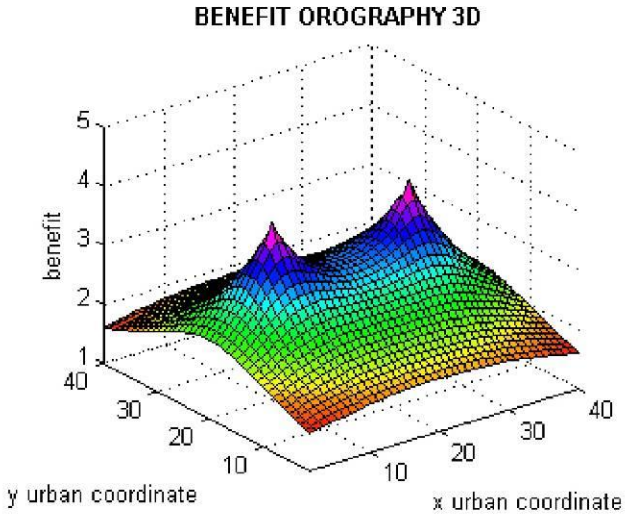
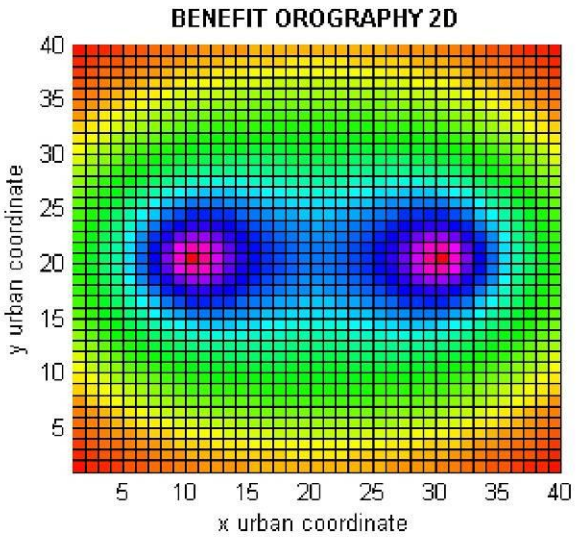
minB=1.2924
U=0.7820

