Well-being and the city: Understanding urban sustainability in terms of the capability approach using land use transport interactions modeling

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Abstract

In this article, we explore linking the ideas of the capability approach developed by the Nobel Prize winner Amartya Sen to LUTi modelling practices, in order to bring new insights in the understanding of the relationship between cities and well-being. The integration of the capability approach and the development of LUTi modelling to understand how different urban actors are interconnected, and what the feedback loops are between them and the city evolution can provide new insights on the evaluation and prospective analysis of urban sustainability. In this context, this article shows a proposal on the integration of both topics via the development of a theoretical and methodological framework for understanding the factors contributing the development of cities through the evaluation of indicators associated to LUTi modelling as decision support instruments for urban planning and land policy.

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1. Sustainable Development in a Future of Cities

There is little doubt that the growth of world urban population has accelerated over recent decades at a remarkable rate. According to the UN, the number of people living in cities increased nearly fivefold over the period between 1950 and 2011, with the expectation of a further 72 per cent increase by 2050 (UN, 2012b). Additionally, there is new analysis suggesting that the world's population will keep rising through to 2100, and not flatten around 2050 as has been widely assumed (Gerland et al., 2014). Cities cover less than 2 per cent of the Earth's surface (Angel et al., 2011), yet they host 52 per cent of world's population (UN, 2012b), generate more than 80 per cent of global GDP (Dobbs et al., 2011), and consume 78 per cent of the world's energy (IEA, 2013). In this context, the question that needs to be addressed is whether this dramatic urbanization has contributed or not to the improvement of well-being (Harvey, 2012), and what should be done through public policy to improve well-being.

The idea that society needs to move in a desirable direction to improve well-being has been a constant issue throughout human history (Du Pisani, 2006). However, it was not until the latter half of the 20th century that the paradigm shift in thinking about it caused the concept of sustainable development to occupy the center stage in political and scientific discourses (WCED, 1987; UN, 1992; UN, 2002; UN, 2012a). So much that, the interest of unique authors and international gatherings addressing related issues has grown exponentially (Bettencourt and Kaur, 2011), and by the beginning of the 21st century, sustainable development, given its ambitious scope, has become the most challenging theory, science, and policy-making concept ever developed, that has served as a vital historical marker on the rise of a remarkable global awareness.

It is widely acknowledged that there is no single theory able to capture in an operational form the richness of the sustainable development concept. Nevertheless, greater clarity of intention and perspective on the part of scholars working in the field is necessary (Levin and Clark, 2010). It is therefore worthwhile to locate the treatment of urban sustainability presented here. It has been recognized that sustainable development links normative and descriptive components (Schultz et al., 2013). Normative components are particularly important to set goals of sustainable development, that is, to specify that sustainable development ought to be in some

form or other. Regarding the normative component, sustainable development can be seen as a process of expanding well-being taking into account intra-generational and inter-generational justice (Cruz, 2010; O'Neill, 2010; Rauschmayer et al., 2010; Sen, 1999b; Sen, 2013). Regarding the descriptive component, the understanding of the "life support systems" provided by the interlinked human-environment system is essential to define the conditions of normative components (UN, 1992; National Research Council, 1999; UN, 2002; UN, 2012a). Having into account the constitutive link between normative and descriptive components, it is proposed in here that, the key for the understanding of the sustainable development concept is given by:

Definition 1. Sustainable development *is a process that expands well-being while conserving the earth's life support systems, taking into account an obligation not only for the current generation, but also for future generations; and not only for some places at the expense of others, but for all humanity as a whole.*

Given this definition, it is proposed in here that, if development is a process, then, sustainability can be interpreted as the ability to maintain that process. Taking into account the general role of human beings as agents of change (Sen, 1999b; Becker, 2010), then, the key for the understanding of the sustainability concept is given by:

Definition 2. Sustainability *is the ability of the coupled human-environment system to expand well-being while conserving the earth's life support systems, taking into account an obligation not only for the current generation, but also for future generations; and not only for some places at the expense of others, but for all humanity as a whole.*

Cities are excellent examples of a human-environment system. Moreover, given the impact that cities have on the earth's life support system, as broadly mentioned before, the study of cities is a useful starting point that could have a major contribution to progress towards sustainable development. In this sense, it is argued in here, given the two previous definitions, that the key for understanding the sustainable city concept is given by:

Definition 3. Sustainable city *is a city that expands well-being of its members while conserving the earth's life support systems, taking into account an obligation not only for the current generation, but also for future generations; and not only for some places at the expense of others, but for all humanity as a whole.*

Moreover, given these three definitions, it is further argued in here that, the key for the understanding of the urban sustainability concept is given by:

Definition 4. Urban sustainability *is the ability of a city to expand well-being while conserving the earth's life support systems, taking into account an obligation not only for the current generation, but also for future generations; and not only for some places at the expense of others, but for all humanity as a whole.*

In this article, section 2 aims to provide an overview of the conceptual foundations of progressing the understanding of urban sustainability (Definition 2) by means of the capability approach. However, even having a conceptual framework to delineate the perspective of urban sustainability, it is still needed to understand the dynamics of cities. Thus, section 3 suggests the need to understand cities as complex spatial system by means of LUTi modelling. Moreover, even understanding the dynamics of cities, is not the same as being able to make them work differently, it is suggests that based on the perspective of urban sustainability outlined in section 2, and the perspective of understanding the dynamics of cities outlined in section 3 there is a latent capacity of measuring progress toward sustainable cities. Finally in section 4 a couple of applications are presented.

2. Functionings and capabilities perspective

Under the assumption that well-being constitutes the matter of urban sustainability, it remains to be clarified what well-being means and encompasses. According to the capability approach, the analysis of the substantive content of well-being may be performed at two levels: at the levels of functionings and at the level of capabilities. Functionings are the primary feature of well-being. They can be seen in terms of how an individual can function, that is, the various beings and doings that individuals value and have reason to value (Sen, 1985a; Sen, 1985b; Sen, 1999a; Sen, 1999b). From the perspective of beings, functionings could be states of existence, referring to physical and mental states (e.g. functionings as beings may vary from elementary ones, such as being nourished, being housed, or being educated, to complex ones such as being part of a supportive social network, being part of a criminal network, being depressed, or being happy). From the perspective of doings, functionings could be activities, referring to what an individual does (e.g. functionings as doings may vary from elementary ones, like drinking, eating, or travelling, to complex ones, such

as working on the labor market, caring for others, or voting in an election). Furthermore, in terms of the substantive content of well-being, the focus on functionings has to be further extended to what individuals are effectively able to do and to be, that is, their capability to function (Sen, 1985a; Sen, 1985b; Sen, 1999a; Sen, 1999b). This capability to function represents the real opportunities to functionings that an individual will be able to achieve (Sen, 1985a; Sen, 1985b; Sen, 1999a; Sen, 1999b). These real beings and doings that an individual can achieve are referred to as capabilities. Functionings and capabilities are intimately connected but independent concepts; in fact, functionings are integral elements of capabilities.

2.1 The formal model of well-being

Taking into account that capabilities are functionings that an individual can achieve, it is possible to say that the analysis of functionings precedes the one of capabilities, so that, the analysis of functionings need to be solved first. In this sense, Sen (1985a) provides a simple representation of the way an individual, *n*, converts a vector of available resources *x* from all the set of possible resource vectors *X*, into a vector of functionings, *b*:

$$b_n = f_n\big(c(x_n)\big) \; \forall \; f_n \in F_n \; and \; \forall \; x_n \in X_n \qquad (1.1)$$

In Sen's view, resources have certain characteristics which make them of interest to individuals. Thus, if c is a function that converts each vector of resources x into a vector of the characteristics of those resources, then, the vector of characteristics of resources available to that individual will be denotated by $c(x_n)$. Moreover, if F denotes the set of all possible ways, those are utilization functions, of using the particular vector of characteristics of resources $c(x_n)$, then, f_n are the specific choice of the set of utilization functions. Then, the vector b_n represents the functionings that an individual has managed to achieve using the characteristics of resources $c(x_n)$ through the chosen set of utilization functions f_n.

