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Policy insights and insights for sustainability

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Policy insights and insights for sustainability

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Abstract

In this deliverable we propose a unified and integrated framework to evaluate policies in UrbanSim and propose a set of policies that can be applied on three case studies, Paris, Zurich and Brussels. We start with a survey of the literature on sustainability from an economists' perspective which can be quite different from other disciplines and highlight the implications of sustainability on a city level. In section 4 we describe the social welfare function which will be used to evaluate the policies and give an overview how this has been implemented in UrbanSim. Next we survey different sustainability policies. In the last section we review what we can expect from the selection of policies in the case studies that are assessed with UrbanSim.

Keywords

Sustainable city, Policy evaluation

Preferred citation style

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Contents

1 Introduction

Nowadays, every policy has to be “sustainable” but the definition is fuzzy for most policy makers. There have been many overlapping and contradicting definitions over the past couple of decades (see Pezzey and Toman (2002) for a review of the literature). One of the most cited definition of sustainability derives from the Brundlandt report (WCED 1987) that wants to guarantee good living conditions for the future generations in the world: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". At the core of sustainability lies the concern for equity both within and between generations. Many definitions of sustainability used today are broader and include, besides economic and ecological issues also issues of social equity and justice. This has been translated in rather vague and non-operational terms by different international and national organizations (UN Habitat, World Bank, OECD, EU, USA). See Shen et al. (2010) for an overview of some of the definitions. The EU has probably devoted most attention to an operational definition. The European Environment Agency, (1995) defines “sustainable cities” using four dimensions: a) minimising the consumption of space and natural resources, b) rationalising and efficiently managing urban flows, b) protecting the health of the urban population c) ensuring equal access to resources and services d) maintaining cultural and social diversity.

Overall, it proved to be a difficult concept to define precisely and many interpretations have proliferated since then.

One of the sources of confusion is the definition of what needs to be “sustained”. This confusion has led to the concepts of ‘weak’ and ‘strong’ sustainability. The distinction between the two is founded on the distinction between economic capital (manufactured capital, knowledge), ecological capital (renewable resource stock, natural land areas as well as ecological factors such as climatic conditions etc..) natural capital (natural resource base which consists of the ecological capital and non-renewable resources) and social capital (socio-cultural values, human capital and labor force, social institutions, social cohesion, human health,…) (Hediger 2000). Strong sustainability is defined with respect to ecological capital whereas weak sustainability is defined with respect to total capital which is an aggregate of economic, natural and social capital: the objective of strong sustainability is to maintain the ecological capital at its initial level while the objective of weak sustainability is to maintain the level of social welfare. Weak sustainability allows for trade-offs between consumption and environmental quality and integrates strong sustainability as a special case (by putting infinite high value to environment compared to consumption). For these reasons weak sustainability seems to provide the most comprehensive approach to sustainable development.

Agreeing on the definition of sustainability is not the only challenge. Ultimately policy makers want to be able to know which policies will lead to a more sustainable economy or city. The multi-dimensional character of sustainability has given rise to two types of operationalization. The first is more typical for non-economists and policy makers and consists in developing a set of indicators that enclose the different dimensions of the sustainability objective. The second approach is more typical for economists and consists of trying to value each of the components and to look at the sum of the components.

1.1 Use of indicators

The indicator approach has been widely used and there is a buoyant literature. How to operationalize the concept of sustainability will, however, also very much depend at which level this has to occur (global, country, city,…). The focus of this chapter lies at the city level and we therefore limit ourselves to two sources that explicitly deal with sustainable cities: a survey focusing on the world level (Shen et al (2011) and an EU project PROPOLIS, (Lautso et al (2004) and Spiekermann and Wegener, (2004)) concentrating on European cities.

Shen et al (2010) compare the use of sustainability indicators for 9 cities (Melbourne, Hongkong, Iskandar, Barcelona, Mexico City, Taipei, Singapore, Chandigahr, Pune). Each of these cities have ambitious plans for the long term (10 to 30 years) with divergent visions as “greenest city” but also “economically vibrant and sustainable city”. Shen et al are interested in comparing the sustainability definition used and not to compare how sustainable the 9 cities are. The sustainability definitions are regrouped into 115 indicators that can be classified into 4 categories:

- Environmental: water, air, noise, biodiversity etc (not greenhouse gasses)
- Economic: consumption and production patterns, economic growth, strengthen small entreprises….
- Social: energy, water, education, transportation access, poverty, recreation …

- Governance: participation, transparent, accountable, efficient governance (so also process matters…)

Their survey reveals three characteristics of the sustainability indicator definitions in what can be called the "non-economic" literature. First not only purely environmental indicators are being used but also social, economic and decision process aspects are taking into account. Second there is no explicit trade-off between different dimensions (more environment for less environmental growth. etc.). Third some of the indicators are sectoral. "Sustainable transport" is one of these criterion and it contains energy use, transport mode and transport time as elements.

The PROPOLIS project (EU-2004) aimed to research, develop and test integrated land use and transport policies, tools and comprehensive assessment methodologies in order to define sustainable long-term urban strategies and to demonstrate their effects in European cities. It developed 3 sets of indicators: environmental indicators, social indicators and economic indicators. Interesting is that they include as economic indicator the total net benefit from transport. So there is at least the option to compare environmental benefits and the costs of realizing them.

The aggregation and internal consistency of the sustainable indicators is however problematic. There are two types of problems. First there is the selection of indicators, some of them overlap and the number of indicators selected may influence the results. Second, there remains a problem of aggregation: all important societal problems require to balance different objectives. In a multi-criteria approach, this trade off loses its transparency.

1.2 The economic approach

The second approach is more typical for economists and consists of trying to value each of the components and to look at the sum of the components. It is the latter approach that we will follow here and this will be discussed in more details in the next section. The main advantages of this approach is that it is more transparent and that it allows more easily the selection of a best policy. The main disadvantage is that it requires valuation of many different dimensions of sustainability.