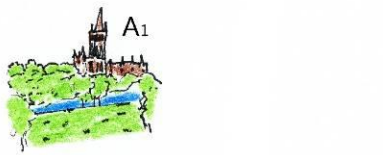


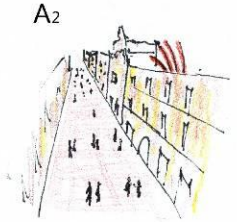












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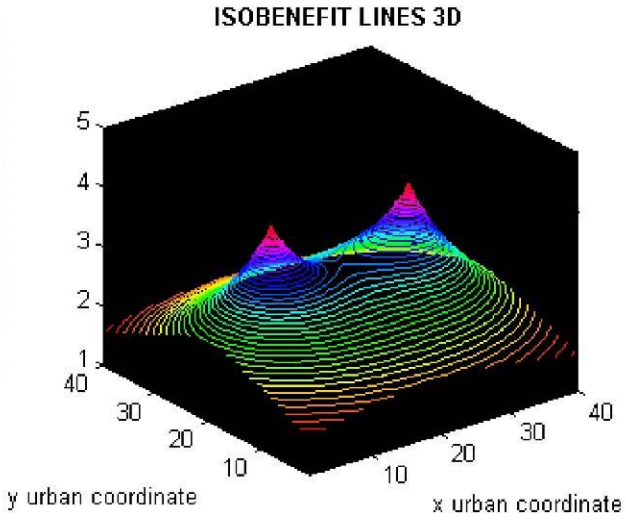
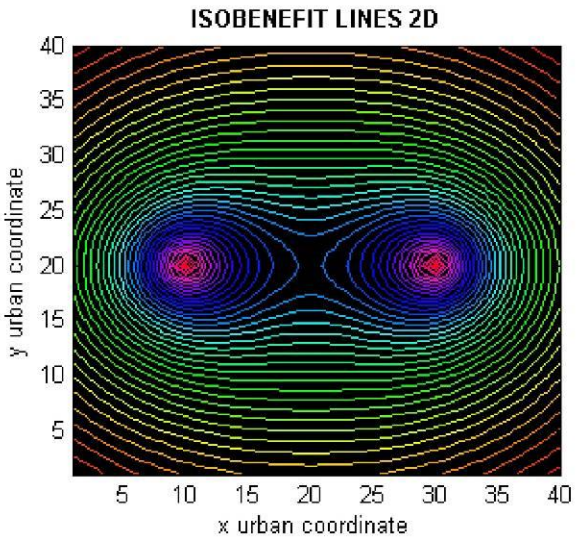
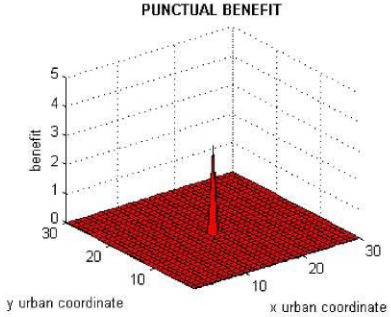
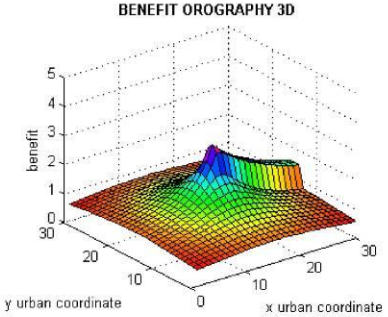
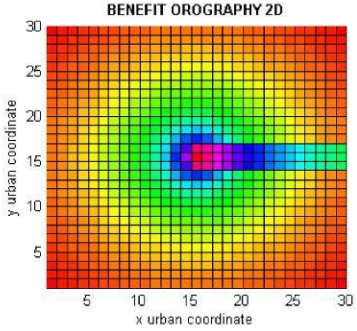


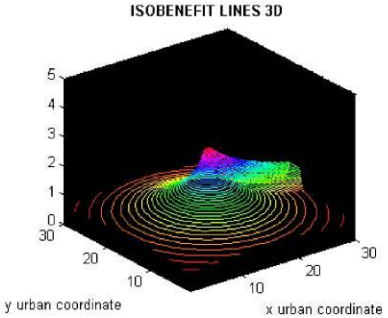


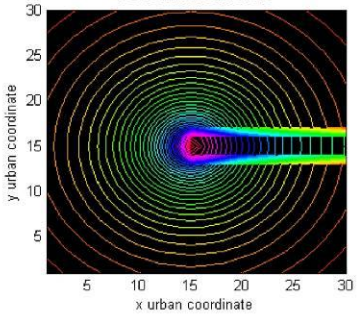
Preferential Pathways (pedestrian and cycle paths, underground, fast streets, etc.)