According to Sen (1999a), there are many sources of diversity that impact the ability of an individual to use different characteristics of resources in order to achieve valuable functionings, thus, a similar bundle of resources will generate different functionings for different individuals. In this sense, the utilization function provided in Equation 1.1, has been further extended by Kuklys (2005) as follow:

$$b_n = f_n(c(x_n)|z_n, z_s, z_e) \; \forall \; f_n \; \in \; F_n \; and \; \forall \; x_n \; \in \; X_n \qquad (1.2)$$

Some of the differences will be dependent upon individual factors, z_n, whether others will be dependent upon structural differences in social, z_s, and environmental, z_e, factors. It is recognised that each of the conversion factors will not have an independent influence over the achievement of functionings. Instead, the achievement of functionings, from the resources available to individuals, is influenced on the overall interaction and combination of conversion factors Sen, 1999b; Kuklys, 2005; Chiappero-Martinetti and Salardi, 2008).

In line with Kuklys, Chiappero-Martinetti and Salardi (2008) offer an extended conceptualization of the utilization function aiming to improve the explanation of the achievement of functionings. In their work, resources available to individuals are divided private resources of each individual and public resources that depends on the social and institutional context where each individual operates. Both, private and public resources are influenced by the aforementioned conversion factors. Then, Kuklys's utilization function (Equation 1.2) can be re-interpreted as follows:

$$b_n = f_n(c(x_n, y_{ns})|z_n, z_s, z_e) \qquad (1.3)$$
$$\forall \; f_n \; \in \; F_n \; , \forall \; x_n \; \in \; X_n \; and \; \forall \; y_{ns} \; \in \; Y_{ns}$$

Now, x_n is the vector of private resources at the command of an individual n, and y_{ns} are the public resources available to that individual depending on the social and institutional context where the individual operates. X_n is the set of all possible private resource vectors, and Y_{ns} is the set of all possible public resource vectors. Without making specific reference to the work of Kuklys (2005), and Chiappero-Martinetti and Salardi (2008), Lessmann and Rauschmayer (2013) remark that private and public resources, as well as conversion factors link functionings at a systemic level. Thus, the utilization function aims to encapsulate private and public resources available to individuals and the conditions that are required to convert those resources into achieved functionings.

2.2 The role of cities

Functionings are to a significant degree determined by interactions between individuals (Robeyns and Veen, 2007). Then, if interactions between different individuals define the nature of cities (Batty, 2013), it is argued in here that, there is a generic link between the utilization function f_n presented in Equation 1.3 and the role of cities in the achievement of functionings. In fact, as remarked by Lessmann and Rauschmayer, the achievement of functionings is dependent on how embedded an individual appears to be in the interlinked human-environment system, in here, namely the city. The central argument of this article is to extend the utilization function presented in Equation 1.3, following the two most general concepts used in LUTi modelling: interaction and location. As presented in Section 3, the representation of cities is grounded in the location of individuals performing shared activities, in accordance with their own views of the life that they value to live (e.g. working, raising families, socializing, shopping, recreation and so on). Then, the fact that the same individuals are involved in the performance of different activities in different places, and that different places have connections between them, means that the city can only function if there are interactions between locations (e.g. going to work, shop, school, hospital, and so on) (Wilson, 2000). In this sense, the achievement of functionings can now be seen to be concerned with individuals performing shared activities that they value to do at different locations, and with the spatial interaction needed to perform those activities. Additionally, by thinking of functionings achievement as being generated by individuals making decisions about what kind of activity to perform with respect to the multitude of locations in the city, the utilization function can be extended to take into account the impact of private and public resources controlling for location and spatial interaction. Then, Equation 1.3 can be re-interpreted as follows:

$$b_{nijm} = f_n\left(c\left(x_{nijm}, y_{ij}\right)|z_{nijm}, z_{sij}, z_{eij}\right) \quad (1.4)$$
$$\forall f_n \in F_n, \forall x_{nijm} \in X_{nijm} \; and \; \forall y_{ij} \in Y_{ij}$$

Now, b_{nijm} is the vector of achieved functionings for individual n interacting from origin location i to destination location j to perform an activity m. Then, the achievement of functionings is given by the private resources x_{nijm} of that individual n interacting from origin location i to destination location j to perform an activity m, as well as the public resources y_{ij} that

allow the interaction from origin location i to destination location j to perform an activity m. X_{nijm} is the set of all possible private resource vectors, and Y_{ij} is the set of all possible public resource vectors.