2 Economist approach to sustainability

2.1 Trade-off between different kinds of stock of capital

It took a while before economists understood and accepted the sustainability concept that deals with the trade-off between current and future stocks of environmental resources. Arrow et al (2004) offer a good synthesis of the economists' view of sustainability. The ultimate objective is to offer quality of life and consumption options to the future generations. So what matters is the preservation of enough productive capital[1] for the future generations. This productive capital is then combined with labour to guarantee a sufficient quality of life. Productive capital should be understood in a very broad sense: it concerns as well traditional "*man made capital*" (knowledge, physical assets as roads and buildings) as "*natural capital*" (depletable resources and the quality of the environment). It is the degree of substitution between the two stocks of capital that will determine the relative scarcity of the environmental quality indicators in the future. Figure 1 shows how, over time, a decrease of natural capital combined with an increase of man made capital can lead to a decrease or increase of production possibilities in the future. The solid line that passes through points A,C,B is the evolution of the stocks of capital over time. The dotted lines give the production possibilities in an optimistic view of the world where both types of capital can be substituted (each dotted line presents combinations of capital stocks that generate the same total production possibilities). The thin continuous lines give each a set of capital stocks that generate the same total production level when both types of capital need always to be used in the same proportion and are thus not substitutable.

[1] Productive capital as defined in Arrow et al (2004) corresponds to the sum of the economic capital (which is called man-made capital in Arrow et al (2004)) and the natural capital as defined in Hediger (2000) and used in the introduction.

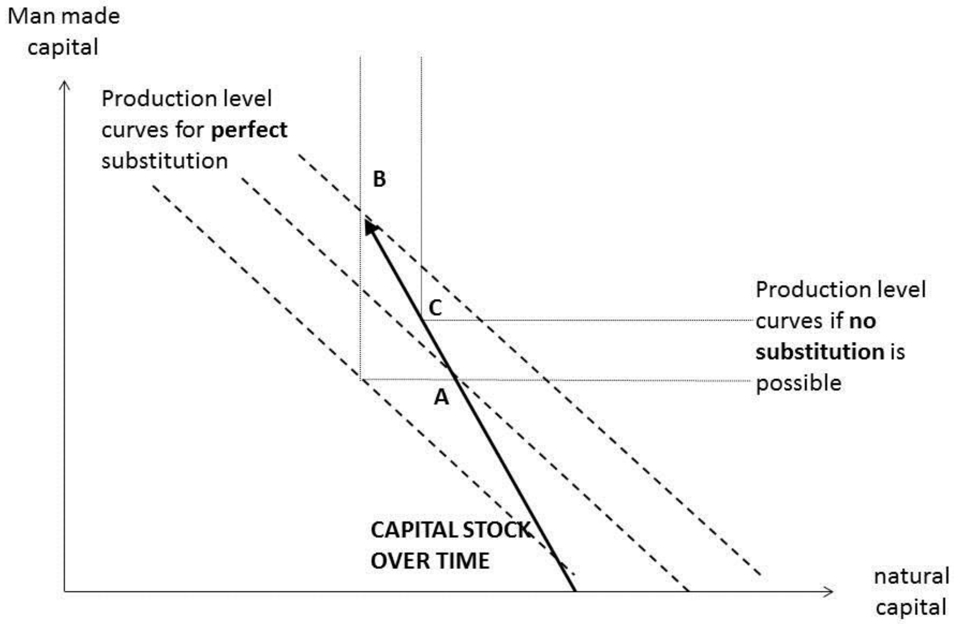

Figure 1: An economic definition of sustainability

Starting in point A and moving over time through points C and B, the future production levels are larger in C than in A according to the two views on substitutability. Moving from C to B is better if one counts on substitution possibilities (B is on a higher dotted curve than C) but this is no longer true if one beliefs that substitution between the two sources of capital is impossible: then point B implies a decrease of production possibilities compared to C.

Obviously one needs to refine the analysis and there could be a need to build in thresholds for both types of capital and discuss the many types of natural capital in more detail. What is important for the definition of sustainability is the idea of a stock of capital and the potential for substitutability among different types of capital.

2.2 Economic approach to the measurement of social indicators

Besides the economic dimension, sustainability also encompasses social aspects. Equity and a minimum access to basic amenities for the poor is considered as an important component of "sustainability" in the original definition of sustainability and is included as indicator by some but some of the definitions. Economists have a different view on this on two accounts.

First they prefer in general to integrate the equity issues into the overall costs and benefits of certain measures. Second they prefer to respect the individual choices in the allocation of in income as long as prices signal the real scarcity. This means that the well-being of a poor individual is best measured by the purchasing power of his disposable income (using his consumption bundle as reference for the price index) rather than by indicators as the price he pays for a public transit ticket. The price of public transport can be a policy instrument but is as such not a good indicator of the relative welfare position of an individual.

The equity dimension of a policy can be measured by computing first the costs and benefits of certain measures by income group and next to add them by giving a higher weight to the net benefits of the poor. The degree of inequality aversion (Atkinson, 1970) chosen by the policy maker will determine the relative weight of the different income classes. A simple weighting scheme could be to use weights inversely proportional to the income per household, where the income is corrected by the number of person equivalents in the household. One could also rely on more general non-welfaristic measures of equity that look into the capacity of households (education etc.) to reach a given welfare level (Fleurbeay,2010).

Other social indicators may be more difficult to measure and value. These are indicators that measure the quality and intensity of social interactions. What makes this more difficult to include is that there are strong externalities between individuals and network effects that are difficult to measure (see Schelling,1976).

3 Operationalising sustainability at the level of a city

To define sustainability at a city level we need to take into account the limited spatial area of a city. This will influence the definition in three ways. First there may be a need to deal differently with local stocks (green areas for daily use, historic buildings, water supply, air quality) or global stocks (stock of greenhouse gasses, fish stocks, biodiversity). Second, one has to deal with the possible migration between cities. Finally one should be aware that objective functions of a local government can be very different from those of a federal government, and this requires to distinguish between positive and normative approaches.

3.1 Local versus global stock

A city is, by definition, confined to a limited spatial area. This implies that the welfare of the individuals will be strongly influenced by the local stocks of capital that are more difficult to substitute (green areas for daily use, historic buildings, water supply, air quality). The locals will be much less interested in global stocks of capital (stock of greenhouse gasses, fish stocks, biodiversity). These global stocks may be very important for the country or world as a whole but they are the result of the actions of many cities. This implies first that the incentives for one city to take efficient action to protect the global stocks will be too small if they are not forced to do so by a higher authority. Second, as the stock concerned is a global stock at country or world level, there is no need to put an absolute limit to the use of the resource in each city individually. It is sufficient to have a system of tradable permits that limits the total use of the resource in the country or the world. Summarizing, for local stocks that are difficult to substitute (say historic buildings), it will make sense to use absolute thresholds or take into account strongly increasing opportunity costs. For global stocks, it is better to make use of shadow prices that represent the national or world values (via prices of tradable permits) and not to impose absolute thresholds per city.