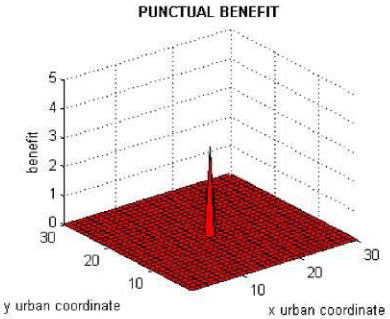


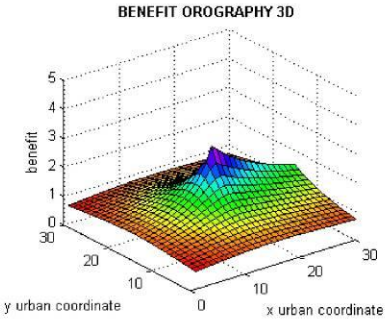


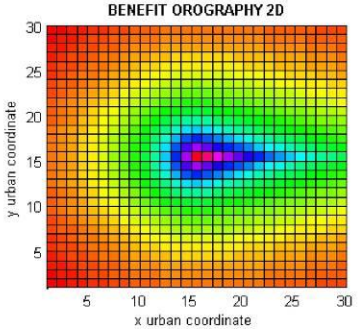


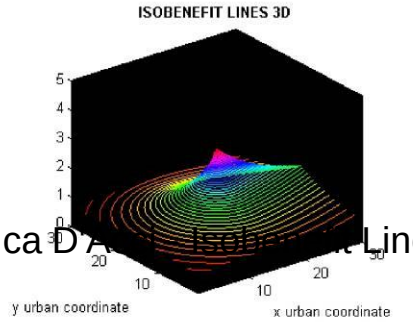


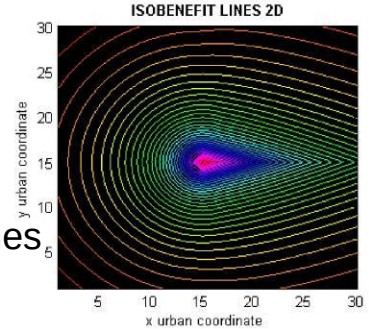








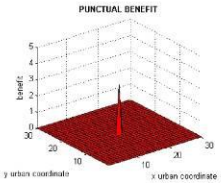


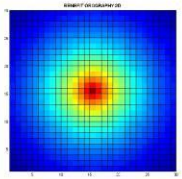


$$B_{i,z} = \frac{B_{i,l}}{1 + d_{i,l)-z} / \varphi E_l)}$$

$$B_{l,k} = f\ B_{i,z}, d_{z-k}, E_{k-z})$$

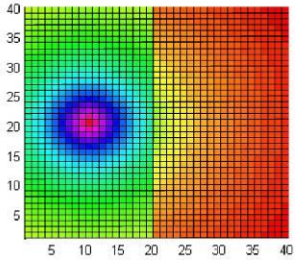
Amenity



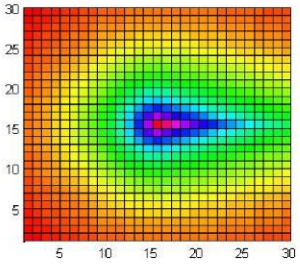


Psycho-temporal-economical alteration of distances and amenity diffusion

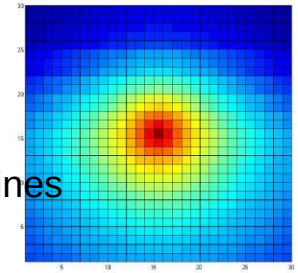
BARRIERS



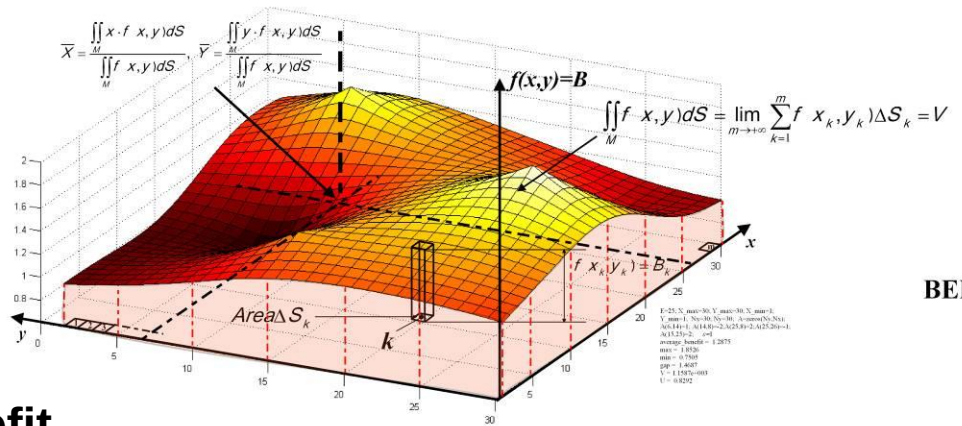
PREFERENTIAL PATHWAYS

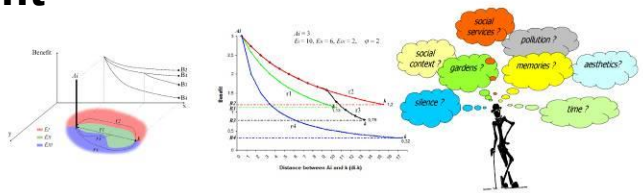