As mentioned before, in terms of the substantive content of well-being, the focus on functionings has to be further extended to what individuals are effectively able to do and to be, that is, their capability to function, namely capabilities. In this sense, and formally following Sen (1985a), Equation 1.4 can be further extended to denote the set of feasible functionings, $P_{nijm}(x_{nijm}, y_{ij})$, for an individual n interacting from origin location i to destination location j to perform an activity m as follow:

$$P_{nijm}\,(x_{nijm}\,, y_{ij}\,) = \{b_{nijm}\,|b_{nijm} = f_n\big(c\big(x_{nijm}\,, y_{ij}\,\big)|z_{nijm}\,, z_{sij}\,, z_{eij}\,\big) \quad \forall\, f_n\ \in\ F_n\,, \forall\, x_{nijm}\ \in\ X_{nijm}\ and\ \forall\, y_{ij}\ \in\ Y_{ij}\,\} \tag{1.5}$$

Then, the effective freedom of pursuing well-being of an individual n interacting from origin location i to destination location j to perform an activity m, given the availability of private resources X_{nijm} and public resource Y_{ij}, and her or his individual possibilities of converting the characteristics of them into functionings b_{nijm}, is represented by her or his capability set, Q_{nijm}, which is defined over the different feasible functionings b_{nijm} of an individual n interacting from origin location i to destination location j to perform an activity m, as foll

$$Q_{nijm}\ = P_{nijm}\,(x_{nijm}\,, y_{ij}\,) \quad \forall\, x_{nijm}\ \in\ X_{nijm}\ and\ \forall\, y_{ij}\ \in\ Y_{ij}\,\} \tag{1.6}$$

3. Interactions and location perspective

Under the assumption that, as argued in section 2, the way in which individuals act and interact with respect to spatial locations, have immediate implications for the achievement of functionings and the expansion of ca-

pabilities, in order to have a sustainable city (see Definition 4), it is still necessary to understand how cities work. In this context, one research field that can be integrated to the capability approach to contribute planning and policy development in such ways consistent with achieving, maintaining, and improving urban sustainability (see Definition 3), is that of LUTi modelling. The basic problems of LUTi modelling can be seen to be concerned with the understanding of a large set of humans, acting as individuals, households, or within organizations, dynamically interact with one another locally in time and space in order to perform shared activities. These interactions, which are influenced by the information that individual use to respond to their environment, define a multitude of coupled social and physical networks which enable individuals to exchange materials and information. These networks tend to mutually reinforce one another as they develop creating different types of engineered structures, information processing technologies, institutions and social organizations which, in some way, condition back the interactions between individuals and their environments.

Based on the two most general concepts used in LUTi modelling: interaction and location, the aim in subsection 3.1 is to present a framework to understand how activities (work, residential, shopping, commercial, health, education, and leisure), that have distinct locations, can be articulated as sets of interactions between them (e.g. journey home to work, home to shop, home to commerce, home to health-care, home to education, home to leisure, and so on), then, subsection 3.2 will aim to explain the implications for the achievement of functionings and the expansion of capabilities derived from location and interaction performance indicators in terms of the utilization function f_n presented in Equation 1.4.

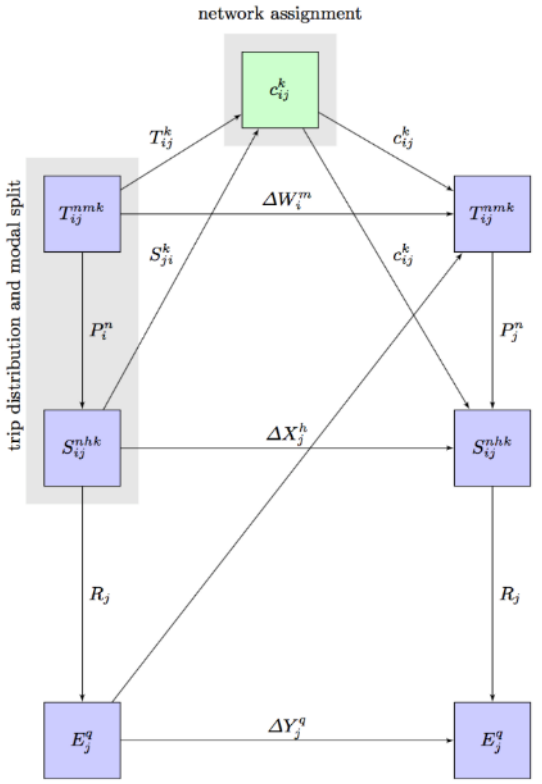
3.1 SIMulating Urban Land use as Commercial and Residential Activities (SIMulacra) framework