For some global stocks, like greenhouse gas concentration, a local effort may be compensated to a large extent by global markets of energy as long as the rest of the world does not engage in a similar climate change policy. Indeed, a unilateral reduction of oil use, a form of energy for which the stock is limited, may lead to a new arbitrage in the intertemporal world price profile. Owners of a limited stock of resources maximize their profits by distributing their sales over time following the Hotelling rule (profit margin increases over time with interest rate). So whenever the demand in one of the periods shifts, there will be a change in the prices now and in the future. There will be a price reduction on the world oil market and a postponement of carbon emissions rather than a net reduction of the carbon emissions. The overall emissions associated to oil use, do not decrease because the stock of cheap oil is limited and will be used anyway. This mechanism is known as the green paradox (Sinn (2012)) and is a major barrier for an effective local climate action.

3.2 Open versus closed city

The second issue we have to deal with is the possible migration between cities. In the US, the mobility of the population, combined with the cheap supply of new housing, is the main explaining factor for the difference in the growth of cities (Glaeser, 2008). In Europe the mobility of the population is much lower than in the US but mobility can still be important within one country. To see the importance of mobility for the type of sustainability policies put in place consider an example with identical individuals and only two cities X and Y. Let the utility of the population in a city depend on local factors in the two cities, represented by vectors of quality characteristics *x,y* as well as on the population levels *pop(X), pop (Y)* so that the utility per capita equals *U(x,pop(X))* and *U(y,pop(Y)).* The utility per capita of a city can be decreasing or increasing in the size of the population. Utility will be decreasing when there is increasing pressure of the population on local resources but could be increasing when there are strong returns to scale in supply of public goods or when there are strong economies of agglomeration in production. If utility is downward sloping in population we can have a stable equilibrium. In Figure 2 we show how the initial allocation of the population implies that, in equilibrium, utility per capita is equal.

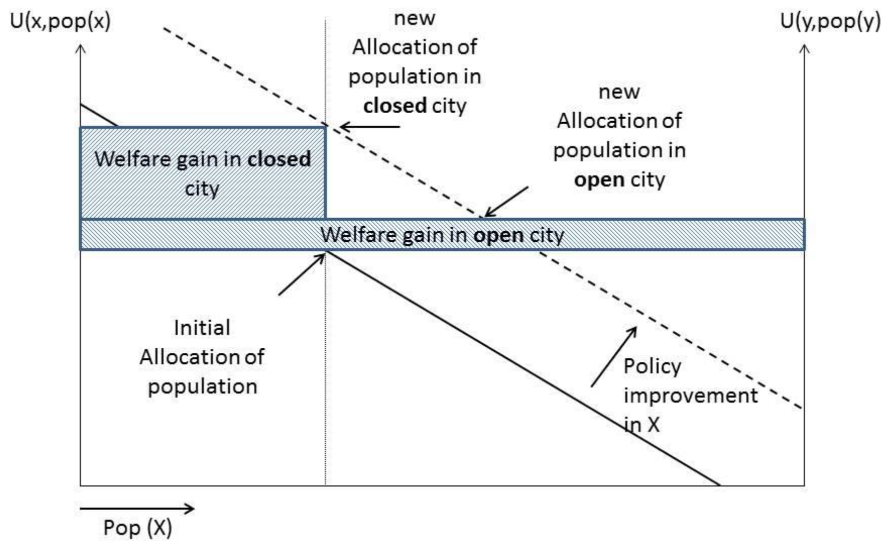

Figure 2: Differential effects of a local policy in a closed and open city

Consider now a policy improvement in city X. This will result in an upward shift of the average utility curve for X. When the city does not allow any growth in number of inhabitants, this improvement will give rise to an important welfare gain for the inhabitants of X. It could be that the welfare gain is captured by the property owners rather than by the inhabitants. But when the city allows expansion, the welfare gains will be dissipated to the new entrants and to the remaining inhabitants of the other city that will see less pressure on their own resources. The **distinction closed/open city** is important because it determines the incentives of a city to implement a policy improvement: in an open city environment, a large part of the gains may dissipate to the rest of the country. The ultimate effect of a policy improvement depends therefore on the supply of extra housing in the city. This dimension is missing in many sustainability assessments.

3.3 Positive versus Normative approach

When a city is only interested in the welfare of its inhabitants, there is also a difference in the objective function pursued by the city and a federal government. Cities neglect positive and negative externalities on the rest of the country. Federal countries also neglect external effects to the rest of the world. This implies that there is a need for clearly distinguishing **the positive and normative approach**. In the positive approach to policy making one tries to understand what drives policy making. In the normative approach one uses ethical criteria to state what "should" best be done. The positive approach will be driven by the political institutions in place and in well-functioning democratic regimes this will be some weighted sum of the utility of the voters and the politicians. The precise weights will depend on the functioning of the political system (Besley, 2006) including the role of pressure groups (Dixit, Grossman, Helpman, 1997). The positive approach will also generate other policies when decisions are taken at city or instead at country level. The following table summarizes the different types of policy objectives. Most of the "sustainability" literature is of a normative nature where most of the discussions focus on the trade–off between environmental values and other values. When it comes to policy making, we need to recognize that policy makers are not driven by sustainability as such but by what they think matters for their voters. In this context, we need to recognize that some policy prescriptions that are justified from a normative perspective, may be difficult to implement.

One specific dimension is the intergenerational equity. Current voters and politicians are likely to be more motivated by their current utility rather than by the utility of the coming generations of inhabitants. In this respect the issue of the protection of local environmental stocks could raise similar problems as the creation of large debts by cities to finance consumption type of expenditures.

	Positive approach **(what drives policy making)**	**Normative approach** **(what should be done on the basis of ethical principles)**
City	Politically weighted sum of utility of current voters	Ethically weighted sum of welfare for current and future generations
Country or region	Politically weighted sum of utility of current voters	
World	Country objectives limited by international agreements	

Table 1: Different policy criteria to judge policies

4 Evaluating Sustainability with UrbanSim

4.1 The Social welfare function

Sustainable development is a concept which involves trade-offs among social, ecological and economic objectives. These trade-offs are conveniently expressed in terms of a social welfare function. Such a social welfare function also allows us to incorporate equity issues by weighing the effect on different income classes. To evaluate a policy package we will compare the social welfare outcome when the policy is implemented with the business as usual scenario.