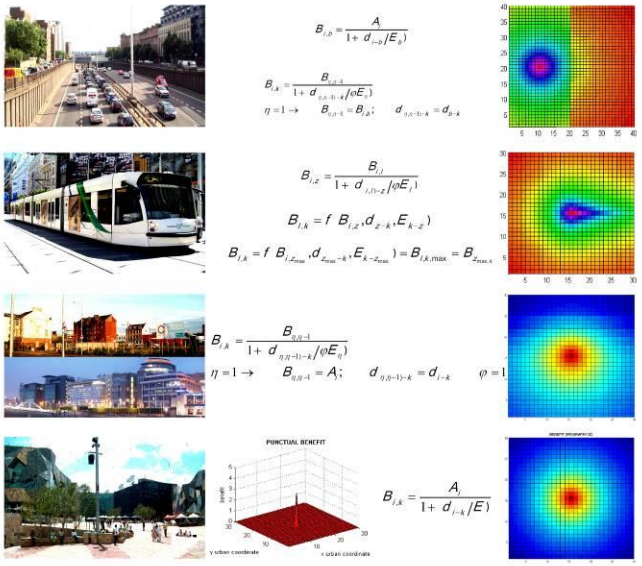
DIFFERENT *E*
i.e. different general urban quality
(fuzzy urban quality + number and distribution of city centralities),
and/or streets/transport efficiency)



Cities as
Maths Volumes of Benefit







Luca D'Acci - Isobenefit Lines

BENEFIT LANDSCAPE

↑

Route choice

+

Barriers (Psychological and/or Physical)

+

Preferential Paths
(Psycologically and/or Temporally and/or Economically)

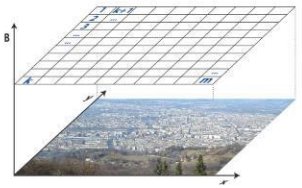
+

Urban Fuzzy Quality, Social Context,
Transports and Streets Efficiency,
Personal Memories and Preferences, etc.

+

Amenities
quantified on Personal Preferences (*Personal Isobenefit Lines*)
or, if exist, on the "ordinary" Preferences