By thinking of functionings and capabilities as been mainly generated by individuals making decisions where to travel and how to locate to perform different kind of shared activities, in accordance with their own views of the life that they value to live, the focus is transferred into theories and models that associate the achievement of functionings and the expansion of capabilities to decisions about how far to travel, what mode of transport to use, and what kind of activity to perform with respect to the multitude of locations that are linked with different activities within the city. According to Batty (2013), with respect to systems of production and consumption of resources, there are at least four interaction patterns that can be taken into

account when trying to understand cities: flows of materials involving the delivery and provision of utilities, flows of commodities involving the delivery and consumption of goods, flows of population involving individuals engaging in different activities, and flows of information which run in parallel with the previous three. Based on the SIMulacra modelling framework (Batty et al., 2013; Smith, Vargas-Ruiz, and Batty, 2013), a much more pragmatic approach is taken in here. Special attention is paid to those flows that are more associated with human activities that have distinct locations and generate spatial demand and supply of private and public resources that can be converted into functionings and capabilities.

SIMulacra is a series of fast, visually accessible, cross-sectional urban models for large metropolitan areas that enable the rapid testing of many different scenarios pertaining, both, short-term and long-term urban futures. The models are multi-sector, dealing with residential, services, and employment location. They are highly disaggregate, and subject to constraints on land use densities and transport capacities. Several versions of the model now exist, however, in here, a brief outline is presented. Figure 3.1 shows a basic outline of the cross-sectional structures and many-sector models that the framework dealt with.

Figure 3.1. SIMulacra framework overall sequence of sub-models.



The model links activity types through spatial interactions: the journey home to work defined by trips T_{ij} linking population to employment, trips S_{ij} from residential areas to services centers (shopping, health, education, and leisure), and through implicit industrial linkages measured as accessibilities to employment and to commercial activities. A formal description of these activities and the way they can be disaggregated and extensions to such classifications are shown in Table 1.

Table 3.1. Description of SIMulacra framework variables in Figure 3.1.

Variable	Description
T_{ij}	Trips home to work
S_{ij}	Trips home to services
c_{ij}	Generalized travel cost
P_i	Population
R_j	Service Employment

E_j	Total Employment
W_i	Residential Floor space
X_j	Service Floor space
Y_j	Commercial Office Floor space
n	Type of person
m	Type of residence
h	Type of service center
q	Type of employment sector
k	Type of mode of transport

3.1 Objective measures of public resources

As discussed before, the utilization function, f_n, presented in Equation 1.4, aims to describe the relationship between the achievement of functionings is given by the private resources x_{nijm} of that individual n interacting from origin location i to destination location j to perform an activity m, as well as the public resources y_{ij} that allow the interaction from origin location i to destination location j to perform an activity m. First, methodological choice has traditionally taken individual and household income as a measures to those private resources. However, as remarked by (Sen, 1999b), individual income can, of course, be very important as means to expanding well-being; but well-being depends also on other public resources, such as social and economic arrangements, as well as political and civil rights. In here, the focus is on those public resources associated to social and economic arrangements. Even in a world where behaviors are rapidly changing by new ICT (Information and Communication Technologies), public resources associated with work, residence, shopping, commercial, health, education, and leisure will remain constant. The argument in here, is that, based on LUTi modelling, objective measures of these public resources can be calculated in relation to individuals making decisions where to travel and how to locate to perform different kind of shared activities, in accordance with their own views of the life that they value to live. This shows the interdependence of the substantive components of well-being, namely functioning and capabilities, with the wider spatial structure of the city.

It is impossible to show in this section the full range of possible indicators investigated within SIMulacra. The whole set of indicators derived from the framework will be presented in the forthcoming (Vargas-Ruiz, 2015). Here only an example will be given to clarify the argument. Suppose that the aim of this study is to define objective measures of the public resources