We propose to use a social welfare which is the sum of six components: (i) the discounted weighed sum of the utilities of the residents of the area under study,(ii) the discounted sum of the utilities of commuters (non-residents who travel within the city borders), (iii) the weighted value of the utility of “the rest of the world” (to capture cross-border externalities), (iv) the value of the local stock (of both natural and physical capital) left for the next generations at the end of the time horizon, (v) the cost of implementation of the policy and (vi) the discounted sum of the revenues collected (these include the tax revenues as well as the toll and the revenues from public transport).

$$
\begin{aligned}
SWF_{city} = & \sum_{t=0}^{T} \frac{1}{(1+\delta)^t} \sum_{\text{inhabitants now}} \phi(U_i).U_{i,t}(I,H,tt) \\
& + \chi \sum_{t=0}^{T} \frac{1}{(1+\delta)^t} U_{commuters,t}(I,H,tt) \\
& + \xi \ \phi(U_w) U_w(\text{GHG, ...}) \\
& + \rho \ \text{Local stock (T)} \\
& - \text{INV} \\
& + \sum_{t=0}^{T} \frac{1}{(1+\delta)^t} \text{Rev}(t)
\end{aligned}
$$

where
$i = 1, \; ....I$ are inhabitants
$t = 0...T$ time horizon considered
$\phi(U_i) =$ weight of individual determined normatively (inequality aversion)
$U_i =$ utility of resident i
χ = weight commuters
$U_{com} =$ utility of commuters
ξ = value of effects on rest of the world
$U_w =$ utility of the rest of the world
$\rho =$ weight of local stock
Local stock = remaining of capital stock and natural stock for futur generations
INV= implemetation cost of the policy (present value)
Rev= total revenues (taxes, tolls, tickets)

Note that we allow for a different valuation of the residents, the commuters and the population outside the borders of the city. In this way a local authority which is only concerned about its own residents can neglect the effects of the policy on “the rest of the world”. The fourth term ensures that local stock and global stocks are evaluated differently as discussed in section 3. In the following subsections we describe each component in more detail.

4.2 The utility of the residents

In the simplest version, the utility of the residents is equal to the generalized income minus the housing cost and the generalized travel costs

$$U_i(t) = I(t) - H(t) - tc(t)$$

Possible extensions are adding elements like the value of amenities, accessibility, social interactions, quality of housing and environmental disutility as well as the use of a more general functional form.

The net income $I(t)$ is the sum of the wage and property income minus federal and local taxes on income and property values. The housing cost $H(t)$ depends on the ownership of the household:

- For households that rent their houses: sum of the rent and the housing related costs such as maintenance and energy utilities
- For households that own the property they live in: sum of property costs and housing related costs (or imputed rent)
- For property owners that do not occupy their own property: return of their property

Finally the travel cost $tt(t)$ is the average generalized cost of transport perceived by the user. This is the sum of the monetary value of total time spent for travelling and the total money paid.

- For car users: the monetary value of total travel time is obtained by multiplying the time spent with the value of time (which depends on income), the monetary cost is the sum of fuel costs, maintenance costs, taxes and tolls.
- For public transit users: the monetary value of total travel time is obtained by multiplying the time spent with the value of time (which depends on income). The monetary cost is the cost of a ticket. In addition one could add a comfort term which will depend on the occupancy rate of the public transit system.

Extensions that could be included are: **accessibility** to rail station or motorway, school, job, city centre, public transport or open space, **housing quality:** average living space per household multiply by the value given to a square meter and l**ocal environmental disutility:** such as noise, particle matter (PM), NOx and traffic accidents.

4.3 The Utility of Commuters

Commuters are defined as people travelling to the area under study but not residing in the area. Their utility is equal to their travel costs

$$U_{commuters}(t) = tc(t)$$

Where the travel costs are computed in the same way as for the residents. Possible extensions could include the local income earned by the commuters.

4.4 The Utility of “the rest of the world”

U_W includes the global environmental damage caused by the city which is take to be the total cost of the emitted greenhouse gasses or the total amount of carbon emitted times the shadow value of carbon reduction.

4.5 The local stock

The local stock of capital and natural resources (green spaces, agricultural land) or cultural heritage which is left for the future generations.

The amount of local stock is multiplied by its value (exogenously specified).

4.6 Investment cost

The investment cost is the total cost needed to implement the policy, this includes the specific investment costs for the measure and, for the whole period of the analysis, the operation and maintenance costs. These costs are all discounted to the present year.

4.7 Revenues

The component Revenues is the total discounted sum of all revenues collected during the period of the analysis. These include the taxes on income, taxes on property, taxes on transport (fuel, etc.), tolls and public transit fares.

$$\begin{aligned}\mathrm{Rev}(t) = {} & \Gamma_{local} \cdot \mathrm{LocalTaxrevenues}(t) \\ & + \Gamma_{federal} \cdot \mathrm{FederalTaxrevenues}(t) \\ & + \Gamma_{j} \cdot \mathrm{Tollrevenues}(t) \\ & + \Gamma_{k} \cdot \mathrm{PTrevenues}(t)\end{aligned}$$

Each component is weighed by the marginal cost of public funds. The marginal cost of funds represents the efficiency cost of collecting tax revenues by other taxes. This is usually a parameter equal to 1 plus the deadweight loss created by these other taxes. For income taxes, this marginal cost of public funds can be of the order of 1.1 up to 2.

4.8 Background variables

Besides the above mentioned components of the social welfare it is useful to have some additional outputs that can help to understand the effects of the policies. These are

Background variable	Unit
Transport	
Travelled distance by mode	pass.km or veh.km
Travel times per mode	pass.h or veh.h
Average travel distance per mode	km/trip
Average travel time per mode	minutes/trip
Average speed per mode	km/h
Modal share	%
Traffic volumes	veh/h
Land use	
Floor space per capita	m2/cap
Rents by zone	Euro/month
Other	
Population per zone	#
Total employment	#

5 Potential sustainability policies

5.1 A first classification

We classify policy approaches in four different groups. There are the purely environmental policies, there are the transport policies, the social policies and finally we have the land use policies. We discuss each of the policies in turn in a more aggregate way in this text. For each policy we first define what is at the origin of the problem and discuss next the different policies that are advanced to address the issue.

Types of policies	Main focus and modeling approach
Environmental policies	Improving the physical environment via reduction of harmful emissions
Transport policies	Improving efficiency of transport system via transport policies
Social policies	Improving community values
Land use policies	Improving welfare via land use changes

Table 2 Different types of sustainability policies

Each of these 4 categories of policies has in principle an effect on all the 3 other dimensions. Transport policies will reach their effect partly via induced changes in land use and land use policies will affect transport issues. But their main focus is different and they can be considered as competing measures to address a common set of problems. For each measure we also briefly touch on the type of models used to analyze the policies.