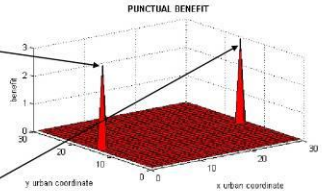
↑

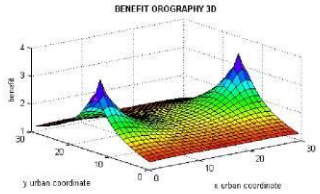


CITY

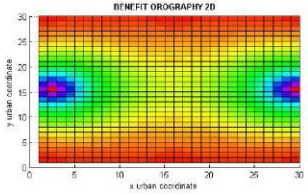
9 Nov 2015 - ETH

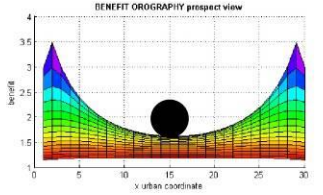
A1



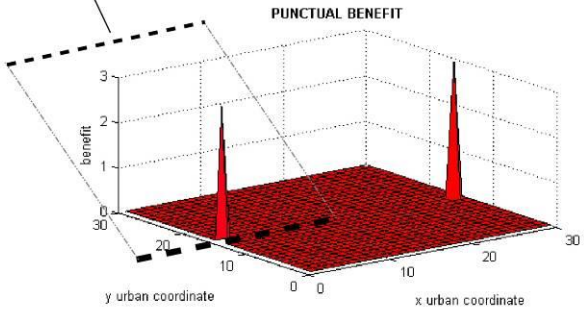


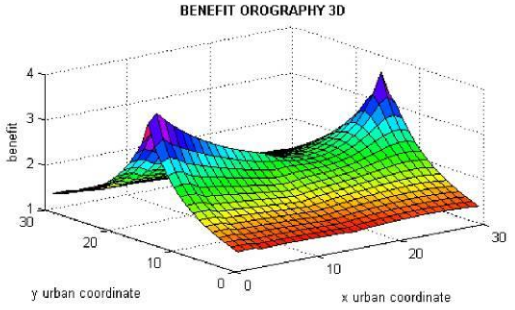
A2

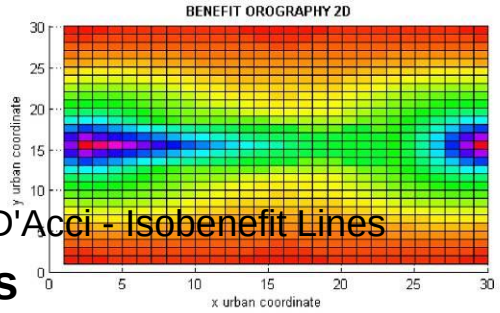


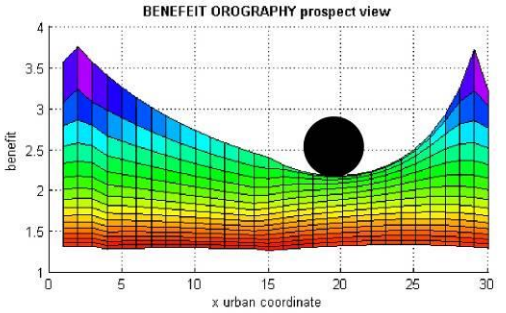


Preferential Pathway



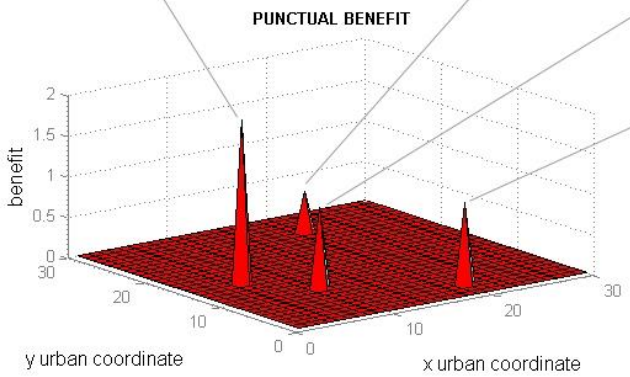