needed to model and to estimate a utilization function for the status of the functioning "being well-sheltered". As mentioned in section 1, this utilization function is a relation where the achievement of functioning status is explained by a set of private and public resources controlling for personal, social and environmental conversion factors. However, for the sake of the example, in defining this functioning utilization function, some simplifications are going to be taken into account. First, the function $c()$ that transforms resources into characteristics will not be considered. Second, the choice of the functioning among a set of possible functionings will not be taken into account. Third, the objective measures are going to be derived from modelling spatial interactions of the journey from home to work defined by trips T_{ij} linking population to employment. Needless to say, that this is an over simplification of the problem as "being well-sheltered" is also influenced by a set of different characteristics such as accessibilities to services (shopping, commercial, health, education, and leisure), exposure to pollutants such as those derived from the use of energy to perform spatial interactions, among others, and this will also linked to other functionings such as "being healthy" or "participating on the labor market" (Vargas-Ruiz, 2015). Bearing in mind these simplifications, Equation 1.4 for the "being well-sheltered" functioning can have a statistical representation as follows:

$$b_{nijm} = f_n\left(\left(x_{nijm}, y_{ij}\right)|z_{nijm}, z_{sij}, z_{eij}\right) + \epsilon \tag{3.1}$$

Now, b_{nijm} is the achievement of the functioning "being well-sheltered" for individual n living in i and going to work in j. Then, the achievement of functionings is given by the private resources x_{nij}, as well as the public resources y_{ij} that allow the interaction from origin location i to destination location j to perform a working activity.

As mentioned before, is to define objective measures of the public resources needed to model and to estimate a utilization function for the status of the functioning "being well-sheltered". Supposing that a city is divided into zones which can be labelled i, j, and so on, then, the journey home to work model can take the form of an attraction-constrained model Wilson, 1971) as follows:

$$T_{ij} = B_j E_j W_i^{\alpha} \exp(-\beta c_{ij}) \tag{3.2}$$

where

$$B_j = \frac{1}{\sum_l W_l^{\alpha} \exp(-\beta c_{lj})} \tag{3.3}$$

and, where T_{ij} is the flow of residential activity, measured as working population flows from residence centers in each zone i to employment centres in each zone j, so that E_j is the total employment leaving j, W_i is taken as a measure of the attractiveness of zone i, sometimes taken as the capacity of the residential zone, say the size in floor space. Note that, the impedance or deterrence function specified as a negative exponential function of travel cost, $exp(-\beta\ c_{ij})$, where β is interpreted as a travel cost deterrence parameter. Parameter β regulates the effect of transport costs on the distribution of residents, as β increases, the preference of employees to travel short distances rather than long distances becomes more pronounced. A very high value of β will result in the employees being allocated very close to their place of work. Lower values of β result in the employees spreading more evenly around their place of work. Additionally, the attractiveness factor is specified as a power function, W_i^{α}, where α can be interpreted as a parameter that mimics the effect of economies of scale. With α greater than unity then large concentration of residential centres become more attractive to workers than small concentrations.

Accessibility. Given the model in Equation 3.2, an obvious objective measure that can be derived is that of accessibility (Hansen, 1959):

$$Q_j = \sum_l W_l^{\alpha} \exp(-\beta c_{lj}) \tag{3.4}$$

It can be seen that the sum of right-hand side can be interpreted as a measure of accessibility for workers of zone j to residential facilities, a term

that can be considered as a measure of the accessibility to residence of a particular zone.

Trip benefits. Given the model in Equation 3.2, as proposed by (Wilson, 2000), after some algebraic manipulation, this can be re-written in the form:

$$T_{ij} = B_j E_j W_i \, exp\left\{\beta\left[\frac{\alpha}{\beta}\log W_i - c_{ij}\right]\right\} \tag{3.5}$$

Since $-c_{ij}$ can be taken as the dis-utility of going from j to i to live, the formulation in Equation 3.5, suggests that the term $\frac{\alpha}{\beta} log W_i$, can be considered as the benefit achieved by using residential center of size W_i. The relative size of the parameters α and β determines the relative importance of size benefits and travel cost, and of course these will be different for different housing types and type of workers, these can be disaggregate as appropriate, but for simplicity, in here, it will be assumed aggregation for the time being. From this argument, a measure of trip benefit can be taken as follows:

$$z_{ij} = T_{ij}\left[\frac{\alpha}{\beta}\log W_i - c_{ij}\right] \tag{3.6}$$

Performance Indicators. Some performance indicators related to various aspects of the system of interest can be derived from the concept of catchment area (Clarke and Wilson, 1987). Given the model in Equation 3.2, a measure of the catchment population is given by:

$$\pi_i = \sum_j \frac{T_{ij}}{\sum_* T_{*j}} E_j \tag{3.7}$$

Equally, using a mirror image of this concept, a measure of the volume of residential facilities that are delivered to the workers at j is given by:

$$\omega_j = \sum_i \frac{T_{ij}}{\sum_* T_{i*}} W_i \tag{3.8}$$

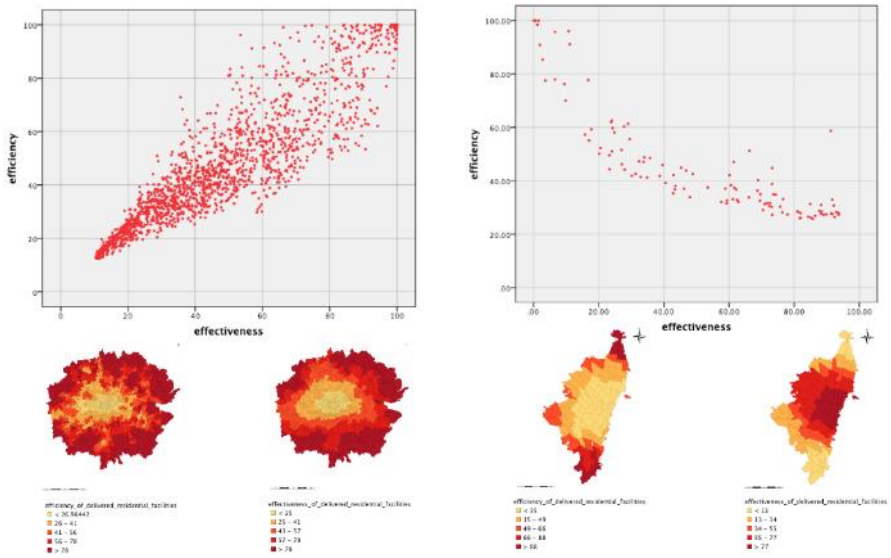
It is then possible to calculate measures, say for the management of the residential center i, such as W_i/π_i, and for the relative provision at j, such as ω_j/E_j. In the case of the functioning "being well-sheltered", W_i/π_i refers to the level of residential floor space provision at residential place, which can be regarded as an efficiency indicator. On the other hand, ω_j/E_j refers to the level of residential floor space provision at workplace, which can be regarded as an effectiveness indicator. The variation in W_i/π_i and ω_j/E_j raise interesting issues in terms of interpreting interaction models in order to offer objective measures for use as proxies of public resources that can be further aggregated (for example by means of techniques such as principal component analysis) to construct an indicator of the impact of public resources in the achievement of functionings based on Equation 3.1 (Vargas-Ruiz, 2015).

4. Applications

As mentioned before, it is impossible to show in this article the full range of issues investigated with the conceptual and methodological framework presented in section 2 and 3. This section briefly outlines the potential of the approach behind LUTi modelling in aiding city planning activities that will help progress toward urban sustainability in the context of the capability approach. Nevertheless, it is important to remark that the scope of this research is aimed to provide the ability to perform evaluative and prospective analysis of urban sustainability (Definition 4) on the basis of the conceptual framework briefly described in section 2 using the methodological framework briefly described in section 3. The vision is to provide scenario planning tools that will allow different actors to explore changes to travel patterns, urban population and employment distributions arising from the development new centers, urban extensions and opportunity areas, changes in aggregate transport costs such as changes in fuel price and changes in travel mode choice, among others. However, here only some examples will be given. For this article, two cities are taken as study areas: Bogota in Colombia and London in the United Kingdom. For example, supposing that the aim of this study is to define objective measures of the public resources

needed to model and to estimate a utilization function for the status of the functioning "being well-sheltered", Figure 4.1 shows the efficiency (W_i/π_i) and effectiveness (ω_j/E_j) indicators derived from Equation 3.7 and Equation 3.8. In the left side of the figure results are presented for London and its wider region. In the right side of the figure results are presented for the core urban area of Bogota. The maps in the bottom part are showing the spatial distribution of the efficiency, W_i/π_i (left), and the effectiveness, ω_j/E_j (right), indicators. The quadrant plots in the upper part of the figure are showing the relationship between these two indicators.

Figure 4.1. Level of residential floor space provision performance indicators.