The models used for the assessment of these four types of policies are also in general rather different. A full set of models allows in principle to assess all dimensions and all problems simultaneously. But, as table 3 shows, there is a price to pay in terms of precision and coverage. One of the elements missing in most models is how different authorities take decisions and interact. This can be important in a context of urban governments that are only interested in the welfare of their own citizens and may compete horizontally (neighboring communes) and vertically (higher level regional governments) with each other (De Borger & Proost,(2012)). This competition may take the form of attracting high income individuals or firms who pay relatively more taxes and discouraging the entry of households that require more public provision.

Types of model	Restrictions
Transport models	Given O-D and land use
Land use models	In principle none but precision and complexity can be problematic and there is a large fixed cost in terms of data and model set up
Ad Hoc models without explicit transport or land use	Allow larger precision and/or much easier to implement Correct if land and transport markets are not distorted (prices = social marginal cost)

Table 3: different models used to assess sustainability policies

5.2 Environmental policies

These are policies that aim to directly improve the state of the environment by decreasing the emissions, sometimes also called “end of pipe” policies. Environmental quality has many dimensions (water, biodiversity, air...) but here we concentrate mostly on air quality, noise and climate.

The main issue is that environmental pollution is an **externality**, associated to the activity of individuals and firms. None of the polluters benefits directly from reducing their pollution so policy measures are needed to reduce pollution. Part of the policy actions is at the level of the EU or country, but some of the damages are more important in urban areas. This implies that one can expect a difference in effort and attention in urban areas: more efforts for the local problems (conventional air pollution) and much lower and insufficient efforts for environmental problems at a more global scale (climate change).

De Borger & Proost (2012) look at the different dimensions of policies that can be used to address external effects in an urban area that is confronted with through traffic:

	Reduces traffic volume in city	Speed reducing effect	Requires large public investment	Reduction of external cost per car kilometer	Impact on urban traffic by the local population
Toll	+	0	0	0	
Noise walls	0	0	+	+	
Speed restriction, increasing the red phase of traffic lights	+	+	0	+	+
New traffic lights, road bumps, etc.	+	+	+	0	+
Emission standard cars	+			+	+
“Bypass”	+	**0**	+	**0**	+

Table 4: Taxonomy of policy measures that address external effects of through traffic (Legend: 0= no effect / + effect)

They show how cities, pursuing their own interests, favour those policies that put higher costs on non-inhabitants. In the next table we focus on environmental externalities and list the most important types of policies and the type of modeling approach that is typically used to assess them. The first 4 measures are transport related measures, the last 2 measures are in a different domain.

Policy	Modeling approach
Subsidy cleaner vehicles, cleaner fuels, promotion electric vehicles	Mostly only transport market is modeled with fixed OD, land use and population Expected: Gradual shift in car stock and increase in car use as generalized price of car use has decreased
Restricted access for dirty vehicles – low emission zones.	Mostly only transport market is modeled with fixed OD, land use and population but if very strict policy, one could see diversion of activities? Expected: Shift in type of vehicles used by inhabitants, dirty cars are sold to the country side. Will also reduce car use in the city as generalized price increases (Ecopass policies in Milano and German cities).
Cleaner public transport (diesel filters, CNG- buses, hybrid buses..)	Only transport market is modeled Expected: No shift in modal choice, only reduction of emissions of public transport
Publicly funded noise walls and noise insulation	Mostly simple cost benefit analysis Expected: no effect on transport flows, affects house quality and could lead to reallocation of population
Greening of existing open space (transforming agricultural land into urban forests or green areas)	Mostly simple cost benefit study comparing value of agricultural land and recreation area Expected: higher recreation utility
Sewage system improvements	Less relevant in developed countries

Table 5: Environmental policies

The cleaning of the car stock has been driven by the EU standards (EURO 1, ..,5) that have gradually decreased the maximum emissions of conventional pollutants per car kilometer. The EU wide standards are important as this avoids protectionist policies within Europe. The standards are imposed on new cars. The only degrees of freedom left to member countries and cities are to impose the stricter standards sooner or restrict access to cars that comply with one of the stricter standards so ruling out older cars or cars using a given fuel.

When it comes to reducing conventional emissions of cars (NOx, CO, PM,..), it is widely recognized that a reduction of emissions by better engine control technologies and by cleaner fuels (less sulfur) are very effective and efficient policies. For example, between 2000 and 2020, the use of catalytic converters, particulate traps and cleaner fuels is expected to reduce conventional air pollution in the European Union (EU) due to road transport by 70 to 95% (TREMOVE, 2007).

This is not to say that all the problems of conventional air pollution can be addressed through these measures. For example, **particulate emissions** are very costly in terms of human health and control technologies remain expensive. Strategies to promote the use of diesel fuels, favoured in some countries for reasons of fuel economy and greenhouse gas emissions, carry a cost in terms of particulate emissions or the control of them. Switching from diesel to gasoline engines is a much cheaper option to reduce PM emissions. Furthermore, as cheap technological fixes are gradually exhausted, policies that target a smaller numbers of other gross polluters (shipping, diesel trains) offer pollution reductions at lower costs (IIASA,2007).

152 cities in 9 EU countries (Wolff & Perry, 2010) have **low emission zones** that limit the access of vehicles to those with EURO standards that imply low PM emissions. PM emissions are the most harmful and are mostly associated to the use of diesel engines. The main reason why German cities have implemented these policies is that these cities are situated in non-attainment zones where the European air quality standard for PM10 is not met. This triggers possible sanctions by the EC and citizens have even the right to request action from their city government. The most important action was to restrict access to the cleanest vehicles. Access is restricted by a system of stickers with different colors, the color determines what zone of the city one can enter.

The main effects of this clean vehicle policy to be expected are a decrease of car traffic coming from outside, inhabitants that buy cleaner vehicles and sell their dirty car to people living outside the city. Milano, using an Ecopass has combined a toll and a clean vehicle system, we return to this type of measure in the next section.

Subsidizing electric vehicles and other alternative fuel vehicles is a popular measure and the EU white paper on transport (2011) wants to halve the use of conventional fuel vehicles by 2030 and phase them out in cities in 2050. This policy can sometimes be effective to reduce local pollution but remains in general a very costly option to reduce carbon emissions when compared to a fuel efficient conventional vehicle (Proost & Van Dender, 2011). From subsidies one can only expect more car use.