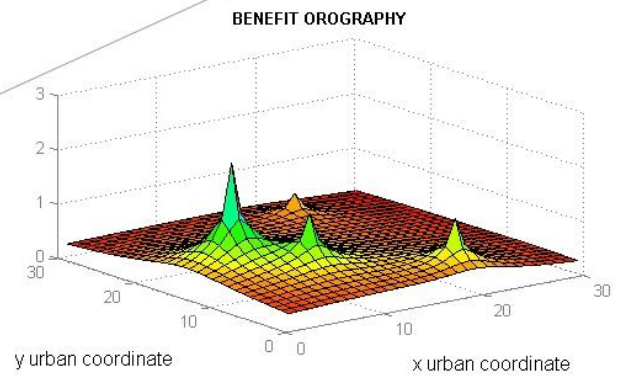


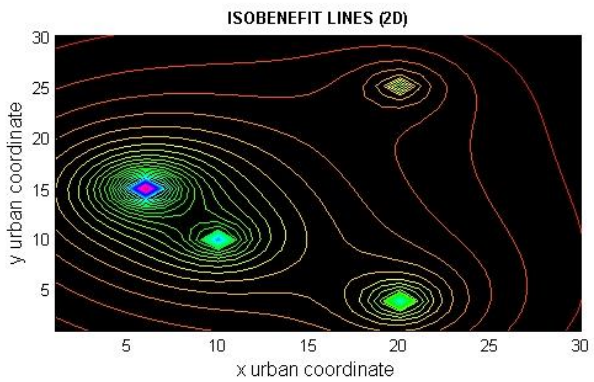


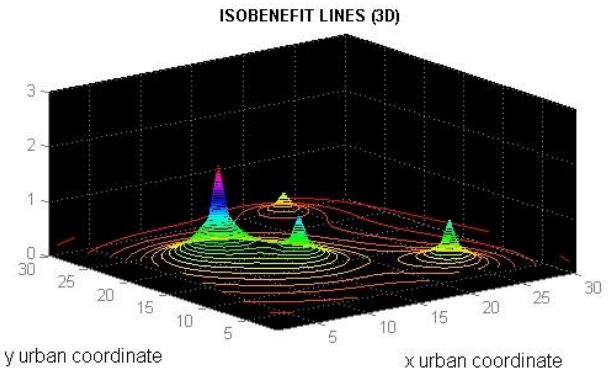
Breaking points of equal attractions

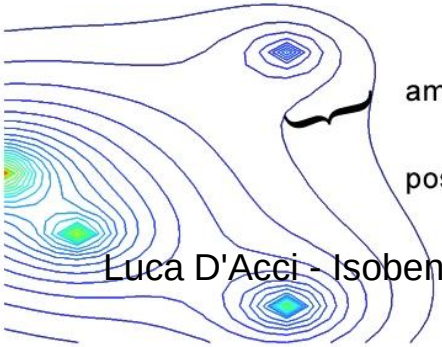
Spatial Equilibrium & Isobenefit Lines







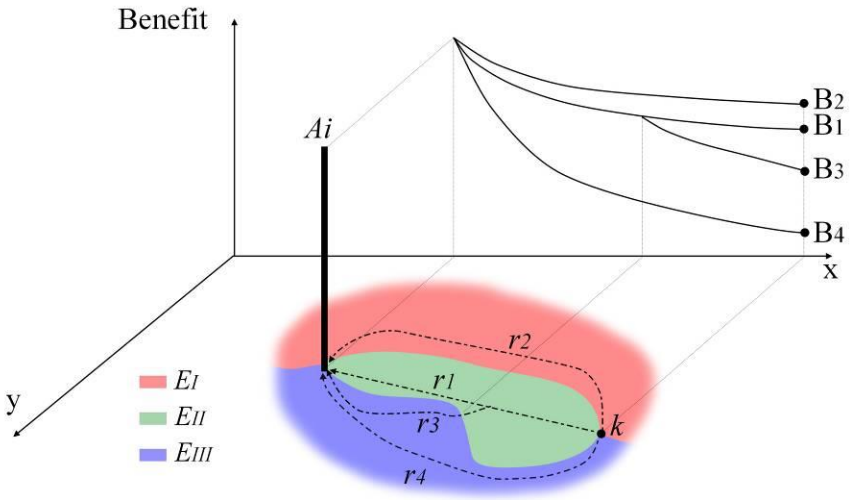


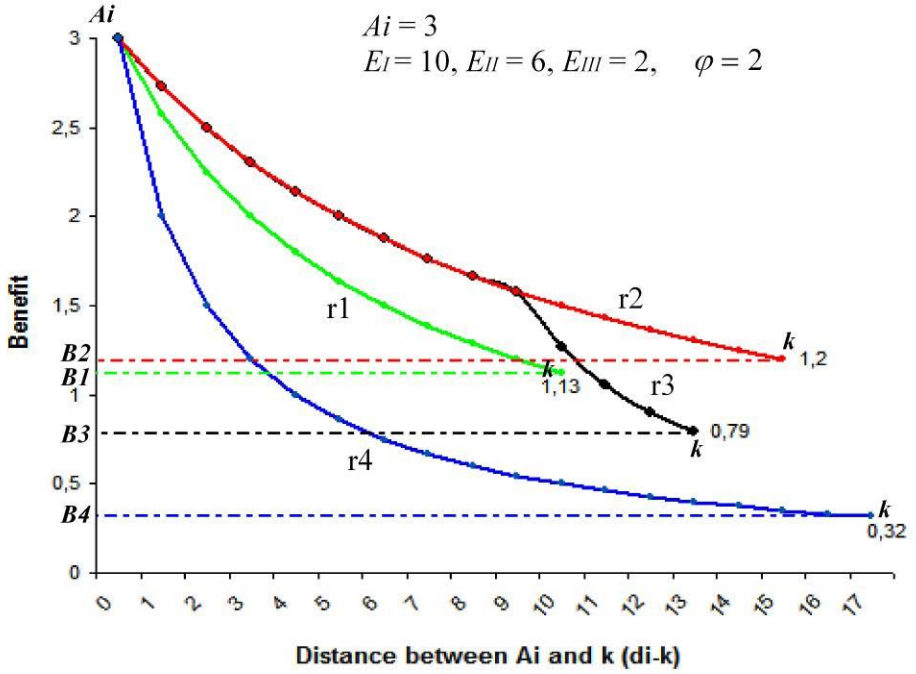


amenties orography step → isobenefit step
↓
positional value step → housing value step