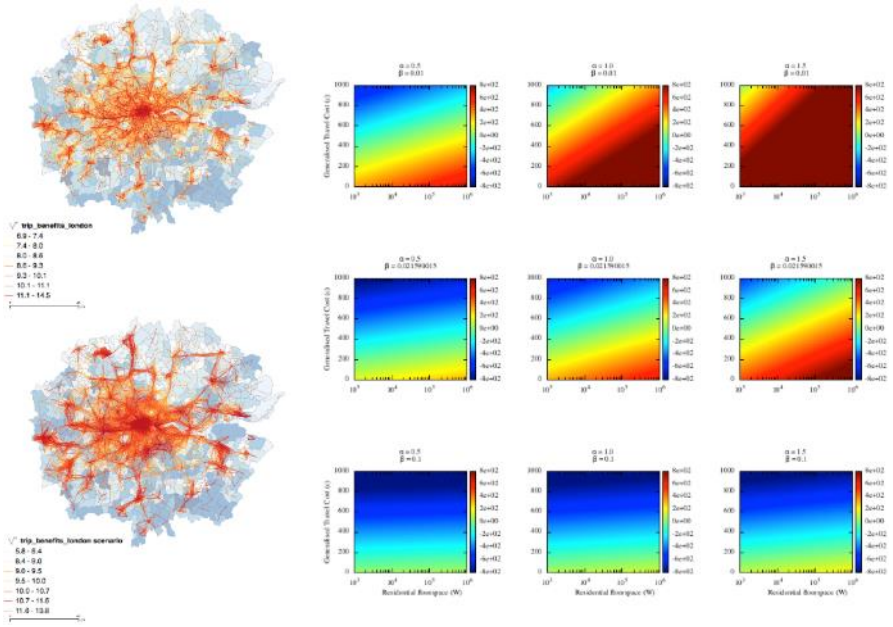


Presenting the two case studies in the same figure is no with the aim of comparing both study areas. Instead the aim is to depict the patterns on levels of residential floor space provision in order to use these indicators as proxy of public resources in the utilization function, Equation 3.1. While in London zones tend to be relatively as efficient as effective, it should be noted that in Bogota the trend is in the opposite direction. This patterns interesting issues in public policy. For example, and more interesting, zones in Bogota that are efficient without being effective, can be considered "pockets" of high relative material deprivation.

Another example of an indicators that can serve as proxy of public resources in the utilization function is that of the relative benefits of making

a trip home to work as formulated in Equation 3.6 presented in Figure 4.2, but in this case just applied to the city of London and its wider region.

Figure 4.2. Relative home to work trip benefits scenarios.



The top map in Figure 4.2 shows the benefits of making a trip home to work after model calibration. Due to the extent of this article calibration will not be presented in here. The bottom map shows the effects on the benefits of making a trip home to work of a scenario in which transport related policies, such as changes in fuel price, are combined with land use plans to make longer trips more attractive. The heat plots show different combinations and realizations of overall system benefits.

5. Conclusions

The aim of this article was to explore linking the ideas of the capability approach developed by the Nobel Prize winner Amartya Sen to LUTi modelling practices, in order to bring new insights in the understanding of the relationship between cities and well-being as the basis of progress toward urban sustainability. After extending the utilization function proposed in the empirical capability approach literature, following the two most general concepts used in LUTi modelling: interaction and location,

the establishment of objective measures derived from LUTi modelling that can served as proxies of public resources was proposed. This objective measures can be calculated in relation to individuals making decisions where to travel and how to locate to perform different kind of shared activities, in accordance with their own views of the life that they value to live. This shows the interdependence of the substantive components of well-being, namely functioning and capabilities, with the wider spatial structure of the city. Without explicit calculating functionings, and under several assumptions, the spatial patterns of this objective measures showed the potential to perform evaluative (e.g. recognition of "pockets" of relative material deprivation) and prospective analysis (how trip benefits change across the metropolitan region when there is a change in aggregate transportation costs such a change in fuel price) under specific and fairly restricted conditions. When interpreting this results, is necessary to remarked that in here a measure of functionings was not performed, instead a derivation of objective measures of public resources were identified. This measures can advanced the progress toward more effective performance of evaluative and prospective analysis of well-being in cities (Vargas-Ruiz, 2015). In here the main focus was to summarize a conceptual and methodological framework that will allow the evaluative and prospective analysis of well-being in cities.

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