Cleaner public transport is a measure that can be effective to reduce conventional pollution by diesel buses. It has no effects on transport flows because the extra costs are in general fully compensated by additional public subsidies.

Noise walls can be an effective end of pipe measure for noise problems with roads and railways. It is typically paid by the government and its benefits show up as higher values of the affected housing stock.

Transforming agricultural areas into urban forests is a measure that can reduce agricultural pollution and can generate high recreation values as most agricultural activities in European urban areas are heavily subsidized (Moons et al, 2008).

5.3 Transport policies

These policies aim at affecting transport flows via changes in modal flows, departure times etc.. The main issue in transportation is **unpriced congestion**. This is considered as the most important externality of transportation as environmental externalities are already taken care of to a large extent via fuel excises and vehicle standards. A secondary issue is the subsidized (or unpriced) use of public space by cars for parking. Measures are listed in Table 6.

Speed reducing policies are typically used in smaller cities. By reducing the speed, one discourages through traffic. This will lead to an excessive number of speed limits and speed bumps when the measure is left to the urban governments.

Road pricing policies are mostly assessed by traffic models at the city level. Anas & Lindsey (2011) compare the road pricing policies for London, Stockholm and Milan. In all the three cities, the policies were accompanied by public transport policies in order to improve public acceptability (De Borger & Proost, 2012). They all result in a reduction of the volume of travel and emissions of the order of 10 to 20%. The major benefits are time savings and a better reliability of road transport.

Policy	Modeling approach
Speed restriction, increasing the red phase of traffic lights	Transport network models Expected: reduction of through traffic
Road pricing	Mostly only transport market is modeled with fixed OD, land use and population, parking models???, But stylised transport-land use models are also used Expected: Smaller volumes of traffic in peak, proportional decrease in emissions, Examples of London and Stockholm
Parking policies	Often integrated in transport models via generalized cost – few specific parking models in literature? Expected: Smaller number of cars, Smaller volume of car use, ...
Road infrastructure (by-passes, ring roads or tunnels for through traffic)	Mostly only transport market is modeled with fixed OD, land use and population, Land use effects could be important if this leads to relocation of activities Expected: more through traffic, more intra city traffic, less externalities inside the city
PT subsidies	Mostly only transport market is modeled with fixed OD, land use and population Expected: Typical second best policy used in EU cities, pricing policies important to address pressing capacity problems (Paris, London)
PT infrastructure	Often only transport market is modeled with fixed OD, land use and population - Land use models are also used as one targets land use changes (commercial development)

	Typical policy in EU cities - main issue is now connection to more distant subcenters and substitution of bus via light rail Expected: generating more traffic, growth
Cycling infrastructure	Transport market models only

Table 6: Transport policies

The simplest way to study the land use effects of road pricing is to use the monocentric city model. This model integrates commuting distances and land use density. Both commuting and housing density contribute to energy use. De Lara et al (2008) study the case of Paris and look into the effect of different road pricing policies. Economic efficiency is the indicator defined as the minimum of total resource cost plus the given damage associated to energy use. As expected, they find that road pricing leads to more compact cities and smaller land use for roads. Larson, Liu and Yeser (2008) use also a monocentric model to estimate the effect of different land use and transport policies for an American city. The choice for the monocentric assumption for the urban structure has important implications for the effects of road pricing policies on land use. Anas (2010) shows that road pricing may shift part of the CBD activities to sub centers.

Parking policies are much more frequently used than road pricing projects. They are a second best policy to reduce car use in the peak in cities, have a clear potential as most of parking is still unpaid and uses scarce public space. It can probably achieve only 50% of what road pricing can achieve (Proost, Van Dender, 2001). Button (2006) addresses some of the political economy issues that shape parking policies.

Another option to reduce inner city traffic is to direct traffic as much as possible to **bypasses, ring roads, tunnels under city etc..** This reduces inner city congestion and improves air quality. If the use of the bypass is not tolled, the additional road capacity will attract higher traffic volumes. Important road construction projects are mostly studied using conventional partial equilibrium transport models. Land use models could generate additional insights as this may affect the location of business centers. One of the main issues is who pays for the additional infrastructure. De Borger & Proost (2012) studied the incentives of the urban government to invest in road infrastructure that will also serve through traffic. If the use of the infrastructure cannot be priced, the city authorities will invest insufficiently in bypass capacity. A more elaborated model of a bypass can be found in Westin et al (2011). They study the political economy of pricing transit traffic through the city and the pricing and investment in a bypass.

Public transport subsidies have been studied extensively as second best policy (Parry & Small (2009), Proost & Van Dender (2007)) to address underpriced car trips. These studies point in general to high subsidies for capital but also for operation costs. The result is mainly driven by economies of scale in public transport operation ("Mohring" effects) and by the induced decrease in peak car travel. According to Parry & Small (2009), an important condition to justify a subsidy for the operation costs of public transport is that a fare decrease attracts a sufficient share of former car users. A simple increase in passengers is not sufficient to justify a subsidy for public transport in the peak period, a significant share (40 to 50%) need to be substitution from peak car use.

5.4 Social policies

Social policies regroup different types of measures that are important for the utility of living in a city and are responsible for an important part of public expenditures at the level of a city. There are several issues. There is the supply of local public goods (community centers, historic buildings..) that are undersupplied when left to the market. There are also more difficult social network externalities that are still poorly understood. One of the strongest interactions is the formation of beliefs. A well-known example is that 60 percent of Americans believe that the poor are lazy (26 percent of Europeans share that view). Benabou & Tirole (2006) show how the differences in the collective belief in certain policies can be explained by social interactions. There is the urban distress, social segregation, crime etc. that seem to be more important in large cities (Glaeser, 2008). Segregation in urban areas is again poorly understood. Glaeser, Kahn and Rappaport (2008) show that for US cities, the provision of cheap public transit is one of the drivers of the concentration of poor people in the urban centers. But Brueckner, Thisse and Zenou (1999) use an amenity-based theory of location by income. The relative location of the different income groups depends on the spatial pattern of amenities in a city. When a center like Paris has a strong amenity advantage over the suburbs, the rich are likely to live at central locations and vice versa. So European cities may offer a very different profile.