} SPATIAL EQUILIBRIUM

Citizens movement within cities



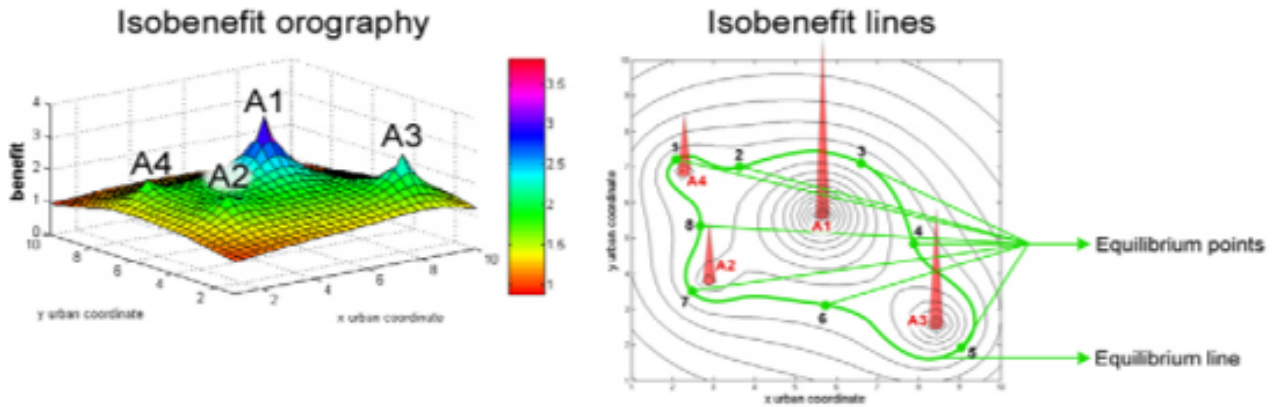


MIT Technology Review

October 18, 2012

Isobenefit Lines Rewrite Rules for Understanding City Life

A new way of mapping cities according to the benefit they give residents has the potential to change the way planners think about city design



From MIT Technology Review, published by **MIT**, Massachusetts Institute of Technology
www.technologyreview.com/view/429679/isobenefit-lines-rewrite-rules-for-understanding/

Cities are vast, dynamic entities that are complex on a multitude of different scales. A visitor to any city can usually gauge within hours whether it "works" on a human level. But it is famously hard to quantify the factors that make one city better than another.

Today, Luca D'Acci at the University of Strathclyde in Scotland suggests an interesting new way

D'Acci L. (2013). Simulating Future Societies in Isobenefit Cities. *Futures*. Volume 54, pp 3-18

D'Acci L. (2015). *Urban DNA for cities evolution*. http://arxiv.org/abs/1408.2874

D'Acci L. (2015). Mathematize urbes by humanizing them. Cities as Isobenefit Landscapes: Psycho-Economical distances and Personal Isobenefit Lines. Landscape and Urban Planning, Volume 139, July 2015, Pages 63–81.

www.urem.eu/isobenefit

www.urem.eu/isobenefit/lectures.html

references:

- D'Acci L., (2013). Monetary, Subjective and Quantitative Approaches to Assess Urban Quality of Life and Pleasantness in Cities. *Social Indicators Research*, January 2014, Volume 115, Issue 2, pp 531-559
- D'Acci L., (2013). Hedonic inertia and underground happiness. *Social Indicators Research*, September 2013, Vol 113, n.3, pp 1237-1259.
- D'Acci L., (2013). Simulating Future Societies in Isobenefit Cities. *Futures*. Volume 54, November 2013, Pages 3–18.
- D'Acci L., (in press 2015). Mathematize urbes by humanizing them. *Landscape and Urban Planning*.