Policy	Modeling approach
Improved community services and education	Mostly studied without relation to transport and land use – but one of the core topics in the urban economics literature (Tiebout model with perfectly mobile households)
Urban distress policies that address segregation, crime and improve social interactions	Mostly empirical research using simple reduced form models

Table 7: social policies

There is empirical evidence that the **quality of education** drives location choices when the residence determines the choice of school. In countries like Belgium, residents can choose a school in another district or even another city. In other countries (France, US), the residence determines more or less the primary and secondary school. When the choice of school is free, this leads to larger transport flows while when it is not free...

Most urban distress literature is focused on the US where crime is proportionally more important in large urban areas. For EU cities this may also hold.

5.5 Land use policies

Policy	Modeling approach
Densification policies	Econometric assessments Land use models
Targeted commercial developments (ABC)	Land use models

Table 8: land use policies

The most common **market failure** associated to land markets is the absence of congestion pricing so that cities are to spread out. This holds for a monocentric city but is less obvious in a polycentric city.

In the US, there are several studies that investigate empirically the link between **residential density and travel distance** as a causal relation. Analyses using disaggregated data show that this causal link exists, but that it is not as strong as it appears at first sight (Bento et al., 2005, Brownstone and Golob, 2009). The reason is that households choose particular locations on the basis of their preferences (captured through observed and non-observed characteristics), and those preferences, along with density, explain transport choices. This means that no major reductions in transport volumes or energy consumption should be expected from land use planning unless truly drastic changes in land-use occur. Brownstone and Golob (2009) find that in California, a change in residential density of 1,000 housing units per square mile (40% of the sample mean) leads to 1,171 fewer miles driven (an average reduction of 4.7%) and 64.7 less gallons of gasoline consumed per year (an average reduction of 5.5%). About 2/3 of the reduction in gasoline consumption is due to less driving and 1/3 is due to the fact that households in more densely-populated areas tend to own more fuel-efficient vehicles. While changing driving and energy consumption levels by about 5% is not negligible, changing population density by 40% is likely to be infeasible in all but a limited number of circumstances. In fact, Brownstone and Golob (2009) find that only about 6.6% of 456 US cities increased population density by more than 40% between 1950 and 1990 (and those that did tended to experience declining living conditions), while in the median city, population density actually declined by 36%. A special report by the National Research Council (NRC 2009) concludes that anti-sprawl policies have limited potential, but that this limited potential should nevertheless be exploited, by removing excessive constraints on development and – ultimately – consumer choice.

Sophisticated land use models can show that reducing urban sprawl can produce unexpected results concerning the connection between urban spatial structure and travel needs, as the latter depend on other factors besides residential density. A typical monocentric city model with all employment concentrated in the CBD easily leads to the conclusion that urban sprawl is too large. For example, a monocentric city (i.e. one with a well-defined single center, such as Paris) in which all travel is directed to the city center, likely has longer average commutes than a polycentric city of the same residential density. Gaigné et al. (2010) point out that under many circumstances polycentricity may be a better way to contain travel demand and energy consumption than striving for a more compact city, especially because making one city more compact may well mean that another becomes more sprawled. Anas (2011) uses the example of Chicago to show that urban sprawl has been actually reducing travel distances to work. Glaeser and Kahn (2010) also discuss this general equilibrium view, which emphasizes that it is the overall outcome that matters, not just what happens in one city. Adopting such a global view would generally lead one to favor the use of carbon taxes over local policies as a means to address emissions of greenhouse gases.

Overall one finds rather limited effects of land use policies on energy use.

5.6 Comparing the different types of policies using integrated land use models

We have identified four types of policies that focus each on one type of market failure. Each policy affects in principle all other markets and this has ideally to be taken into account so the assessment should be as broad as possible. Integrated land use models offer the potential to allow a very broad comparison of policies.

Spiekerman & Wegener (2004) is a good example of a rather comprehensive assessment of urban sustainability using land-use models. This is one of the outcomes of the European PROPOLIS project. Sustainable development is viewed as comprising the environmental, socio-cultural and economic dimension, so they use a different approach to sustainability than we do. Sustainability is approached via 35 indicators. The indicator values are computed using urban land-use and transport models. The environmental and social dimensions of sustainability are measured using multicriteria analysis for the evaluation of the indicators, but cost-benefit analysis is used for the economic dimension. The approach is implemented for seven European urban regions: Bilbao (Spain), Brussels (Belgium), Dortmund (Germany), Helsinki (Finland), Inverness (Scotland), Naples (Italy) and Vicenza (Italy).

The same models are also used to assess a common set of policies as there are land use policies, transport infrastructure policies, transport regulation and pricing policies and combinations of these. In this approach, additional modeling tools are used to translate the results of more aggregate model results into results at the smaller zone level. This is necessary for emission and exposure to air pollution and noise as well as for the accessibility to open spaces.

Interesting in this approach is that it recognizes that there are trade-offs between the different objectives and that the tradeoffs are best studied using models. The transport & land use models generate the ultimate effects of different policies. Their set of indicators focuses on environment but also extensively on transport quality. For the environmental and social indicators, they used expert advice to weigh the different indicators and to aggregate them.

What is missing in their approach and could be remedied in the SUSTAINCITY approach are a more consistent definition of sustainability that improves upon the multi-criteria approach and more attention for the incentives of the urban decision makers in the selection of policies.

6 Description of selected policies and what we can expect

In this section we describe the different policies that are assessed in the three case studies of SUSTAINCITY. We classified sustainability policie in four different groups. There are the purely environmental policies, the transport policies, the land use policies and the social policies. URBANSIM is not yet capable to assess social policies, so they are already ruled out. Since land use models are probably not the best tool to assess environmental policies we opted to concentrate the case studies on two transport policies (one regarding the pricing of the existing network and one which involves a major new investment) and one land use policy. We briefly review the expected results of these three different policies based on real world experience in some cities and as was found with other models. The PROPOLIS project (Lautso et al. 2004 and Spiekermann and Wegener, 2004) is particularly interesting as it uses land use models to assess various policies.

6.1 Road Pricing

The first policy to be applied concerns road pricing (either a cordon pricing or increased parking fees in the inner city). Road pricing policies are mostly assessed by traffic models at the city level. Anas & Lindsey (2011) compare the road pricing policies for London, Stockholm and Milan.

City (extend of tolled zone)	London zonal toll (22 km³)	Stockholm cordon toll (30km²)	Milan cordon Ecopass (8km²)
Congestion			
Traffic volume	-34% cars, +22% taxi, -12% all vehicles	-22% passing through cordon; -16% within cordon	-12.3% within zone; -3.6% around the zone
Travel times	-30% congestion (2005)	Congestion minus 1/3 to 1/2 on arterials; smaller decrease within cordon	
Accidents	-2 to -5% accidents with victims	-5 to -9% victims -3.6% accidents	-20.6%
Emissions PM10	-12%	-13%	-19%
Public Transport trips	+30% in zone	+4.5% on cordon roads	+7.3%
	mio € (2005)	mio € (2006)	mio € (2008)
Gross Benefits	345	102	30
Total Costs	245	31	15
Net Benefits	100	71	16
Implementation costs	256	206	7

Table 9: Experience with urban road pricing (source: Anas & Lindsey (2011))

In all the three cities, the policies were accompanied by public transport policies in order to improve public acceptability (De Borger & Proost (2012))..

The main expected (direct) impact of road pricing is a reduction of congestion (i.e. reduction in travel times) on the road network. This will improve overall accessibility, safety and reduce emissions in the region where the pricing applies. But if only part of the network is priced we can expect a displacement of congestion, accidents and pollution rather than a reduction. We can also expect an increase in the share of public transport. In the long run we can expect changes in housing prices and location of businesses. The land use effects of the policies have not yet been studied in great detail but all three cities tend to be rather monocentric. If road pricing is only applied in the inner city, a decentralization could occur. In terms of benefits and costs, the main benefits will be time savings, increase use of public transport, reduction in accidents and emissions. The main costs will be the implementation costs and the cost of deterred drivers.

An alternative to road pricing is to charge car use through parking fees. There is not so much applied literature on this type of measure. Looking to the results obtained in the PROPOLIS project (Lautso et al (2004)) we can expect a decrease in the number of car trips to the city centre when central-area-parking fees are increased since a trip to the city-centre will be more expensive. Other results that can be expected are that more trips will be made by public transit, increasing the modal share of public transport and decreasing overall congestion in the centre. However, some people will no longer travel to the city-centre but choose other places outside the area where the parking fees are implemented to go shopping etc. which could harm businesses and in the long run the viability of the city-centre

6.2 Investment in transport capacity

As already mentioned before, most important transport investments have been studied using conventional partial equilibrium transport models. The expected results from these analyses have been summarized in section 5. Here we concentrate on results obtained using land use models. We are, however, only aware of a very few case studies that uses land use models. We report here the results of two case studies that have used UrbanSim to study the impact of a major investment. The first study concerns a new light-rail connection in Phoenix metropolitan area (Joshi et al 2006). The authors consider two scenarios: one with the new light-rail and one without. The impact of light rail are different for the different zones. In general they found a slight increase in density near the new stations. The increase in rents due to the improved attracts, however, higher income households who prefer larger dwellings. This means that in some zones they actually see a decline of the density. A second application of UrbanSim is given in a paper of Kakaraparthi and Kara M. Kockelman (2011). In this paper the authors describe, amongst others, the UrbanSim modeling results of 2 investment scenarios for Austin, Texas. One of the scenarios is an expansion of the highway capacity and another is an added state highway. The main results for these two scenarios was that households and jobs shift towards the expanded corridors but at lower densities (than in the BAU case), thanks to improved travel conditions along the corridor.

6.3 Land-use regulation

The number of trips and the mode choice is obviously a function of the spatial distribution of economic activities. The potential to reduce the total mileage by car and therefore the total emissions via changes in land use have been studied in detail over the last ten years. A stylized fact in this context is that many households prefer living in relatively low-density urbanized environments and that employers choose to locate out of city centres in response to high central city prices. Where legislation and other framework conditions allow it (or favour it, e.g. via parking regulations), the result is urban development with fairly low-densities and decentralized distribution of employment. This pattern is particularly prevalent in – but not unique to – the post-war United States, and is often referred to as urban sprawl. Sprawl has a negative connotation, as it is associated with a range of problems. For example, decentralization and low densities are thought to generate lifestyles that induce excessive car travel, too much air pollution and energy consumption, and too little walking and cycling.

Basic microeconomics suggests that urban sprawl is a policy issue because market failures render market outcomes inefficient. Some important market failures associated with urban development are that markets do not account for the benefits of open space and that they contain no mechanism for charging developers for infrastructure. Furthermore, the external costs of traffic congestion and energy consumption (in countries with low gasoline taxes) may not be accounted for without policy. The problem is that a wide range of instruments (e.g., zoning policies, property and transport taxes) affect already location decisions and transport costs. Thus, it is not clear ex ante in which direction urban development is distorted, although the dominant view is that zoning policies and the underpricing of transport lead to densities that are too low.

Recent empirical studies have investigated whether the strong link between residential density and travel distance is a causal connection. Analyses show that no major reductions in transport volumes or energy consumption should be expected from land use planning unless truly drastic changes in land-use occur.

A potential lesson for newly (re-)developing cities is that rapid declines in residential density along the US model ought to be avoided if carbon emissions are to be contained. But designing land-use patterns to minimize transport energy use may have high opportunity costs in terms of foregone benefits. In addition, reducing urban sprawl can produce unexpected results concerning the connection between urban spatial structure and travel needs, as the latter depend on other factors besides residential density. For example, a monocentric city (i.e. one with a well-defined single center, such as Paris) in which all travel is directed to the city center, likely has longer average commutes than a polycentric city of the same residential density (Anas, 2010).

The expected effect of densification is that it will reduce commuting times (Anas (2011) , Gaigné et al. (2010)), although the link between residential density and travel distance is not as strong as it appears at first sight (Bento et al., 2005, Brownstone and Golob, 2009). The reason is that households choose particular locations on the basis of their preferences (captured through observed and non-observed characteristics), and those preferences, along with density, explain transport choices.

7 Conclusions

In this deliverable we have discussed an economic approach to sustainable cities.

This approach differs from the more common sustainable indicators approach in several ways. First it aggregates all values in one function that summarizes the different dimensions. This has the advantage of valuing in a transparent way the different dimensions. A second important characteristic of the economic approach is that attention is paid to the incentives of the local decision maker. The local decision maker does not have the incentives to take all sustainability incentives on board and this may lead to inefficient local policies.

In this deliverable we have also surveyed the available evidence on the costs and benefits of several urban sustainability policies. For some policies like road pricing, there is robust evidence on its effects and its potential. For other policies like densification and clean vehicles the benefits are less clear and for these policies the UrbanSim simulations for the three case study cities will generate more precise insights.

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